Analytical Decision Making

DECISION ANALYSIS FOR OPTIMAL PURCHASE

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1.Project Information:

1.1. Problem Statement:

We have observed an unprecedented increase in temperatures hitting the Pacific Northwest region last year, with temperatures reaching up to 101°F costing more than 95 lives as reported by Washington State. Intense heatwave has both threatened lives and critical infrastructure alike. The vulnerable group of the population- children, elderly, sick and homeless- has borne the most. These climate change events are becoming more recurrent and severe. Considering the Seattle's monsoon weather history, more than 95% of the houses are not equipped to withstand such harsh conditions.

To sustain the extremity in climate change during summer season, we would be trying to do a decision analysis for a homeowner to decide whether to install an AC unit or to rent a cooler for specific days.

The decision conundrum is based on the probability of severity of summer and associated costs. We would be concluding the annual cost of operating and maintaining an AC unit over renting a cooler for specific days to be our decision metric. A longer and more extreme summer will mean more days of renting a cooler which could be offset by buying an AC unit. On the other hand, the exorbitant charge of purchasing an AC unit can be offset only by anticipating using it consecutively over a period of years. The purpose is to understand the most cost-effective decision by understanding various parameters.

1.2. Objectives:

The main objectives of the problem are mentioned below:

- Quantitative methods to identify the magnitude of problem statement: To collect the climate data from National Centres from Environmental Information (https://www.ncdc.noaa.gov/cdo-web/) and National Weather Service (https://www.weather.gov) websites to identify the climate change pattern in Seattle over the past few years to understand the change in climate. The probabilities of severity of summer will be based on that data.
- Take in to account the product shortages and increase in the prices of buying AC units and renting Coolers during the peak summer amidst the heatwaves. The rental prices could increase with shortage of coolers available to rent and stores can run out of AC units to sell or be left with only the most expensive ACs.
- To measure the cost/payoff for an AC unit by taking into consideration various factors while buying an AC which includes size, brand, Seasonal Energy Efficiency Ratio rating and tax credits. The intrinsic installation costs include plumbing, electrical work, duct work and modifying the framing or surfacing of the home for installation.
- To analyse multiple factors for the maintenance of an AC which include leakage and drainage issues, compressor replacement, fan or air blower issues, electrical circuits etc.

- To Analyse the cost/payoff of buying an AC vs Cooler by understanding the electricity consumption and efficiency by referencing on a private website: https://hvacdirect.com/seer-efficiency-savings-calculator.html
- To understand the pros and cons of buying and renting a cooler to analyse the possible decision based on the location.

