A PRACTICAL APPLICATION OF REAL OPTIONS UNDER THE REGULATORY INVESTMENT TEST FOR TRANSMISSION

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1. Background

This paper summarises analysis undertaken by NERA Economic Consulting on behalf of Grid Australia with respect to the calculation of option value as part of the evaluation of alternative transmission investments. This analysis has been prompted by the new requirement under the National Electricity Rules (NER) to include the option value of transmission investments as part of the assessment of net market benefit under the Regulation Investment Test for Transmission (RIT-T), in cases where it is expected to be material.

Specifically, NERA has been asked by Grid Australia to provide a practical example of the calculation of option value and the incorporation of option value within the RIT-T assessment. We have undertaken a case study based on a simplified but realistic transmission investment decision, and have focused on:

How option value would be calculated in this case, including the models and techniques that are required; and

How the calculation of option value could be incorporated into the overall calculation of net market benefit under the RIT-T.

2. An Introduction to Option Value and Real Options

From a traditional perspective, the "core" value of a transmission investment alternative can be defined as the difference in net benefit (typically net present value or NPV) over a forecast period between choosing that alternative or choosing a "do nothing" status quo case. In determining this core value, the investment alternative is traditionally considered to be fixed; that is, a commitment is made at the beginning of the forecast period to a particular strategy and that strategy is followed without adjustment over the entire period.

In contrast, the additional "option" value of a transmission investment alternative can be defined as the difference in net benefit between committing to a fixed strategy for the entire forecast period (that is, the core value discussed above) and committing to the strategy initially at the beginning of the forecast period, but switching as appropriate to other strategies during the period as new information is revealed. Since this switching is a right but not an obligation – ie, an option – the additional option value must always be non-negative. That is, the company always has the right to stay with the fixed strategy, so having an option to switch cannot decrease the net benefit associated with that investment.

In an investment planning context, there are three necessary conditions for materially positive option value:

1. First, there must be **uncertainty**. Without uncertainty, there is no need to consider the possibility of switching strategies in the future. The future is known and the best decision under certainty can be made now.
2. Second, there must be **learning**; that is, the state of information regarding uncertainty must change over time. With uncertainty but without learning, the future may not be known but that state of knowledge (or lack thereof) remains constant. There is no reason to postpone any decision-making and the best decision under uncertainty can be made now.
3. Third, there must be **flexibility**; that is, there must be the possibility of acting on the basis of new information over time. With learning but without flexibility, there is no ability to take advantage of that learning and switch strategies.

"Option value" is captured when uncertainty, learning and flexibility are incorporated appropriately into the decision-making process. "Real options" is the technique used to calculate this option value and determine the appropriate potentially-flexible strategy on the basis of both the core and option values.

3. The Real Options Approach

In the context of the RIT-T assessment process, the real options approach involves the following steps.

1. **Determine if the *problem structure* suggests there could be material option value for the investment alternatives being considered**

   Is there significant *uncertainty* over future conditions? Is there expected to be *learning* regarding that uncertainty? Do some of the potential alternatives exhibit investment *flexibility*?

   Is there no 'obvious' best alternative under most/all future outcomes? Or said another way, is there a significant "possibility of regret." (i.e., If I choose A and X happens, will I really regret not having chosen B in the first place?)

2. **Develop a *scenario model* and associated data of the possible decisions and uncertainties over time**

   Incorporate the potential for staged investments, acceleration, delay and the like. (flexibility)

Incorporate uncertainties in key variables, and changes in uncertainty over time (learning)

3. **Develop a *financial model* and associated data for estimating net market benefit in each scenario**

    Identify appropriate tools for assessing the market benefits of the investment alternatives (eg, fuel cost savings, deferral of generation benefits). These tools will typically be the same large-scale wholesale market models currently used to estimate benefits for RIT-T assessments where option value is not included.

    Develop a parametric "model of the models" that uses these tools to estimate market benefits as a function of scenario variables. This will model market benefits in way that is feasible for option value analysis by allowing thousands of possible scenarios to be evaluated in a short amount of time.

4. **Generate results using option simulation and evaluation (decision tree roll forward, tree roll back)**

    Determine range of net market benefits and the expected value of the net market benefit for each strategy

    Identify the investment strategy that maximizes the expected-value of the net market benefit.

5. **Validate recommendation using large-scale models as necessary**

    Confirm the recommendations by validating key results using the large-scale models.

