Chapter 11 Options Thinking and Valuation in Decision Analysis

"Wealth is not about having a lot of money; it's about having a lot of options."

11.1 Introduction

- Consideration of options or managerial flexibility in decision-making can potentially provide great strategic benefits to corporations in today's fast-paced business environment.

Consider the following scenario:

- A decision on an investment opportunity has to be made, subject to many uncertainties in the future.

- A straightforward discounted cash flow analysis may either accept or reject the investment opportunity outright.

- Questions:

  1. If an investment is accepted, does the computed NPV really reflects the true value of the project?

  2. If an investment is rejected, is there anything that can be added to make it feasible?

- The problems in the above scenario could have been avoided if real options or managerial flexibility are considered in the analysis.

- Options can potentially allow management the flexibility to respond to new information or situation thereby exploding new favorable opportunities and avoiding unfavorable actions.

- Consideration of options or managerial flexibility in decision-making may therefore allow companies to compete more effectively in a world of great uncertainty and competition.

- In this Chapter, we will introduce the concept of Options Thinking. We will show how identifying and embedding real options in decision situations may enhance the overall values of the decision to the decision maker.

11.2 Financial Options versus Real Options

- Fundamentally, an option is the right but not the obligation, to take an action either now or in the future.
- We discuss here the differences and relationships between Financial Options and Real Options.

11.2.1 Financial Options

- Financial options are instruments for managing risk in the financial market by investors.
- There are two basic types of financial options.
    1. **Call Option** gives the investor the right but not the obligation to purchase an underlying financial asset (e.g., stocks) at a specific price within a specific period or at a specific time.
    2. **Put Option** gives the investor the right but not the obligation to sell an underlying financial asset (e.g., stocks) at a specific price within a particular period or at a specific time.
- The *Option Premium* is the price that an investor pays to own the option.
- The date at or before which the option may be exercised by the buyer is called the *Maturity Date* or *Exercise Date.*
- An option that can be exercised earlier than its maturity date is called an *American Option*.
- An option that can be exercised only at the maturity date is called a *European Option*.
- The price at which the option buyer has the right to buy or sell the underlying asset is known as the *Strike* or *Exercise Price* of the option.

Financial Options Pricing

- Option pricing theory is concerned with the valuation of financial options.
- The Black-Scholes model is the most common option pricing theory.
- See John Hull's book on "Options, Futures, and Other Derivatives" for details.

11.2.2 Real Options or Managerial Flexibility

Development of Real Options Theory

- Real options theory was developed in the late 1970s due to growing discontent with the traditional methods for assessing projects under uncertainty, like the traditional discounted cash flows method.

- Around the same time there was significant development in financial option pricing techniques such as the Black-Scholes formula and the binomial lattice approach

- The idea behind Real Options analysis is to model managerial flexibilities as analogous to financial options in order to adjust projects or act in response to the resolution of uncertainty. Principles and formulas from investment analysis and financial options theory are used to value investment in real assets.

- However, financial options models may not work well when applied to real options because many of the assumptions on the underlying stochastic processes that drive stock prices and market efficiency, etc., are drastically different from those outsides of the financial market.

- Force fitting these assumptions to investment opportunities on real assets often lead to inaccurate or misleading valuations.

- Examples of Real Options in Investments:

Option Type	**Description**
Abandonment	The option to terminate a project realizing its salvage value.
Flexibility to switch	The option to change business processes or models in response to changes in demand, prices, etc.
Enter and Exit	The option to exit an investment activity and re-enter as conditions become more favorable.
Right to defer	The option to delay investment outlays until such time that the investment is more profitable.
Staged investment	The option to make investment outlays in successive stages with the right to abandon the project as more information becomes available.
Growth	The option to capitalize on an earlier investment, such as one in R&D, to enter into related investment projects.
Compound Options	Multiple interacting options, including for example the option to defer, to expand and to switch.

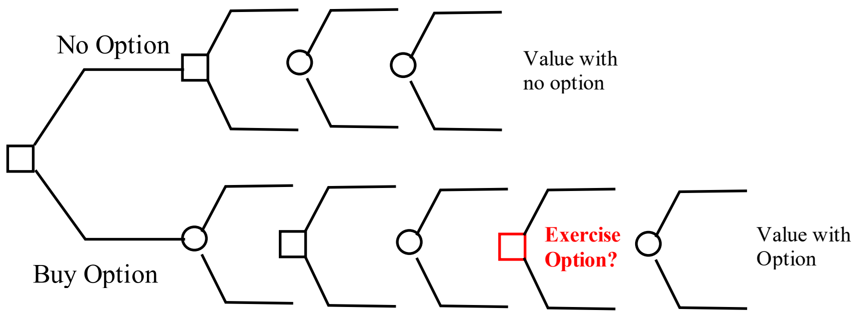
11.3 Decision Analysis Approach to Real Options

11.3.1 Modeling Real Options in Decision Models

- From the Decision Analysis perspective, an option is simply a decision point or node that is embedded downstream of the initial decision in response to the uncertainty that will be resolved considering possible future uncertainty.

- We define the **Value of an Option** as the cost of the option at which the decision maker is indifferent between having and not having the option.

- It is the maximum amount that the decision maker is willing to pay for the option.



- When the decision maker has constant absolute risk aversion (CARA) or the Delta Property:

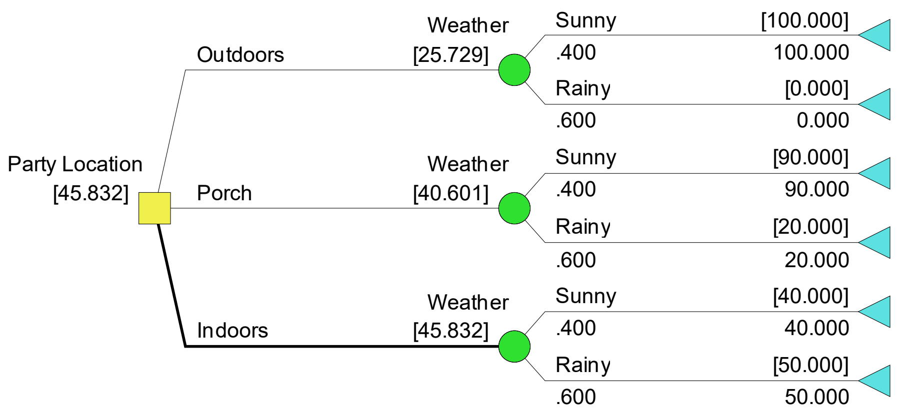
  Value of Option = CE with Free Option – CE with No Option.

11.3.2 Party Problem with Options

- We will use the Party Problem to illustrate the various types of options that might be considered in order to enhance the overall value to the decision-maker.