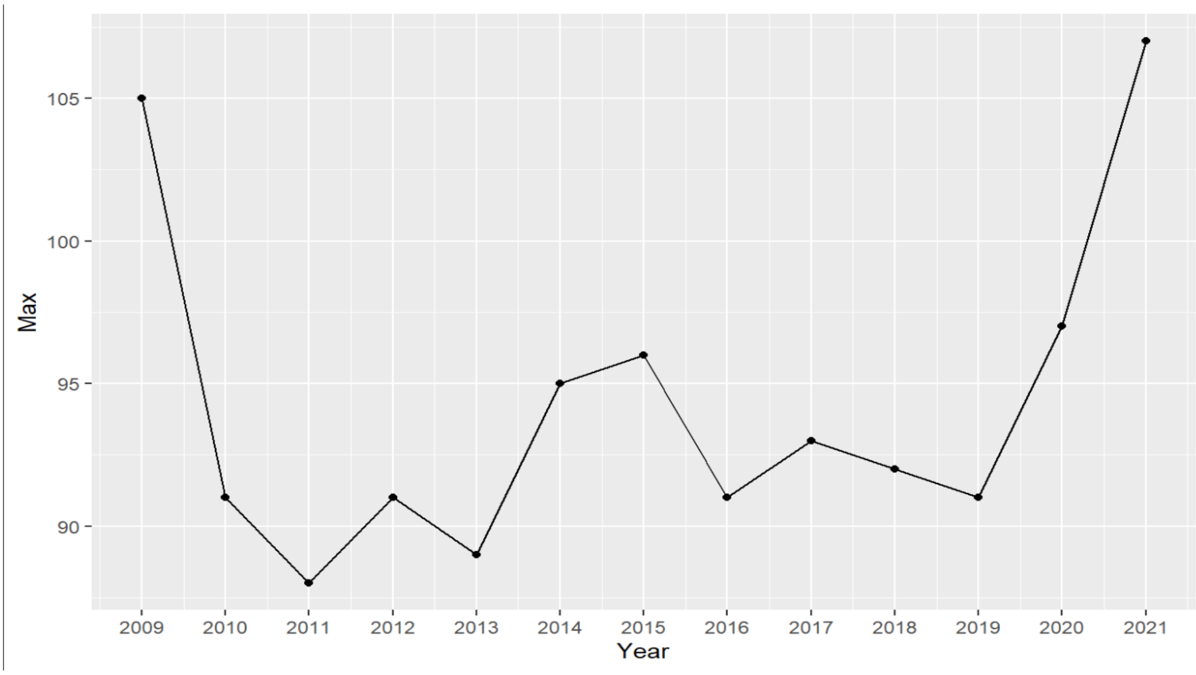
2. Project Research:

2.1. Data Analysis and Research Methodology:

We have collected the climate data from National Weather Service (https://www.weather.gov) websites to identify the climate change pattern in Seattle over the past few years to understand the change in climate. The probabilities of severity of summer will be based on that data.

Source Data: Data used for climate predictions is linked here: Seattle Weather

We have tried analysing the maximum temperature from 2009 to 2021 using R to understand the pattern which is depicted below:



We observe a rising trend in the maximum temperatures from 2019 which intensifies the measures to be prepared for the adverse climatic conditions.

2.2. Evaluation Methods and Evaluation Measures:

Evaluation Methods:

- Decision Tree Analysis to help identify a strategy most likely to reach a goal.
- Optimal Decision: To determine the best payoff scenario among the available uncertain scenarios.

2.3. Evaluation Measures and Decision Scenarios:

We have identified 3 decision scenarios:

A. Purchase of Air conditioning unit
B. Purchase of cooler/ fan
C. Rent of cooler

Particulars	Amount
A. Purchase AC	$700
B. Purchase fan/cooler (2)	$1200
C. Rent of cooler per week	$30
D. Period	5 years

3. Project Data:

3.1. Probability of Summer:

To arrive at the following probabilities, we have analysed data collected from the website of National Weather Service and National Centres from Environmental Information. As observed in the graph earlier, the temperature is Seattle is on a rising trend over the past 10 years, which makes it imperative that we anticipate rise in temperature for this year too

A. Probability of a harsh summer- implying 3 months of warm days (>30^{O}C/ 86^{O}F)- .30 or 30%
B. Probability of a normal summer- implying 1 month of warm days (>30^{O}C/ 86^{O}F)- .50 or 50%
C. Probability of a mild summer- implying 1 week of warm days (>30^{O}C/ 86^{O}F)- .20 or 20%

3.2. Probability of breakdown of machinery:

Assuming all machinery are prone to breakdown at some point, especially beyond warranty period, we have included probability of breakdown. The warranty period covers 3 years in case of newly purchased electronic home equipment's (AC, fan, cooler) and our period is 5 years. This justifies the incorporation of machinery breakdown probabilities. These are the **prior probabilities** in our decision analysis.

Moreover, heightened machinery usage due to extra summer days increases the probability of machinery breakdown. We have taken that into consideration and incorporated probabilities adjusting to severity of weather conditions. By considering these new probabilities, we turn the prior probabilities into **posterior probabilities** in our decision analysis.