The case study below illustrates the application of this approach to a simplified but realistic transmission investment problem. The case study was undertaken as a 'proof of concept' to illustrate the analysis required, rather than with a focus on the particular results. As a consequence, some steps in the process were abbreviated. In particular, we used existing generic results from large-scale models in order to generate the parametric 'model of the models' in step 3, rather than undertaking wholesale market modeling specific to the case study. As a result, only minimal validation with large-scale models as in Step 5 was conducted. The focus of this case study is instead on Steps 1 through 4: problem structure, scenario model, financial model and results.

4. Case Study

4.1. Problem Structure

Our case study involves a hypothetical region where electricity demand is growing with an anticipated future shortfall in transmission capacity in the absence of investment. The investment would therefore be characterised as ‘reliability corrective action’ under the NER. However we have assumed that it would also have an impact on NEM dispatch outcomes, and that there would therefore also be market benefits arising from the investment, which would need to be included in the RIT-T assessment. The best investment alternative is chosen based on maximizing expected net market benefit, whilst ensuring that the reliability standard is met, consistent with the NER.

The case study includes two credible options to address the anticipated growth in demand, reflecting “fixed” network investment alternatives:

(A) A single circuit line, with a capital cost of $20m

(B) A double circuit line, with a capital cost of $32m

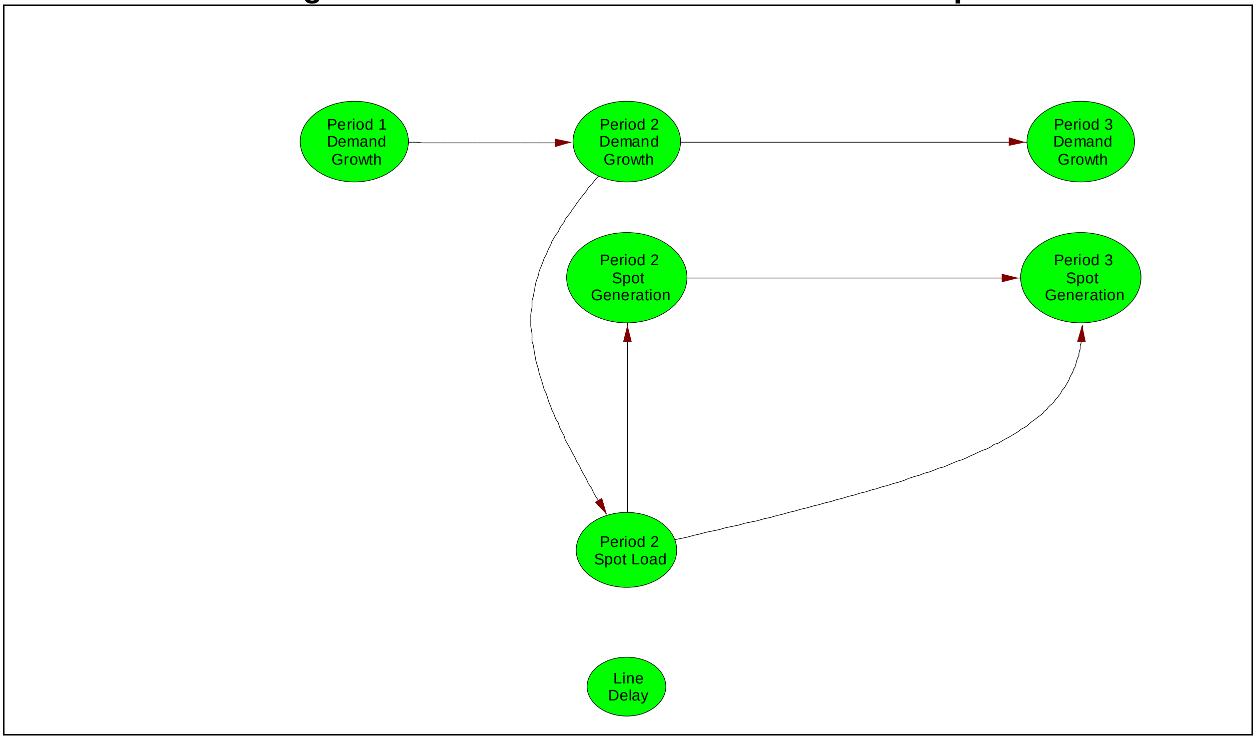
With each of these fixed investment alternatives, once the initial decision is made, the additional transmission capacity provided by the investment remains constant over the entire forecast period. In this example, the forecast period is 15 years divided for convenience into three periods.

