Development and implementation of a risk model and contingency estimation for the Panama Canal Expansion Program

Final Report

CONFIDENCIAL

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AUTORIDAD DEL CANAL DE PANAMÁ

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I. Introduction

I.1. Risk Management

Risk is a measure of the exposure to a future event involving the probability of experiencing an unfavorable result within defined cost, schedule and technical constraints. In investment projects risk is the exposure to events that may affect the economic-financial performance of a project. Risks are the product of two factors:

- The probability of occurrence of an event, and
- The expected severity of its impact.

The expected value of the risk would be the product of these two factors:

Expected value of the risk = Risk probability x Risk impact

The richer the information about the risks, the easier it becomes to prevent, reduce, eliminate or transfer the risks. In order to learn more about the risks of a project, the project company must engage in risk management. Risk management is the act or practice of dealing with risk. It includes assessing (identifying and analyzing) risk areas, developing risk-handling options, monitoring risks to determine how risks have changed, and documenting the overall risk management program. It allows for the key threats to the project to be managed in a structured way, and to better secure the value of money.

The risk management process can be described in the following phases (see Figure 1):

- *Risk identification* is the process of identifying and analyzing project areas and critical technical risks to increase the probability/likelihood of meeting cost, schedule, and performance objectives for a project.
- *Risk analysis* is the process of examining each identified risk area or process to refine the description of the risk, isolating the cause, and determining the effects. It includes risk rating and prioritization in which risk events are defined in terms of their probability of occurrence, severity of consequence/impact, and relationship to other risk areas or processes.
- *Risk planning* is the process of developing and documenting an organized, comprehensive, and interactive strategy and methods for tracking risk areas, developing risk handling plans, performing continuous risk assessments to determine how risks have changed, and assigning adequate resources. This includes the specifics on what should be done, when it should be accomplished, who is responsible, and the associated cost and schedule.
- *Risk monitoring* is the process that systematically tracks and evaluates the performance of risk-handling actions against established metrics throughout the project and develops further risk-handling options, as appropriate.
- *Risk documentation* is recording, maintaining, and reporting assessments, handling analysis and plans, and monitoring results. It includes all plans, reports for the PD/PM and decision authorities, and reporting forms that may be internal to the PD/PM.

The key to successful risk management is early recognition, planning, and aggressive execution. To support these efforts, assessments should be performed as early as possible in the life cycle to ensure that critical technical, schedule, and cost risks are addressed with mitigating actions incorporated into planning and budget projections.

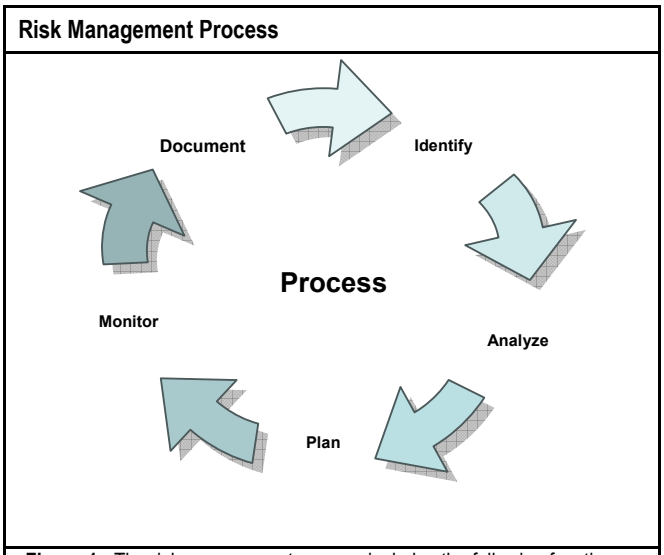

Figura 1 The risk management process includes the following functions: identify, analyze, plan, monitor and document the risks

I.2. Risk Modeling and Contingency Estimation

At any stage in the development of a significant infrastructure project, cost estimates will be composed of three components for which there are differing amounts of information: "Known/Knowns," (known and quantified costs), "Known/Unknowns," (known but not quantified costs), and "Unknown/Unknowns" (as yet unrecognized costs). (See Figure 2).

Great uncertainties accompany project estimates in early design. Cost estimating methods and tools must be understood in terms of the design definition (detail) available during the various phases of project development. Overall project risk is not embedded in the detailed line items but must be analyzed and priced as project contingency. The costs associated with the three components require different methods and tools to define and quantify their possible contribution to the estimate at any particular time in the project development process. As the project develops, the quantifiable portion of the costs increases and the contingency portion will decrease as cost factors are finally incorporated into the project plan.

Composition of cost estimate components through project development

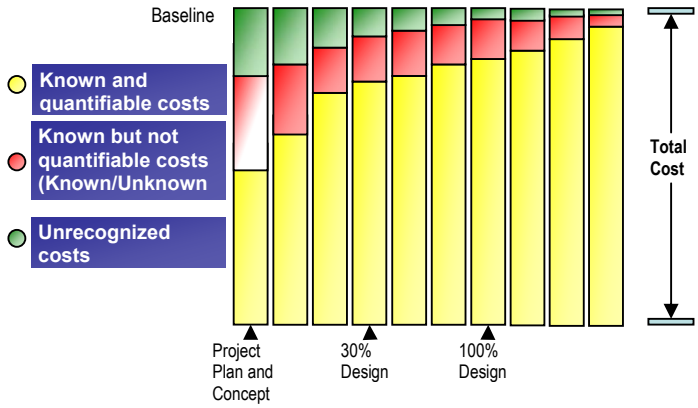

Figure 2 At any stage in the development of a project, cost estimates will be composed of three components: "Known/Knowns," "Known/Unknowns," and "Unknown/Unknowns".

The final project cost depends upon identifying, quantifying, and managing cost and schedule uncertainties (see Figure 3). Where an estimate, at some early stage in the design process, has included uncertainty, the range of cost or schedule uncertainty should decrease as a project proceeds from concept to final design. Estimate accuracy improves as design develops, cost variables are better defined, and uncertainties become unfold.

Reduction of Uncertainty through Project Development

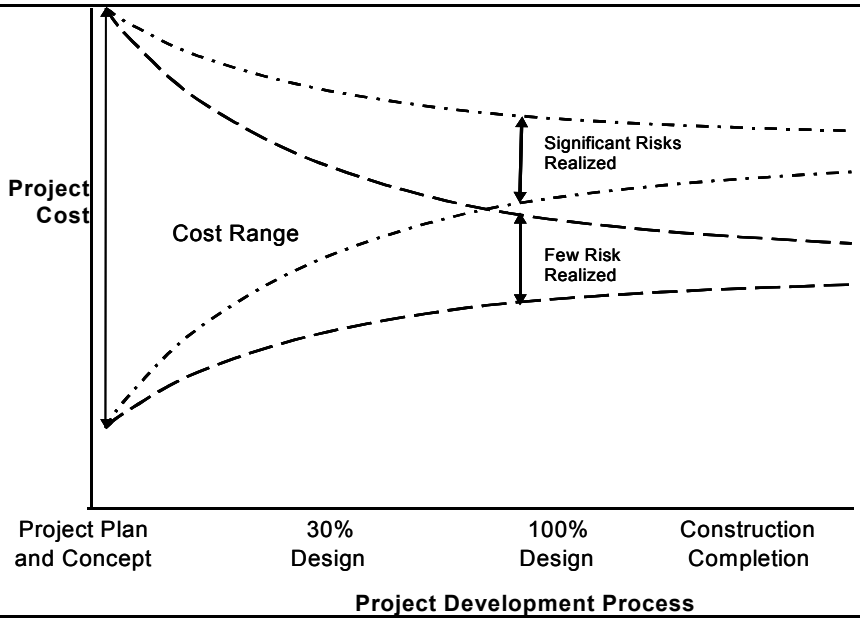

Figure 3 The final Project cost depends upon identifying, quantifying and managing risks.

If the uncertainties included in the estimate as a contingency amount in the early stages of project design materialize, then the estimated total will still be

as expected. However, as risk management and other cost control processes are applied to the identified uncertainties (risk), it is often possible to mitigate risks (contingency costs) and deliver the project at a lower cost.

II. Development of the Risk Model

Throughout the process of identifying risks and developing the risk model, the ACP has incorporated the participation of a large number of experts and their input has proven to be a valuable resource for the purpose of our model. In identifying risks ACP participants and international advisors have indicated what they believe could be the potential risks of the Third Lane Locks Project.

In developing the risk model the guidance of world renowned experts has enriched this management tool in a way that drives the experts themselves to praise the resulting model. (See Appendix 3). The steps taken to arrive at this result are detailed below.

II.1. Risk Identification and Selection of Critical Risks

The Panama Canal Authority, as part of the evaluation of the Third Lane Locks Project, has performed several key efforts to identify the critical risks that could pose a threat on the Canal Expansion Program. The efforts include:

- Canal Expansion Risk Assessment
- Value Management Workshop
- Expansion Program Risk Workshop

Risk Categories based on the "Canal Expansion Risk Assessment Report"

Administrative & Operational:
Risks already inherent in the ACP's operations that could have an impact on the canal expansion project. These risks group factors such as inefficiencies in decision-making within the organizational structure of the ACP, increase in operational costs with the expansion, and lack 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. These include the risk in handling of water resources (water supply), pressure of environmental groups and other interest groups, delays in program approval and 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 difficulties 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).

Figure 4 Risks were identified and classified according their criticality or importance to the project.

Canal Expansion Risk Assessment

Aon Risk Services conducted the study "Canal Expansion Risk Assessment Report". Among its objectives were identifying risks and classifying them according to how critical each risk becomes for the overall project results.

The risks of the Program were identified, and classified under four general categories: market risks, project execution risks, administrative and operational risks, and environmental, political and social risks (See Figure 4).

The risks contained in these categories were evaluated in terms of probability of occurrence, financial impact and time of warning, based on the following qualifications (See Table 1):

Risks evaluation in terms of probability of occurrence, time of warning and financial impact

Score	Probability
1	Extremely rare
2	rare
3	Periodic
4	Recurrent
5	Occurs frequently

Score	Time of Warning
1	long term warning (months or years)
2	short term warning (days or weeks)
3	Without warning

Score	Impact
1	Less than $10,000,000 (Less of 1 month of delay)
2	$ 10,000,001 - $ 60,000,000 (1-3 months of delay)
3	$60,000,001 - $100,000,000 (4-11 months of delay)
4	$100,000,001 - $ 200,000,000 (1-1.5 years of delay)
5	More than $200,000,000 (Delay of more than 1.5 years)

Table 1 The identified risks were evaluated in terms of probability of occurrence, time of warning and financial impact.

A representative group from different areas of ACP participated in the above mentioned evaluation, including top management of the Panama Canal Authority. The results of the above mentioned study generated a risk map which clearly identified critical risks, moderate risks and minor risks potential objects of the expansion program. The critical risks were evaluated in depth, and as a result of this evaluation, a preliminary risk model was created (See Figure 5).

Risk Map

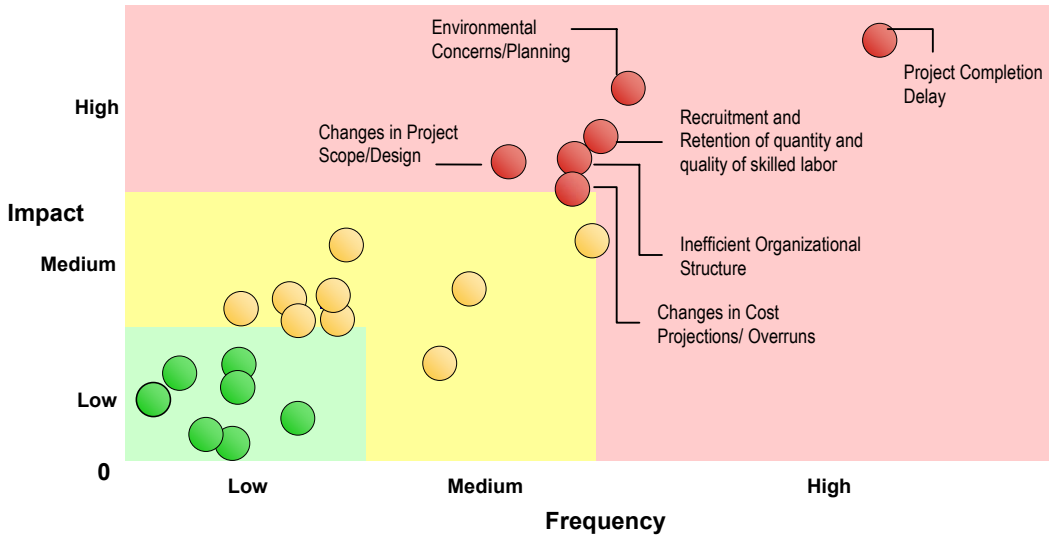

Figure 5 A risk map clearly identifies critical risks, moderated risks and minor risks.

Value Management Workshop

Following the Risk Assessment Study, a Value Management (VM) workshop was conducted. The group was composed with experts from the United States, Sweden, Germany, Belgium, Venezuela, Colombia, France, England, Australia and Panama. The VM workshop had a component of risk administration in which, by means of the methodology of a risk hierarchy, more than three hundred Expansion Program risks were identified. The hierarchy of risks was given with the following general classification:

1. Administration
2. Labor
3. Operations
4. Design
5. Site Conditions
6. Finance
7. Politic
8. Construction

The risks identified in the workshop were qualitatively evaluated in terms of their probability and impact (See Table 2):

Qualitative Risk Evaluation	
Probability	**Impact**
H = High = Will happen	H = High = Disastrous effects
M = Average = 50% probability	M = Average = Manageable but needs many resources
L = Low = Almost certain won't occur	L = Low = Only an irritant

Table 2 The risks identified in the Value Management Workshop were qualitatively evaluated in terms of their probability and impact.

As a result of the VM evaluation process, risks were classified under three broad classes based on their probability-impact as major (MA), moderate (MO) and minor (MI) following the system detailed below (See Table 3).

Risks Classification	
Probability-Impact	**Classification**
HH	Major (MA)
MH	Major (MA)
HM	Moderate (MO)
MM	Moderate (MO)
LH	Moderate (MO)
HL	Minor (ME)
ML	Minor (ME)
LM	Minor (ME)
LL	Minor (ME)

Table 3 The risks identified in the Value Management Workshop were classified qualitatively according to their probability and impact

Accordingly, having conducted two different assessments: the Risk Assessment study, and the VM workshop, ACP decided to integrate both efforts to generate a single list of the possible risks of the Expansion Program. The risk categorization of the integrated risk list was based upon the classification used in the VM workshop, adapting the risks identified by the Aon study to the probability and impact qualifications used in the VM workshop. This list of risks was revised in order to group similar risks and to eliminate those risks that were evaluated as minor risks.

Expansion Program Risk Workshop

In October of 2005 a risk assessment workshop was conducted. About 40 participants from several ACP areas took part in the workshop, including the Deputy Administrator and several Department Directors. During the workshop 184 risks were evaluated in terms of their probability of occurrence and their impact in time and cost. In addition, preliminary mitigation measures for each of the risks were identified. The results were discussed with the participants and adjustments were made to reach consensus. (See Appendix 2).

The workshop results were reviewed to identify the critical risks of the project. The resulting list of critical risks was consistent with the results of the Risk Assessment Study and of the Value Management workshop, reinforcing the validity and strength of the exercise. Below is the list of 14 risks considered

critical and important to be analyzed through a quantitative model to estimate contingency. (See Table 4 and Appendix 3).

List of Critical Risks	
1	Organizational risks
2	Lack of controls
3	Inefficient planning
4	Inefficient contracting process
5	General inflation
6	Referendum delay
7	Extreme bad weather
8	Owner driven changes
9	Insufficient revenues
10	Inadequate claims administration
11	Local labor strikes
12	Evolving design, changes in quantities
13	Lack of skilled and local labor
14	Material, equip. & labor cost increases

Table 4 The resulting list of critical risks was consistent with the results of the Risk Assessment Study and the Value Management workshop

II.2. Initial Model

Stochastic modeling has great benefits for project owners. In a static analysis of a project, a set of assumptions and variables produce a single point result, while a stochastic or probabilistic analysis provides the analyst with a range of values as a result. The stochastic results are much more realistic than the commonly used single point estimates, since they address both the probability of occurrence and consequences/impacts of potential risks. (See Figure 6). Due to this property, probabilistic models allow measurement of the unpredictability of key variables, facilitate data collection about the behavior of critical variables, and make possible measurement of the uncertainty related to projects by the owner.

