Quantitative Risk Assessment and Risk Management of a Large Transportation Project

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ABSTRACT

Government agencies, including those responsible for transportation, are beginning to adopt the use of modern project management techniques which incorporate risk management. In particular, for large transportation construction projects, quantitative risk management is being utilized as an optimal process. Quantitative risk management involves quantitative (i.e. probabilistic) risk assessment in addition to risk response. Probabilistic risk assessment of a project takes into account all significant uncertainties that affect project performance. It replaces point estimates of overall cost and schedule with probability distributions. Moreover, probabilistic risk assessment provides diagnostic information regarding which risk events have the most potential impact on cost and schedule. This information can be used to improve project management by exerting project controls on certain key activities. In this paper we describe the results of a fully probabilistic risk assessment of a large highway construction project currently being undertaken by Saskatchewan Highways and Transportation (DHT): Highway 11 Twinning. One of the major findings of this risk assessment was that property purchase along the right-of-way was a major issue on the first construction phase of the project. Delays produced by purchasing properties in both towns and rural land for Highway 11 resulted in DHT paying contractual penalties for grading and paving due to a delay in commencement in construction of an entire year. For the second and subsequent phases of construction, risk mitigation is being applied by initiating ROW negotiations up to two years in advance of grading and paving tendering.

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1. BACKGROUND

Risk management is becoming increasingly used for managing projects within government agencies and major corporations in the western world. These organizations have recognized the importance of managing risk as part of their everyday business and have implemented policies such as the Government of Canada's Integrated Risk Management Framework (IRMF) [1]. IMRF addresses the need for Federal government agencies to demonstrate greater transparency in decision-making, interact with better educated citizens, deal with uncertainty, capitalize on opportunities and inform stakeholders to ensure better decisions in the future. In addition IRMF is designed to use a systematic approach to risk management, contribute to building a risk-smart workforce that allows for innovation and responsible risk-taking while ensuing legitimate precautions are taken to protect the public interest, maintain public trust and ensure due diligence.

Similarly, the UK has developed a framework [2] for business risk management for use by the central government's Highways Agency. The framework is an implementation of the policy shift to a risk-averse culture involving "well thought out risk taking". As part of its position on operational risk analysis the framework includes identification of all risks, evaluation of identified risks (assessment of likelihood and impact) and evaluation and the appropriateness of mitigation arrangements.

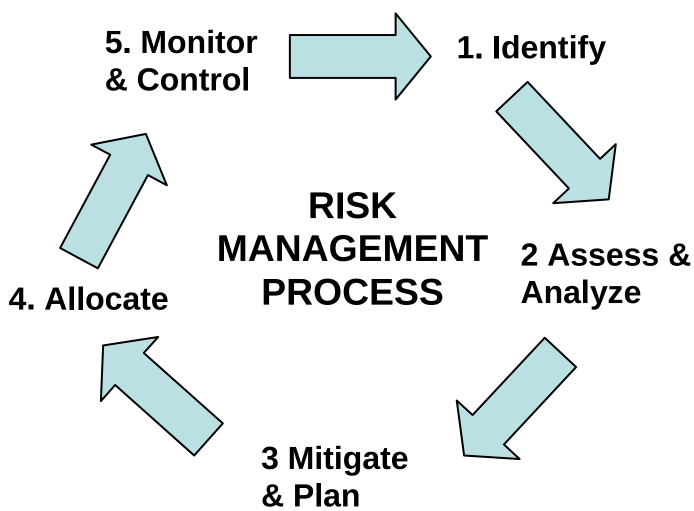

Figure 1: Integrated Risk Management Process

The US Federal Highways Administration has reviewed developments in the use of risk management in transportation agencies around the world in their *Guide to Risk Assessment and Allocation for Construction Managemen*t [3]. They conclude that risk management processes, tools and documentation and communication are less standardized than any other dimension of transportation project management. They go on further to state that risk assessment and allocation techniques are beginning to evolve at US highway agencies. As part of the business case for pursuing risk management, the authors conclude that "the business case for including risk management as a standard project management component of major capital projects is unambiguous: The ability to better understand potential risks and how to manage them yield benefits far in excess of the costs of adopting risk management practices."

In addition to summarizing the need for risk management practices to be incorporated into the business of government transportation agencies, the authors [3] give two examples of states which have wholeheartedly embraced risk management protocols: Washington State (WSDOT) and California (Caltrans). In particular, WSDOT uses the Cost Estimate Validation Process (CEVP™) which was developed with input from Golder Associates [4]. This is the approach used for the cost and schedule risk assessment of SK Department of Highways and Transportation's (DHT) Highway 11 Twinning project.

Figure 1 contextualizes the risk management process as taken from [3]. The risk assessment described here involves the first two steps in this process. A more detailed breakdown of the risk management process is shown in Figure 2 for the case of quantitative risk management. A description of quantitative risk management is given in the next section. In Section 3 we describe how the quantitative risk assessment was carried out for Highway 11 Twinning and the results of this risk assessment are presented in Section 4. In Section 5 we describe the risk response for Highway 11 Twinning. We show how both the *results* of the risk assessment and the *process* of carrying out the risk assessment were used to control cost and schedule of the project and, in particular, to negotiate better contracts. The conclusions of the paper are presented in Section 6.