The case study also includes three major categories of uncertainty:

1. Regional demand growth ranging from 2% to 6%.
2. Regional spot load and generation additions on the order of 100MW. A sizable new spot load (such as a mine) may enter over the forecast period. If this occurs, it may bring with it new generation in the area
3. Future line construction delays (in the order of years). In time, it may become more difficult to obtain easements and environmental approval for transmission capacity additions.

Figure 1 illustrates the evolution of these uncertainties and their relationships over time in what is called an influence diagram. The arrows between uncertainties indicate probabilistic dependence. The arrows from Period 1 Demand to Period 2 Demand to Period 3 Demand are an example of learning over time. The arrows from Spot Load to Spot Generation are an example of correlation.

Figure 1. Uncertainties and their Relationships



To illustrate the role of option value, two additional credible options are included in the case study representing "flexible" network investment alternatives. These alternatives can take advantage of learning regarding each of the above three categories of uncertainty. With each flexible alternative, an initial decision is made that can be adjusted at a later date. With each flexible alternative, the additional transmission capacity during the forecast period can vary in response to evolving conditions.

The two flexible investment alternatives are:

(C) A single circuit line with a capital cost of $20m, with the option of adding a second single circuit line later at capital cost of a further $20m.

(D) A double circuit line with a single side strung with a capital cost of $23m, with the option of stringing the second side later at an additional capital cost of $10m.

By construction then, this case study includes the critical pieces necessary for materially-positive option value: uncertainty, learning and flexibility. Further, there is no "obvious" alternative that is clearly best across the range of potential future conditions.

4.2. Scenario Model

As noted above, the real options approach requires a "scenario model" that lays out the decisions and uncertainties over time. The scenario model in this example is illustrated in Figure 2 in the form of a schematic decision tree.

In the figure, a yellow square box represents a decision to be made and the branches emerging from that box are the alternatives associated with that decision – for example, whether to construct a single circuit line, double circuit line, or double circuit line with one side strung at the beginning of the forecast period. A green circle represents an uncertainty and the branches emerging from that circle are the outcomes associated with that uncertainty – for example, high, base or low demand growth. Each path through the tree is effectively a possible scenario of many decision alternatives and uncertain outcomes. In this tree, there are many thousands of such scenarios.

This tree clearly illustrates the three critical elements of option value: uncertainty, learning and flexibility. Uncertainty is reflected directly in the individual uncertain outcomes: regional demand growth, spot load/generation, and line construction delays. Learning is reflected in the evolution of each of these uncertainties over time. For example, as discussed earlier, demand growth in one period provides information which informs forecasts of demand growth in later periods. Finally, flexibility is reflected in the existence of future or "downstream" investment decisions that are made based on the latest information.

4.2.1. Scenario data

In the real options approach, uncertainty and learning are treated formally and probabilities are assigned to each uncertain outcome at each point in time in the scenario model.

Figure 3 provides a sample of the probability data for demand growth. In the first period, there is considerable uncertainty. There is a small chance that demand will grow at the "base" rate, and a substantial chance that it will grow at either the "low" or "high" rate. In the second period, the level of uncertainty about demand growth is greatly reduced based on the learning in the first period. Specifically, high demand growth in period one means there will very likely be high demand growth in period two; low demand growth in period one similarly implies low demand growth in period two, and even base demand growth in period one increases the probability of base demand growth in period two. This is an example of substantial learning.

Similar data is included in the scenario model for all uncertainties.