Advantages of a Probabilistic Approach

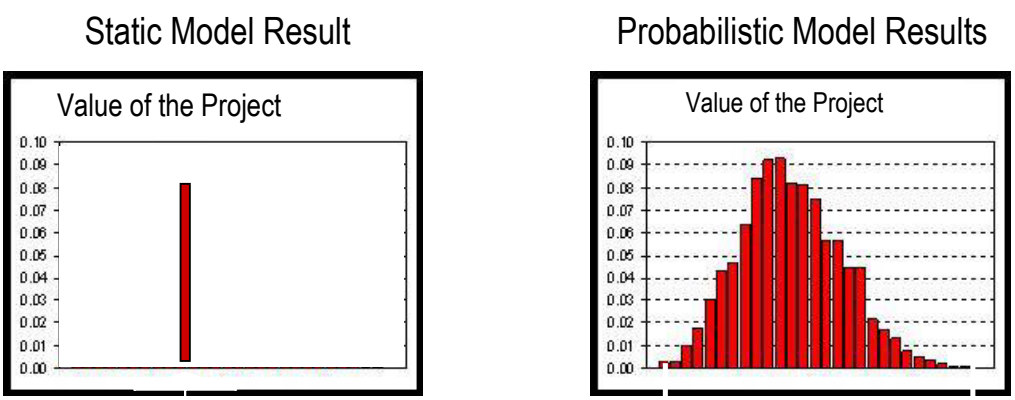

Figure 6 In the static model, we have one value given specific assumptions. Each time assumptions change a new value has to be calculated. On the other hand, the probabilistic model brings a range of values based on probability and impact of potential risks.

ACP took advantage of its analytical capabilities to develop a model that would:

- Increase the probability of success of the Expansion Project through the analysis of possible risks.
- Reduce the cost of troubles that might arise during the project.
- Minimize the amount of rework and unforeseen project efforts.
- Promote changes to the project plan as weaknesses are uncovered.
- Establish reasonable result ranges in terms of time and money for the project.
- Develop awareness of project exposures to the events that might occur.
- Demonstrate the uncertainty of project outcomes and facilitate setting reserves for schedule and resources.
- Aid in the decision to proceed or not with the Expansion Project. (See Figure 7).

Risk and Decision to Proceed with a Project

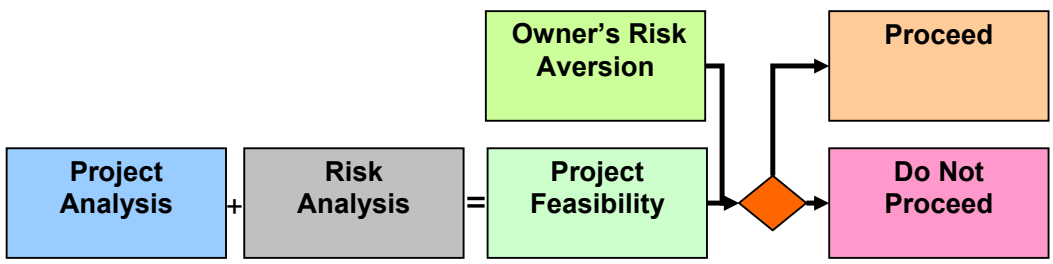

Figure 7 The owner's risk aversion is an important consideration for the decision to proceed or not with a project

A first stochastic model was built to better understand the distribution of possible outcomes of the expansion project. This stochastic model introduces randomness in variables to produce both results and the associated probability of those results occurring through a Monte Carlo simulation. These random variables feed into financial and operational calculations that measure the value of the Canal Expansion Program.

The Monte Carlo simulation is a risk analysis technique that incorporates multiple simulations of outcomes with the variability of individual elements to produce a distribution of potential results. For each simulation, the Monte Carlo simulation engine randomly chooses one value for each risk event from within its range of possible values, but in agreement with the likelihood of occurrence of each value. These randomly chosen values are then combined to generate a single result for one simulation. This process is repeated a number of times (typically more than 1,000 iterations), and a range of equally likely potential outcomes is produced.

The concept behind the initial model was to incorporate the risks of the program into the projected cash flow and evaluate how the cash flow would

be affected by them. The initial model varied the macroeconomic and competitive scenarios to generate different demands of cargo and transits. The investment cost was affected by delays and cost overruns. Delays in completion date were affecting future revenues as well. All those variations generated different cash flows, and, therefore, different economic and financial indicators. (See Figure 8).

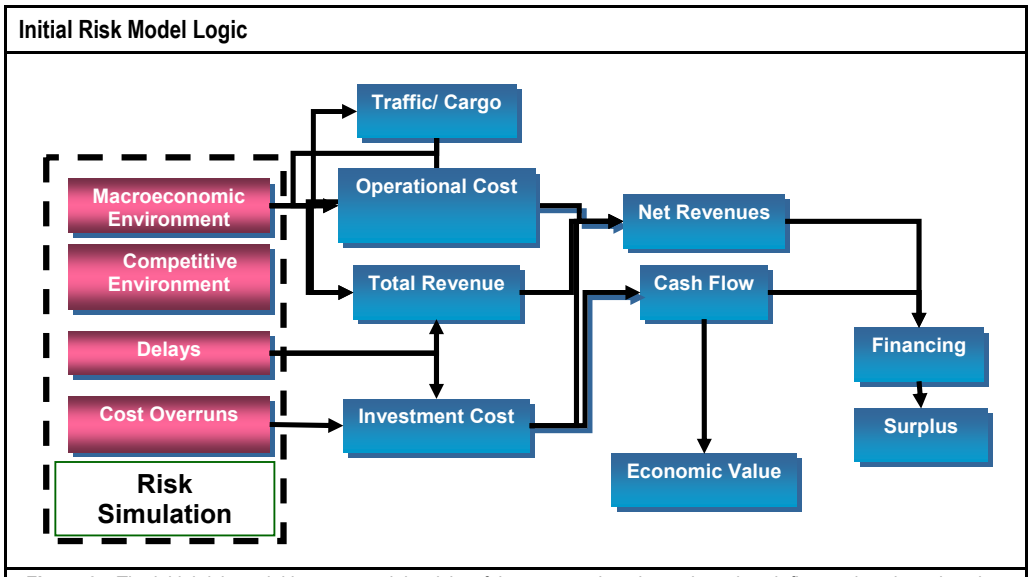

Figure 8 The initial risk model incorporated the risks of the program into the projected cash flow and evaluate how it will be affected by them.

This initial model was a top-down model. It captured the main risks but at a very general level. It did not capture the high level of detail used to prepare the cost estimate. It was not able to manipulate specific cost variables, such as productivity and quantities. Furthermore, this initial model was event-based. Most of the risks were modeled using very general probability distributions.

On the other hand, the cost estimate was developed using a bottom-up approach. The cost team developed a very detailed cost and schedule estimate for the current level of design. However, the contingency was estimated as a percentage. As a consequence of a cost estimate review by independent consultants, it was determined that the contingency in the cost estimate was not a result of a detailed risk analysis.

Consequently, ACP started an effort to integrate the cost estimate into the risk model to generate a risk-based contingency estimate. To that respect, a team was created to develop a new integrated risk model to estimate the contingency cost for the Third Lane Locks project. (See Figure 9). The team was composed of personnel from the Engineering Department, the Finance Department and the Office of Program Development. A group of consultants with expertise in risk model design for construction projects was contracted to provide guidance and support to the team.

Multidisciplinary Team to Generate Risk-based Contingency

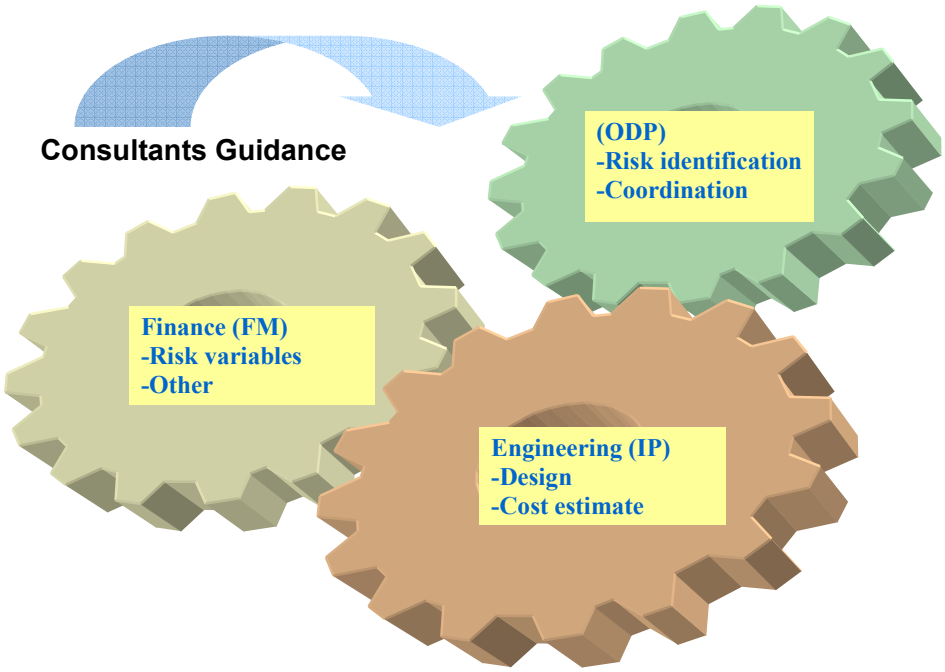

Figure 9 The team was composed of personnel from the Engineering Department, the Finance Department and the Office of Program Development. A group of consultants with expertise in risk model design provided guidance and support to the team.

II.3 Methodology for an integrated risk model:

The risk analysis to estimate the contingency was based on the design cost estimate developed by the Engineering Department. Under this arrangement, the risk model would provide the contingency to be added to the base cost and schedule, reflecting the ranges of values in cost and completion date.

One of the objectives of this integrated effort was to establish a baseline cost estimate for the Expansion Program that would include market demand, financial and critical risk variables. In order to develop this risk-based contingency estimate, the team considered the following methodological steps:

1. Concept standardization
2. Adjustments to cost estimate
3. Model structure definition
    a. Market
    b. Delays
    c. Cost overruns
    d. assumptions
4. Model validation

The team started by focusing on standardizing project definition and risk concepts aiming to integrate the cost estimate prepared by the Engineering

Department and the risk model developed by the Finance Department. The next step was to define the new structure for the risk model ensuring that the model represented the critical risks identified in the workshop. The new model structure allowed direct links between critical risks and variables included in the cost estimate and schedule. Finally, the integrated model was validated through a series of working sessions in which participants had the opportunity to assess all assumptions and parameters.

The group of consultants provided support throughout the process contributing to the revision of variables and the model structure.

Following is a detailed explanation of the stages of the methodology utilized:

1. Concept standardization

The group agreed on the need to eliminate the 20% contingency that had been included in the design cost estimate of the access channel, and the locks, the 8.5% contingency for dry excavation, and 3% contingency for dredging activity included in the cost estimate of the navigational channel, in order to derive a new contingency for each component based on a risk analysis and group contingencies under one value denominated total contingency.

The goal of the risk based-contingency effort was to generate probability distributions for total cost and schedule to completion that would include the base cost/duration estimate and the probable cost/duration of risk and opportunity events.

As a result of the review, the team identified that a significant portion of the contingencies included some un-quantified costs that are normally part of the cost estimate. These costs were included in the cost estimate as "allowances". (See Appendix 4).

2. Adjustments to cost estimate

The cost team modified the cost estimate to make the integration with the risk model possible. These modifications are the following:

- structure cost estimate by component
- classify activities with the same type of crew and productivity
- group similar activities in broader categories
- introduce allowances to cost estimate

3. Model structure definition

ACP had developed a static financial model estimating the value of the expansion project. Instead of building a completely new model, the group modified the previously developed static financial model.

The 14 risks, which were identified during the workshop as critical, could be modeled in three major areas: the impact of reduced revenues, the impact of

delays and the impact of cost overruns to the expansion project. Some of the risks directly affect delays, some of them affect mainly cost overruns and some of them have an incidence on both delays and cost overruns at the same time. (See Figure 10, for additional details, see Appendix 5).

Areas affected by critical risks

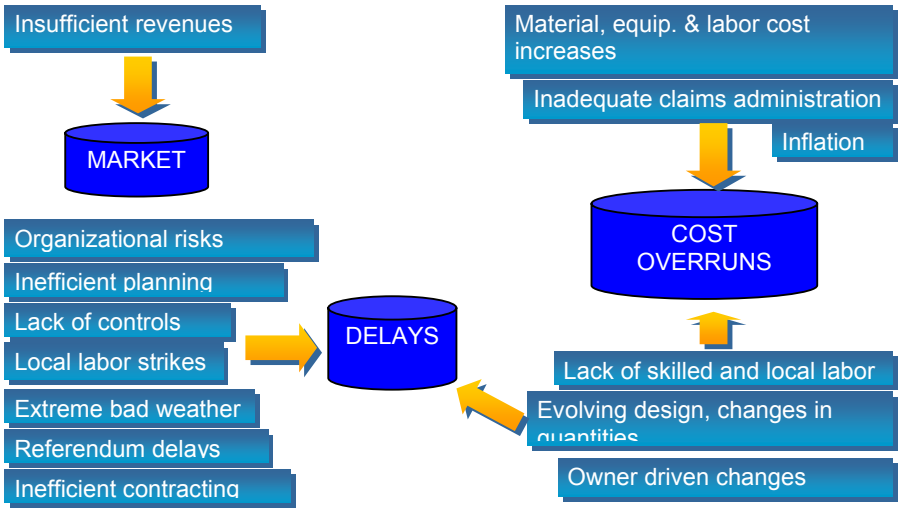

Figure 10 Some of the risks directly affect delays, some of them affect mainly cost overruns and some of them have an incidence on both delays and cost overruns at the same time.

a. Market

The main inputs in this area of the model are the projected transits, cargo and revenues under various macroeconomic and competitive environments generated by a demand model provided by Mercer Management Consulting Corporation. The first step was to introduce into the ACP financial model different macroeconomic and competition forecasts. To accomplish this, the ACP chose three macroeconomic scenarios and three competitive scenarios. These scenarios were defined as optimistic, expected, and pessimistic. The ACP assigned a probability of 17.5%, 65% and 17.5% to each of the macroeconomic scenarios and a probability of 10%, 80% and 10% to each of the competitive scenarios. Combining these macroeconomic and competitive scenarios will result in nine market scenarios with the following probabilities (See Table 5):

Market Scenarios

Competitive Scenario	**Macroeconomic Scenario**		
	Pessimistic	Probable	Optimistic
Pessimistic	1.8%	6.5%	1.8%
Probable	14.0%	52.0%	14.0%
Optimistic	1.8%	6.5%	1.8%

Table 5 For each iteration of the simulation, one of nine market scenarios is selected with its forecasts for cargo, transit and revenues.

For each iteration of the simulation, one of the nine market scenarios is selected with its forecasts for cargo, transits and revenues, given the probabilities associated with each market scenario. These scenarios consider a pricing policy of real increase in tolls of 3.5% annually from 2005 to 2025 taking into account all segments. This pricing policy applies to the expanded Canal and the unexpanded Canal.

b. Delays

Delays impact the Expansion Project in two ways: first, there is a delay in additional revenue resulting from the opening of a third set of locks in the Canal; and second, there is an additional cost that arises from extending the works beyond the schedule (contractor's fixed cost and owner's fixed cost). The model estimates the project-level schedule by developing probability distributions that affect the duration of each activity. The effects of individual risk variables are aggregated using a Monte Carlo simulation to obtain a probability distribution of the schedule or completion date. The resulting project-level schedule is then analyzed to determine the actual schedule risk and to identify the schedule drivers. (For more details, see Appendix 5)

This technique expands the commonly used Critical Path Method of developing a project schedule to obtain a realistic estimate of schedule risk. The basic Critical Path Method approach uses single point estimates for the duration of program activities to develop the project's expected duration and schedule. It invariably leads to underestimating the time required to complete the project and schedule overruns, primarily because the point estimates do not adequately address the uncertainty inherent in individual activities.