2. QUANTITATIVE RISK ASSESSMENT

As mentioned in Section 1, for large projects such as the highway construction project assessed here, quantitative risk assessment is becoming more commonly used throughout the western world. The case for using a quantitative risk assessment process for assessing large transportation construction projects was made in [5] as presented at the TAC Conference in St John's in 2003 and also in [6,7]. A quantitative (probabilistic) approach to cost and schedule estimation on large transportation projects is optimal because uncertainties are usually large at the time of estimation. Also traditional cost estimates have been observed to be historically too low by almost 30% on average [8,9]. In quantitative risk assessment, probability distributions of cost and schedule replace the usual point estimated values. Monte Carlo Simulation is used to compute the overall cost and schedule distributions because it can take into account the effects of many uncertainties as well as model the many interconnections between major project activities which influence the overall cost and schedule. In addition, Monte Carlo simulation can take into account the couplings between cost and time due to inflation.

Different methods have been developed to provide realistic cost and schedule estimates over the years. Traditionally, contingency methods have been used in a deterministic way in which component costs and durations are summed and an overall contingency is then included for uncertainties in cost and schedule separately. Probabilistic approaches to project estimation were originally developed in the management science community for managing large projects as early as the 1950's when PERT was invented for schedule estimation on the Polaris submarine project

For example, see Chapter 20 of [10] and Chapter 9 of [18]. PERT uses three values to demark a duration component: lower estimate, upper estimate which define the range of possible values coupled with a most likely value. These estimates are used to construct a series of triangular probability distributions which are fed into a simulation model which computes the overall duration.

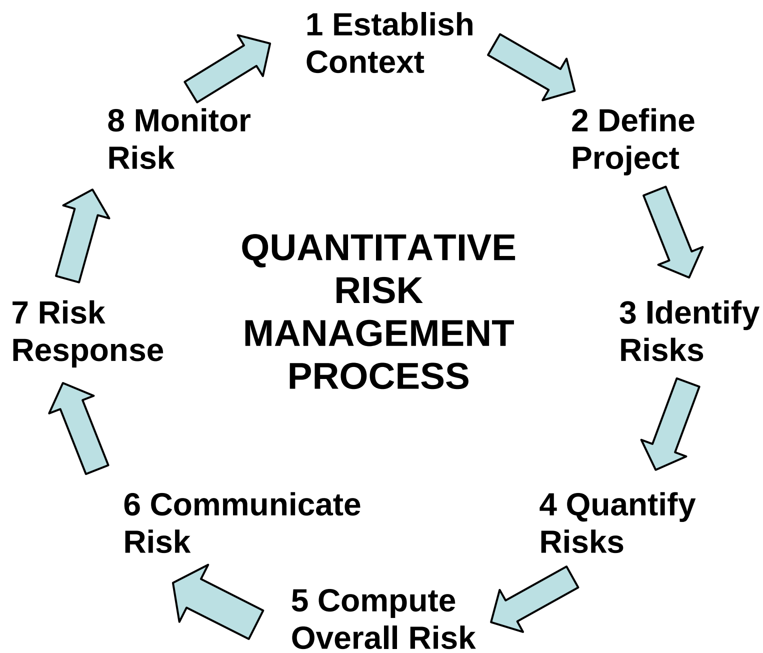

Figure 2: Quantitative Risk Management Process

The risk assessment method used here, which is described definitively in [11], is an improvement to traditional project estimation techniques because each project component and risk event is quantified separately and also probabilistically too. This allows prioritization of risks in terms of their overall impact. Unlike PERT, cost and duration are treated in an integrated way so that the time-value of money is explicitly incorporated into each cost component. Also unlike PERT, which is a widely available project management tool, the approach used here is a risk assessment *process* in which the quality of project information is assured by use of project experts, independent experts and skilled facilitators [4]. Finally, unlike traditional methods, project assumptions are explicitly articulated during the workshop stage. Later these assumptions are tested systematically by using sensitivity analysis during the modelling phase.

The principal outputs of this risk assessment process are a combination of probabilistic estimates of cost and schedule and a ranked list of the main drivers of risk – those which significantly impact cost and schedule. Taken together this allows project engineers and planners to perform effective risk management by controlling cost and schedule on critical project components and selecting among viable alternatives. Risk management of SK DHT's Highway 11 Twinning project using the results from the quantitative risk assessment is described in Section 4.

3. RISK ASSESSMENT OF SK HIGHWAY 11 TWINNING

3.1 Review of the Project

Before the quantitative risk assessment process can begin, it is essential that all the members of the risk assessment team come to a mutual understanding of the most up-to-date version of the scope, status and delivery strategy for the project in a project review. The project review team comprises members of the client's project team who are knowledgeable about the project, any appropriate independent subject matter experts, and one or more of the risk assessors. Project details are usually communicated by the clients to the risk assessors prior to the commencement of the review.

For the Highway 11 Twinning risk assessment a kick-off workshop was facilitated by the risk assessors after reviewing the project description document. At the beginning of this workshop a review of the probabilistic risk assessment methodology was presented to the team. Next SK DHT's project team presented the details of the project. They then clarified how the project was defined for the purposes of the risk assessment, including some project design alternatives. Note that in a quantitative risk assessment, it is important to understand the project at the correct level of detail. Because risk assessments are used primarily for decisions about the project, including risk management, it is not necessary to analyze every line item in a work breakdown structure. On a project of this size, the risk assessment team only considered project components equal or greater than $20K in magnitude. The total cost for the project was re-evaluated, free of contingency. This latter point is important because risks which affect cost and schedule are handled probabilistically. These risks are quantified in a second workshop.