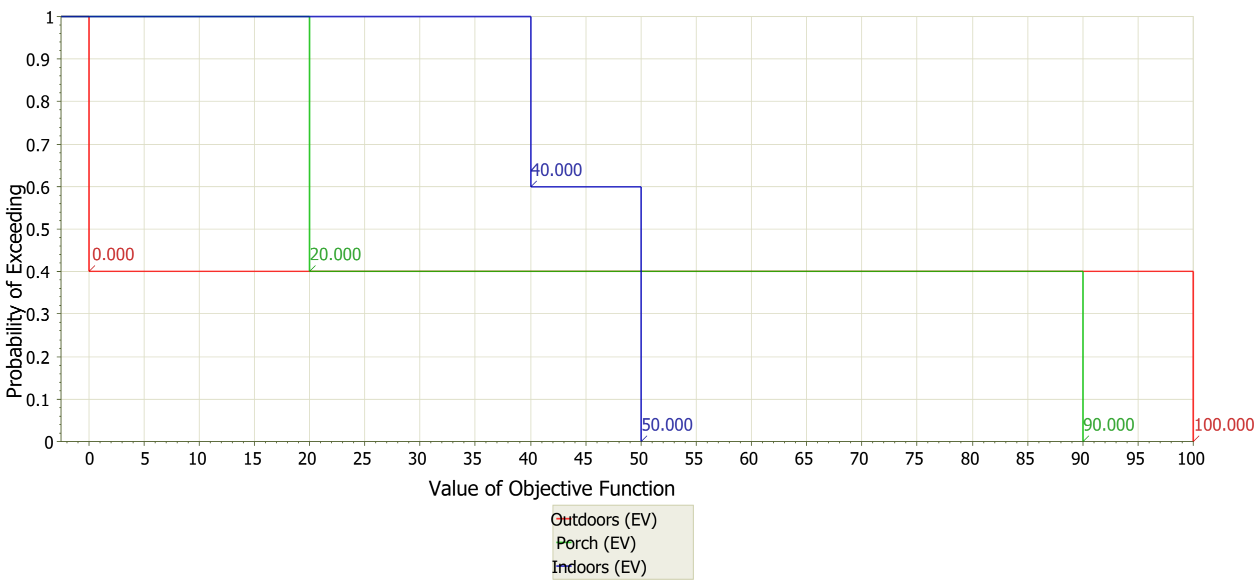
Base Decision Model with No Option

- The decision model for Kim's Party Problem with no options is shown below:



- The decision is to hold the party indoors and the certainty equivalent is $45.832.

- The risk profiles for the alternatives are:



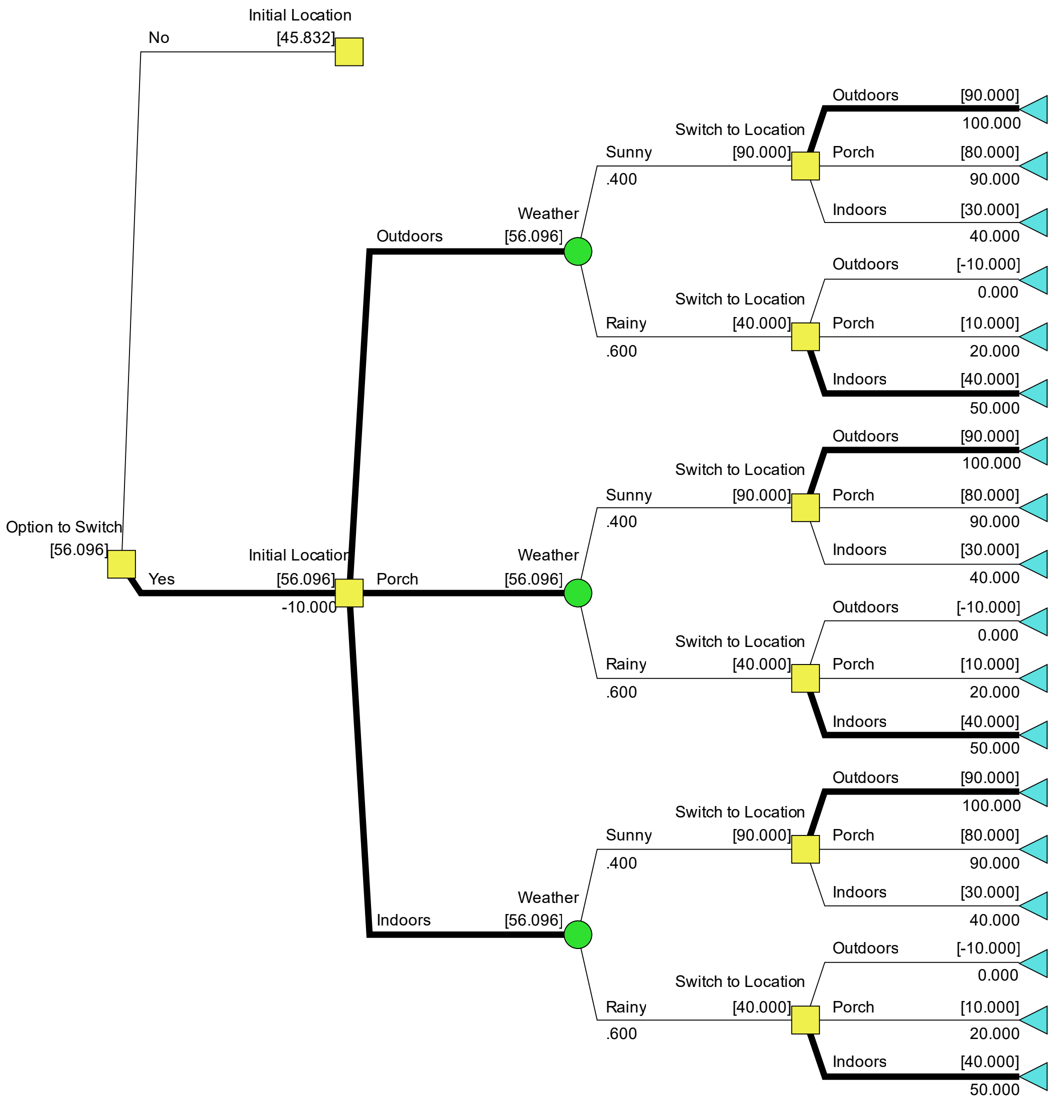
- We will analyze the following 5 Options for the Party Problem:
  1. Option to Switch Party Location Anytime
  2. Option to Switch Party Location with Exercise Cost
  3. Option to Defer until Uncertainty on Weather is Resolved
  4. Option to Defer until More Information on the Weather
  5. Option for Multiple Deferments for Information

1. Option to Switch Party Location Anytime

- Suppose Kim can purchase an option from the party caterer that allows her to switch the party location anytime at no further cost (i.e., zero strike price), but this option must be purchased in advance.

- If the cost of this option is $10, should she purchase it, and what is the maximum she is willing to pay for the option?

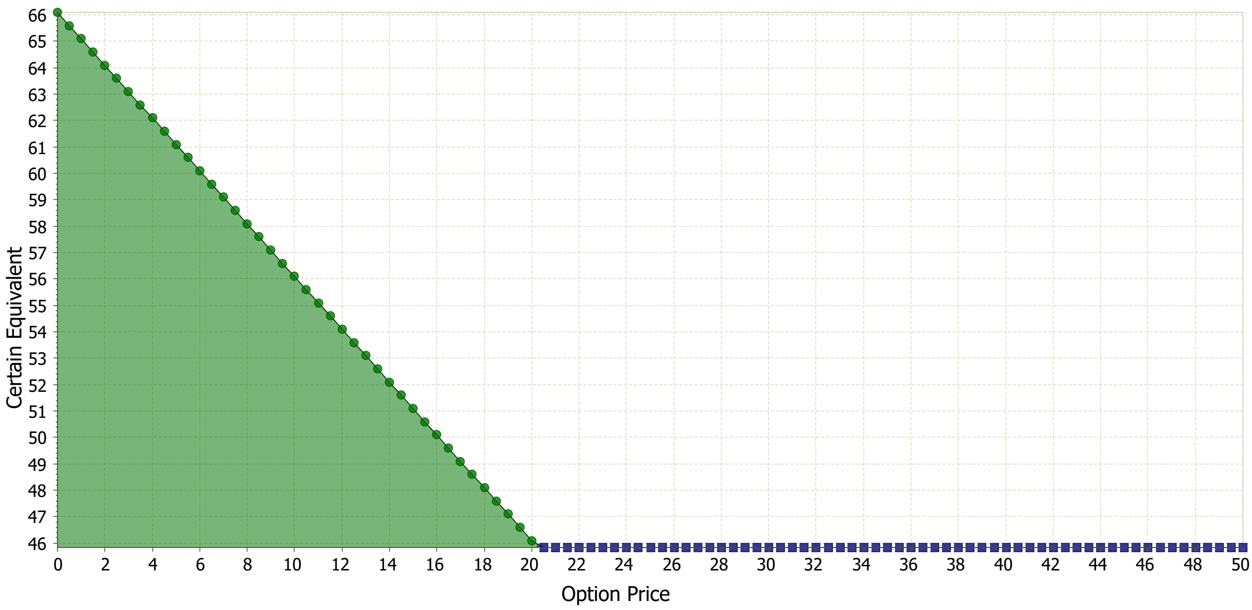
- The optimal decision policy tree is as follows:



- Kim should purchase this option at $10.