The stochastic schedule accounts for uncertainty by using a range of time that it will take to complete each activity instead of single point estimates. These ranges are then combined to determine the project-level schedule estimate. (See Figure 12).

c. Cost Overruns

In order to model cost overruns, a detailed cost estimate was incorporated to the risk model. The cost estimate has the following components:

1. Pacific Locks
2. Atlantic Locks
3. Access Channel Contracts (6)
4. Navigational Channels
5. Raise Lake Gatun

The previously identified critical risks modify the cost estimate through a set of critical variables, such as: quantities, productivity, wages, prices and so forth. (See Figure 11). The effects of individual risk variables are aggregated using a Monte Carlo simulation to obtain a probability distribution of the total cost. These results are then analyzed to determine the actual risk of cost overruns and to identify the cost overrun drivers. (For more details, see Appendix 5)

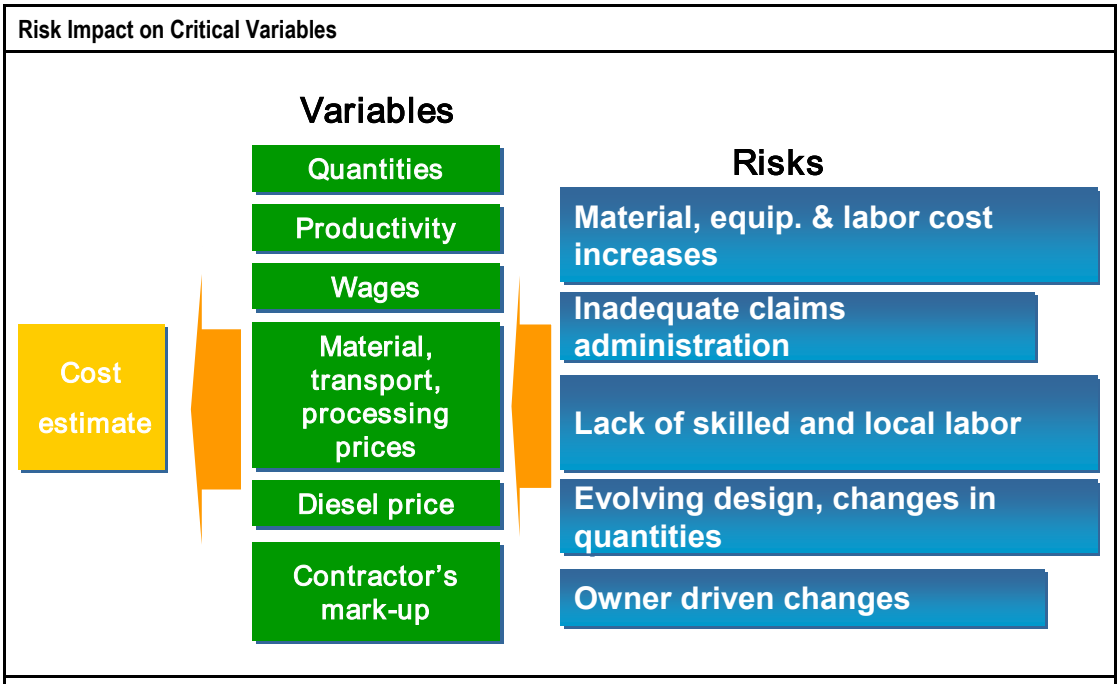

Figure 11 The identified critical risks modify the cost estimate through a set of critical variables such as quantities, productivity, wages, material transport, processing prices, diesel price, and contractor's mark-up.

The use of these cost probability distributions as the basis for the contingency estimate is more realistic than the use of a single percentage (let's say 20%), since they address both the probability of occurrence and consequences or impacts of potential risks. Their use eliminates a major cause of contingency underestimation and allows the evaluation of causes of risk costs. Thus, this technique provides a basis for the determination of an "acceptable" level of contingency or cost risk. (See Figure12).

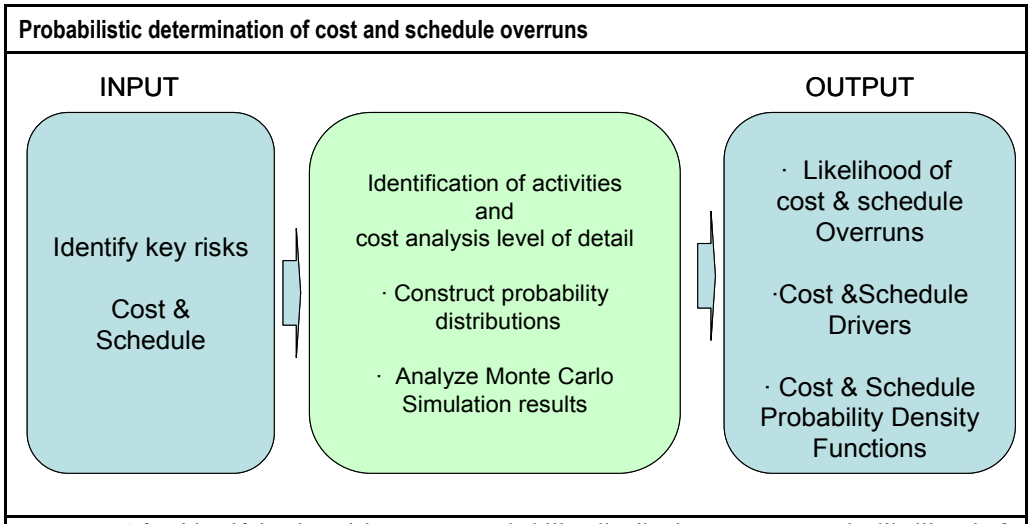

Figure 12 After identifying key risks, we use probability distributions to generate the likelihood of cost and schedule overruns and drivers

To calculate a distribution of results, the model was run through 3,000 iterations[1]. During an iteration, the software assigns a new value based on their individual probability distribution to each random variable. The variations in demand, schedule (time) and cost are aggregated using a Monte Carlo simulation to obtain a probability distribution of the following variables:

- Total cost
- Contingency
- Completion date
- Internal rate of return

In order to obtain this result, the model calculates and stores specific cost, schedule and variables of each iteration. When the simulation is complete, a distribution, as opposed to a single point estimate, of cost, schedule and financial variables is returned. (See Figure 13) (For more details about probability distributions, see Appendix 5).

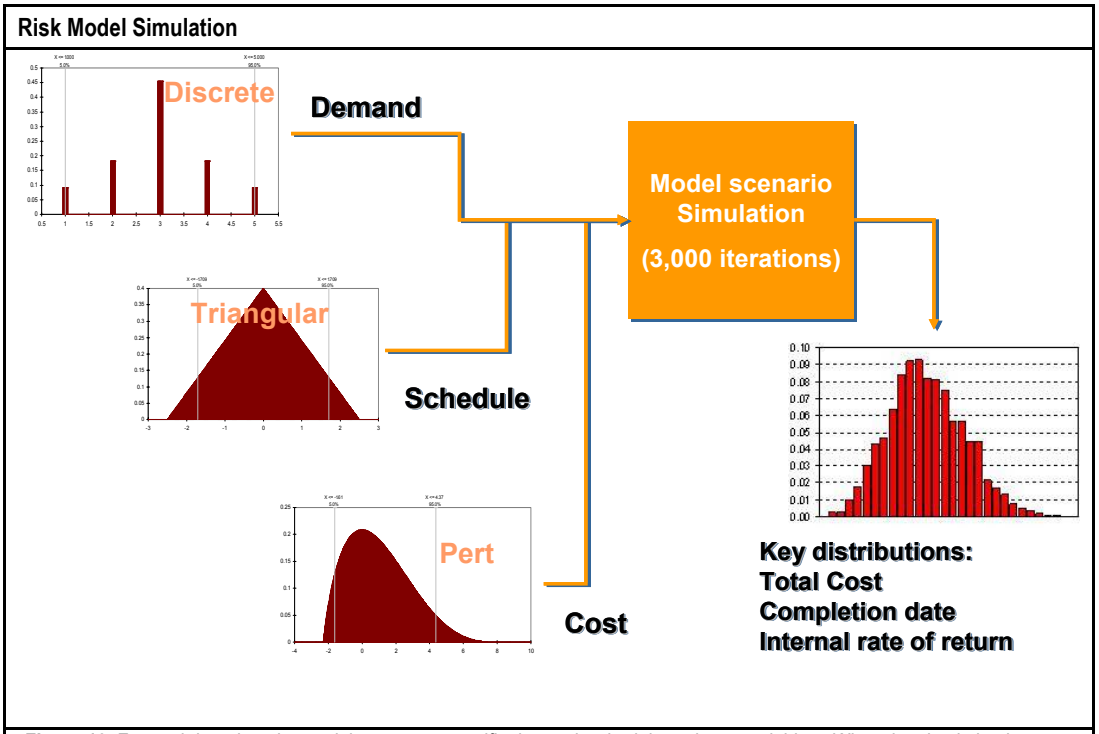

Figure 13 For each iteration, the model computes specific demand, schedule and cost variables. When the simulation is completed, a distribution of total cost, completion date and internal rate of return is generated.

d. General assumptions:

All the assumptions used in the cost estimates and the financial model apply to the risk model. The following are basic assumptions of the model.

[1] The optimal number of iterations was defined by convergence of the mean and standard deviations of key outputs to 2.5%

- The contracting method is design-bid-build.
- ACP dredges would perform about 50% of total expansion dredging volume.
- All unskilled labor is hired locally.
- Contractor's key technical and administrative personnel are foreign.
- Cost contingency allocation in time was based on the distribution of the base cost estimate flows across time.

4. Model Validation

The parameters applied to all the variables were initially established by the cost estimating team and subsequently discussed and reviewed with a group of technical experts from the ACP through several working sessions during November, December and January of 2005. In addition to the revision of parameters in the model, the methodology was presented to and discussed with other key ACP employees. Extensive debate took place during discussions resulting in thorough revision and modification of parameters previously assigned to the variables.

III. Results

Various statistical terms are used in this section. The mean is the average value for a given variable across the 3,000 iterations. 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 80th percentile is the point where 80% of the trials will fall below, and 20% will fall above. An 80% value for the cost implies that four out of five times the final cost would be below this number.

The percentile level used in establishing contingency is related to the level of risk aversion. The most typical value used in the industry for projects of this magnitude is 80% because it is a reasonable criterion and has a straightforward interpretation[2]. For this model we are using the 80th percentile as a good estimate confidence level.

The distribution of the total cost takes into account all schedule and cost overrun risks simultaneously. (See Figure 14). If we pick the value at the 80th percentile, the probability that the total cost is equal to or less than B/.4,720 million (in real terms 2005) is 80%. Selecting this percentile, we set the level of contingency for the cost estimate. At this level, the contingency will be B/.1,027 million or 27.8% of the base cost.

[2] For more details, see "Development of Risk Based Contingency Values for a Baseline Project Budget Estimate for the Panama Canal 3rd Lane Locks" Report, March 2006.

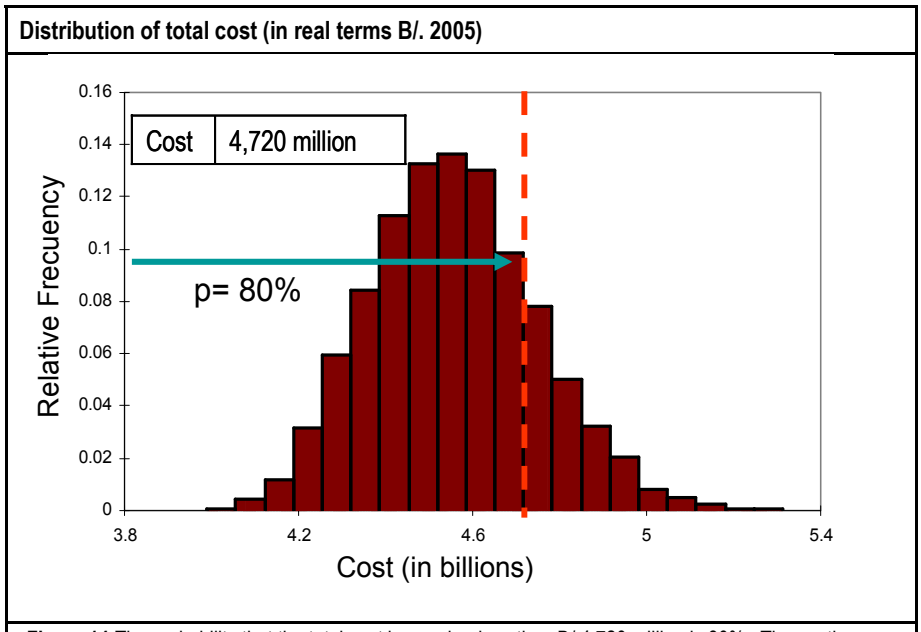

Figure 14 The probability that the total cost is equal or less than B/.4,720 million is 80%. The contingency, at the same level of confidence, will be B/.1,027 million.

The breakdown of the risk-based contingency by major component of the Panama Canal Expansion Project is shown in the table below. The base cost represents the project estimate without any risk events or contingency. In other words, the base estimate includes the known and quantifiable costs, as well as the known yet unquantifiable costs (construction allowances). The 80th percentile cost estimates (80% confidence level) represent the total cost with the identified risks (See Table 6).

Contingency Breakdown by Major Components (in millions B/. 2005)

Components	Original Base Cost	Contingency	Contingency (%)	Base cost at 80%*
Access Channel	401	128	31.9%	530
Pacific Locks	1,241	344	27.7%	1,580
Atlantic Locks	1,379	388	28.1%	1,770
Dredging	640	118	18.4%	760
Raise lake	33	50	152.3%	80
Total Investment	3,694	1,027	27.8%	4,720

Table 6 Table shows the contingency breakdown for each major component. (* Last column was rounded to 10 million).

The distribution of the project-level completion date takes into account all schedule risks. (See Figure 15). The probability that the project finishes by the end of fiscal year 2014 or sooner is 80%. At this level, the contingency in time translate to 12 months.

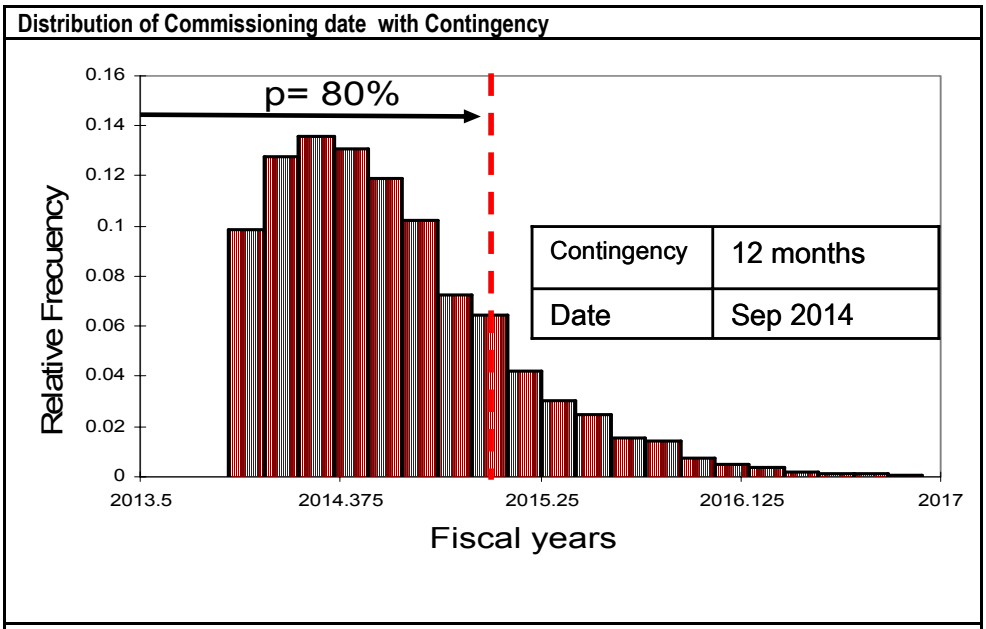

Figure 15 The distribution of the project commissioning date with contingency takes into account all schedule risks. The probability that the project finishes by September 2014 or sooner is of 80% approximately.

The distribution of the project-level internal rate of return takes into account all demand, schedule and cost overruns risks simultaneously. (See Figure 16). The project's internal rate of return (IRR) is capturing all market and capital expenditure variations.

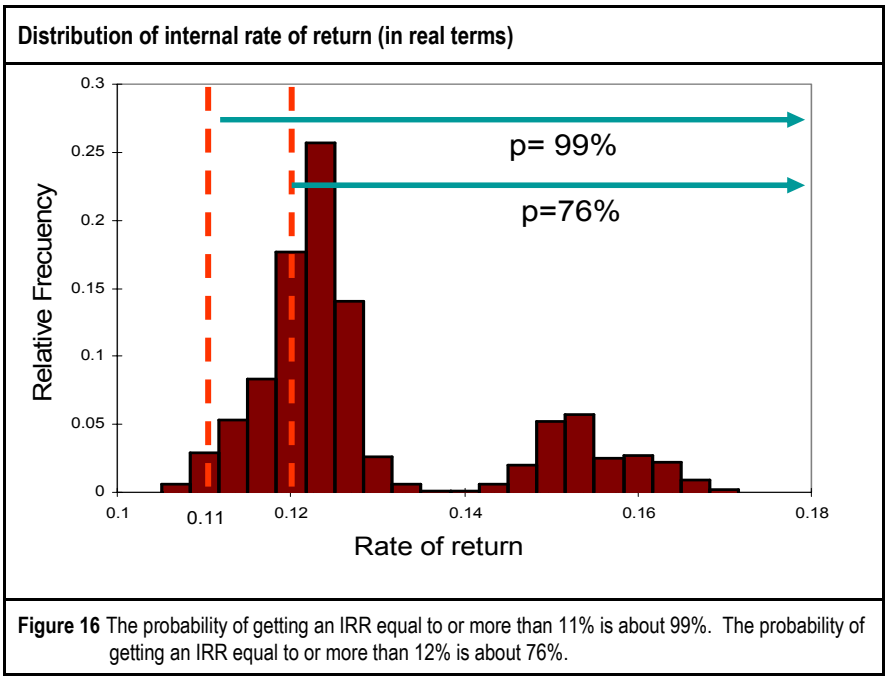

Figure 16 The probability of getting an IRR equal to or more than 11% is about 99%. The probability of getting an IRR equal to or more than 12% is about 76%.

The probability that the IRR is equal to or more than 12% (in real terms) is approximately 76%, and the probability that the IRR is equal to or more than

11% (in real terms) is approximately 99%. If we pick the value at the 80th percentile, the probability that the IRR is equal to or more than 11.9% is 80%.