3.2 Project Flowchart

The next step in the quantitative risk assessment process was the development of the project flowchart. The project flowchart is the "backbone" of the risk model which is used later to compute the overall cost and schedule information. The flowchart is a network diagram that comprises the major cost components of a project, known as *activities* which are ordered in time sequence in the same manner as a standard software flowchart. Like a software flowchart, decisions are also included as well as project alternatives. Milestones are included as in a project Gantt chart. The times between the project activities are included as well as the times to complete each activity. Together all the information constitutes the integrated time-cost framework of the risk model. Figure 3 shows the flow chart for the first of five phases of the Highway 11 Twinning. Almost identical flowcharts were developed for the four remaining project phases. Note that the flowchart in Figure 3 comprises 15 major activities. Typically a project flowchart for a major transportation construction project is of the order of approximately 20 to 200 elements.

The flowchart provides the risk assessment team with a visual summary of the project, including major milestones and schedule logic delivery which enables the team to reach a common validation. This is in contrast to client schedules which often contain thousands of line items, including incomplete information, and are understandable by only one or two individuals. Flowcharts reflect the time at which the risk assessment is carried out within the project life-cycle. For example, during planning and early stages of project development, the focus may be on differences between project alternatives whereas during final design the focus may be on contracting, construction and bidding processes. Types of activities included in flowchart activities and milestones include steps in the design process, environmental, funding and other political approvals, property/right of way access, utilities relocations and other pre-construction work, procurement and construction. Windows for winter shutdowns should be included in northern climates such as encountered in Canada and project constraints should be included such as accelerated schedules when a certain threshold is exceeded. Also incorporated into the flowchart are lags and overlaps between activities and the correct sequencing of activities.

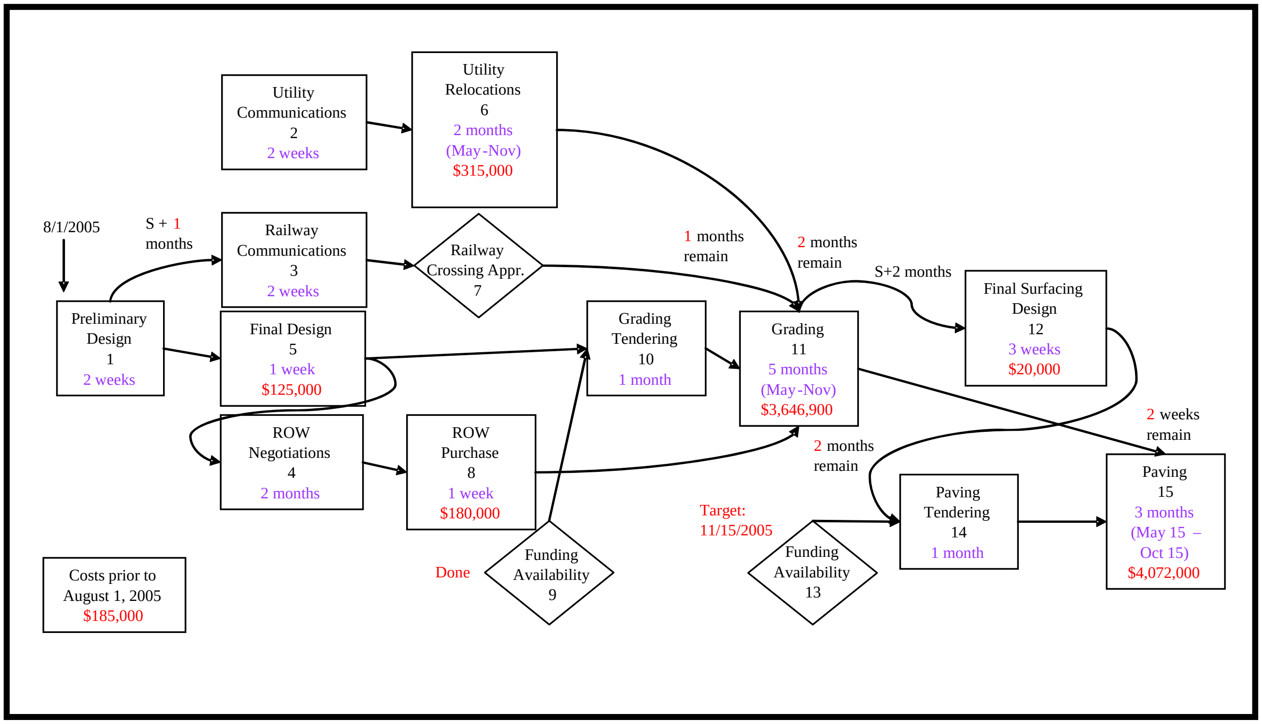

Figure 3: Flowchart for Phase 1 of SK Highway 11 Twinning

3.3 Review of Cost & Schedule Estimates

Once the structure of the flowchart was in-place for Highway 11 Twinning, the risk assessment team assigned cost and duration values to all the project activities. Also the team assigned duration values for the times between the activities too. This information is shown in Figure 3. The information was reviewed by the project team personnel and also the independent experts to confirm that the cost and schedule estimate matched the project scope and design. In the process, the group identified and removed all contingencies and conservatism. As previously mentioned, these components are accounted for separately later in the risk assessment using probability distributions.

After review of the project flowchart, the set of project activity costs and durations were compiled into a set of base factors. Table 1 shows a set of base factors for Phase 1 of the Highway 11 Twinning Project. The base costs are quoted in currency values at the time of the risk assessment, which was August, 2005. A base inflation rate of 2.5% was assumed for all base factors. Conversion to year of expenditure currency was performed later by taking into account the effects of inflation. The total base cost for all 5 phases of Highway 11 Twinning, free of contingencies, was estimated to be $34M in 2005 currency. Note that the original cost estimate for the project prior to performing the risk assessment was $44.7M.