Figure 2: Scenario Model

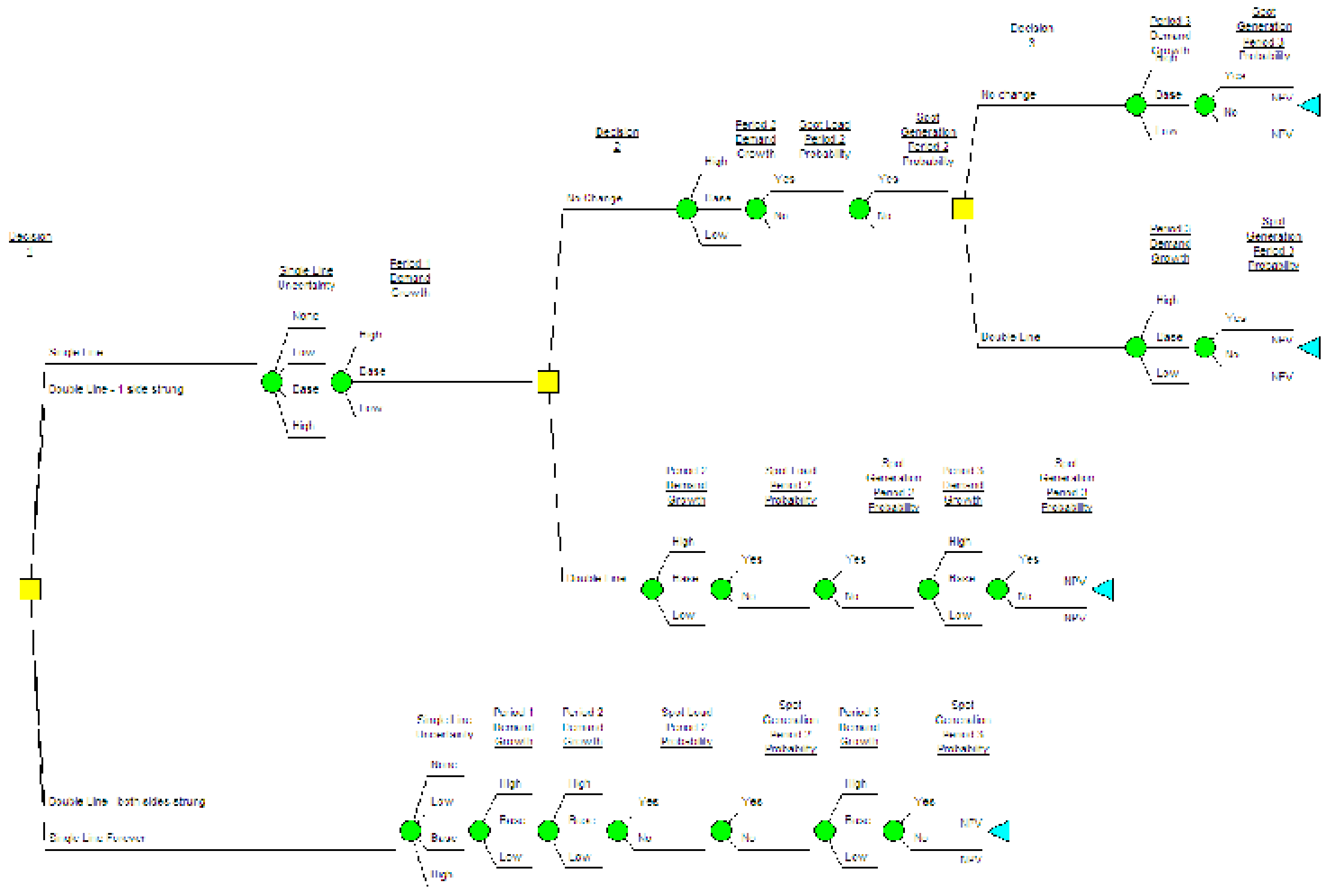
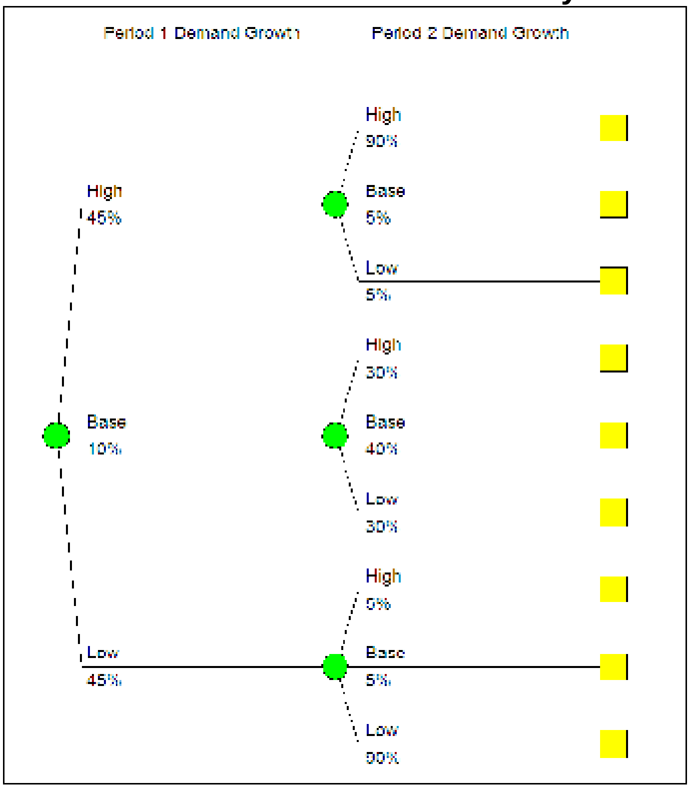