- She will be indifferent between the three party locations initially but will switch the party location to outdoors if the weather is sunny and to indoors if the weather is rainy if she is not already in the correct location.

- If we vary the Option Price from $0 to $50, Kim's CE will be as shown in the following Rainbow diagram:



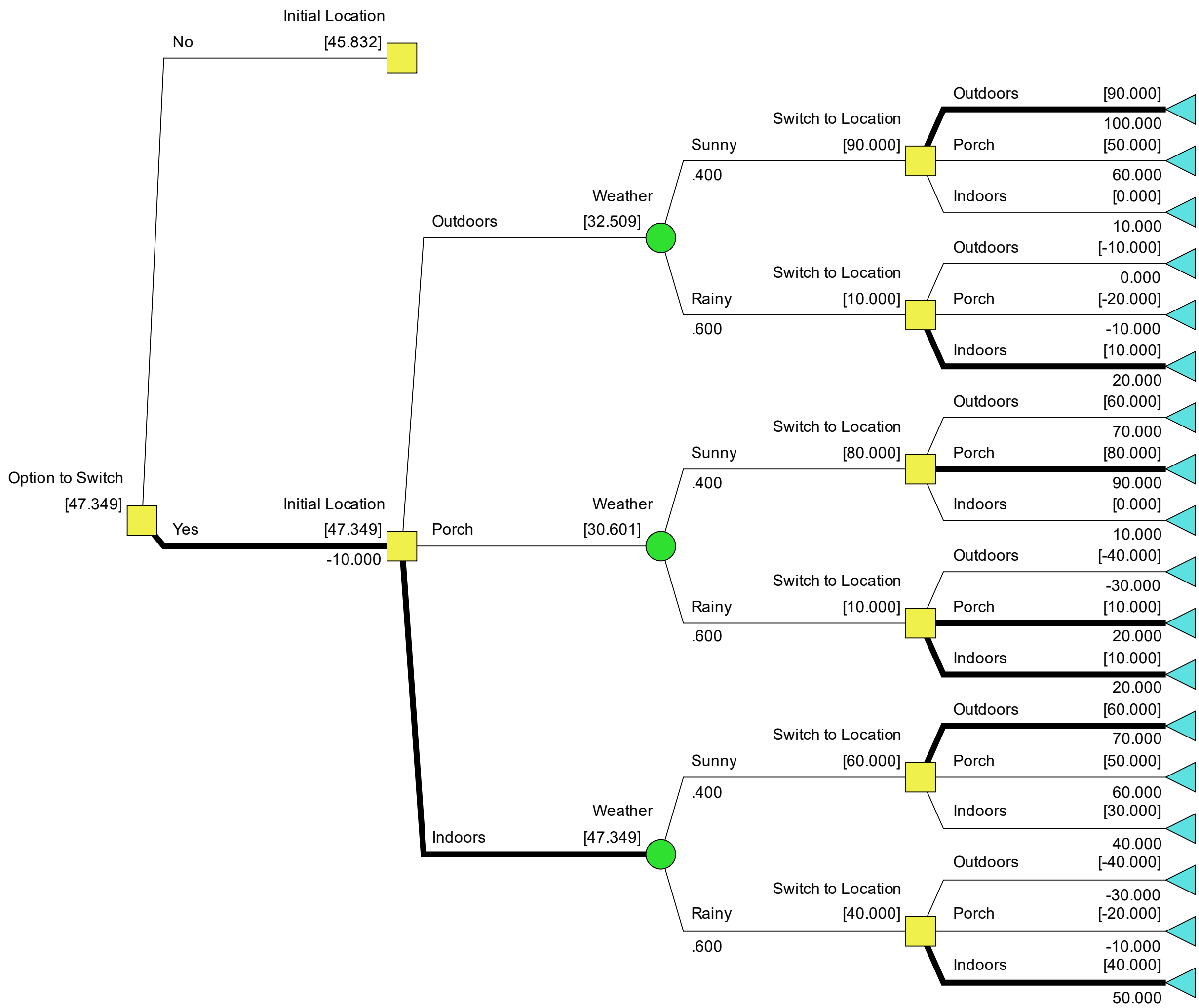
- The maximum Kim is willing to pay for this option is about $20.2 from the rainbow diagram.

- Hence the value of this option to Kim is about $20.2

2. Option to Switch Party Location with Exercise Cost

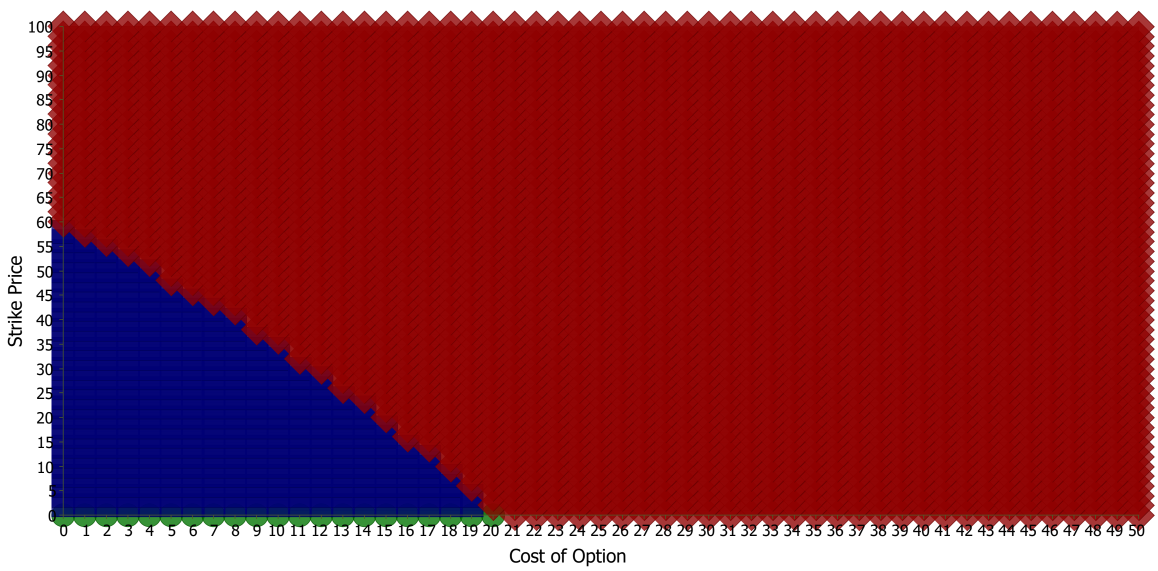
- Suppose Kim can purchase an option at $10 that allows her to switch the party location anytime at an exercise cost of $30, should she purchase it?

- The optimal decision policy tree is as follows:



- Kim should purchase this option at $10 with an exercise price of $30.