Table 1: Example Set of Base Factors for Phase 1 of Highway 11 Twinning

Flowchart Activity Number	Project Activity	Base Cost (2005 $M)	Base Duration (months)	Average Escalation Rate (%/yr)
0	Costs to Date	0.19	-	0.0
Activity No.	**Activity**			
1	Preliminary Design	0.00	0.50	2.5
2	Utility Communications	0.00	0.50	2.5
3	Railroad Communications	0.00	0.50	2.5
4	ROW Negotiations	0.00	2.00	2.5
5	Final Design	0.00	0.25	2.5
6	Utility Relocations	0.32	2.00	2.5
7	Railway Crossing Approval	0.00	0.00	2.5
8	ROW Purchase	0.18	0.25	2.5
9	Funding Availability - Grading	0.00	0.00	2.5
10	Grading Tendering	0.00	1.00	2.5
11	Grading	3.47	5.00	2.5
12	Final Surfacing Design	0.02	0.75	2.5
13	Funding Availability - Paving	0.00	0.00	2.5
14	Paving Tendering	0.00	1.00	2.5
15	Paving	4.07	3.00	2.5

3.4 Identification of Risk Events

The last activity of the first workshop was to identify those risk events which can affect the project activities and durations documented in the project the flowchart. Hence these risk events contribute to the overall project cost and duration. A risk event has both a range of consequences on cost and schedule and two associated sets of likelihoods. Note also that a risk event can have either a negative or positive impact. We use the term 'risk' here in the sense of including opportunity events, not just events which result in an adverse impact on the project.

As in the development of the base activities, identification of risk events follows a systematic procedure. First an initial set of risks was generated through a brainstorming session using the flowchart as guidance. Risk events included those arising from all credible technical, environmental and socioeconomic issues. Once the initial set of possible risks was completed, the facilitator led the process of refining the set of risks to make sure it was all encompassing and mutually exclusive. Then the risks were categorized according to a checklist.

The risk categories on the checklist were:

- Construction;

- Design, Environmental and Permitting;
- Political;
- Right-of-Way Acquisition;
- Scope Changes
- Utilities, and
- Other.

Included in the categories of *other* risks include the set of unidentified risks which were missed during the risk assessment process. Typically for a project of this size of the order of 100 risks are usually identified during this process. During the facilitation process, risk events were also documented to form the project risk register. Once the risk register was completed, the risk assessment team reviewed it and screened out risks which were deemed to be of insignificant impact in terms of cost and schedule, upon further reflection. The final list of risk events affecting cost and schedule on Highway 11 Twinning is shown in Table 2 below.

Table 2: Risk Events for Highway 11 Twinning project

Risk Category	Risk/Opportunity Event	Affected Project Activities
Construction	Significantly wet delays due to start of construction or other causes	Utility Relocations, Grading, Paving
	Uncertain Construction Market Conditions	Grading
	Contractor Productivity Issues;	Grading, Paving
	Other Construction Change Orders	
	Cost penalties paid to paving contractor due to delays in grading contract	Paving
Design, Environmental & Permitting	EIA Required	
	Heritage Issues	
	Endangered Species Issues	
	Uncertainty in Horizontal Alignment	Grading, Paving
	Uncertainty in Access Requirements	
	Uncertainty in Earthworking/Grading: Quantity, shrinkage, grade lines, unit cost	Grading
	Uncertainty in Paving: Surfacing unit cost, quantity	Paving
	Uncertainty in other construction activities: drainage, illumination, traffic control, landscaping, subsurface conditions, etc	Grading, Paving

Table 2: Risk Events for Highway 11 Twinning project (cont.)

Risk Category	Risk/Opportunity Event	Affected Project Activities
Design, Environmental & Permitting (cont.)	Uncertain soft costs: design, construction, engineering, project management, etc	Grading, Paving
	Uncertainty in aggregate and common borrow	
	Uncertainties with Haul/Haul Roads	Paving
	Borrow pit relocation	Grading
	Topsoil removal	Grading
	Uncertainty in Fuel Prices	Grading, Paving
	Uncertainty in Oil Prices	Grading
	Uncertainty in design standards	
	Design Errors and Omissions	Grading, Paving
	Uncertainty in inflation rate	All
Political	Issues related to obtaining Railway Permits	
	Other Political or External Issues (not captured elsewhere)	
ROW Acquisition	Uncertain ROW Acquisition cost	ROW Purchase
	Uncertain ROW Acquisition Schedule	ROW Negotiations
Scope Changes	Other changes in scope not captured elsewhere	
Utilities	Utilities not relocated on time	
	Unanticipated utilities, including damage, during construction	Paving
Unidentified risks	Aggregate minor risks	All
	Aggregate minor opportunities	All
	Unidentified risks	All

3.5 Quantification of Risk Events

So far in the risk assessment process we have described the project review and risk identification processes. The next step is to put numbers around the identified risks. This is a more complicated process than was performed previously and it was performed in a second workshop for the Highway 11 Twinning project by the risk assessment team.