Figure 3: Scenario Data: Demand Uncertainty and Learning



In practice, assigning probabilities to each of the uncertain outcomes in the scenario model involves a mix of data and judgment. Judgmental probabilities are generally developed using two well-established techniques. The first is to use a structured probability encoding[1] process to assess the opinion of individual experts. The second is to use a structured expert aggregation[2] process to combine these individual opinions. These two processes have been used in a wide range of applications both in the public and private sectors. In this case study, representative probabilities were developed based on discussions with individual experts within the transmission businesses.

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1 Carl S. Spetzler and Carl-Axel S. Stael von Holstein, *Probability Encoding in Decision Analysis*, Management Science, Volume 22, Number 3, November 1975, pp. 340-358.

2 Robert T, Clemen and Robert L. Winkler, *Combining Probability Distributions from Experts in Risk Analysis*, Risk Analysis, Volume 19, Number 2, 1999, pp. 187-203.

4.3. Financial Model

As noted earlier, the real options approach also requires a second “financial” model that calculates the net market benefit for each scenario. Figure 4 provides a screenshot of the financial model used for this case study. This model calculates the NPV of the net market benefit for each scenario.

The net market benefit for this case study includes capital costs, operating costs, changes in network losses and market benefits arising from the impact of the investment on the operation of the wider wholesale market (i.e., fuel consumption, unserved energy, deferral of generation investment). This case study excludes other potential categories of market benefit, such as deferral of unrelated transmission investment and impact on voluntary load-shedding. In practice, these benefits can and should be included where material for a particular problem.

We note that this financial model is similar to the NPV modelling used for the RIT-T analysis where there is no separate option value being calculated. However, for real options analysis the model needs to be capable of providing the NPV results for all of the thousands of possible scenarios depicted in the scenario model.

4.3.1. Development of a parametric ‘model of the model’

As noted above, the real options approach requires an estimate of net market benefits for all the scenarios in the scenario model. In this case study, there are thousands of such scenarios. In other applications, the number of scenarios could be considerably larger. It is unrealistic to run one or more large-scale wholesale market models thousands of times (or more) for this purpose, Instead, we must develop a parametric ‘model of the models’ – indicating how the results of such models change as a result of changes in the scenario variables. The ‘model of the models’ emulates the large-scale results in a way that makes rigorous option value analysis feasible.

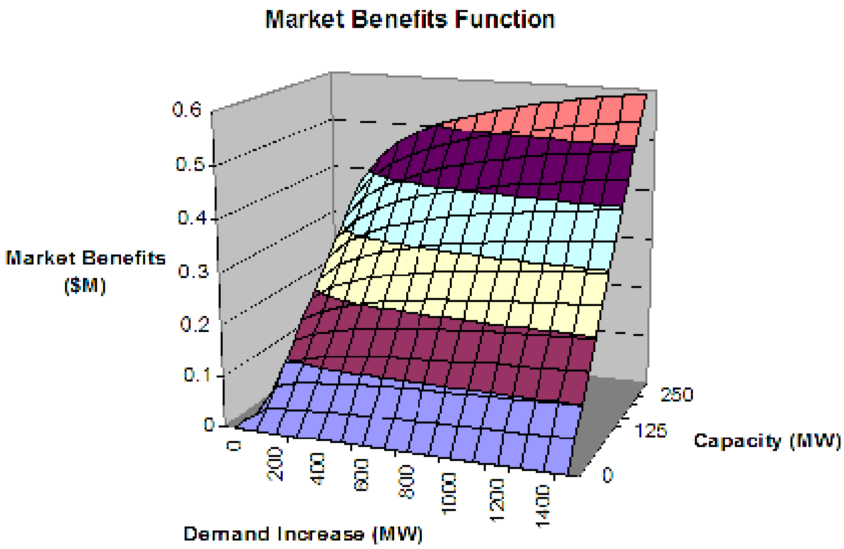
To develop this “model of the models”, we first run a small number of the large wholesale market model cases for different settings of the key scenario variables, such as demand and capacity. We then develop a “best fit” model from these runs that relates each market benefit to the setting of each key scenario variable. Figure 5 shows an example of this form of data; that is, the function used to capture market benefits based on the demand increase and capacity additions in MW.