In Figure 17, we show the distribution of the total cost taking into account schedule risk, cost overrun risk and variations in general inflation. The probability that the total cost is equal to or less than B/.5,250 million is 80%. Panama's inflation was varied from 0.6% to 3% annually. This variation reflects both the historically low inflation of the country and the increased inflation during the last year.

Distribution of Total Cost (in nominal terms - B/.)

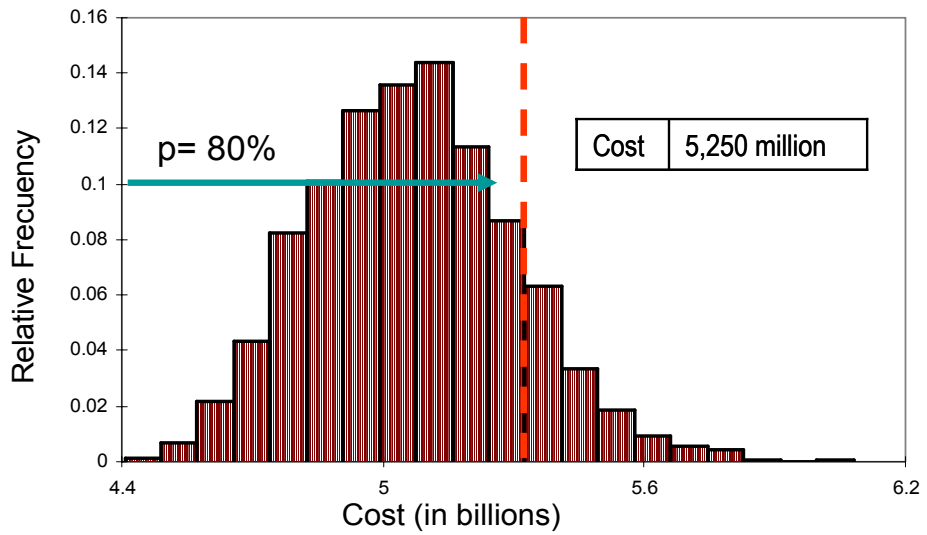

Figure 17 The probability that the total cost with contingency and inflation is less than B/. 5,250 million is 80% approximately.

After defining the distribution of total cost for the expansion project, we use a tornado graph to determine the factors or drivers that appear to have the biggest influence on total cost variation and completion date. The results show the top 10 drivers of total cost variation. (See Figure 18). The drivers of total cost variation are ranked by a coefficient that represents the impact of a variation of the driver into the variation of total cost. This ranking of factors or drivers will lay the foundation for the mitigation analysis.

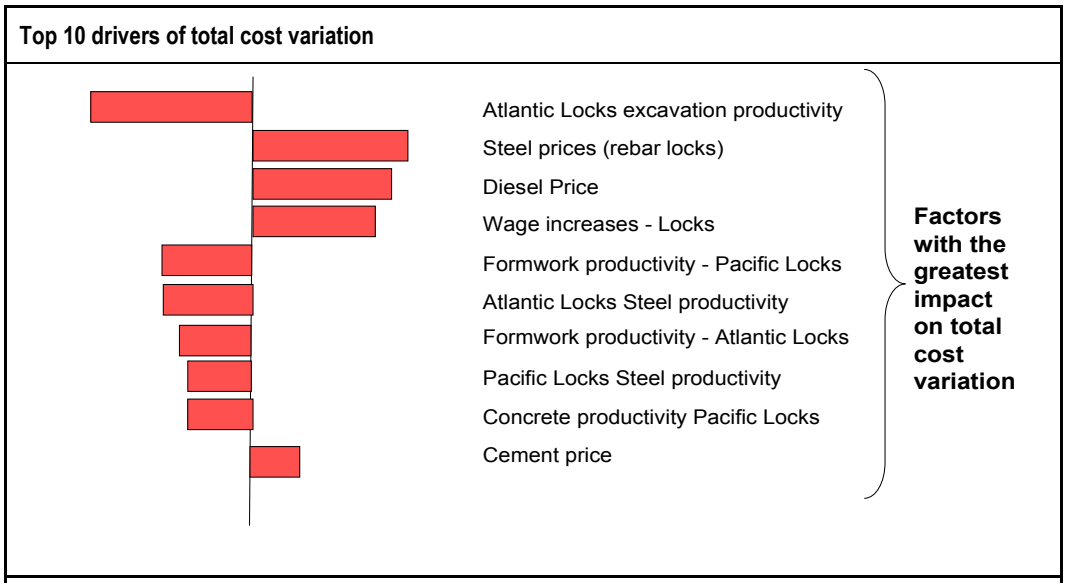

Figure 18 The top 10 drivers are ranked by the impact of a variation on the driver into the variation of total cost.

The results show the top 10 drivers of the completion date. (See Figure 19). The drivers of completion date variation are ranked by a coefficient that represents the impact of a variation of the driver into the variation of commissioning date. This ranking of factors or drivers will lay the foundation for the mitigation analysis.

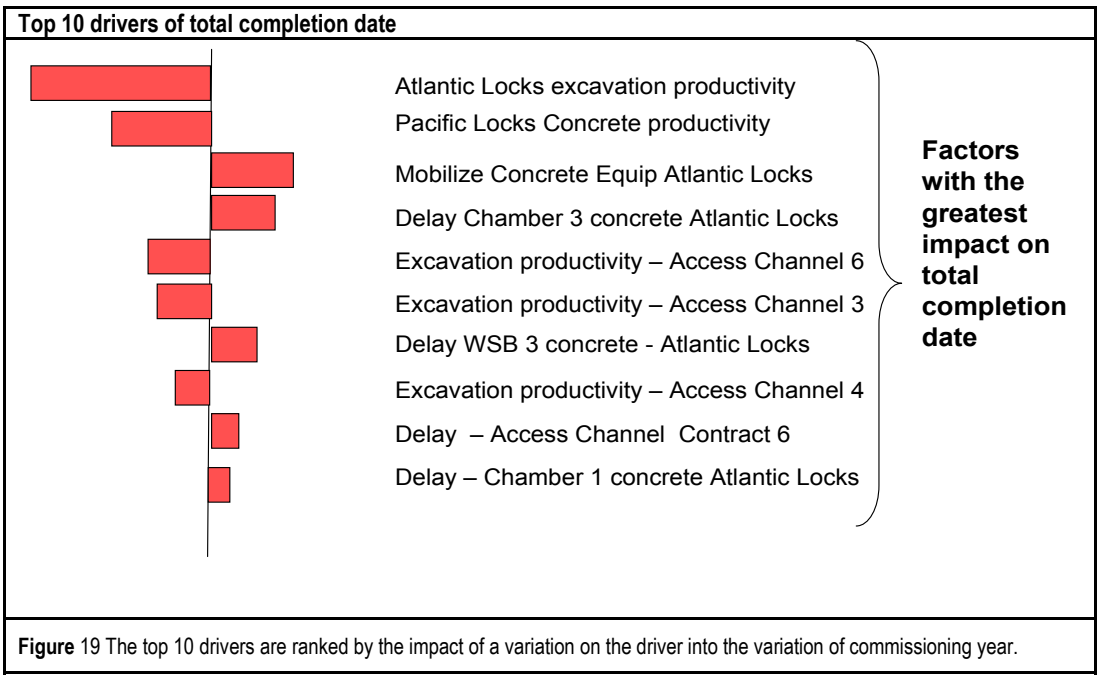

Figure 19 The top 10 drivers are ranked by the impact of a variation on the driver into the variation of commissioning year.

In the following table we show how the contingency is distributed across time (See Table 7). This time line corresponds to a scenario with 80% contingency in cost and 80% contingency in time. The total cost of B/.4,720 million is distributed up to the end of fiscal year 2014. Basically, cost contingency

allocation was based on the distribution of the base cost estimate flows across time.

Contingency distribution across time (in real terms, millions B/. 2005, fiscal year)									
	2007	2008	2009	2010	2011	2012	2013	2014	Total
Base cost	77	264	695	1,125	873	389	197	74	3,694
Contingency	31	82	164	288	205	92	92	72	1,027
Total Cost	108	346	860	1,412	1,078	481	289	146	4,720

Table 7 The table shows the contingency distribution across time. (Total was rounded to 10 million)

IV. Future Steps

Having identified and analyzed the risks of the project, the next step in the risk management process is to identify and evaluate mitigation measures for critical risks and to establish tools and procedures to manage those risks. (See Figure 20).

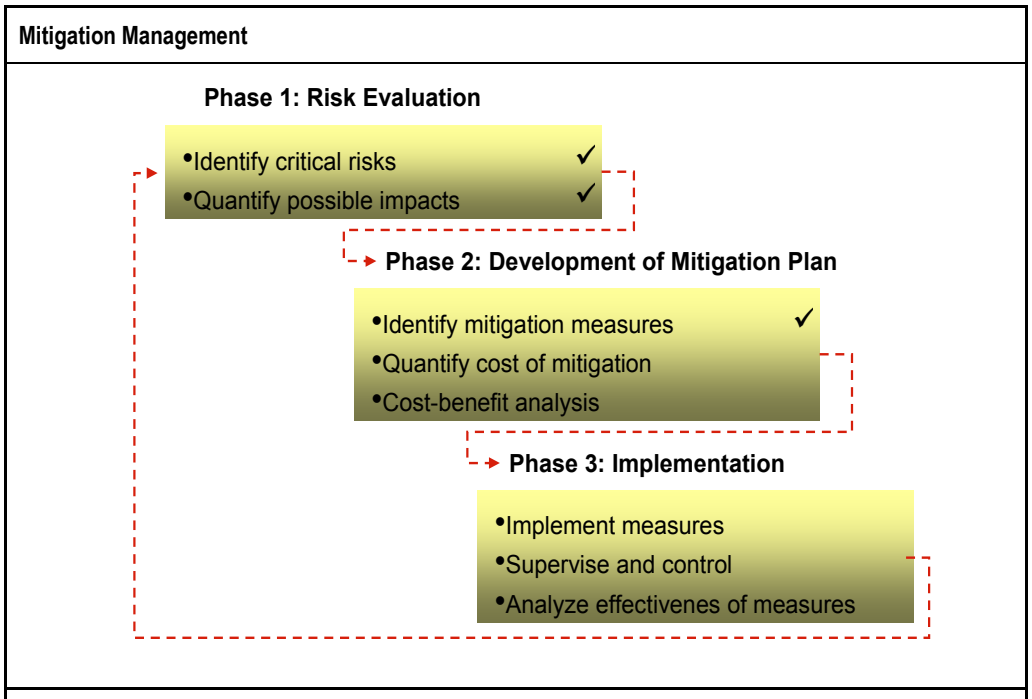

Figure 20 Having identified and analyzed risks, the next is to identify and evaluate mitigation measures

There are four ways to face risks:

- **Avoid exposure to the risk**: reduce a risk through the modification or elimination of those projects, operational requirements, processes or activities that cause the risks.
- **Accept the risk**: acknowledge the fact that, in any project, risks exist that will have to be accepted without any special effort to control them (i.e. weather).

- **Transfer the risk**: the reduction of risk exposure by the reallocation of risk from one part to another (i.e. reallocation of risks between the Government and the prime contractor, or between the prime contractor and its sub-contractor).
- **Mitigate or prevent the risks**: to take active steps to reduce the probability/likelihood of a risk event occurring and to reduce the potential impact on the project. Most risk-control steps share two features: they require a commitment of project resources, and they may require additional time to accomplish them. Thus, the selection of risk-control actions will undoubtedly require some tradeoff between resources and the expected benefit of the actions.

Because potential mitigation measures have been documented throughout the risk identification process, specifically during the Risk Assessment Study performed by Aon and the Expansion Risks Workshop, ACP now has a vast pool of information where it can search for solutions to any potential risk. Additionally, the risk model will allow ACP analysts to quantify some of the key risks, facilitating the development of a cost benefit analysis.

Furthermore, ACP, as advised by the Expert Technical Committee consultants (professors Ashley, Molenaar and Alarcón), is beginning to develop a risk register. The risk register is a tool that will allow ACP to monitor the status of a risk and its mitigation strategy.

Another initiative in this regard is the use of both the risk register and risk model to establish a contingency resolution baseline. The idea behind the contingency resolution is that through the establishment of key project milestones, one can go back and review the risk/contingency model and re-evaluate contingency, effectively reducing it. For example, if a major contract for the locks is awarded, several of the risks should be reduced at this point, such as the risk of having few bidders; then parameters in the model must be updated to reflect the new situation. At the same time, the risk register must be reviewed to reflect the status of the risk.

Throughout the life of the project ACP can, and should, use the risk model, the risk register, and the resolution schedule, aided by risk management software, to help manage any potential risks, track the use of contingency, control mitigation strategies and more efficiently use project resources. The work done so far is the cornerstone in setting the path towards effective risk management for the Third Lane Locks program.

V. Appendices

Appendix 1 - Risk Analysis Milestones
- Workshop participants
- Value Management Workshop
- Expansion Program Risks Workshop
- Parameter Revision Workshop
- Additional Consultant Information

Appendix 2 - Expansion Program Risks Workshop Results

Appendix 3 - Definition of the Critical Risks
Appendix 4 - Lock Allowances
Appendix 5 - Model Parameters and Assumptions

Appendix 1 – Risk Analysis Milestones

Date	Milestone	Developed by	Results and Documentation
January 2004	Evaluation of ACP's regulatory framework strength and weaknesses in the Context of the Canal Expansion Program	Sullivan & Cromwell LLP, Global leading law firm in legal advice. Consulting lawyers Sergio Galvis and Frederic Rich.	Among the multiple recommendations, Sullivan & Cromwell identified risks and their possible mitigation measures. Report: *Investigation and Legal Analysis at the International Level*, January 2004
October 2004 – May 2005	ACP contracts Aon Risk Services, experts in risk management, to evaluate Canal expansion program risks	Aon team, leader in the risk management solutions market and present in 120 countries. Consultants: Paul Bitner, Lisa Kremer, Corey Gooch, Danielle Jones, Christopher Bohn, Joe Rizzo.	Preliminary list of risks, risk map, development of risk model. Report: *Canal Expansion Risk Assessment Report*, May 2005
August 2005	Value Management Workshop	Experts from The United States, Sweden, Germany, Belgium, Venezuela, Colombia, France, England, Australia, and Panama (see list of participants below)	More than 300 project risks were identified in the Administration, Labor, Operations, Design, Site Conditions, Finance, Politics and Construction categories Report: Preliminary Report on Expansion Program Risks, September, 2005
September 2005	Financial and Risk Model Review	Dr. Mauricio Jenkins, Academic Director of the Executive Program and Professor at the INCAE.	Report on his findings, October 2005. Recommended several changes to the risk model. Report: Informe de Mauricio Jenkins, PhD-Consultor, October 2005
September 2005	Review of the Cost Estimate and Schedule	Renowned experts in construction project risks: Dr. David Ashley (Executive Vice Chancellor and Provost University of California), Dr. Keith Molenaar (Assistant Professor, University of Colorado) and Dr. Clifford Schexnayder (Eminent Scholar Emeritus, Arizona State University).	It was concluded that the contingency of the cost estimate was not base on a risk analysis and an effort to integrate the cost estimate and the risk model was initiated.. Report: *Review of the Cost Estimate and Schedule for the Panama Canal 3rd Lane Locks*, Oct. 2005
October 2005	Consultants contracted to advice on the development of a risk analysis based contingency	Renowned experts in construction project risks: Dr. David Ashley (Executive Vice Chancellor and Provost University of California), Dr. Keith Molenaar (Assistant Professor, University of Colorado) and Dr. Luis Alarcón (professor, Pontificia Católica de Chile).	Terms of reference were developed for advice on the contingency estimation, and risk mitigation and management. Report: *Developmental Support of Project Risk Management for the Third Lane Locks Project*, October 2005

Date	Milestone	Developed by	Results and Documentation
October 2005	Expansion Program Risk Workshop	ACP Team (specialists and top management)	A list of 184 risks was consolidated. Each risk was evaluated in terms of probability and impact and preliminary mitigation measures were identified. Report: *Resultados del Taller de Administración de Riesgos,* November 2005
October-November 2005	Working sessions to develop project contingency based on risk analysis and integration of risk model and cost estimate	Renowned experts in construction project risks: Dr. David Ashley (Executive Vice Chancellor and Provost University of California), Dr. Keith Molenaar (Assistant Professor, University of Colorado) and Dr. Luis Alarcón (professor, Pontificia Católica de Chile). ACP team was composed of personnel from FM, IP and OPD.	The list of 184 risks was reduced to 14 using the quantitative results of the expansion program risk workshop. Risk model was integrated with the cost estimate. Contingency based on risk analysis achieved. Total cost of investment estimated. Report: *Overview of Risk Modeling Accomplishments*, November 2005
November 2005	Parameter Revision Workshop	Personnel from ODP, PAC, IP, IP, SI, ES, and FM	Risk model parameters were validated. A document describing the methodology of the model and its parameters was developed. Report: *Risk Model and Contingency Estimation*, December, 2005
December 2005 – January 2006	Follow up to risk/contingency model development	Renowned experts in construction project risks: Dr. David Ashley (Executive Vice Chancellor and Provost University of California), Dr. Keith Molenaar (Assistant Professor, University of Colorado) and Dr. Luis Alarcón (professor, Pontificia Católica de Chile).	Model methodology and risk parameters were reviewed. Refinements were recommended. Initial look at development of a Risk Charter. Report: *Summary of ACP vist*, December 2005
February 2006	Risk Model deployment	Renowned experts in construction project risks: Dr. David Ashley (Executive Vice Chancellor and Provost University of California), Dr. Keith Molenaar (Assistant Professor, University of Colorado) and Dr. Luis Alarcón (professor, Pontificia Católica de Chile).	Final review to risk model and presentation to ACP. Additional recommendations for Mitigation Management Process. Report: *Final Report*, February 2006