SCENARIOS	Probability of summer severity	Probability of breakdown	Probability of no breakdown
Harsh summer (3 months)	0.3 or 30%		
Breakdown probabilities		.5 or 50%	.5 or 50 %
Regular summer (1 month)	0.5 or 50%		
Breakdown probabilities		.3 or 30%	.7 or 70%
Mild summer (1 week)	0.2 or 20%		
Breakdown probabilities		.1 or 10%	.9 or 90%

In our situation, where we have assigned specific probabilities for both severity of summer and probability of breakdown, we can calculate the **conditional probability** under **Bayes' rule**. For instance, i. the conditional probability that a newly purchased AC will break down when the summer is harsh is:

{(3/10) *(5/10)} / {(3/10) *(5/10) + (7/10) *(5/10)} = 15/50 = .3 or 30%

ii. the conditional probability that a newly rented AC will not break down when the summer is mild is:

{(9/10) *(2/10)} / {(9/10) *(2/10) + (1/10) *(8/10)} = 9/13 = .69 or 69%

We have considered 2 fans/coolers in our second decision scenario since a single fan will not be as efficient as an AC unit and the perception is that either of the choices will deliver similar results, in this case, cool and comfort.

3.3. Description of costs associated with each decision:

A. Purchase of Air conditioning unit (in $)

	a. Electricity charges	b.Repair charges	c.Maintenance charges	Breakdown (a+b+c)	No breakdown (a+c)
Harsh (3 months)	264.6	300	200	764.6	464.6
Normal (1 month)	88.2	300	100	488.2	188.2
Low (1 week)	20.58	300	75	395.58	95.58
Repair cost	150-650				
Maintenance cost	75-200				
National avg of electricity	0.14/hr				
Avg no. of hours used	21				

B. Purchase of 2 fans/coolers (in $)
We have considered 2 fans/coolers in our second decision scenario since a single fan will not be as efficient as an AC unit and the perception is that either of the choices will deliver similar results, in this case, cool and comfort.

	a. Electricity charges	b.Repair charges	c.Maintenance charges	Breakdown (a+b+c)	No breakdown (a+c)
Harsh (3 months)	21.6	200	50	271.6	71.6
Normal (1 month)	7.2	200	30	237.2	37.2
Low (1 week)	1.68	200	30	231.68	31.68
Fan repair cost	200-400				
National avg of electricity	.005/hr				
Avg no. of hours used	24				

C. Rent of AC (in $)
We have not considered breakdown costs in this scenario since a customer is usually not liable to repair any breakdown of rented equipment. In the event of any malfunctioning, the equipment is either returned and replaced. To counter any chance of breakdown, costs are usually included in rent charges itself.

	a. Electricity charges	b.Repair charges	c.Maintenance charges	Breakdown (a+b+c)	No breakdown (a+c)
Harsh (3 months)	472.5	Nil	200	672.5	672.5
Normal (1 month)	157.5	Nil	100	257.5	257.5
Low (1 week)	36.75	Nil	75	111.75	111.75
AC repair cost	150-650				
Maintenance cost	75-200				
National avg of electricity	0.25/hr				

Avg no. of hours used	24

3.4. Anticipated charges under each scenario:

Severity of summer + breakdown costs	Probability of summer severity	Probability of breakdown	Yearly costs during A	Yearly costs during B	Yearly costs during C
Harsh summer (3 months)	0.30	50/50	764.6	271.6	672.5
Regular summer (1 month)	0.50	30/70	488.2	237.2	257.5
Mild summer (1 week)	0.20	10/90	395.58	231.68	111.75
Severity of summer + no breakdown costs	**Probability of summer severity**	**Probability of breakdown**	**Yearly costs during A**	**Yearly costs during B**	**Yearly costs during C**
Harsh summer (3 months)	0.30	50/50	464.6	71.6	672.5
Regular summer (1 month)	0.50	30/70	188.2	37.2	257.5
Mild summer (1 week)	0.20	10/90	95.58	31.68	111.75

To optimize our solution, we have considered the perceived benefit to be received under each scenario as a specific payoff. This is assuming that an air conditioning unit will deliver better comfort than a cooler or a fan, though at a higher cost. Hence, we have input some value to that benefit to better analyse the decisions. Since in scenario B, consumer will purchase 2 coolers or fans, the perceived difference between B and A is not very vast. Moreover, the benefit across all decision alternatives is considered same in case of a mild summer. Considering the above conditions, we have allocated the payoffs to different scenarios.