For this case study, we did not undertake wholesale market modeling specific to the case study, but utilized generic model runs used in a previous regulatory test assessment as a ‘proof of concept’.

Figure 4: Example of Financial Model for the Case Study

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		START	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2	DEMAND / CAPACITY																
3	Base Demand	150	153.75	157.59375	161.5336	165.5719	169.7112	173.954	178.3029	182.7604	187.3294	192.0127	196.813	201.7333	206.7767	211.9461	217.2447
4	Spot Load Growth						0	0	0	0	0	0	0	0	0	0	0
5	Spot Generation Growth						0	0	0	0	0	0	0	0	0	0	0
6	Total Demand	150	153.75	157.59375	161.5336	165.5719	169.7112	173.954	178.3029	182.7604	187.3294	192.0127	196.813	201.7333	206.7767	211.9461	217.2447
7																	
8	Capacity	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150	150
9																	
10	COSTS																
11	Capital Expenditures		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Total Capital Expenditure		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
13																	
14	OpEx		0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
15	Residual Value of Assets		0	0	0	0	0	0	0	0	0	0	0	0	0	0	-14.4
16																	
17	Total Costs		20	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-14.1
18																	
19	RELIABILITY STANDARD																
20	Penalty Function			0	0	0	0	0	0	0	0	0	0	0	0	0	0
21																	
22																	
23	MARKET BENEFITS																
24	DECISION 1: $M of Capital Expenditure Operational		0	20	20	20	20	20	20	20	20	20	20	20	20	20	20
25	Years of Operation		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
26	DECISION 2: $M of Capital Expenditure Operational		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Years of Operation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	DECISION 3: $M of Capital Expenditure Operational		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Years of Operation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30																	
31	Fuel Consumption		0	0.0404423	0.04878	0.054768	0.059471	0.063359	0.066687	0.069605	0.07221	0.074567	0.076725	0.078719	0.080575	0.082313	0.08395
32	Load Shedding		0	0.0034824	0.0042	0.004716	0.005121	0.005456	0.005742	0.005994	0.006218	0.006421	0.006607	0.006778	0.006938	0.007088	0.007229
33	Deferral of Investments		0	0.0256081	0.030887	0.034679	0.037657	0.040119	0.042226	0.044074	0.045723	0.047216	0.048583	0.049845	0.05102	0.052121	0.053157
34	Network Losses (Savings over business as usual)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35																	
36	Total Benefits			0.0695328	0.083867	0.094164	0.102248	0.108934	0.114656	0.119673	0.124151	0.128204	0.131915	0.135343	0.138533	0.141522	0.144337

Figure 5: Financial Data: Market Benefits as a Function of Demand Increase and Capacity Additions



4.4. Results

Based on the problem structure, models and data described above, the net market benefit of each path through the decision tree is calculated using a process called "tree roll forward." Then, using a process called "tree roll back," the investment strategy that maximize expected (ie, probability weighted) net market benefit is identified. Well-established commercial software packages are available for conducting this form of analysis, including DPL by SyncopationSoftware and PrecisionTree by Palisade. For this case study, DPL was used.

In this case study, the investment strategy consists of an initial decision and downstream or contingent decisions that are made based on the evolution of uncertainties over time. The key results for the case study are illustrated in Figure 6. This figure compares each of the four investment alternatives on two dimensions: overall return as measured by the expected net market benefit, and overall risk as measured by the "worst" or 10^{th} percentile of net market benefit. We note that the RIT-T criteria relates only to maximising the expected net market benefit. However, it is informative to see how the outcomes also differ in terms of their associated risks.

The first two rows of the table show results for the two fixed investment alternatives. These results indicate that, if faced just with these two alternatives, the single circuit choice has higher overall return (by $2m) but higher risk (by $12m).