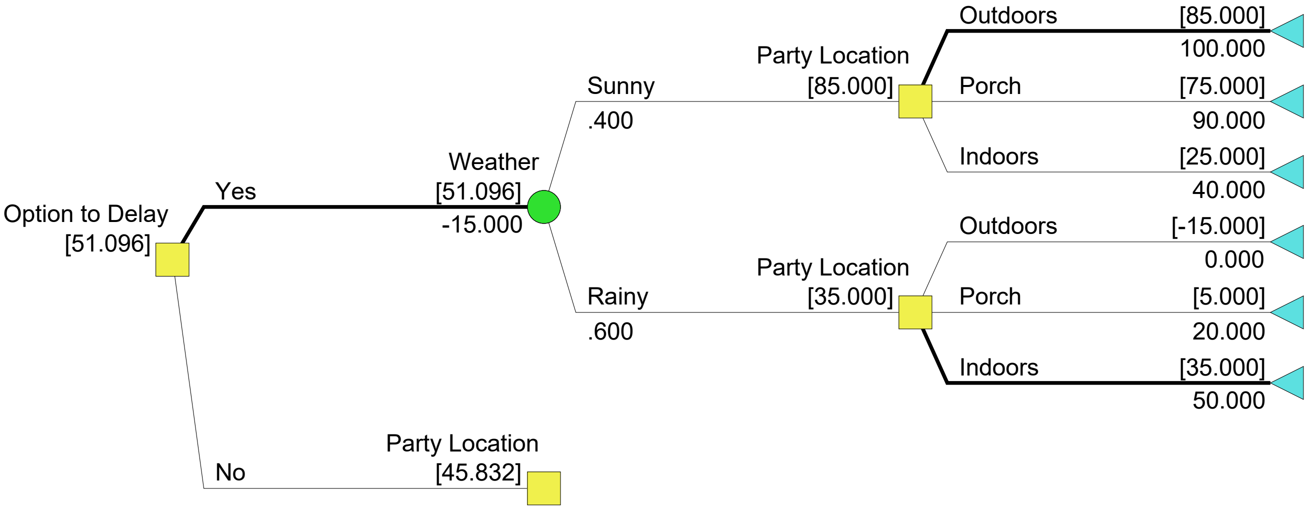
- A 2-way rainbow diagram for the decision to purchase or not at various option and exercise prices is shown below:



3. Option to Defer until Uncertainty on Weather is Resolved

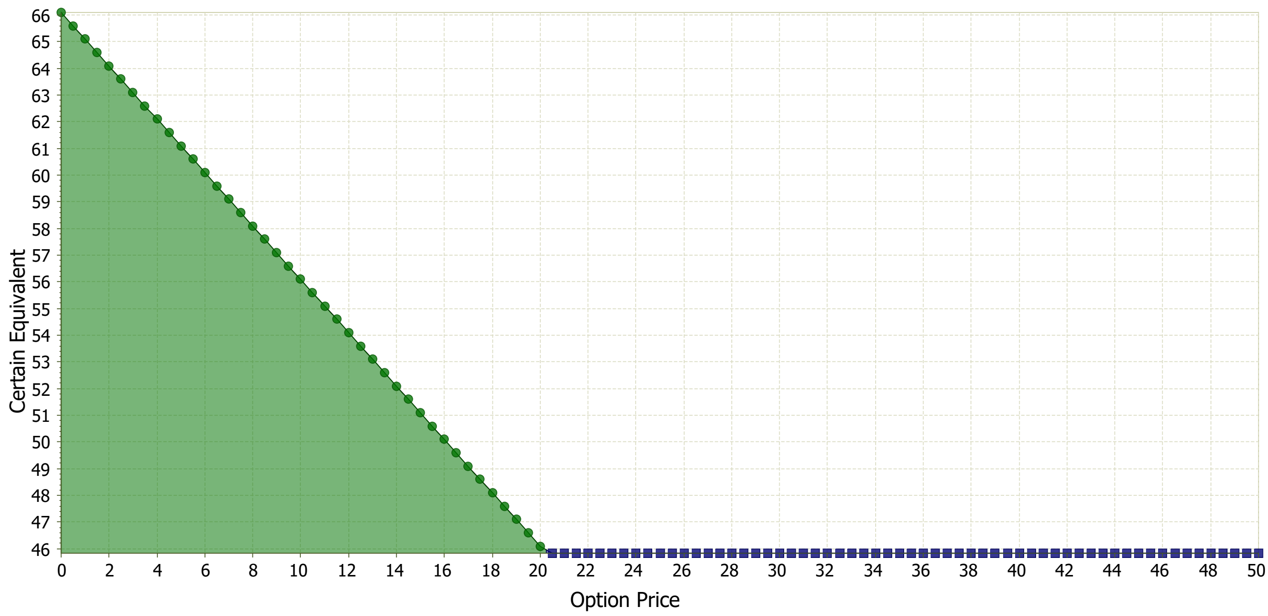
- Suppose Kim can purchase an option at $15 that allows her to defer her decision until the uncertainty is fully resolved, should she purchase it? This is equivalent to the value of perfect information analysis:

- The optimal decision policy tree is as follows:



- Kim should purchase this option at $15.

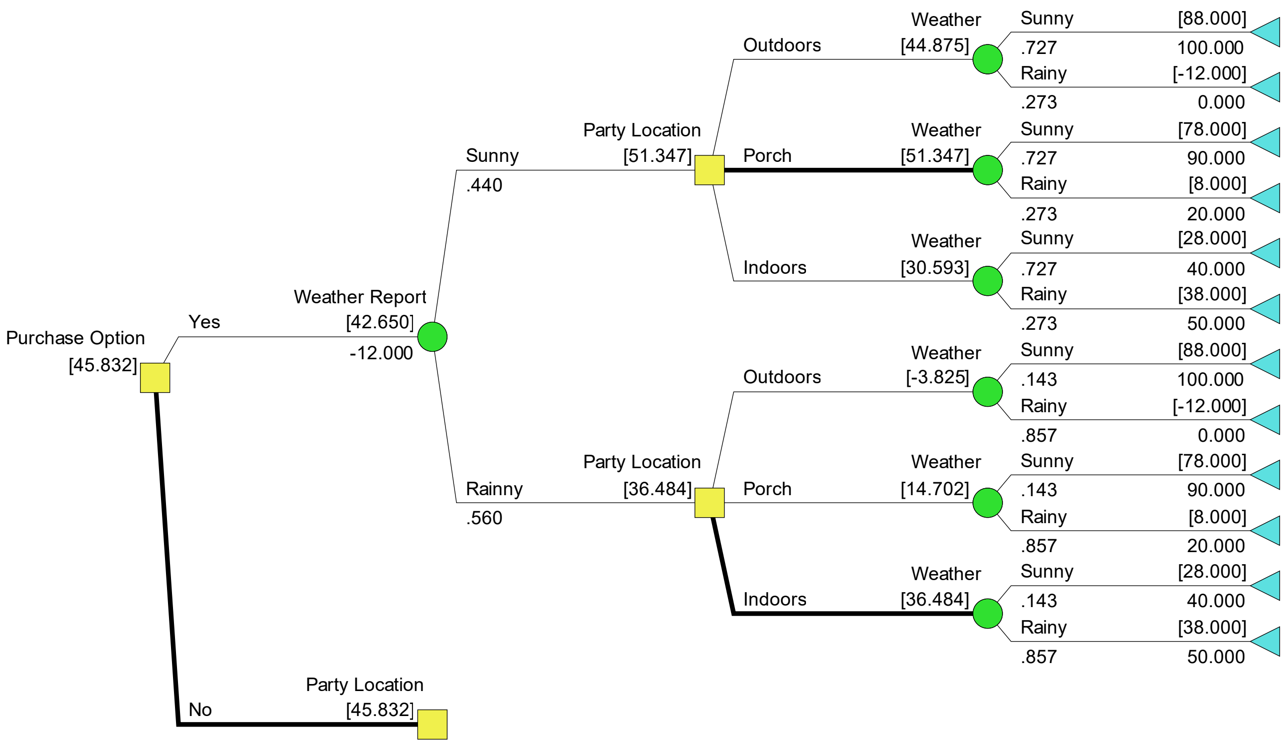
- Rainbow diagram for Cost of Option.