Workshop participants

Value Management Workshop

	Name	Organization / Title
1	Jorge L Quijano	Autoridad del Canal de Panamá
2	Agustin A Arias	Autoridad del Canal de Panamá
3	Jorge de la Guardia	Autoridad del Canal de Panamá
4	Ilya de Marotta	Autoridad del Canal de Panamá
5	Albert Joyce	Autoridad del Canal de Panamá
6	Cheryl George	Autoridad del Canal de Panamá
7	Adriano Espino	Autoridad del Canal de Panamá
8	Boris Moreno	Autoridad del Canal de Panamá
9	Angie S. de Hanily	Autoridad del Canal de Panamá
10	Juan Wong	Autoridad del Canal de Panamá
11	Rogelio Gordon	Autoridad del Canal de Panamá
12	Efrain Isaza	Autoridad del Canal de Panamá
13	Luis Alfaro	Autoridad del Canal de Panamá
14	Cesar Kiamco	Autoridad del Canal de Panamá
15	Enrique Sanchez	Autoridad del Canal de Panamá
16	Bernhard Kemnitz	Bundesaustalt fur Wasserbau
17	Rick Schultz	US Army Corps of Engineers
18	Jens Korsgaard	Han Padron
19	Bengt Forsberg	Retired Construction Manager - Skanska
20	Jose De Regge	Consorcio Post-Panamax
21	Laurie Mahon	Parsons Brinckerhoff International, inc
22	Dr Gabriel Fernandez	Montgomery Watson Harza
23	Eberhard Grimm	Bundesaustalt fur Wasserbau
24	Jean Louis Mathurin	Consorcio Post-Panamax
25	John Roberts	Parsons Brinckerhoff International, inc; USA
26	Larry Dalton	US Army Corps of Engineers
27	William Caitlin	Retired Construction Manager – Washington Group
28	Rik Thomas	Consorcio Post-Panamax
29	Reece Shaw	Parsons Brinckerhoff International, inc; Panama
30	David Williams	Parsons Brinckerhoff International inc; USA
31	Sebastien Roux	Consorcio Post-Panamax
32	George Currie	Parsons Brinckerhoff International, inc; Malaysia
33	Corina Briceno	Parsons Brinckerhoff International, inc; Panama
	Facilitation Team	
34	Dr. David Stevens	Social Enterprise Consulting
35	Caroline Shindlair	Social Enterprise Consulting

Expansion Program Risks Workshop

	Name	ACP Area
1	Manuel Benítez	DA
2	Hortencia Broce	ESM
3	Daniel Muschett	ESM
4	Efraín Isaza	FMC
5	Enrique Sánchez	FMC
6	Carmen Pagés	FMP
7	Ana Reyes	FMP
8	Walter Luschinger	FMPC
9	Ricardo Ungo	FMPD
10	José Arias	FMPD
11	José Salinas	FMXR
12	Liliana Arias	FMXR
13	Patricia Alvarado	FMXR
14	Ana María Chiquilani	HR
15	Boris Moreno	HR
16	Augustín A. Arias	IP
17	Cheryl George	IPCE
18	Rigoberto Delgado	IPCE
19	Juan Wong	IPCE
20	César Kiamco	IPCE
21	Rogelio Pinilla	IPCG
22	José Pascal	IPCH
23	Yolanda Chin	IPCN
24	Luis Santanach	IPDO
25	Ramiro Parada	IPIC
26	Rogelio Gordon	IPIM
27	Yasmin Small	IPIS
28	Max Newman	MRRT
29	Arcelio Hartley	MRT
30	Peter Langman	MRTC
31	Chet Lavalas	MRTP
32	Jorge de la Guardia	ODP
33	Ilya de Marotta	ODP
34	Albert Joyce	ODP
35	Angie de Hanily	ODP
36	Raúl Brostella	PAC
37	Corina Briceño	PB
38	Reece Shaw	PB
39	Valentyne Lynch	PMMP
40	Onésimo Sánchez	PMXI

Parameter Revision Workshop

	Name	ACP Area
1	Hortencia Broce	ESM
2	Héctor Cotes	FMBC
3	Efraín Isaza	FMC
4	Ricardo Ungo	FMPD
5	Patricia Alvarado	FMXR
6	Augustin Arias	IP
7	Cheryl George	IPCE
8	Rigoberto Delgado	IPCE
9	Rogelio Pinilla	IPCG
10	Yolanda Chin	IPCN
11	Larry Mirones	IPDI
12	Luis Santanach	IPDO
13	Raúl Figueroa	IPDO
14	Ramiro Parada	IPIC
15	Luis Paniza	IPIO
16	Yasmin Small	IPIS
17	Angie de Hanily	ODP
18	Jorge de la Guardia	ODP
19	Ilya de Marotta	ODP
20	Francisco Miguez	PAC
21	Sergio Burke	SIIE

Additional Consultant Information

Sullivan & Cromwell
Sullivan & Cromwell LLP provides the highest quality legal advice and representation to clients around the world. Today, S&C is a leader in each of its core practice areas such as legal, finance and corporate governance in each of its geographic markets. S&C comprises approximately 600 lawyers. They serve clients around the world through a network of 12 offices, located in leading financial centers in Asia, Australia, Europe and the United States. Headquartered in New York.

Aon Risk Services
Headquartered in Chicago, Aon Corporation is a leading provider of risk management services, insurance and reinsurance brokerage, human capital and management consulting, and specialty insurance underwriting. Aon has an employee base of 47,000 people working in 500 offices in more than 120 countries around the world. Headquartered in Chicago.

David Ashley
PHD in Civil Engineering with emphasis in Engineering and Construction Management, Stanford University, 1977.
David B. Ashley is the Executive Vice Chancellor y Provost of the University of California, Merced. He is also the Shaffer-George Chair of Engineering at University of California, Merced.
His work focuses on risk analysis for project management and project construction engineering decisions. He has worked in the development of mitigation strategies for potential sources of cost overruns.

Luis Alarcón
PhD and Masters (M.S.) (1991) in Project Management and Masters (M.Eng.) in Civil Engineering (1984) from University of California, Berkeley. Professor of the

Engineering Department and Construction Management at Universidad Pontificia Católica, Chile.

Keith Molenaar
PhD in Civil Engineering with emphasis in Construction Management and Engineering from the University of Colorado at Boulder.
Research focus: Alternative Project Deliver Methods for Infrastructure and the Build Environment (Design-Build), Construction Cost and Schedule Risk Analysis.

Corina Briceño
Civil Engineer from the University of New Brunswick, Fredericton, New Brunswick, Canada. Vast experience in large construction project cost estimation with emphasis on tunnels, great underground structures, dams and hydro electrical plants, lines of transmission, water treatment plants, highways, rails, etc.

Mauricio Jenkins
PhD in Internacional Enconomics and Finance from Brandeis University. Masters in in Internacional Enconomics and Finance from Brandeis University. Masters in Business Administration with honors from INCAE, Costa Rica. Jenkins has served as consultant for the Harvard Institute for International Development (HIID), the government of Costa Rica, and important enterprises in the Latin-American region. Consulting activities focus on enterprise valuation, investment project valuation and financial strategy.

Appendix 2 – Expansion Program Risks Workshop Results

Resultados del taller

El 26 de octubre del 2005 se llevó a cabo un taller de evaluación de riesgos. En este taller participaron unas 40 personas de diversas áreas de la ACP, contando con la presencia del Sub-administrador, y varios Directores de Departamento. Esta sesión buscaba introducir a los participantes a conocimientos generales de riesgos, validar el impacto de los riesgos identificados, y determinar medidas preliminares de mitigación de riesgos.

Durante el taller se evaluaron 184 riesgos en términos de probabilidad de ocurrencia e impactos en costo y tiempo. Adicionalmente se identificaron, para cada uno de los riesgos, medidas de mitigación preliminares. Los resultados del taller fueron discutidos por todos los participantes en una sesión plenaria donde se hicieron ajustes y se llegó a un consenso. A continuación los resultados generales del taller:

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
1	Administración: Administración de Proyectos	Carencia de capacidad para ejecutar	80	Establecer sistema de control y monitoreo (project management control)
2	Político: Política interna	Falta de experiencia	72	Capacitar personal interno y/o contratar personal externo
3	Administración: Controles	Falta de controles	54	Implementar una reorganización
4	Administración: Planificación	Inexperiencia en planificación	54	Definir y alinear recursos
5	Administración: Planificación	Estructura organizacional inadecuada	54	Asegurar información adecuada y definir líneas de autoridad
6	Administración: Planificación	Recursos no alineados con las necesidades del proyecto	54	Asignar recursos requeridos con plan de acción y seguimiento
7	Administración: Planificación	Proceso de toma de decisiones deficiente	54	Entrenamiento y capacitación:
8	Administración: Contrataciones	Método de contratación inadecuado (DBB, DB)	54	Asesorarse para determinar tipo de contrato adecuado
9	Administración: Administración de Proyectos	Falta de autoridad	50	Asignar responsabilidades
10	Finanzas: Inflación	Incremento en el costo del proyecto por razón inflacionaria	50	Crear reserva / contingencia
11	Administración: Controles	Falta de asignación de responsabilidades	40	Asignar responsabilidades
12	Administración: Controles	Archivos incompletos/inadecuados	40	Establecer sistema de control y monitoreo (project management control)
13	Administración: Contrataciones	Carencia de responsabilidad asignada a los miembros de la ACP	40	Asignar responsabilidades
14	Administración: Administración de Proyectos	Comunicación inadecuada (a lo interno de ACP, contratistas, etc.)	40	Establecer estrategias de comunicación con protocolos adecuados
15	Político: Referéndum	Tardanza en el Referéndum	40	Apoyar a la Administración con la identificación del costo y la información
16	Político: Política interna	Líneas de autoridad no definidas	40	Cambio en la estructura organizacional
17	Político: Público panameño	Oposición pública organizada	40	Estrategia de comunicación, identificar la urgencia
18	Administración: Contrataciones	Definición inadecuada del alcance del proyecto/tarea	36	Definir el proyecto
19	Mano de obra: Productividad	Malas condiciones atmosféricas	36	Transferir al contratista
20	Diseño: Desempeño	Mala escogencia de diseñadores	36	Precalificación exhaustiva
21	Finanzas: Presupuesto	Subestimación del presupuesto	36	Incluir contingencias adecuadas, revisión constante del mismo, monitoreo
22	Finanzas: Flujo de Caja	Sobrecostos	36	Establecer controles adecuados, mantenerse informado sobre cambios en el mercado,

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
				controles en la ejecución del proyecto, cláusulas contractuales en el contrato (fixed), identificar contingencia
23	Construcción: Programa y retrasos	Retrasos de compras	36	Establecimiento de programa detallado de compras, suplidores alternativos
24	Construcción: Calidad	Materiales de baja calidad	36	Especificaciones detalladas y claras, control de calidad, fianzas de cumplimiento
25	Administración: Controles	Falta de interacción con el contratista	32	Establecer canales de comunicación claros y protocolo
26	Administración: Administración de Proyectos	Coordinación inadecuada con los contratistas	32	Establecer canales de comunicación claros y protocolo
27	Administración: Contrataciones	Proceso de compras/contratación ineficiente	30	Agilizar proceso de contratación
28	Diseño: Materiales	Costo alto de materiales especificados	30	Al contratista
29	Condiciones de Sitio: Clima	Lluvia	30	(Contratista puede tener acciones para no impactar su productividad)
30	Finanzas: Cambio Monetario	Impacto de cambio monetario en los ingresos del contratista	30	Se establece por contrato
31	Político: ONGs	Alto en el financiamiento	30	Transparencia en la divulgación
32	Político: ONGs	Oposición organizada de las ONGs	30	Transparencia en la divulgación
33	Construcción: Costos	Incremento en cantidades requeridas	30	Investigación de campo, pruebas geosísmicas
34	Administración: Administración de Proyectos	Administración de reclamos inadecuada	28	Establecer sistema de control y monitoreo (project management control)
35	Finanzas: Flujo de Caja	Insuficiencia en ingresos	28	Mantener confiabilidad, ajustar peajes, mantener reservas adecuadas
36	Administración: Ambiente	No completar a tiempo los estudios ambientales	24	Mejor planificación, definición del proyecto y realizar estudio oportunamente
37	Administración: Ambiente	Retaso en la aprobación del estudio de impacto ambiental	24	Darle prioridad y asignar recursos con mejor planificación
38	Administración: Ambiente	Planificación insuficiente para el proceso ambiental	24	Mejor planificación adecuada
39	Mano de Obra: Disponibilidad	Falta de mano de obra local	24	Plan Nacional de capacitación
40	Mano de Obra: Disponibilidad	Falta de habilidades requeridas	24	Plan Nacional de capacitación
41	Mano de obra: Relaciones laborales	Huelga	24	Exigir al contratista que ofrezca buenas condiciones laborales y de seguridad (continuo)
42	Mano de obra: Habilidades	Falta de programas de capacitación	24	Plan Nacional de capacitación
43	Diseño: Criterios	Cambios en los criterios durante el diseño	24	Consultas y participación permanente del usuario
44	Condiciones de Sitio: Sísmico	Definición incorrecta de estándares	24	Realizar más estudios y hacer una revisión por expertos, consultoría
45	Condiciones de Sitio: Sísmico	Data de campo incompleta	24	Hacer más investigaciones, recomendaciones del Geotechnical Board
46	Político: Público panameño	Falta de mano de obra local especializada	24	Capacitar y contratar mano de obra especializada
47	Construcción: Costos	Incremento en el costo de insumos, equipo, servicios y mano de obra	24	Establecer acuerdos de precio fijo
48	Administración: Administración de Proyectos	Falta de cantidad y calidad de recursos de administración de proyectos	20	Asignar recursos requeridos con plan de acción y seguimiento
49	Operaciones: Navegación	Pérdida de Lago Gatún	20	Mantenimiento y mejoras. Vigilancia y seguridad.
50	Operaciones: Agua	Desborde de la represa (subestimación de la afluencia de agua, selección inadecuada del tipo de represa)	20	Peer review de diseño
51	Diseño: Programa	Cronograma de diseño inflexible para ajustarse a cambios en la	20	Con una buena investigación, diseño y consulta con expertos

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
		construcción		
52	Condiciones de Sitio: Geotécnica	Falta de información correcta	20	Hacer más investigaciones
53	Condiciones de Sitio: Geotécnica	Condiciones no previstas	20	Transferir en los términos del contrato, permitir que el contratista haga más investigaciones
54	Condiciones de Sitio: Clima	Calor	20	
55	Político: Referéndum	Referéndum negativo	20	Estrategia de comunicación
56	Político: Política interna	Cambios en la alta dirección	20	Reemplazo
57	Político: Internacional	Oposición pública organizada	20	Estrategia de comunicación, identificar la urgencia
58	Construcción: Programa y retrasos	Imposiciones externas al programa	20	Establecer acuerdos bilaterales, trilaterales tanto a nivel local e internacional
59	Construcción: Programa y retrasos	Falta de coordinación (ACP, contratistas, subcontratistas)	20	Buen "Program Manager", control del programa estricto
60	Construcción: Costos	Cambio o crecimiento significativo del alcance del proyecto	20	Definición del alcance
61	Construcción: Costos	Terrorismo, eventos inesperados	20	Coberturas específicas
62	Administración: Contrataciones	Carencia de licitaciones o pocas licitaciones	18	Precalificación con requisitos mínimos y divulgar el proyecto
63	Finanzas: Cambio Monetario	Incremento en el precio de materiales	18	Elaborar manejo de aumento en el contrato, manejo de índices.
64	Finanzas: Inflación	Impacto de la inflación en el financiamiento	18	Negociar buenos términos en los préstamos, programación adecuada de las necesidades
65	Construcción: Calidad	Especificaciones pobres	18	Buen "Program Manager", equipo de supervisión multidisciplinario
66	Construcción: Calidad	Incumplimiento de planes y especificaciones	18	Precalificación adecuada
67	Administración: Administración de Proyectos	Exceso de subcontratistas	16	Transferir al contratista
68	Administración: Ambiente	Manejo inadecuado de organizaciones ambientales (ONGs)	16	Establecer estrategia de coordinación y manejo de grupos interesados. Mejorar comunicación
69	Mano de Obra: Disponibilidad	Alta rotación del personal	16	Exigir al contratista que ofrezca buenas condiciones laborales y de seguridad (continuo)
70	Mano de obra: Relaciones laborales	Competencia entre contratistas ("robo" de personal especializado)	16	Incluir en la contratación prohibición de contratación de empleados de otro contratista
71	Diseño: Programa	No cumplimiento con los hitos del diseño	16	Con planificación, recursos, y con seguimiento, buen sistema de project management (consultor externo)
72	Finanzas: Presupuesto	Propuestas más altas que los estimados de costos	16	Buena definición del proyecto, estimaciones independientes
73	Finanzas: Presupuesto	Problemas de diseño	16	Revisión por expertos
74	Finanzas: Financiamiento	Inhabilidad de cumplir los requisitos de prestamistas en materia ambiental	16	Guiarse por los principios de Ecuador, tener un plan de mitigación y de monitoreo ambiental adecuado, tener un plan de consulta
75	Construcción: Programa y retrasos	Eventos inesperados (clima, naturaleza, crisis)	16	Contratar coberturas específicas
76	Construcción: Programa y retrasos	Programa irrealista	16	Buen "Program Manager", control del programa estricto
77	Construcción: Costos	Retrasos significativos en el programa	16	Coberturas específicas
78	Construcción: Materiales	Insuficiencia de materiales (ejemplo: arena)	16	Mercados alternativos
79	Construcción: Equipo	Falta de disponibilidad de equipo	16	Equipos alternativos, trabajos manuales
80	Operaciones: Operaciones de nuevas esclusas	Asentamientos diferenciales de las nuevas estructuras	14	Revisión de diseño y control durante la construcción
81	Operaciones: Equipo	Redundancia insuficiente	14	Revisión criterios de diseño, de diseño y especificaciones de equipo