For each risk event identified in the first workshop, the risk assessment team estimated the probability distribution function pertaining to changes in cost and schedule to one or more project activities in the project flowchart. Some risk events are considered minor because they have only a minimal effect on cost/schedule changes. They are labelled as such and no further quantification is necessary. Some risk events will affect only one activity whereas other risk events, such as the price of oil, may affect several activities. Moreover risk events must be assessed at the appropriate level of detail. If a risk event affects a project activity which contributes a very small amount to overall project cost, this risk should not be assessed in great detail. The converse is also true – more time is spent in the risk quantification process on risks which are deemed to be of high importance.

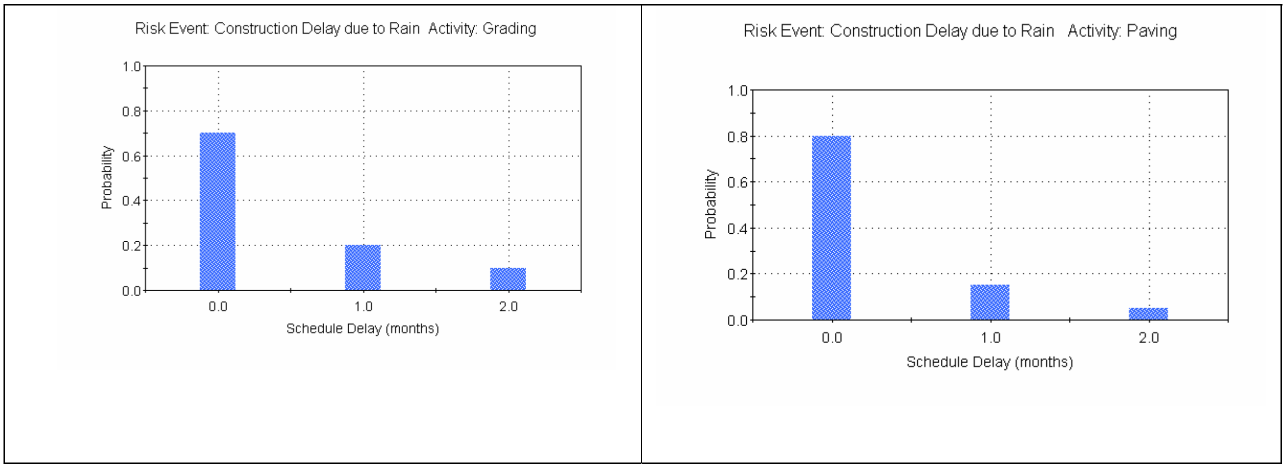

Figure 4: PMF's for Construction Delay due to Rain Risk Events

The process of quantifying risk events (using probability distribution functions) is known in the risk assessment literature as *elicitation*. Elicitation of the appropriate probability distribution of a risk event requires a significant amount of care. If data are available, statistical fits to those data may be used using standard probability theory (based on the relative frequency notion of probability). Most of the time, however, empirical data are not available which was the case for the Highway 11 Twinning project. Hence subjective probability notions were applied. The subjective or Bayesian approach to probability has been adopted by practitioners in the risk and decision community [12-14] and also by the consulting engineering community [15-17] because of its practical usefulness in quantitative risk assessments. In the subjective approach, probability is interpreted as a degree of belief or uncertainty and relies on engineering judgement and experience [17].

When eliciting probability distributions, balanced viewpoints are usually obtained from three to five individuals. This is why the risk assessment team comprises at least one risk assessor and personnel from both the project team and outside the project team. Use of personnel external to the project team helps remove bias from the estimates produced. More details of how to assess complex risks using decomposition techniques are given in [12] and [16].

Figure 4 shows the probability distributions for construction delay risks from wet weather for Highway 11 Twinning. Note that this risk event affects two activities: Grading and Paving. It applies only to schedule (but not cost). It also applies to all 5 phases of the construction. Both distributions are discrete in nature. Discrete distribution functions are known as Probability Mass Functions (PMF's) in probability nomenclature. The PMF for construction delay to grading is interpreted as follows: the probability of no schedule delay for grading is 70%, the probability of a 1 month delay in schedule for grading is 20% and the probability of a 2 month delay in schedule for grading is 10%. Similarly for the construction delay to paving PMF we have: the probability of no schedule delay for grading is 80%, the probability of a 1 month delay in schedule for grading is 15% and the probability of a 2 month delay in schedule for grading is 5%. Note that most risk events on Highway 11 Twinning had discrete probability distributions associated with them. Some risk event distributions, such as Uncertainty in Paving Costs Uncertainty in Soft Costs, were continuous. Continuous probability distribution functions are known in probability nomenclature as probability density functions (PDF's).