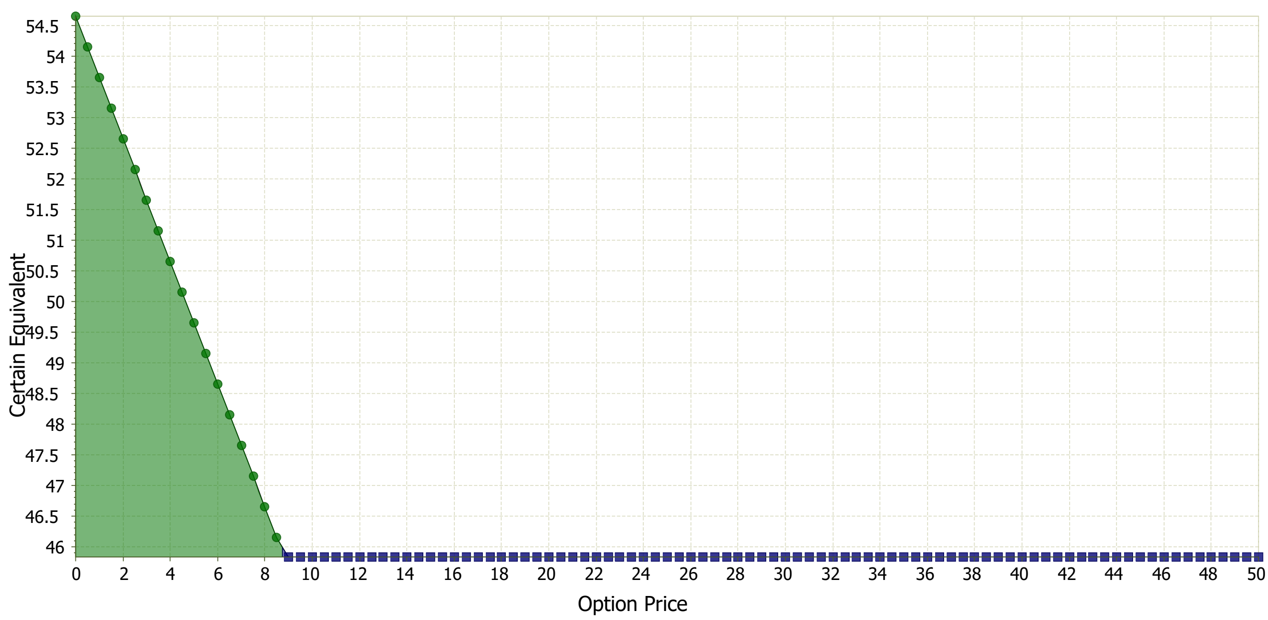
- The value of this option to Kim is about $20.2

4. <u>Option to Defer until More Information on the Weather</u>

- Suppose Kim can purchase an option at $12 that allows her to defer her decision and wait for more information on the weather. This information has a true detection rate of 80% for both sunny and rainy weather.
- This is equivalent to the value of imperfect information analysis.
- The optimal decision policy tree is as follows:



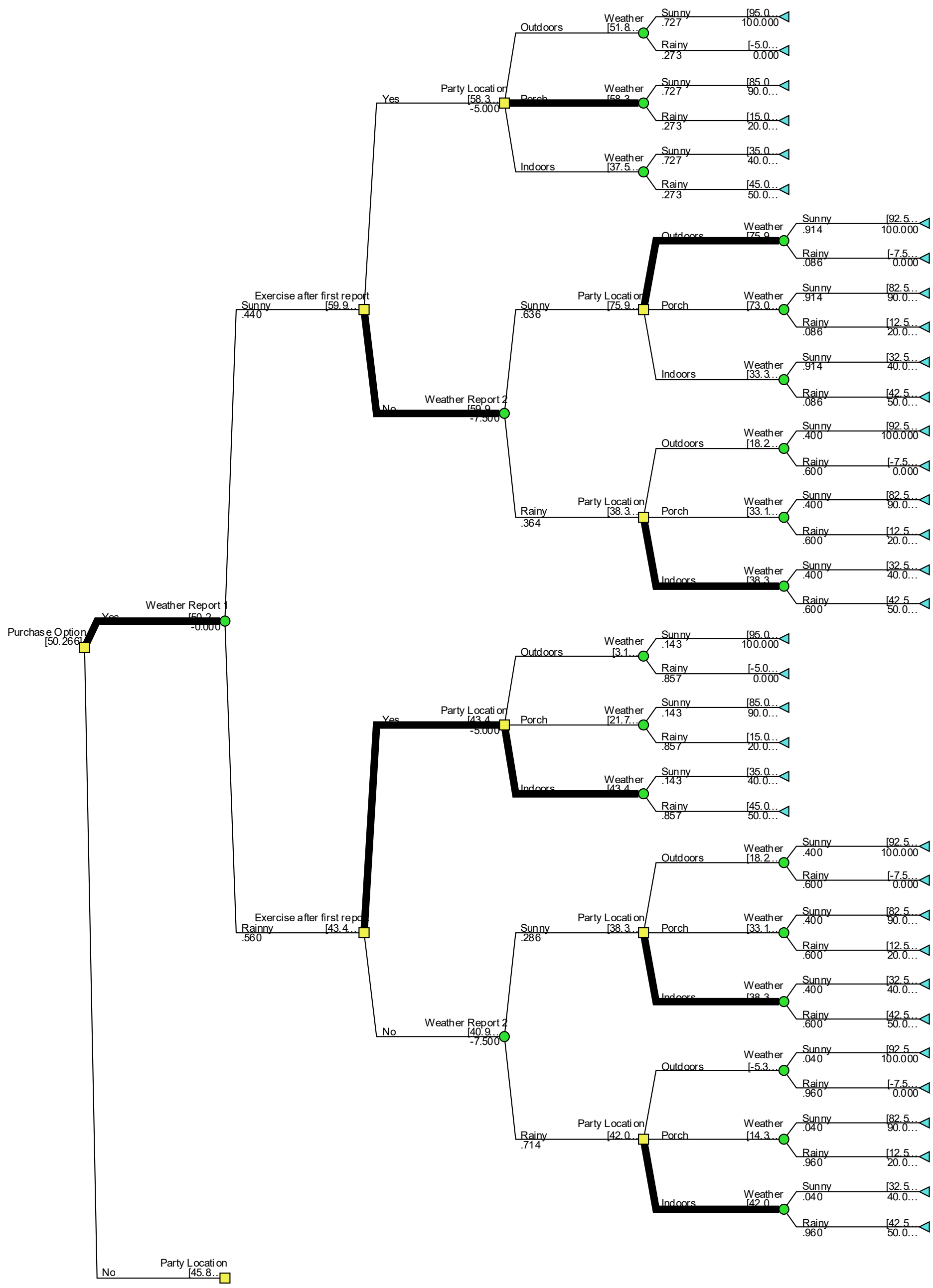
- Kim should not purchase this option at $12.
- Rainbow Diagram for Cost of Option:



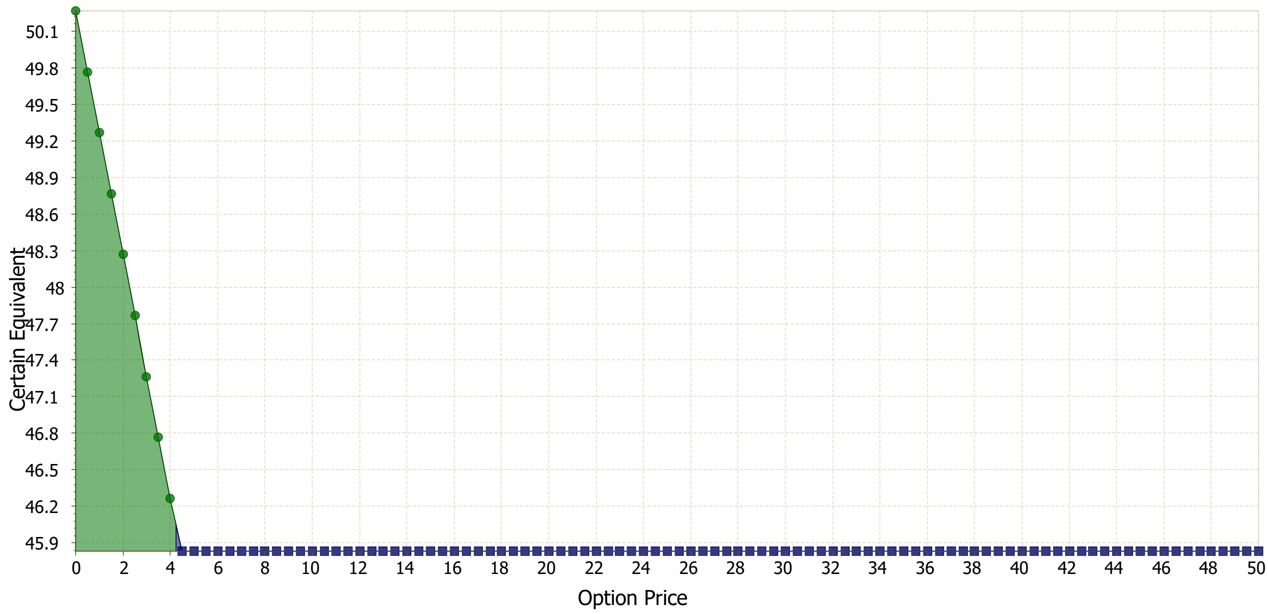
- The value of this option to Kim is about $8.8

5. <u>Option for Multiple Deferments for Information</u>

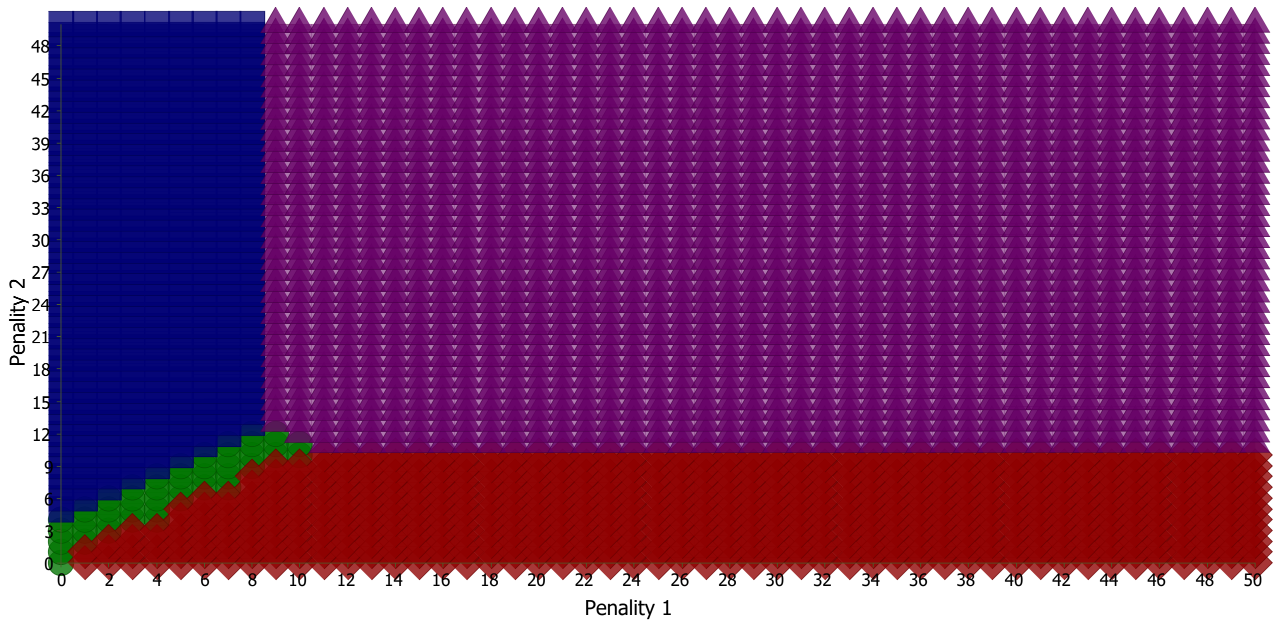
- Suppose Kim has a FREE option to decide on the location now (no penalty) or defer her decision and wait for the first information on the weather. If she makes this delayed decision now, there is a penalty of $5.
- She can also choose to delay again and wait for second information on the weather. At this time, she must make a decision and there is a penalty of $7.50.
- Both information sources have a true detection rate of 80% for both sunny and rainy weather and they are conditionally independent given the weather.
- This is equivalent to the value of sequential imperfect information analysis:
- The optimal decision policy tree is as follows:



- Rainbow Diagram for Cost of Option:



- Two-Way Rainbow Diagram



11.4 Options Valuation in Investment Decision Analysis

Case Study: *iDesigner.com* Investment Problem

Background

- Wendy has been working on creating an intelligent online interior design system (iDesiger) that is capable of creating design concepts, generating design plans, make furniture and fabric recommendations all online based on users' preferences, lifestyles, and budgets.

- Wendy hopes to set up the *iDesign.com* website as a startup company. However, the followings work still needs to be done:

  1. Bring the iDesigner intelligent engine to full functionality and test run it.

  2. Create a first-rate website with extensive data and knowledge bases of existing design concepts and knowledge of expert interior designers, complete with shopping cart and payment capabilities.

  3. Raise a sum of $100,000 to pay her a subsistence salary and to lease computer and networking equipment for the next 6 months.

- By the end of 6 months, she would know whether *iDesign.com* is economically viable.

John the Investor

- Wendy approaches John to invest in her proposed startup, whereby he would put up $100,000 and take up 1/3 ownership of iDesign.com.

- Should John accept the investment proposal if he is risk neutral and his *MARR* is 10% per 6 months?

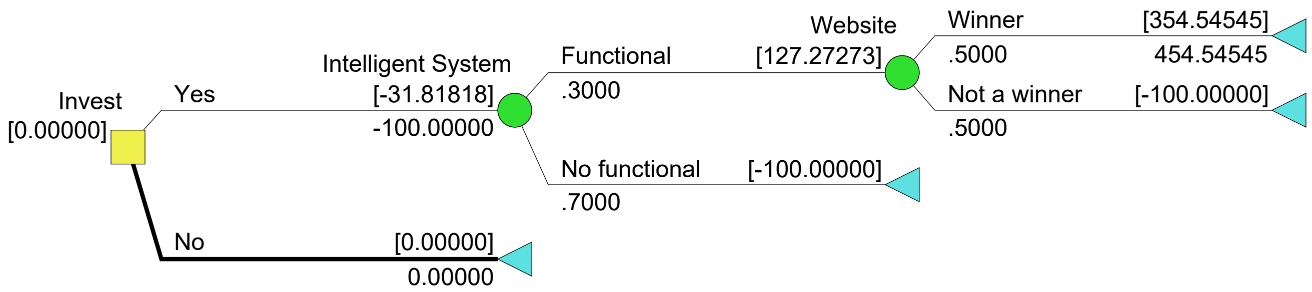
Decision Model with No Option

- After viewing some demos of the incomplete iDesigner.com engine, John thinks that there is a 0.3 chance that it would become fully functional in 6 months.