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
82	Condiciones de Sitio: Sísmico	Tsunami o terremotos	14	
83	Construcción: Programa y retrasos	Desempeño inadecuado del contratista	14	Pre-calificación adecuada, supervisión y seguimiento de las obras en construcción
84	Construcción: Costos	Reclamos mayores	14	Definición adecuada de contratos
85	Mano de obra: Relaciones laborales	Disminución del ritmo de trabajo	12	Exigir al contratista que ofrezca buenas condiciones laborales y de seguridad (continuo)
86	Operaciones: Equipo	Equipo sobre diseñado o diseñado deficientemente	12	Revisión criterios de diseño, de diseño y especificaciones de equipo
87	Condiciones de Sitio: Arqueología	Falta de información	12	Estudios adicionales
88	Político: Política interna	Comunicación laboral interna	12	Estrategia de comunicación, posicionar la urgencia del proyecto
89	Político: Política interna	Inhabilidad de reestructurar la organización	12	Tomar la decisión de cambio
90	Construcción: Programa y retrasos	Huelgas	12	Medidas Contractuales/Penalización por incumplimiento, Seguros
91	Construcción: Costos	Accidentes	12	Seguridad Industrial/Salud Ocupacional
92	Construcción: Calidad	Control de calidad inefectivos	12	Establecer programa adecuado de inspección, control
93	Construcción: Materiales	Insuficiencia a nivel global	12	Concentrarse en áreas del proyecto en las cuales se pueda avanzar
94	Construcción: Materiales	Retrasos de entregas	12	Penalizaciones y cláusulas del contrato
95	Construcción: Equipo	Retrasos en la movilización del equipo	12	Planeación adecuada, "Program manager"
96	Condiciones de Sitio: Clima	Inundación	10	Requerir del contratista Instalación de bombas, manejo apropiado de crecidas, plan de ejecución adecuado para la construcción de la presa del PMD y diseño adecuado de los tapones y estructuras
97	Político: Público panameño	Falta de entendimiento público	10	Estrategia de comunicación, identificar la urgencia
98	Construcción: Materiales	Planificación de compras y administración de inventarios inadecuada	10	Planeamiento adecuado
99	Mano de obra: Habilidades	Contratación de personal inadecuada	8	Programa de adiestramiento para personal potencial
100	Mano de obra: Costo	Diferencial en salarios (local vs. importado)	8	Transferir al contratista
101	Operaciones: Navegación	Unión de los prácticos	8	Nuevas contrataciones para Post-Panamax
102	Operaciones: Agua	Sequía	8	
103	Diseño: Desempeño	Especificaciones de desempeño incompatibles con el diseño de proyecto	8	Al diseñador
104	Condiciones de Sitio: Geotécnica	Roca no apropiada como agregado	8	Establecer en el contrato la libertad al contratista de decidir procesar el material disponible o utilizar material de otro sitio.
105	Finanzas: Financiamiento	Quiebra del contratista	8	Obtener fianza de cumplimiento
106	Político: Referéndum	Estrategia de comunicación pobre	8	Implementar estrategia de comunicación
107	Construcción: Programa y retrasos	Retrasos causados por el dueño (ejemplo: equipo suministrado por el dueño)	8	Desarrollo de Planes de seguimiento del proyecto "Fast Track Approval System"
108	Construcción: Programa y retrasos	Daño a compuertas durante su transporte	8	Coberturas específicas
109	Construcción: Calidad	Coordinación inapropiada con el contratista	8	Canales de comunicación abiertas, reuniones periódicas de seguimiento
110	Construcción: Equipo	Daños irreparables	8	Reemplazo de equipo
111	Mano de obra: Habilidades	Falta de supervisión efectiva	6	Programa de adiestramiento para supervisores potenciales. Desarrollo de perfil deseado.
112	Operaciones: Navegación	Derrumbes (inestabilidad de la represa)	6	Programa de control de derrumbes. Diseño adecuado

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
113	Condiciones de Sitio: Sísmico	Criterio de diseño incompatible	6	Hacer más investigaciones, recomendaciones del Geotechnical Board
114	Condiciones de Sitio: Clima	Derrumbes	6	Estudio geotécnico, diseño adecuado, seguridad en el área, estabilización de las excavaciones
115	Condiciones de Sitio: Arqueología	Descubrimientos arqueológicos en sitio	6	Hacer rescate
116	Finanzas: Presupuesto	Alcance del proyecto incompleto	6	Peer Review, consultores independientes, otras unidades
117	Finanzas: Financiamiento	Inhabilidad en la obtención de un financiamiento aceptable	6	Buena calificación de riesgo, mejorar la eficiencia de rendimiento de la empresa
118	Finanzas: Demanda	Cambio en las condiciones de mercado	6	Utilizar el escenario pesimista de demanda (conservador)
119	Construcción: Ambiente	Contaminación de aire	6	Utilización de equipo de protección personal
120	Construcción: Ambiente	Contaminación por ruido y vibración	6	Utilización de equipo de protección personal
121	Construcción: Ambiente	Contaminación por polvo	6	Utilización de equipo de protección personal
122	Administración: Contrataciones	Corrupción	4	Promulgar normas de ética y establecer sistemas de control
123	Administración: Ambiente	Incumplimiento con los requisitos del programa de ambiente	4	Comunicar y asegurar cumplimiento (continuo)
124	Administración: Ambiente	Monitoreo inadecuado	4	Asegurar recursos para monitoreo adecuado (continuo)
125	Administración: Ambiente	No coordinación con ANAM	4	Coordinar efectivamente con ANAM (continuo)
126	Mano de Obra: Disponibilidad	Restricciones en mano de obra importada	4	Coordinar con el Gobierno mecanismos para facilitar la mano de obra requerida
127	Mano de obra: Seguridad	Falta de programas de seguridad	4	Transferir al contratista
128	Operaciones: Navegación	Accidentes de buques	4	Control en la navegación
129	Operaciones: Navegación	Desestabilización de pendientes existentes	4	Programa de control de derrumbes.
130	Operaciones: Navegación	Interferencia del contratista con las operaciones existentes	4	Coordinación y comunicación
131	Operaciones: Operaciones de esclusas existentes	Daños por vibración y explosión	4	Al contratista pero monitorear
132	Operaciones: Operaciones de esclusas existentes	Equipo flotante del contratista interfiere con la operación	4	Coordinación y comunicación
133	Operaciones: Operaciones de nuevas esclusas	Subestimación en el tiempo de tránsito (Problemas inesperados con remolcadores; velocidad del sistema de llenado y vaciado; cálculo estimado de las compuertas, etc.)	4	Modelo a escala. Simulaciones. Análisis predictivo
134	Diseño: Desempeño	Incompatibilidad del tamaño de la esclusa con relación a la flota futura	4	Estudios de mercado, y visión
135	Diseño: Desempeño	Revisiones de “contructability” insuficientes	4	Hacer revisiones
136	Diseño: Criterios	Falta de previsión	4	Consultas y participación permanente del usuario
137	Diseño: Criterios	Falta de optimización de criterios	4	Consultas y participación permanente del usuario
138	Diseño: Programa	Imposiciones externas que impactan la programación de diseño	4	Comunicación, diplomacia
139	Diseño: Programa	Programación irreal para el desarrollo del diseño	4	Al diseñador
140	Condiciones de Sitio: Geotécnica	Interpretación incorrecta de muestras geológicas	4	Peer Review, control de calidad
141	Condiciones de Sitio: Clima	Viento	4	
142	Condiciones de Sitio: Clima	Tormentas	4	
143	Condiciones de Sitio: Clima	Neblina	4	
144	Condiciones de Sitio: Clima	Sequía	4	

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
145	Condiciones de Sitio: Ambiente	UXO (Explosivos inesperados)	4	Adecuar el área
146	Condiciones de Sitio: Ambiente	Descubrimiento de especies nuevas o en extinción	4	Preservar y/ o rescatar
147	Finanzas: Financiamiento	Baja rango en la tasa crediticia de la ACP	4	Mantener manejo financiero adecuado y el manejo de la empresa
148	Finanzas: Financiamiento	Inhabilidad en la obtención de requisitos legales del prestamista	4	Adecuar nuestras regulaciones y procedimientos
149	Finanzas: Flujo de Caja	Cambios en el flujo de pagos	4	Establecer y monitorear los requisitos de flujo de caja y de los ingresos
150	Finanzas: Demanda	Errores en el análisis de sensibilidad de precios	4	Realizar estudios para actualizar las proyecciones en precio
151	Finanzas: Demanda	Crisis económica mundial	4	Utilizar el escenario pesimista de demanda (conservador)
152	Político: Gobierno	Gobierno no actúa a tiempo	4	Estrategia de comunicación, posicionar la urgencia del proyecto
153	Político: Gobierno	Cambios legales/leyes	4	Estrategia de comunicación, posicionar la urgencia del proyecto
154	Político: ANAM	Cambios en las reglas y procedimientos	4	Incluir medidas de mitigación en el proyecto
155	Político: ANAM	Retrasos en el proyecto relacionados con ANAM	4	Incluir medidas de mitigación en el proyecto
156	Político: ANAM	Interferencia de ANAM	4	Incluir medidas de mitigación en el proyecto
157	Político: ANAM	Requisitos de mitigación	4	Incluir medidas de mitigación en el proyecto
158	Construcción: Ambiente	Contaminación de agua (Ejemplo: derrames de derivados de petróleo)	4	Supervisión y diseño de Planes de Contingencia
159	Construcción: Programa y retrasos	Retraso debido a problemas en el flujo de caja de ACP (ACP y contratista)	4	Alternativas de financiamiento, fondos de contingencia
160	Construcción: Programa y retrasos	Interferencia debido a operaciones	4	Coordinación y comunicación interna
161	Construcción: Materiales	Requisitos de procesamiento inesperados (ejemplo: tamaño de agregado de concreto)	4	
162	Construcción: Equipo	Falta de mantenimiento	4	Supervisión adecuada
163	Construcción: Equipo	Bajo desempeño	4	Pre-calificación adecuada, supervisión y seguimiento de las obras en construcción
164	Construcción: Equipo	Falta de piezas de repuesto	4	Alquiler de equipos
165	Mano de obra: Costo	Aumento escalonado de salarios	2	Transferir al contratista
166	Operaciones: Navegación	Corrientes de densidad diferenciada	2	Adiestramiento a pilotos
167	Operaciones: Operaciones de nuevas esclusas	Desperfecto en el funcionamiento de las compuertas	2	Garantía del suplidor
168	Operaciones: Operaciones de nuevas esclusas	Fuerzas "hauser" excesivas	2	Modelos analíticos y físicos (parte del modelo hidráulico)
169	Operaciones: Equipo	Programas de mantenimiento inadecuados	2	Planificar mantenimiento
170	Diseño: Materiales	Redundancia insuficiente	2	Al contratista
171	Diseño: Criterios	Necesidades del agua subestimadas	2	Análisis, pronósticos
172	Finanzas: Demanda	La competencia aumenta su penetración de mercado	2	Utilizar el escenario pesimista de demanda (conservador)
173	Finanzas: Demanda	Imprecisas proyecciones de ingresos	2	Utilizar el escenario pesimista de demanda (conservador)
174	Político: Referéndum	Falta de claridad en la propuesta	2	Escribir con términos simples y sencillos la propuesta (una sola pregunta, sí o no)
175	Político: Gobierno	Interferencia de gobierno	2	Estrategia de comunicación, posicionar la urgencia del proyecto
176	Político: Gobierno	Demanda de fondos adicionales	2	Regirnos por el Titulo Constitucional y la Ley Orgánica
177	Político: Gobierno	No proveer los permisos necesarios	2	Estrategia de comunicación, posicionar la urgencia del proyecto

#	Categoría: Área de Riesgo	Riesgo Específico	Puntuación	Mitigación
178	Político: Internacional	Guerra	2	Utilizar el Tratado de Neutralidad, aumentar la seguridad
179	Político: Internacional	Intervención de los EU - Tratado de Neutralidad	2	
180	Político: Internacional	Falta de respaldo por parte de otros países	2	Comunicación, cabildeo
181	Construcción: Ambiente	Cambios a los requisitos de áreas de bote de material cavado	2	Evaluar costos y otros sitios
182	Administración: Planificación	Asignación de dueños del tiempo flotante del cronograma	0	Repetido
183	Operaciones: Agua	Pérdida del Lago Gatún por la ruptura de la represa	0	Repetido
184	Construcción: Costos	Incremento de costo de insumos	0	Repetido

Comentarios finales

Los riesgos con mayor puntuación tienden a ser riesgos administrativos, resultado que es apoyado por los estudios anteriores. Los riesgos políticos también presentaron altas calificaciones, seguidos por riesgos financieros, de mano de obra, de construcción, diseño y condiciones de sitio. Esto indica que por el momento existe mayor preocupación por riesgos inmediatos como son los organizacionales y políticos; lo que pudiera cambiar a medida que el proyecto evoluciona. |

Los resultados del taller se utilizan actualmente en el modelo de riesgos generado de la ACP. Aquellos riesgos identificados como prioritarios se simulan ayudando a calcular las contingencias necesarias para el proyecto. De esta manera se incorporan tanto los esfuerzos realizados anteriormente en materia de evaluación de riesgos de la ampliación, como el conocimiento de los colaboradores de la ACP en sus áreas de experticia.

Se espera continuar con la evaluación de los riesgos de la ampliación mediante el continuo refinamiento del modelo de riesgos. Adicionalmente, se debe llegar a un esquema de administración de riesgos que permita el monitoreo, la administración y la mitigación de los mismos. Para ello es necesario, no sólo la continua evaluación y planificación, sino también la participación activa del personal de diversas áreas de la ACP.

Appendix 3 – Definition of the Critical Risks

The following risks were identified as the most critical and therefore are included in the model

1. Organizational issues: This risk refers to a variety of risks directly related to the organization executing the project. Organizational risks include:
    a. Lack of execution capability
    b. Inadequate communications within ACP, between ACP and contractors, and among contractors,
    c. Unclear lines of authority
    d. Lack of accountability/responsibility of ACP personnel
    e. Inadequate organizational structure: Inability to restructure the organization, changes in top management

2. Lack of controls: The risk of lacking an adequate program control system, of having incomplete records, and poor coordination with contractors affecting the capability of mitigating and controlling risks.

3. Inefficient planning: Poor planning execution and capability. Includes the following:
    a. Lack of project planning experience
    b. Schedule risks – unrealistic, inflexible schedule, no assignment of schedule float ownership
    c. Poor or slow decision making process
    d. Un-alignment of resources with project needs
    e. Materials and equipment planning – delays in mobilization, unavailability of equipment, lack of equipment maintenance, poor material purchase and inventory management
    f. Lack of coordination with ongoing operations

4. Inefficient contracting process:
    a. Poor coordination with contractors
    b. Too many contractors and subcontractors
    c. Few bids
    d. Corruption
    e. Purchase delays
    f. Poor choice of designers
    g. Non compliance with specifications

5. General inflation: Cost changes due to variations in the overall level of prices.

6. Referendum delays: Delays in referendum date due to the following
    a. Environmental process delays – poor NGO relations management, non-compliance with environmental program requirements, lack of coordination with ANAM, and late approval of environmental impact study
    b. Government delays
    c. Public opposition

   d. Poor communication strategy
   e. Lack of public understanding

7. Extreme bad weather: Any weather condition beyond what has already been contemplated in the schedule. Does not include events such as tsunamis or hurricanes.