	Purchase AC	Purchase cooler/fan	Rent AC
a. Harsh summer(3 months)	2000	1500	2000
b. Regular summer(1 month)	1200	900	1200
c. Mild summer(1 week)	500	500	500

The following are the anticipated charges under each scenario after considering the payoff.

Severity of summer + breakdown costs	Payoffs	Yearly costs during A	Yearly costs during B	Yearly costs during C
Harsh summer (3 months)	2000(A), 1500(B), 2000(C)	1235.4	1228.4	1327.5
Regular summer (1 month)	1200(A), 900(B), 1200(C)	711.8	662.8	942.5
Mild summer (1 week)	500(A), 500(B), 500(C)	104.42	268.32	388.25

Severity of summer + no breakdown costs	Payoffs	Yearly costs during A	Yearly costs during B	Yearly costs during C
Harsh summer (3 months)	2000(A), 1500(B), 2000(C)	1535.4	1428.4	1327.5
Regular summer (1 month)	1200(A), 900(B), 1200(C)	1011.8	862.8	942.5
Mild summer (1 week)	500(A), 500(B), 500(C)	404.42	468.32	388.25

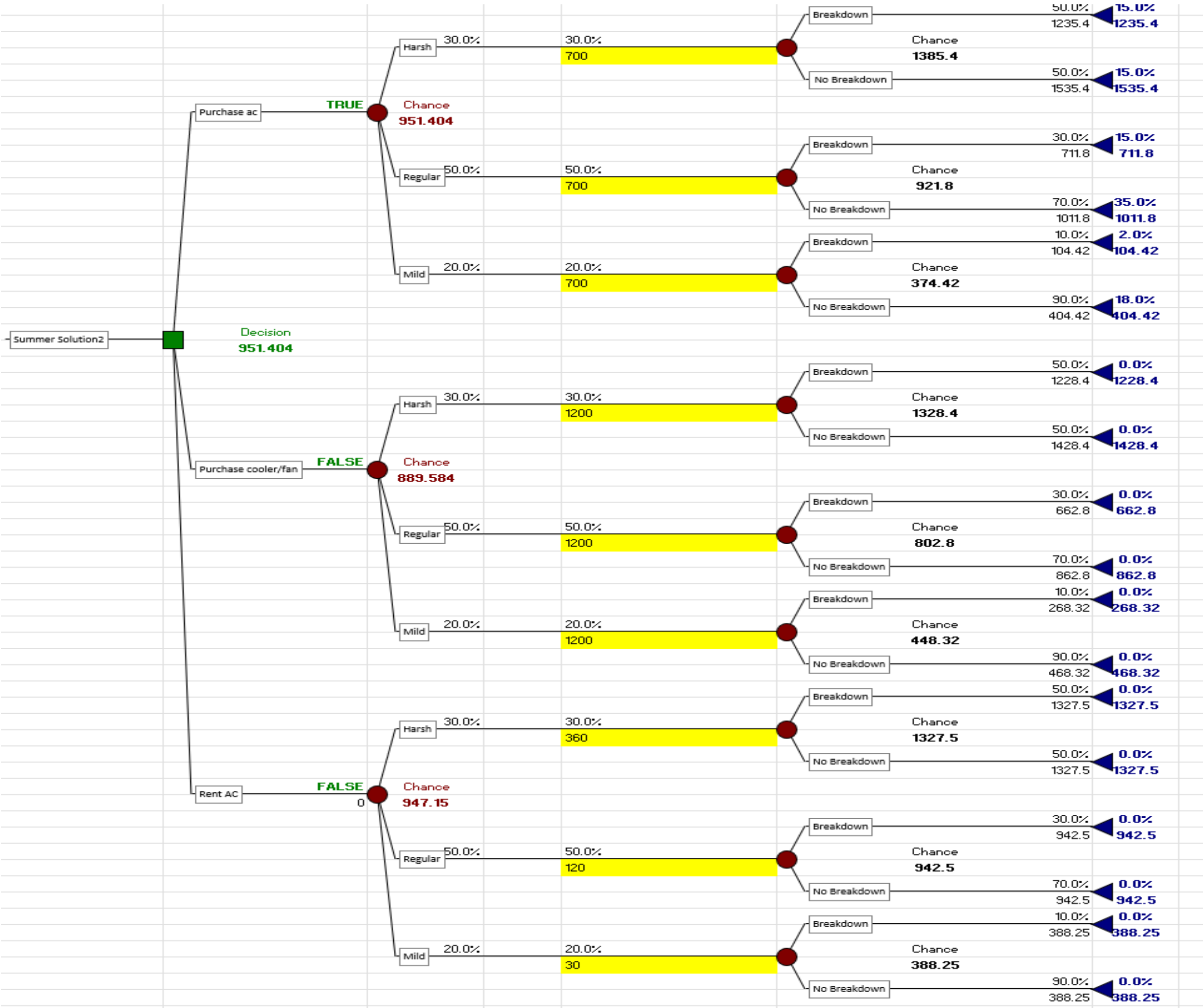
4. Project Model:

4.1. Figural Model of Decision Process:

We have structured our decision tree to deliver the maximum payoff, here Expected Monetary Value (EMV). We have structured the decision tree using Precision Tree tool in MS Excel. We adjusted the settings to calculate 'Cumulative Payoff' and optimum path to 'Maximum Payoff'. We arrived at EMVs under different scenarios of which the most favourable decision alternative that maximises our payoff is marked as 'True'.

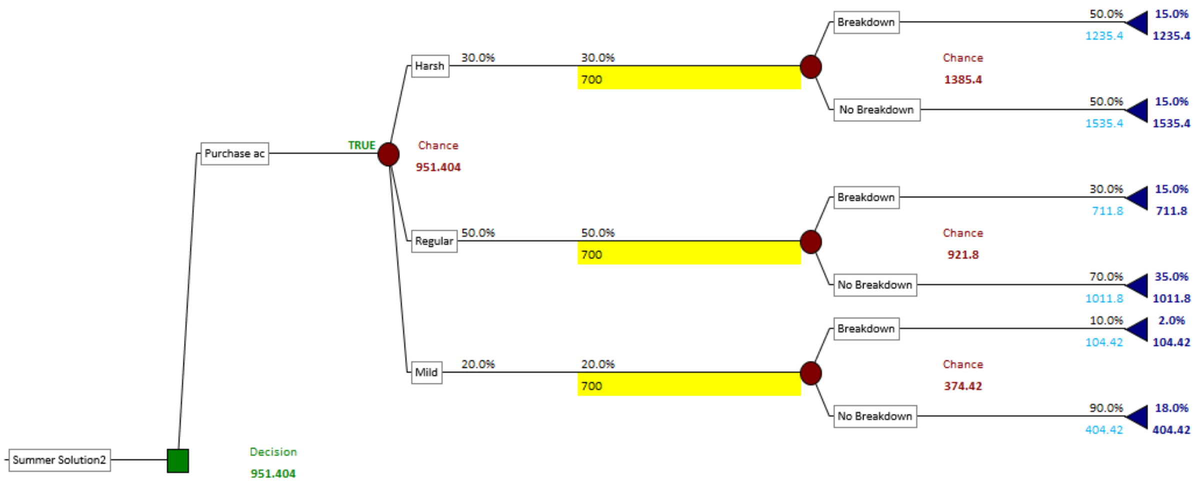
We have also incorporated the fixed costs under each decision, as highlighted in yellow. Those fixed costs represent the purchase cost of AC after the first decision node, purchase of cooler after the second decision node and rent of AC varying across 3 different periods after the third decision node.