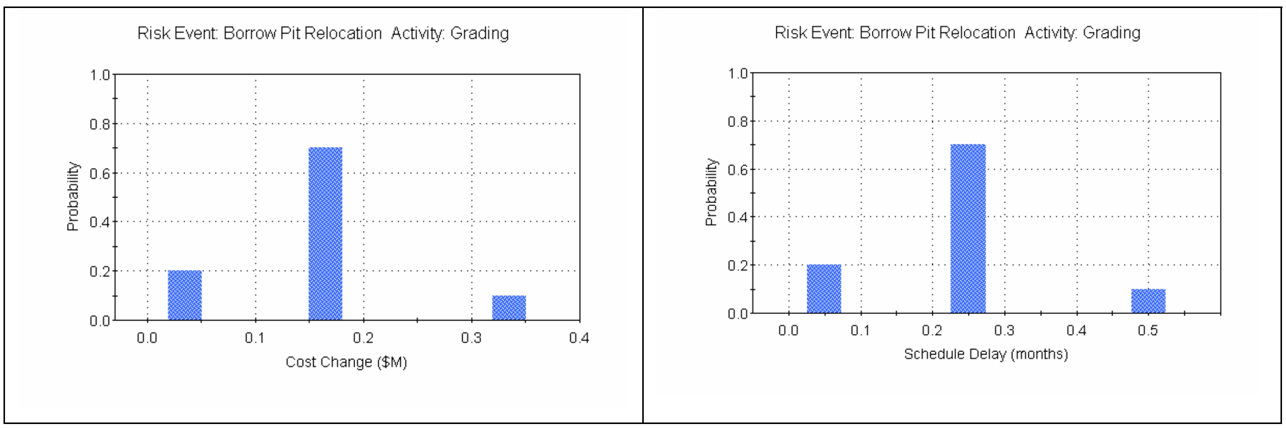

Figure 5: PMF's for Borrow Pit Relocation Risk Event for Grading (Cost and Schedule)

Figure 5 shows the risk event PMF's for borrow pit relocation as it affects Grading Cost and Grading Schedule for Highway 11 Twinning. The PMF for borrow pit relocation as it affects grading cost is interpreted as follows: the probability of no cost change for grading is 0%, the probability of a $35,000 increase in cost is 20%, the probability of a $165,000 cost increase is 70% and the probability of a $335,000 cost increase is 10%. Similarly for the construction delay (schedule) for grading PMF we have: the probability of no schedule delay for grading is 0%, the probability of a 1½ day delay in schedule for grading is 20%, the probability of a 7½ day delay in schedule for grading is 70%% and the probability of a 15 day delay in schedule for grading is 10%.

When the process of eliciting risks for Highway 11 Twinning was completed, over 40 probability distribution functions for risk events as they pertain to cost and schedule impacts on project activities were estimated. These functions were then used to compute overall cost and schedule PDF's as described in the next section.

3.7 Simulation Modelling

After the second workshop was completed a simulation model was developed by the risk assessors to compute the effects of all the risk events on the overall project cost and schedule. Because of the large number of risk events and project activities as well as and their interconnectivity, Monte Carlo simulation is the most effective way to compute probability distributions for overall cost and schedule. As described in Section 1, Monte Carlo simulation has been used in management science since the origins of PERT in the 1950's. For an overview of how Monte Carlo is used to manage risks in the context of modern project management methods, consult Chapter 9 of [18]. Although there are many available commercial software packages to perform Monte Carlo simulation for business applications, the authors use a combination of MS and @RISK to perform the requisite Monte Carlo calculations for project risk assessments.

The logic of the flowchart was captured in Excel for Highway 11 Twinning as well as the values for cost and duration for both the project activities and the durations between activities. To incorporate the effects of risk events into the simulation, probability distributions of the risk events were then programmed into the spreadsheet by using @RISK. The outputs of the simulation, which are now probability distribution functions, were computed using the Monte Carlo capability of @RISK. Initially cost computations were performed in $2005 (the same year as the risk assessment was carried out). By taking into account inflation compounded over the appropriate durations, costs were converted into dollar values in the year of expenditure (YOE), which is usually preferred by client organizations. While the total cost of the project is just the sum of the activities corrected for risk events, the total duration takes into account overlapping of activities. After the model was built by one of risk assessors, it was also validated and verified by another employee trained in risk modelling. For a more comprehensive account of simulation modelling in quantitative project risk assessment, consult [11].

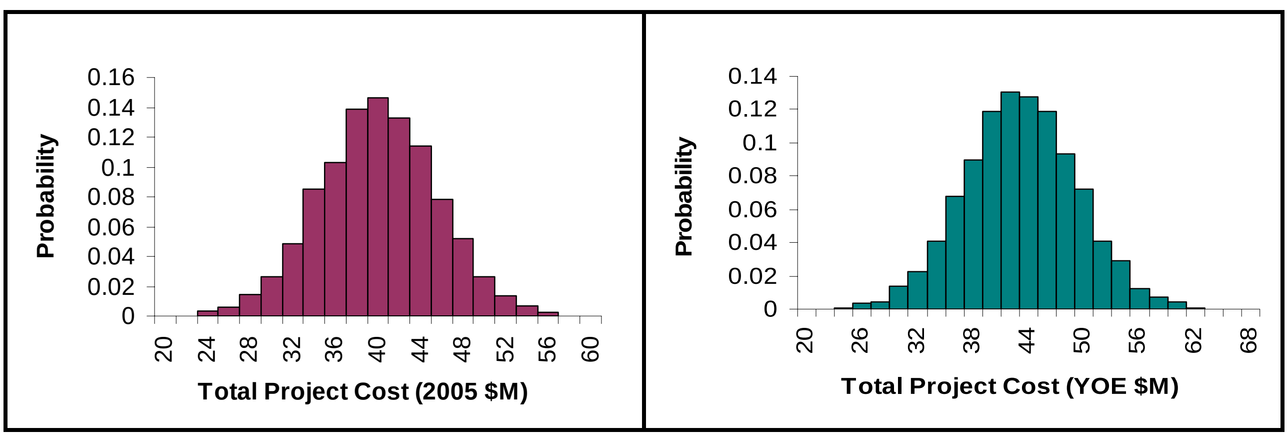

Figure 6: PDF's of Total Project Cost in 2005 Currency and YOE Currency

While the information provided by the cost and schedule probability distributions (see the next Section) is useful for engineering planning purposes, what is often more useful for project risk management is risk ranking. In risk ranking the risk events which contribute the greatest impact are ranked in order of importance. In the risk assessment protocol used on Highway 11 Twinning, the top few risk events which had the largest impact on cost were identified as well of the top few risk events which had the largest impact on schedule. In addition to the risk events which had a negative impact on the project, the risk events which had the largest positive impact, i.e. the opportunity events were also identified for both cost and schedule too.