8. Owner driven changes: Changes in quantities due to
   a. Owner driven changes in project scope
   b. Changes in design criteria
   c. Poor specs
   d. Changes in design standards
   e. Incorrect definition of standards
   f. Incomplete field data
   g. Changes in estimated quantities

9. Insufficient revenues: Insufficient revenues due to a reduced number of Canal transits.

10. Inadequate claims resolution: Poor management of claims due to lack of controls, poor record keeping, or other.

11. Local labor strikes: Strikes during construction directly affecting progress.

12. Evolving design: Changes in quantities due to design changes.

13. Shortage of labor with required skills: Lack of skilled and local labor, lack of training.

14. Cost increases: Material, equipment, labor and services cost increases due to supply and demand issues.

Appendix 4 – Lock Allowances

Atlantic Locks

Bid Description	Unoff Holiday	Errors	Slides	Rain-Conc	Quan. Var.	Overbreak	Conc Waste	Cem Waste	Agg Waste	Stl Waste	Eqp Prod	Total	%
CONTRACTORS INDIRECTS	1,094,217	1,094,217									4,123,637	6,312,070	4%
MOBILIZATION & DEMOBILIZATION												-	
PRECONSTRUCTION WORKS												-	
EXCAVATION	2,072,299		2,072,299		2,486,758	2,486,758					6,548,992	15,667,106	10%
FILL	3,445,906		3,445,906		3,445,906	3,445,906					2,692,061	16,475,687	11%
CONCRETE - LOCK	5,560,160	5,560,160		5,560,160	13,344,384	2,668,877	13,266,337	2,491,271	10,820,544	7,069,440	9,138,422	75,479,755	49%
CONCRETE - WSB	2,409,926	2,409,926		2,409,926	5,783,822	1,156,764					4,442,055	18,612,419	12%
MECHANICAL					6,063,233					6,063,233		12,126,465	8%
ELECTRICAL					3,827,000							3,827,000	3%
SUPPORT SYSTEMS					4,125,325							4,125,325	3%
Total Allowance	14,582,507	9,064,303	5,518,205	7,970,086	39,076,429	9,758,306	13,266,337	2,491,271	10,820,544	13,132,673	26,945,168	152,625,827	100%
Allowance % of Total Cost	1.63%	1.01%	0.62%	0.89%	4.37%	1.09%	1.48%	0.28%	1.21%	1.47%	3.01%	17.06%	0%

Unofficial Holiday: 5 days/year (Death of ex-president, Carnival Monday, Holy Thursday)
Correction of errors: 6 days/year (Additional cost for contractor to repair/correct mistake)
Slides: 12 days total
Rain effect on concrete: 20 days (Additional cost for work to due to rain during concrete pour)
Quantity Variations: 10% on concrete, excavation, fill; 5% EM; 20% Electrical and Support systems
Overbreak: 10% of excavation; 1% of concrete
Concrete Waste: 10%
Cement Waste: 5%
Aggregate Waste: 15%
Reinforcing Steel Waste: 10% (to account for laps and waste)
Structural Steel Waste: 5%
Equipment Productivity: 83% effective
Hydraulic Mitigation (included in chamber concrete to account for design change)

Pacific Locks

Bid Description	Unoff Holiday	Errors	Slides	Rain-Conc	Quan. Var.	Overbreak	Conc Waste	Cem Waste	Agg Waste	Stl Waste	Eqp Prod	Total	%
CONTRACTORS INDIRECTS	968,500	968,500									3,481,015	5,418,015	4.4%
MOBILIZATION & DEMOBILIZATION											-	-	0.0%
PRECONSTRUCTION WORKS											255,305	255,305	0.2%
EXCAVATION	2,036,006		2,036,006		3,664,811	3,664,811					4,295,196	15,696,831	12.8%
FILL	510,191				1,836,686	1,836,686					3,030,203	7,213,767	5.9%
CONCRETE - LOCK	4,473,311	4,473,311		4,473,311	10,735,946	2,147,189	7,282,234	2,577,003	5,820,410	7,298,928	9,028,298	58,309,942	47.7%
CONCRETE - WSB	1,957,124	1,957,124		1,957,124	4,697,098	939,420					4,039,266	15,547,155	12.7%
MECHANICAL WORKS					6,127,902					6,127,902	-	12,255,803	10.0%
ELECTRICAL WORKS					3,417,000						-	3,417,000	2.8%
SUPPORT SYSTEMS					4,125,325						-	4,125,325	3.4%
Total Allowance	9,945,132	7,398,935	2,036,006	6,430,435	34,604,769	8,588,107	7,282,234	2,577,003	5,820,410	13,426,830	24,129,282	122,239,143	100.0%
Allowance % of Total Cost	1.23%	0.92%	0.25%	0.80%	4.29%	1.06%	0.90%	0.32%	0.72%	1.66%	2.99%	15.15%	

Unofficial Holiday: 5 days/year (Death of ex-president, Carnival Monday, Holy Thursday)
Correction of errors: 6 days/year (Additional cost for contractor to repair/correct mistake)
Slides: 12 days total
Rain effect on concrete: 20 days (Additional cost for work to due to rain during concrete pour)
Quantity Variations: 10% on concrete, excavation, fill; 5% EM; 20% Electrical and Support systems
Overbreak: 10% of excavation; 1% of concrete
Concrete Waste: 10%
Cement Waste: 5%
Aggregate Waste: 15%
Reinforcing Steel Waste: 10% (to account for laps and waste)
Structural Steel Waste: 5%
Equipment Productivity: 83% effective
Hydraulic Mitigation included in chamb (included in chamber concrete to account for design change)

Appendix 5 – Model Parameters and Assumptions

Model Structure

The 14 risks identified as critical, could be modeled in three major areas: the impact of reduced revenues, the impact of delays and the impact of cost overruns to the expansion project. In order to evaluate a risk-based contingency, detailed distributions and parameters were added to delays and cost overruns. Demand variations do not have any effect on the contingency. Some of the risks directly affect delays, some of them affect mainly cost overruns and some of them have an incidence on both delays and cost overruns at the same time.

Area	Risks
Delays	Extreme bad weather Referendum delay Organizational Risks Organizational Risks Lack of controls Inefficient planning Inefficient contracting process Local labor strikes
Cost overruns	General inflation Material, equip. & labor cost increases Inadequate claims administration
Delays & Cost overruns	Lack of skilled and local labor Evolving design, changes in quantities Owner driven changes
Market	Insufficient revenues

a. Market

This model takes as input projected transits, cargo and revenues under various macroeconomic and competitive environments generated by a demand model provided by Mercer Management Consulting Corporation. The first step was to merge the ACP financial model with the Mercer macroeconomic and competitive environment forecasts. To accomplish this, the ACP chose three macroeconomic scenarios and three competitive scenarios. These scenarios were defined as optimistic, expected, and pessimistic. The ACP assigned a probability of 17.5%, 65% and 17.5% to each of the macroeconomic scenarios and a probability of 10%, 80% and 10% to each of the competitive scenarios. Combining the macroeconomics and competitive scenarios will result in nine market scenarios with the following probabilities:

Competitive Scenario	**Macroeconomic Scenarios**		
	Pessimistic	Probable	Optimistic
Pessimistic	1.8%	6.5%	1.8%
Probable	14.0%	52.0%	14.0%
Optimistic	1.8%	6.5%	1.8%

For each iteration of the simulation, one of the nine market scenarios will be selected with its forecasts for cargo, transits and revenues, given the probabilities associated with each market scenario.

b. Delays

Delays impact the Expansion Project in two ways: first, there is a delay in additional revenue resulting from the opening of a third set of locks in the Canal; and second, there is an additional cost that arises from extending the works beyond the schedule (contractor's fixed cost and owner's fixed cost).

In order to model delays, the original schedule was varied by adding four different effects: first, variations to activities duration; second, variations in time due to changes in productivity and design changes; third, delays due to general events such as extreme bad weather and strikes; and delays due to activity-specific events. The sum of all those effects will generate the commissioning year plus time contingency.

Original commissioning year
+ activity duration variation
+ productivity/quantity variation
+ General events delay (weather, strikes)
+ Activity-specific events delay
= Commissioning year + time contingency

In first place, the duration of each activity in the schedule was scaled by a factor to increase or decrease the length of the activity. This factor summarizes the impact of the following risks on each activity: referendum delay, organizational risks, lack of controls, poor coordination, inefficient planning, lack of skilled and local labor, evolving design, owner driven changes and inefficient contracting process. (See Appendix 5).

The activities in the general schedule of the expansion project were used in the risk model. The model takes into account the schedule dependencies between activities. If an activity is delayed, which has activities depending on it to start, its dependents, and their subsequent dependents, will be delayed as well. For modeling purposes, we used only critical path activities or near-critical path activities in the risk model schedule. Below is the list of the main activities and the variation applied to each. All activities were varied using Triangular General[3] distributions.

[3] A Triangular General (Trigen) is a triangular distribution of three points with one most likely value and two at the specified bottom and top percentile (5% and 95% respectively).

Duration Variation	Triangular General Dist. Percentile 5%	most likely	Percentile 95%
Pre-construction Activities			
Approval process (BOD, N. Assembly)	1	1	1
Public Information Program	1	1	1
Environmental Appraisal	1	1	1
Referendum	1	1	1
Implementation Management System	0.9	1	1.25
Hydraulic Model Preparation & Testing	0.9	1	1.5
Detailed design and contracting docs	0.9	1	1.2
Contract process and Award - Locks	0.95	1	1.5
Contract process and Award - Access Channel	0.95	1	1.3
Contract Award and delivery - New Dredge	1	1	1.3
Access Channel			
Pacific Access Channel 1	0.9	1	1.2
Pacific Access Channel 2	0.9	1	1.2
Pacific Access Channel 3	0.9	1	1.2
Pacific Access Channel 4	0.9	1	1.2
Pacific Access Channel 5	0.9	1	1.2
Pacific Access Channel 6	0.9	1	1.2
Pacific Locks			
Mobilize Excavation Equipment	1	1	2
Mobilize Concrete Equipment	0.9	1	1.5
WSB 3 excavation	0.95	1	1.5
Chamber 3 excavation	0.9	1	1.4
Chamber 2 excavation	0.9	1	1.4
Chamber 3 concrete	0.9	1	1.3
Chamber 2 concrete	0.9	1	1.3
Chamber 1 concrete	0.9	1	1.3
Flood downstream	0.9	1	1.25
Electro-Mech Installation	0.8	1	1.25
General Testing	0.95	1	1.05
Atlantic Locks			
Mobilize Excavation Equipment	1	1	2
Mobilize Concrete Equipment	0.9	1	1.5
WSB 3 excavation	0.95	1	1.5
WSB 3 Concrete	0.9	1	1.5
Chamber 3 concrete	0.9	1	1.3
Chamber 2 concrete	0.9	1	1.3
Chamber 1 concrete	0.9	1	1.3
Flood downstream	0.9	1	1.25
Electro-Mech Installation	0.8	1	1.25
General Testing	0.95	1	1.05
Dredging			
1a. Atlantic North plug (Dry exc)	0.95	1	1.1
1b. Atlantic North plug (CSD 3)	0.9	1	1.1
2a. Atlantic South plug (Dry exc)	1	1	1.05
2b. Atlantic South plug (CSD 1)	1	1	1.05
3a. Gaillard Cut (CSD 1)	1	1.1	1.2
3b. Gaillard Cut (RMC)	1	1.2	1.3
4a. Gaillard Cut Canal Access (RMC)	1	1	1.05
5a. Gaillard Cut plug (Land D&B)	1	1	1.05
5b. Gaillard Cut plug (Dry exc)	0.95	1	1.05
5c. Gaillard Cut plug (Backhoe B)	1	1	1.1
5d. Gaillard Cut plug (RMC)	1	1	1.1
6a. Intermediate plug (Land D&B)	1	1	1.05
6b. Intermediate plug (Dry exc)	0.95	1	1.05
6c. Intermediate plug (Backhoe B)	1	1	1.1

Duration Variation	Triangular General Dist. Percentile 5%	most likely	Percentile 95%
Dredging (cont.)			
6d. Intermediate plug (RMC)	1	1	1.15
7a. Pacific South plug (Cofferdam removal)	1	1	1.05
7b. Pacific South plug (Land D&B)	1	1	1
7c. Pacific South plug (Backhoe No. B)	1	1	1.1
Raise Lake Gatun	1	1	1

Furthermore, the activities listed above could last more or less depending on the variation in quantities and/or in productivity. The same factors applied in the cost variation are applied here (see next section) with a minor adjustment. The adjustment factor is based on the current results of these variations in Primavera scheduling software. The different level of aggregation of activities between the cost estimate and the schedule is the main reason for the adjustment. The duration of each activity was adjusted as follows:

$$Duration \bullet \left(\frac{Quantity\ \ factor \bullet Adjustment\ \ factor}{\Pr oductivity\ \ factor \bullet Adjustment\ \ factor} \right)$$

	Adjustment factor
Access Channel	
productivity excavation access channel	1.09
Locks	
Productivity excavation locks	1.08
Productivity concrete locks	1.08
Quantity	0.96
Navigation Channel	
Productivity dredging	1.05
Quantity	0.96

In addition to the variations stated above, we modeled general events delays such as extreme bad weather and labor strikes. These types of events affect specific activities only a few times during the project. First, the risk model determines weather the event happens or not through a Binomial[4] distribution and then it applies a time impact through a Triangular distribution.

	Weather (days)	Strikes (days)
Minimum	5	8
Expected	10	30
Maximum	15	45

Finally, we included variations due to activity-specific events, such referendum delays, one bidder delay, design error, major equipment breakdown, slides, poor construction, problems with gates and corrections during testing. First, the risk model determines weather the event happens or

[4] The Binomial distribution is a sequence of probabilities with each probability corresponding to the likelihood of a particular event occurring. The prefix *bi* in binomial experiment refers to the fact that there are two possible outcomes (e.g., head or tail, true or false) to each trial in the binomial experiment.

not through a Binomial distribution and then it applies a time impact through a Triangular distribution. The parameters applied are below.

Other Major Events	Probability	Minimum Days	Most Likely Days	Maximum Days
Referendum delays	50.00%	0	120	180
One bidder delay	1.00%	90	120	180
Design error	5.00%	10	20	40
Major equip breakdown - Access	5.00%	15	30	40
Major equip breakdown - Locks	5.00%	30	60	90
Slides	5.00%	0	15	30
Poor construction	5.00%	10	20	40
Gate installation delay	10.00%	10	30	60
Gate catastrophe (sink)	0.10%	250	300	320
Corrections during testing	10.00%	15	45	120

The effect of delays on revenues is achieved through the completion date. If the completion date is delayed, the capacity of the Panama Canal will remain the same until the new third set of locks is ready. In this way, the future revenues of the expansion will be deferred by the time delay in commissioning year. This effect will show up at the financial indicators, such as the internal rate of return and the net present value.

c. Cost Overruns

In order to model cost overruns, a detailed cost estimate was incorporated to the risk model. The cost estimate has the following components:

6. Pacific Locks
7. Atlantic Locks
8. Access Channel Contracts (6)
9. Navigational Channels
10. Raise Lake Gatun

<u>Components: Locks and Access Channel</u>

For the first three components, the cost estimate was computed as follows:

Cost of labor and equipment
+ Cost of materials
= Cost of civil works
+ Indirect costs
+ Others
= Cost estimate

The cost of labor and equipment in the cost estimate is defined in terms of working crews. This means that the cost of labor and equipment in a specific activity is defined by the total crew hours times the crew cost per hour. Total crew hours are defined by the quantity divided by the crew productivity. Crew cost per hour can be split in wages per hour and cost of equipment and others per hour. Therefore, we can express the cost of labor and equipment as follows:

$$Cost\ of\ labor\ \&\ equipment = \left(\frac{Quantity}{\Pr oductivity}\right) \bullet \left(Wages\ \$/hr + Equipment\ \$/hr\right)$$

The cost of materials is simply prices multiplied by the physical quantity of the material.

$$Cost\ of\ materials = \left(Quantity\right) \bullet \left(\Pr ices\ \$/unit\ \right)$$

The team determined the risks that have an incidence on these key variables. (see table below)

Variables	**Risks**
Quantities	Evolving design, changes in quantities Owner driven changes
Productivity	Lack of skilled and local labor
Wages	Lack of skilled and local labor labor cost increases (due to demand & supply)
Prices	Material cost increases (due to demand & supply)
Civil works	Owner driven changes
Indirect costs	
Others **Gates** **Valves** **Electrical** **Mark-up** **Insurance & taxes**	Manufacturing cost increases (due to demand & supply) Few bidders Equipment problems

The following is a description of the parameters used to vary the selected variables.

Variable: Quantities

To simulate changes in quantities due to changes in project design, it was deemed appropriate to generate logical design change scenarios. Each scenario was assigned a probability of occurrence using a Discrete[5] distribution. Each time a scenario is selected, concrete and excavation quantities estimated for the Atlantic and Pacific locks are increased by the factors predetermined in the selected scenario. The limited variations reflect the sense of the estimating team of having a conservative estimate. Scenario number 3 corresponds to the quantities currently included in the original cost estimate.

[5] A Discrete probability function is a function that can take a discrete number of values (not necessarily finite) Each of the discrete values has a certain probability of occurrence that is between zero and one. The condition that the probabilities sum to one means that at least one of the values has to occur.