The last two rows show the two flexible investment alternatives. Both show higher net market benefit compared with the fixed alternatives. Overall return as measured by expected value increases by \$2m to \$3m over the best single circuit fixed alternative. Overall risk as measured by the 10th percentile decreases by \$16m to \$17m over the best single circuit fixed alternative. The strategy which satisfies the RIT-T criteria (i.e., maximising the expected value of the net market benefit) is the double circuit, initially stringing only a single side. In this example this is also the best choice based on risk.

Figure 6: Summary of Net Market Benefit Results

	Alternative	Expected Benefit	"Worst Case" (10th Percentile) Benefit
	Single Circuit	\$0M (by definition)	\$0M (by definition)
	Double Circuit	-\$2M	+\$12M
	Single Circuit (with another single circuit option)	+\$2M	+\$16M
Best	Double Circuit Single Side strung (with second side strung option)	+\$3M	+\$17M

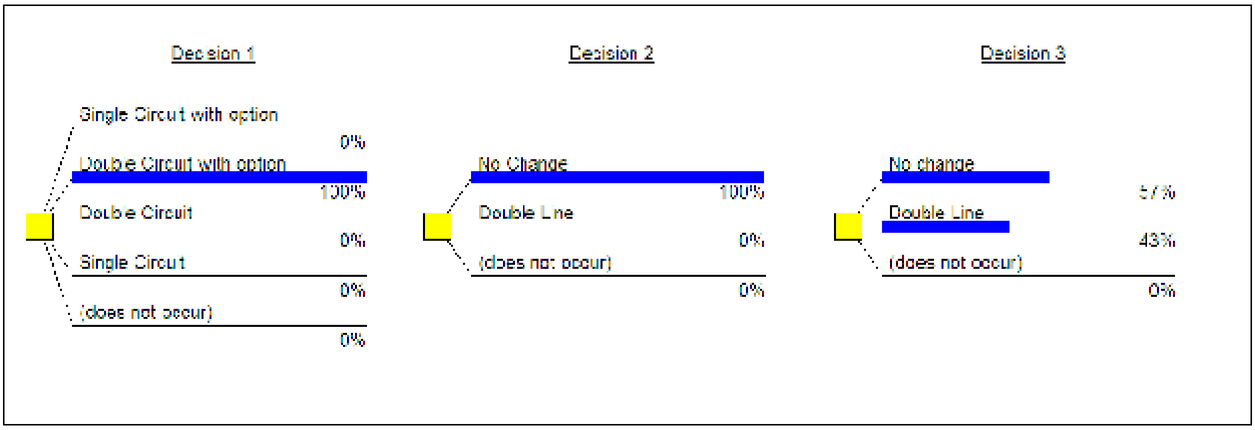
Option value (increased return)

Option value (reduced risk)

Note: ''Worst Case' (10th Percentile) Benefit' results refer to the ***improvement*** in the net market benefit in the lowest 10th percentile of outcomes, rather than the actual level of net market benefit in those outcomes.

Figure 7 shows exactly what the flexible investment strategy entails over time. As the figure indicates, the strategy begins with the double circuit, single side strung. This choice remains unchanged through the second period. In the third period, depending on how the uncertainties evolve, the best investment may be to continue to only have one side strung (around 57% of the time) or to string the second line (around 43% of the time). As is intuitive, the added capacity in the third period is associated with higher demand, added spot load and the like.

Figure 7: Description of Investment Strategy which Maximises the Net Market Benefit



5. Insights and Recommendations

In our example, the real options approach that explicitly quantifies the option value of flexible investment alternatives has identified a strategy that increases net market benefit by $2-3m on an NPV basis, and reduces risk by $15-20m in NPV terms.[3] This is consistent with experience elsewhere that a real options approach can increase return by 5-20% of the investment cost and reduce risk by up to 25-100% of that investment cost.

Of course, the use of real options analysis comes at a price. The real options approach is more complex than traditional analysis in two major ways. First, it requires a more extensive scenario model – a model of the decisions and uncertainties over time – and the data to go with it. Second, it requires a more robust financial model that can estimate the net market benefit over all of these many scenarios.

This real options approach is therefore not likely to be advisable where option value is anticipated to be small, as it would represent a disproportionate level of analysis. On the other hand, where option value is likely to be material, the real options approach provides a much more rigorous

[3] Expressed as an improvement in the NPV of the net market benefit in the lowest 10^{th} percentile of market benefit outcomes.

identification of the optimal investment strategy and has the potential to identify investment strategies which result in a sizable increase in overall net market benefit