- Furthermore, even if it is fully functional, there is only a 0.5 chance that the website would be a winner.

- If all is successful, John values the business then to be worth \$1.5 million and his 1/3 share of the company would be worth \$500,000.

- A decision tree for John's problem is:



- Note on endpoint computations:
  - If all goes well at the end of 6 months, NPV = $-100{,}000+\dfrac{500{,}000}{(1+0.1)}=\$\,354{,}545.45$
  - If the engine is functional, but the website is not a winner, NPV = –\$100,000.
  - If don't invest, NPV = \$0.

- Rolling back the tree
  If Invest = yes, Expected NPV = – \$31,818.18 < 0
  If Invest = no, NPV = \$0

- Hence John says NO to Wendy.

- This is an option-free valuation

- John was prepared to walk away from this investment. In doing so, however, he would be overlooking latent value in the business. He has not considered what might be done with partial success and other opportunities in the future.

- For example, if the technologies of the underlying computational engine are good, but the website fails, he could abandon the web business and sell the technology.

- Alternatively, if he finds that he has a winning website but a failed computational engine, he may switch to a different technology and make use of the website.

- Each of these are real options, which if included in the analysis, could make turn the decision from No to Yes.

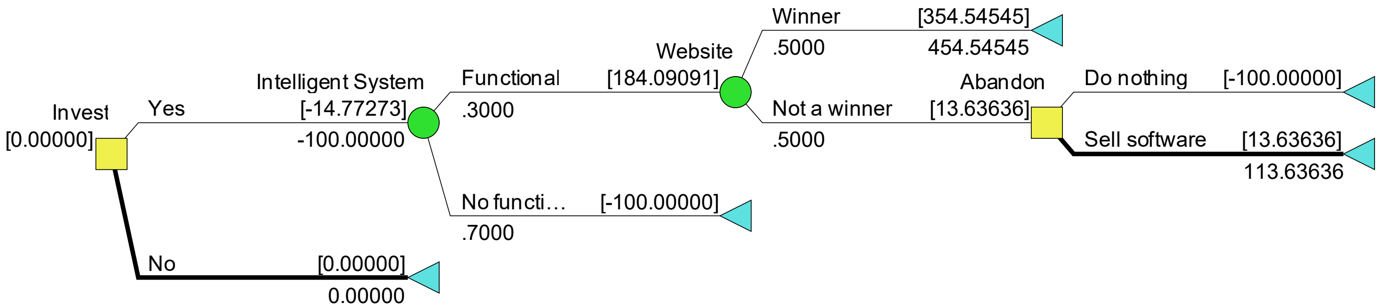
Option to Abandon

- If the underlying computational intelligent engine succeeds but the website fails, the business may be abandoned and the technology sold.

- If this happens, John can invest another \$25,000 and the software can be modified and sold for \$450,000 of which John receives his 1/3 share of \$150,000.

- Under this scenario, NPV = $-100{,}000+\dfrac{-25{,}000+150{,}000}{(1+0.1)}$ = $\$13{,}636.36$

- Decision tree with Option to Abandon:



- Expected NPV for investing with option to abandon = - \$14,772.73 < 0

- The Present Equivalent Value of the Abandon Option
  = Expected NPV with option – Expected NPV with no option
  = (– \$14,772.73) – (– \$31,818.18)
  = 17,045.45

- However, the value of this option is not sufficient to make the investment acceptable.

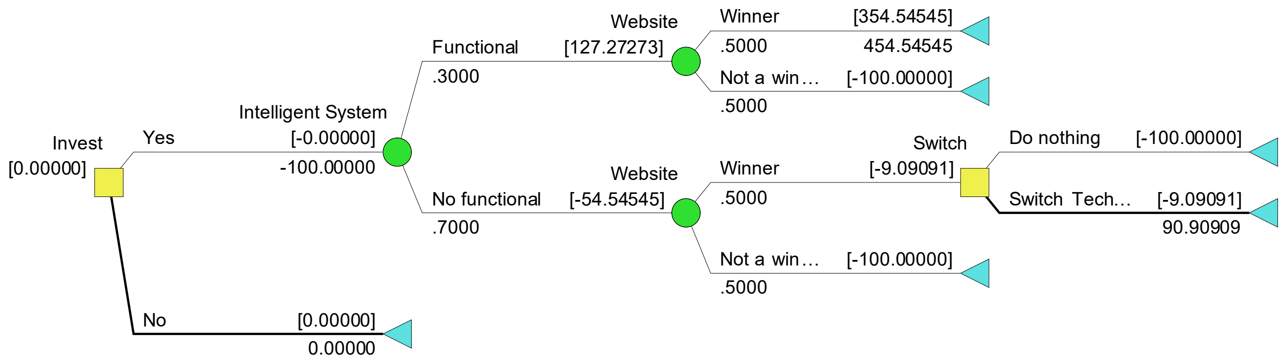
Option to Switch

- If the Website is a success but the technology is not, it is possible to switch to an alternative technology with slower computational performance but there will be fewer features.

- Because the system is now inferior, John would only receive \$100,000 for his share of the business.

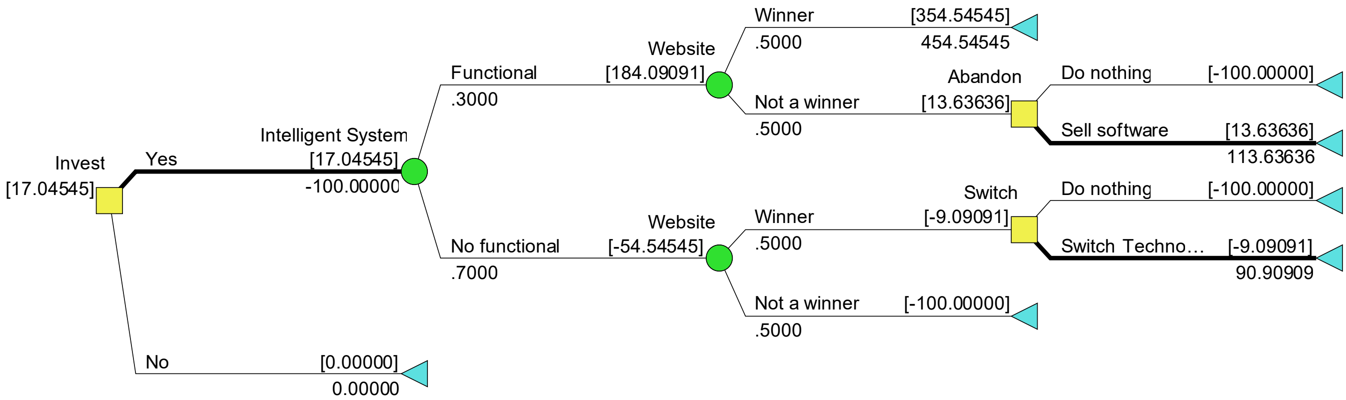
- NPV under this scenario = $-100{,}000 + \dfrac{100{,}000}{(1+0.1)}$ = -\$9,090.91

- Decision tree with Option to Switch only:



- Expected NPV with Option to Switch only = \$ 0
- Present Equivalent Value of only Option to Abandon = 0 – (–\$31,818.18) = **<u>\$31,818.18</u>**
- The investment with the only option to switch just economically viable.

- Decision tree with Options to Abandon and Switch:



- Expected NPV for investing with Option to Abandon and Switch = \$17,045.45
- Present Equivalent Value of Options to Abandon and Switch
  = \$ 17,045.45 – (– \$31,818.18) = **<u>\$48,863.63</u>**

- The investment with options to switch and abandon is now economically viable.