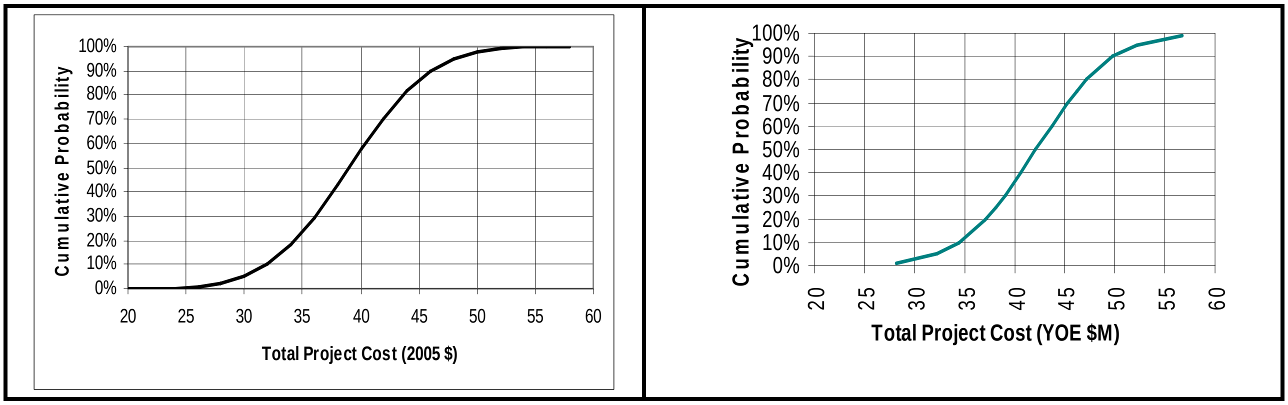

Figure 7: CDF's of Total Project Cost in $2005 and YOE Currency

4.0 Results

Figure 6 shows the PDF for cost in 2005 $ and YOE currency. The mean cost predicted by the risk assessment is $35.6M in 2005 $ and $42.2M in YOE $. The original cost estimate was $44.7M. To see how well the original cost estimate compares with the results of the risk assessment it is more useful to use the Cumulative Distribution Function (CDF) representation of cost. The CDF is the integral of the PDF and is shown in Figure 7 in both 2005 and YOE currencies. From examination of the figures, we can observe that the original cost estimate corresponds to approximately 85^{th} percentile and 65^{th} percentiles of the two CDF's respectively. This means that even adjusting for inflation, the risk assessment predicts that there is a 65% chance of the original budget still meet its target. This number is relatively high. Hartman [18] cites that his observation of practice is that construction projects usually come in at around 30 to 55 probability of achieving budget target. If we use the 80% percentile value in (inflation adjusted) YOE $ for the project cost, then the original budgeted estimate is $2.5M short of this value.

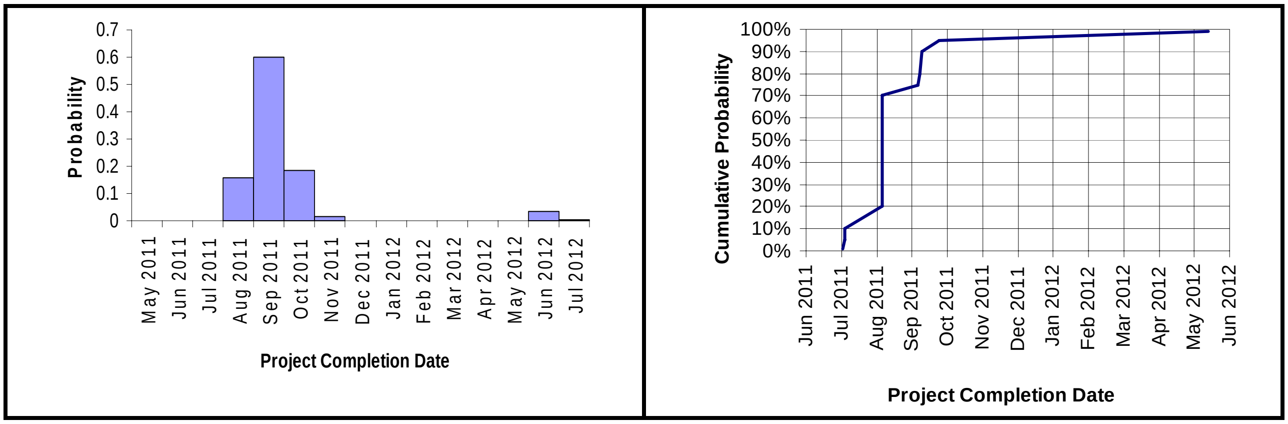

Figure 8: Probability Distributions for Total Project Completion Date

Figure 8 shows the PDF and CDF for the project completion date. Inspection of the left hand side of the Figure 3 shows that the probability mass function has two peaks which reflect the lack of construction during the winter season when ground is frozen. The mean completion date is September 2011. The median completion date (50:50 odds) is August 2011 and the 80 percentile value is September, 2011. From the information gathered in the first workshop we can conclude that the risk assessment predicts that there is a greater than 90% chance that the Highway 11 Twinning will be completed before the end of the construction season of 2011.