Design Changes

Scenario #	1	2	3	4	5
Description	Maximum increase in approach walls	Increase in approach walls and changes in F/E system	Current Scenario	Changes in WSB	Increase in approach walls, changes in F/E system & WSB
Probability	10%	30%	30%	20%	10%
	Concrete				
Walls	1.5	1.2	1	1	1.1
Lock head	1	1	1	1	1
Chambers	1	1.2	1	1	1.2
WSB	1	1	1	1.1	1.1
	Excavation				
Walls	1.1	1.1	1	1	1.1
Lock head	1	1	1	1	1
Chambers	1	1.3	1	1	1.3
WSB	1	1	1	1	1

Variable: Crew Productivity

Originally, the risk model did not include variations in productivity. Crew productivity variations were introduced to reflect risks such as lack of skilled labor, learning curve time and inefficient planning. This crew productivity variation allows the simulation of the impact on the number of crew hours of work, and subsequently, on activity cost deriving from risks affecting production. Basically, the productivity used in the estimate was multiplied by a random factor, depending on the type of work, through a Triangular[4] distribution. A factor between 1.1 and 0.55 was used for Pacific Locks concrete, mass rock excavation and La Boca and overburden works, for Atlantic locks concrete, mass excavation and process material for roads, and for access channel concrete and excavation works. A factor between 1.1 and 0.52-0.54 was used for Pacific and Atlantic Locks steel and formwork, and Pacific Locks lock base excavation.

Locks and Access Channel

Productivity		
More productive	1.1	1.1
Expected	1	1
Less productive	0.55	0.52-0.54
Distribution	Triangular	Triangular

Variable: Wages

In order to reflect possible local labor shortages, poaching risks between contractors and their impact on labor costs, wage variation was introduced. All local social benefits applicable in the Republic of Panama were taken into account and a minimum hourly wage of US$2.90 was used in the estimate. Changes in labor wages were varied from 0% to 50% more than estimated, using a Triangular distribution with the following points:

[4] A Triangular is a three point distribution. The probability of occurrence of the lower and higher points is cero.

Wages	Locks	Excavation
Maximum	1.5	1.5
Most likely	1.1	1.1
Minimum	1	1
Distribution	Triangular	Triangular

Variable: prices

Diesel

The variation below reflects the volatility of oil prices and the risk of increased cost of transportation (which is included in the price) due to a higher number of transits and deriving costs of man power and equipment. The same diesel price variation is applied to all the components of the cost estimate through a Pert distribution[7].

All Components

Material prices	Diesel
Locks	**$/gal**
Minimum	1.80
Expected	2.50
Maximum	4.00
Distribution	Pert

Steel and Cement

Steel and cement prices reflect the historical and projected behavior of the prices of these commodities.

Atlantic and Pacific Locks

Material prices	Steel (Rebar, supply only)	Cement
	$/ton	$/ton
Minimum	400.00	80.00
Expected	560.00	95.00
Maximum	750.00	130.00
Distribution	Pert	Pert

Steel, cement and oil prices were correlated so that their prices, instead of being completely independent of each other, move in the same direction according to economic cycles so that the relationship between them is reflected in the results.

Correlation matrix			
	Cement	Steel	Oil
Cement	1.00	0.70	0.80
Steel		1.00	0.80
Oil			1.00

Backfill cost

Backfill is processed from basalt excavation in the Pacific. Backfill cost was varied in terms of cost per cubic meter.

[7] A Pert distribution is a type of Beta distribution that models events which are constrained to take place within a range defined by a minimum and maximum value. The Pert distribution uses matching moment equations in which the minimum and maximum values are known to calculate shape factors which are consistent with the mean and standard deviation.

Pacific Locks

Material Prices	Backfill $/m3
Minimum	2.75
Expected	3.26
Maximum	4.00
Distribution	Pert

Aggregate transportation

The transportation cost varied below is that of the aggregates which would be transported from the Pacific to the Atlantic lock site. In this case transportation cost can vary by a factor of 1, meaning the same as the estimated cost, to a factor of 1.5, or 50% more than the estimated cost. The transportation cost is based on the cost per cubic meter for rail transportation. This variation is due to possible difficulties in the transportation method used for this purpose.

Atlantic Locks

	Transportation
Maximum	1.50
Most likely	1.30
Minimum	1.00
Distribution	Pert

Grout, backfill and crushed rock

Access channel works require grout, backfill and crushed rock, which were varied in the following way based on price trends.

Contracts 1&2

Material prices	Grout Curtain $/m2	Backfill $/m3	Slab (only in C1) $/m3
Minimum	50.00	4.50	70.00
Expected	60.00	4.75	80.00
Maximum	120.00	5.25	160.00
Distribution	Pert	Pert	Pert

Contracts 3, 5 & 6

Material prices	Crushed Rock $/m3
Minimum	0.01
Expected	0.01
Maximum	0.08
Distribution	Pert

Predetermined sources of material may be a cause of claims if supplies are not sufficiently abundant or do not have the desired quality. Funds for claims are included in the cost estimate as allowance.

Civil works

The cost of civil works is varied using change orders. Change orders reflect minor scope changes during construction, omissions, minor mistakes and other minor changes, and are simulated using Pert distributions. The factors are applied per type of activity within civil works.

Change orders

Pacific & Atlantic Locks	Activity					
% Change	Steel	Concrete	Excavation/Backfill	Gates	Electromechanical	Other
Minimum	1	1.02	1.02	1	1	1.01
Expected	1.03	1.06	1.06	1.025	1.015	1.03
Maximum	1.06	1.10	1.10	1.05	1.03	1.05
Distribution	Pert	Pert	Pert	Pert	Pert	Pert

Contracts 1 & 2	Slab	Excavation
Minimum	1.05	1.02
Expected	1.07	1.06
Maximum	1.10	1.10
Distribution	Pert	Pert

Contracts 3, 4, 5 & 6	Excavation
Minimum	1.02
Expected	1.06
Maximum	1.10
Distribution	Pert

Gates and Valves

Gate and valve price variation reflects the variation on structural steel fabrication cost.

Atlantic and Pacific Locks

Material prices	Gates (Structural Steel)	Valves
	$/ton	$/ton
Minimum	5,200.00	6000.00
Expected	6,000.00	6,100.00
Maximum	7,500.00	7,000.00
Distribution	Pert	Pert

Electromechanical works

The cost of electromechanical works, which include control system, electricity, and operational systems of the locks, was varied using a pert distribution with the following characteristics. This variation is based on the current level of design.

Electromechanical works	
Maximum	1.2
Most likely	1.1
Minimum	1
Distribution	Pert

Markup and insurance variation

To reflect the risk of having few contractors (less than three) bidding the locks and access channel works, a variation was introduced in the markup based on industry practices. Insurance was also varied to reflect fluctuations of insurance coverage due to contract amount and market conditions as follows:

	Locks	Contracts	Insurance
Maximum	0.12	0.12	0.025
Most likely	0.1	0.1	0.020
Minimum	0.07	0.07	0.015
Distribution	Pert	Pert	Pert

Component: Navigational Channel

For the navigational channel component, the cost estimate was computed as follows:

Cost of dredging
+Cost of drilling & blasting
+ Cost of dry excavation
+ Owner's cost
= Cost Estimate

The cost of dredging is defined in terms of pieces of equipment. This means that the cost of a specific equipment in a specific location is defined by the total hours of dredging times the cost per hour. Total equipment hours are defined by the quantity dredged divided by the equipment productivity. Therefore, we can express the cost of dredging as follows:

$$Cost\ of\ dredging = \left(\frac{Quantity}{\Pr oductivity}\right) \bullet (\$/hr)$$

The cost of drilling and blasting is defined in a similar way.

The cost of dry excavation is defined as quantity excavated times unit cost ($/m3)

$$Cost\ of\ dry\ excavation = (Quantity) \bullet (Cost\ \$/unit\ )$$

The team determined the risks that have an incidence on these key variables. (see table below)

Variables	Risks
Quantities	Changes in quantities Owner driven changes
Productivity	Equipment problems
Cost/hr	Lack of skilled labor labor cost increases (due to demand & supply)
Cost/m3	Contractor cost increases (due to demand & supply)

In addition to the Diesel price and the time variations stated above, which apply to the Navigational Channels, the following variations were applied to this part of the estimate.

Variable: Dredging

Dredging variations are based on the four dredging processes which affect productivity; costs and performance time. These are rock and soil pretreatment (drilling and blasting), dredging equipment, dredged material transportation and disposal site.

Variations take into account dredges' productivity, dredging volume, and dredges' hourly costs. According to its dredging effectiveness in each area, a type of dredge was proposed to widen and deepen the Canal Post-panamax navigation channel. Dredge productivity would vary according to Canal channel complex and diverse geologic condition in addition to current Canal traffic, and transportation of dredging material. Dredging material volume variations are based on sedimentation rate, eventual bank slides, and a greater margin of over-dredge than estimated. Also, a new cutter suction dredge should be in operation by mid 2009.

It is not foreseen that Canal dredges cost would have significant cost variation other than normal general inflation cycles. Their unit cost would mainly depend on equipment performance through average productivity. However, cost for contracted external dredging resources would vary according to dredging market[8].

Variations on the extracted volume, equipment cost per hour, and equipment productivity were introduced by multiplying these items by the factors produced by the probability distributions shown below:

	Quantity		
Type of equipment	**Minimum**	**Probable**	**Maximum**
Tolva – Medium (5-10k m^3)	1	1.1	1.15
DCS – Medium (1 a 2k kW cutter)	1	1.1	1.15
DCS – Rock – Lake	1	1.1	1.15
DCS – Rock – Cut	1	1.1	1.15
DCS – Rock - Atl & Pac	1	1.1	1.15
DCS – Rock – Pac	1	1.1	1.15
Dredging - land	1	1.1	1.15
Dredge – Dipper (Backhoe) (Cut)	1	1.1	1.15
Dredge - Mechanical (Cut)	1	1.1	1.15
Dredge – Mechanical (Access Channel)	1	1.1	1.15
Dredge – Dipper (Backhoe) (Pacific)	1	1.1	1.15
Distribution	Triangular		

Tolva – Medium (5-10k m^3)	**Cost / m3**
Minimum	1.00
Expected	1.20

[8] The cost can vary according to availability, due to other mega projects around the world.

Maximum	1.30
Distribution	Triangular

	Cost per hour			Productivity		
TYPE OF EQUIPMENT	**Minimum**	**Probable**	**Maximum**	**Minimum**	**Probable**	**Maximum**
DCS - Medium (1 a 2k kW cutter)				0.75	1.0	1.2
DCS - Rock – Lake				0.75	1.0	1.3
DCS - Rock – Cut				0.7	1.0	1.1
DCS - Rock - Atl & Pac	0.9	1.0	1.4	0.8	1.0	1.2
DCS - Rock - Pac	0.9	1.0	1.4	0.7	1.0	1.1
Dredging – land	1.0	1.0	1.1	0.7	1.0	1.1
Dredge – Dipper (Backhoe) (Cut)				0.8	1.0	1.2
Dredge - Mechanical (Cut)				0.75	1.0	1.1
Dredge - Mechanical (Access Channel)				0.9	1.0	1.3
Dredge – Dipper (Backhoe) (Pacific)	0.9	1.0	1.3	0.7	1.0	1.1
Distribution	Triangular			Triangular		

Variable: Drilling and blasting

Rock and soil pretreatment variations include estimated quantities and drill-boat performance. Quantities variations depend mostly on channel navigation geologic condition (rock fragmentation), and dredge capability to remove material with or without prior channel bottom material blasting. Drilling and blasting productivity is subject to the type of drill-boat designated for each area along Canal navigation channel, traffic conditions, and channel area, and conditions. Drilling and blasting cost was introducing a variance in quantity and productivity through triangular distributions with the following parameters.

Drilling and Blasting Equipment	Quantity			Productivity		
	Minimum	**Probable**	**Maximum**	**Minimum**	**Probable**	**Maximum**
Wet excavation – Lake -THOR	1.0	1.0	1.1	0.85	1	1.1
Wet excavation – Lake - BARU	1.0	1.0	1.1	0.85	1	1.1
Wet excavation – Cut - THOR	1.0	1.0	1.1	0.75	1	1.1
Wet excavation - Cut - BARU	1.0	1.0	1.1	0.75	1	1.1
Wet excavation – North Access Channel & Pac BARU	1.0	1.0	1.1	0.75	1	1.1
Wet excavation – waters (<3m)	1.0	1.0	1.1	0.9	1	1.1
Dry excavation	1.0	1.0	1.1	0.8	1	1.2
Distribution	Triangular			Triangular		

Variable: Dry excavation

Contracting external resources to perform dry excavation phase have been a quite successful experience for ACP due local contractors effectiveness in excavating dry material at competitive prices as shown in Canal previous excavation projects such as Gaillard Cut widening to 192 m, and current Cut straightening, and widening to 218 m. Dry excavation variations are based in

volume, and prices. Due to Gaillard Cut proposed deepening to 9.14 m PLD, it is most likely that some slides occur as reflected in the following table. The cost of dry excavation was varied by introducing factors affecting quantities and cost per cubic meter.

Canal Área	Quantity			Unit cost		
	Minimum	Probable	Maximum	Minimum	Probable	Maximum
Access Channel – Atlantic North @ 218m	1	1	1.1	1	1	1.1
Atlantic North Plug @ 2m PLD	1	1	1.1	1	1	1.1
Atlantic South Plug @ 27.4m PLD	1	1	1.1	1	1	1.1
Deepening Gaillard Cut @ 30' PLD	1	2	3	1	1	1.1
Access Channel – Pacific North - Cut @ 218m	1	1	2	1	1	1.1
Pacific North Plug – Cut @ 27.4m PLD	1	1	1.2	1	1	1.1
Pacific Intermediate Plug - Lock @ 27.4m PLD	1	1	1.2	1	1	1.1
Distribution	Triangular			Triangular		

Variable: Owner's costs

The owner's costs of the navigation channel works (dredging, dry excavation and drilling and blasting) were varied using a triangular distribution allowing this cost to go from the original estimate up to 15% more. Owner costs include navigation aids support, mitigation (reforestation), design, contract administration, disposal sites preparation, and survey support. In addition to owner's costs there is another item called ACP support to external contractors which includes aids to navigation (range towers, buoys, and lights), hydrographic survey, tugboats, launches, pilots, inspectors, coordinator, marine traffic control, contracting officer, contract specialist, and cranes.

Navigation Channel	Indirect
Minimum	1.00
Expected	1.00
Maximum	1.15
Distribution	Triangular

Variable: Disposal sites

Disposal sites depend on type of material, type of equipment, distance from the project area, capacity, and environmental evaluation. Two means of transportation of dredged material are considered: barges and pipeline, these will be limited by their size, transit and disposal site availability.

In order to simulate possible problems with disposal sites for dredging material, such as limited capacity, the total cost of the dredging works was multiplied by a factor which varies from 1 to 1.02, increasing dredging cost up to 2% more. Such disposal site capacity limitation is mostly foreseen in Gaillard Cut deepening program at 9.14 m PLD. Designated area Frijoles would be near full capacity by the time this deepening program would be completed.

Therefore, it is probable that Frijoles would not have enough remaining capacity to accommodate the total Cut dredging volume. Inland disposal sites

require an assessment of capacity, foundation analysis, dike evaluation, rehabilitation and design. An alternative to Open Water and Inland Disposal Sites would be to use dredged material. This alternative will require deeper analysis and consideration.

Disposal sites design problems	
Minimum	1.000
Expected	1.010
Maximum	1.020
Distribution	Triangular

Component: Raise Gatun Lake

For the Raise Gatun Lake component, the cost estimate was computed as follows:

Cost of Raise Gatun lake
+ Others
= Cost Estimate

The cost of raising Gatun Lake is defined in terms of modifying gates and locks for higher water levels, as well as modifying other ACP structures and facilities. Due to the early conceptual stage of the design of this component, it was applied the following variation to the cost of raising Gatun Lake.

Raise Lake	
Maximum	3
Most likely	2
Minimun	1
Distribution	Triangular

After defining the variations on the total cost estimate in real terms, it was necessary to evaluate the impact of general inflation on the cost estimate expressed in nominal terms (including inflation).

Variable: Inflation

Panama's long run inflation was varied from 0.6 to 3% annually. This variation reflects both the historically low inflation of the country and the increased inflation during the last year.

Inflation	
Maximum	0.030
Most likely	0.019
Minimum	0.006
Distribution	Pert

Basic Assumptions

All the assumptions used in the cost estimates and the financial model apply to the risk model. The following are basic assumptions of the model.

- The contracting method is design-bid-build.

- There are 6 contracts for the access channel works.
- There are 2 contracts for the locks. (one for the Pacific, and one for the Atlantic)
- ACP dredges would perform about 50% of total expansion dredging volume.
- Work schedule includes paid lost days due to rain, due to family affairs, miscellaneous leave and holidays.
- Cost contingency allocation in time was based on the distribution of the base cost estimate flows across time.
- All unskilled labor is hired locally.
- Contractors' key technical and administrative personnel are foreign.