Option to Expand

- The business might be expanded one year from now if it is viable.

- This option requires John to invest another \$150,000 six months from now, and the expanded business will yield net profits equivalent to a uniform perpetual series of

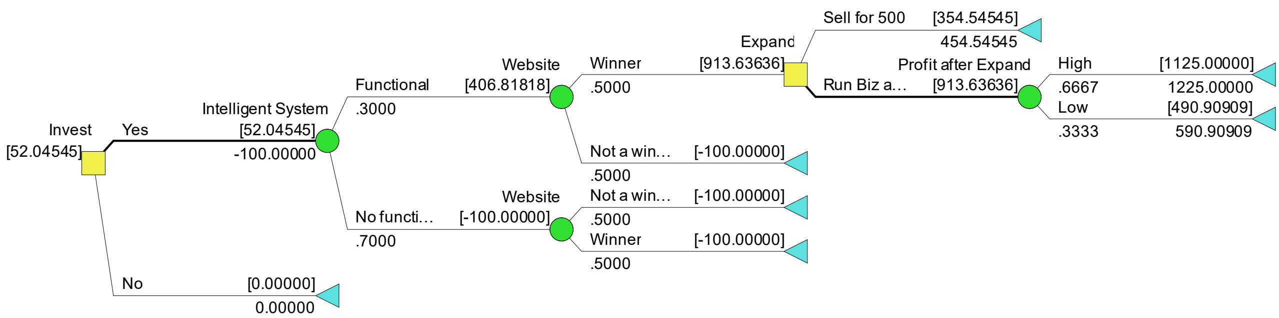
  \$149,750 per six-month with probability 2/3
  \$ 80,000 per six-month with probability 1/3

- Possible NPVs if the option is exercised

$$= -100{,}000 + \frac{-150{,}000 + 149{,}750/0.1}{(1+0.1)} = \$1{,}125{,}000.00 \quad \text{with probability } 2/3$$

Or $$= -100{,}000 + \frac{-150{,}000 + 80{,}000/0.1}{(1+0.1)} = \$490{,}909.09 \quad \text{with probably } 1/3$$

- Decision tree with only Option to Expand:

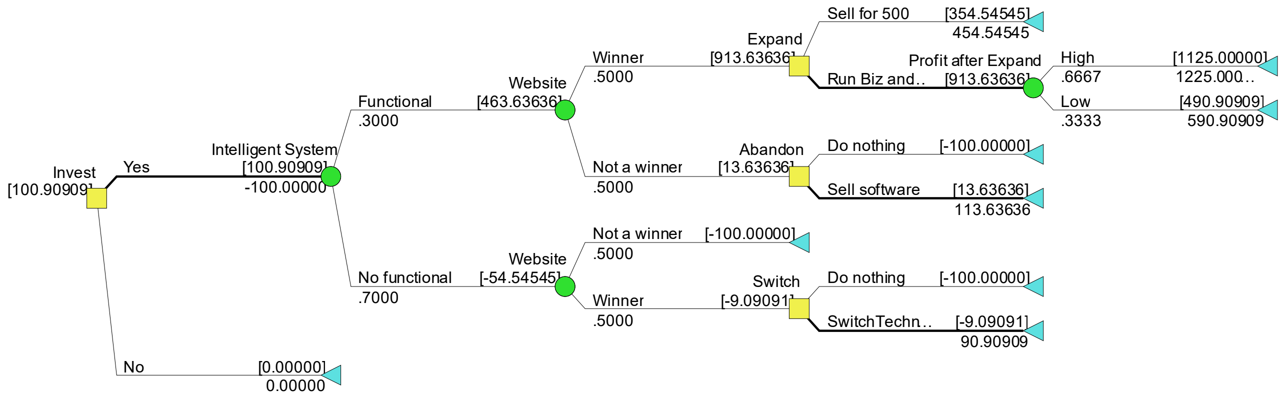


- Expected NPV with only Option to Expand = \$ 52,045.45

- Present Equivalent Value of Options to Expand

  = \$ 52,045.45 – (–\$31,818.18)
  = **\$ <u>83,863.63</u>**

- Decision tree with Options to Abandon, Switch, and Expand:



- Expected NPV with Options to Abandon, Switch and Expand
  = $100,909.09

- Present Equivalent Value of Options to Abandon, Switch and Expand
  = $100,909.09 – (–$31,818.18)
  = **$132,727.27**

Summary of Results

	Alternative	Expected NPV ($)
0	Do not Invest	0
1	Invest with No Option	–31,818.18
2	Invest with only Option Abandon	–14,772.73
3	Invest with Options to Abandon and Switch	17,045.45
4	Invest with only Option to Switch	0
5	Invest with only Option to Expand	52,045.45
6	Invest with Options to Abandon, Switch and Expand	100,909.09

	Option(s) to	Present Equivalent Value ($)
1	Abandon	17,045.45
2	Switch	31,818.18
3	Switch and Abandon	48,863.63
4	Expand	83,863.63
5	Switch, Abandon and Expand	132,727.27

References

1. David G. Luenberger. *Investment Science*, Oxford University Press, 1998.

2. John C. Hull. *Options, Futures, and Other Derivatives,* 9th Edition. Pearson Education, 2015.

3. F. Black and M. Scholes. The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81:637-645, 1973.

4. T. Copeland and V. Antikarov. *Real Options, A Practitioner's Guide,* Texere, 2003

5. K.L. Poh. IE2140 Engineering Economy Lecture Notes, 2019, or IE5003 Cost Analysis & Engineering Economy Lecture Notes 2016.

Exercises

P11.1

(*a*) Ella is risk neutral and is offered a dice tossing game: A fair dice is thrown and Ella will receive \$100x if the outcome is x points (where x = 1, 2, …, 6). What is Ella's personal indifferent buying price for the game?

(*b*) Suppose Ella can purchase the game in part (*a*) with an option to throw the dice again after making the first throw. If she does throw the dice again, and she will be paid based on the outcome of second throw. What is Ella's personal indifferent buying price for the game with a re-throw option? What is the value of the re-throw option?

(*c*) Suppose Ella can purchase the game in part (*a*) with options for up to two re-throws and she will be paid based on the outcome of the final throw. What is Ella's personal indifferent buying price for the game with two re-throw options? What is the value of the option with up to two re-throw?

P11.2

Repeat Problem 10.1 if Ella is risk averse with a constant risk tolerance of \$200. Compare the results obtained here with those in Problem 10.1.

P11.3

A startup company has recently developed a new product based on a new technology. The product has two major potential markets A and B. The success or failure of the product in both markets is not independent. It is assessed that there is a 50% chance that the product will succeed in market A. Furthermore, if the product is successful in Market A, it will also succeed in Market B with probability 0.8, and if the product fails in Market A, it will also fail in Market B with probability 0.9.

Market A requires an initial investment of \$100,000 regardless of when it is entered. One year after entry, it will have a market value of \$160,000 or \$80,000 for product success and failure, respectively.

Market B requires an initial investment of \$55,000 regardless of when it is entered. One year after entry, it will have a market value of \$140,000 or \$25,000 for product success and failure, respectively.

The company is risk neutral and its MARR is 5% for this project. Ignore any income taxes.

(*a*) If the company must decide on which market (i.e., A only, B only, both A&B or Nil) to enter now, what is its best decision and expected NPV?

(*b*) If the company has the option to delay entering one of the markets by one year, what is its optimal decision policy and expected NPV? Note that the company must enter at least one market now to be able to enter the other market after one year.

(*c*) What is the value of the option to delay entering the market in part (*b*)?

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