Table 3: Risk and Opportunity Rankings for Cost

Risk Rank	Contribution to Expected Cost Risk		Risk Event
	%	Current $M	
1	26.7%	0.99	Uncertainty in Soft Costs / Consultant Design
2	23.7%	0.88	Issues related to haul / haul roads for surfacing material
3	21.0%	0.78	Relocation of Borrow Pits
4	7.9%	0.29	ROW Acquisition Cost
5	6.7%	0.25	Cost Penalties paid to paving contractor due to delays in grading contract

Opp Rank	Contribution to Expected Cost Opportunity		Opportunity Event
	Percent	Current $M	
1	90.9%	-0.27	D4. Uncertainty in Horizontal Alignment
2	4.5%	-0.01	Identified Minor Opportunities (aggregate)
3	4.5%	-0.01	Unidentified Opportunities (aggregate)
		-0.29	Sum of Expected Opportunity

In addition to providing overall probability distributions of cost and schedule for a project, perhaps a more useful set of quantities are the ranked list of risk events in order of impacts to the project. Table 3 shows the 5 most important risk events which contribute to overall cost and Table 4 shows the 4 most important risk events which contribute most to schedule. Note that ROW Acquisition and Borrow Pit Relocation have a large impact on both cost and schedule. In the next section we describe how SK DHT used the results of the risk assessment to manage risks on Highway 11 Twinning.

Table 4: Risk and Opportunity Rankings for Schedule

Risk Rank	Contribution to Expected Time Risk (Months)	Risk Event
1	3.3	Significant wet year delays start of construction or causes other construction problems
2	2.3	ROW Acquisition Schedule
3	1.2	Relocation of Borrow Pits
4	0.3	Uncertainty in Horizontal Alignment

Opp Rank	Contribution to Expected Time Opportunity (Months)	Opportunity Event
1	-3.5	C3 Contractor productivity or constructability issues
2	-0.2	Identified Minor Opportunities (aggregate)
3	-0.2	Unidentified Opportunities (aggregate)

5. RISK RESPONSE

One of the prime motivators for carrying out the risk assessment on Highway 11 Twinning was to improve the cost estimation process which had previously underestimated the construction costs on the last three major highway construction projects prior. Given that the outcome of the risk assessment was that the original budget was at the 85th percentile in 2005 $ and at 65th percentile in YOE $ of the risk-based cost estimate, risk management of the project post assessment did not utilize the risk-based cost distribution functions as a starting point.

Instead, the risk management process used the diagnostic risk event information as a starting point. As mentioned in the previous section, the ROW risk event for both cost and schedule figured prominently in the project risk assessment cost and schedule risk rankings. In practice, this risk event has proven to be a major problem in management of the project for both cost and schedule. Delays in ROW acquisition of land at fair market value in both the towns and the rural areas was such a major problem that it caused the delay in commencement of construction for the first phase of the project. In fact because of ROW acquisition delay, no construction work was performed in the entire 2005 summer season, as assumed in the original project plans. Hence commencement of construction was pushed back into 2006 and paving will not begin until 2007. This delay increased the overall cost of the project because of contractual obligations to pay penalties to grading and paving contractors for non-commencement of work. Note that these penalties were much greater than the cost of performing the risk assessment.

As a result of delays in ROW acquisition for the first phase of the project, SK DHT is now negotiating with rural landowners and home and business owners in towns along the ROW – up to two years ahead of planned commencement of construction. This process of planning ahead should mitigate the problem of ROW acquisition delay risk events and eliminate future payment of contractor penalties arising from ROW acquisition delays. As a result of the analysis, the process used in the flowchart (Figure 2) has also changed. ROW Negotiations (Activity #4) will now follow Preliminary Design (Activity #1). ROW Purchase (Activity # 8) must be completed prior to Grading Tendering (Activity #10).

In addition to the results of carrying out a quantitative risk assessment - either information from cost and schedule distribution functions or diagnostic information of quantifying the main drivers of risk – there is a third benefit of performing a risk assessment which can have an important effect on risk management. This benefit arises from professionals from client/owner directly participating in the risk assessment process itself. During the risk assessment of Highway 11 Twinning, project planners and project engineers and managers from DHT gained exposure to environmental issues by interacting with internal Environmental Staff. Environmental issues have proven to be more important to the construction project than had been anticipated originally. The risk assessment process raised awareness to members of the project team in DHT of environmental issues. This awareness will be useful in delivering Highway 11 Twinning and also in upcoming highway construction projects.

6. CONCLUSIONS

This paper has described the risk assessment of cost and schedule for SK DHT’s Highway 11 Twinning project. This was set in the context of a movement towards utilizing quantitative risk assessment processes in government agencies for large transportation construction projects throughout the western world as part of modern project management practice. The risk assessment process involved members of SK DHT’s project team as well as external experts and was facilitated by risk assessors from Golder Associates. Results from the risk assessment included probability distributions for cost and schedule and diagnostic information about which risk events had the greatest impact (either positive or negative) on overall project cost and overall project schedule. One of the most significant risks to both cost and schedule was identified in the risk assessment to be ROW acquisition. This risk has caused significant delays to commencement of the construction and also caused significant penalties to be paid to contractors. Mitigation of this risk is being currently pursued by SK DHT by negotiating ROW purchase for subsequent phases of construction of the project up to two years prior to commencement of tendering grading and paving contracts. Finally, the importance of environmental issues is more greatly appreciated by SK DHT’s project design and construction teams as a result of participation by the internal Environmental Engineer during the risk assessment.

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