We also observe that payoffs are higher when there are no breakdown costs.



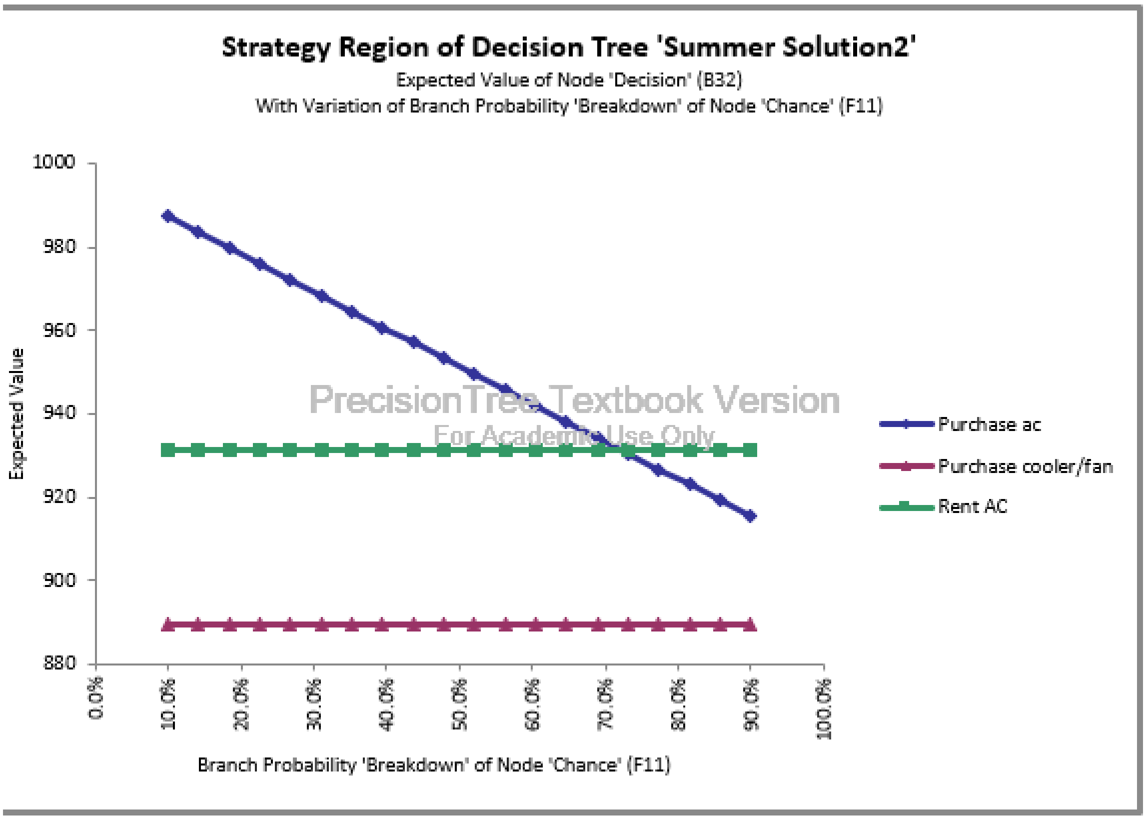
4.2. Optimal Tree:

The optimum decision as identified below is to purchase an AC. The highest payoff, identified here as the Expected Monetary Value (EMV) is highest for the first decision at $951.40, which is more than EMV for second decision at $889.5 and EMV for third decision at $947.15.

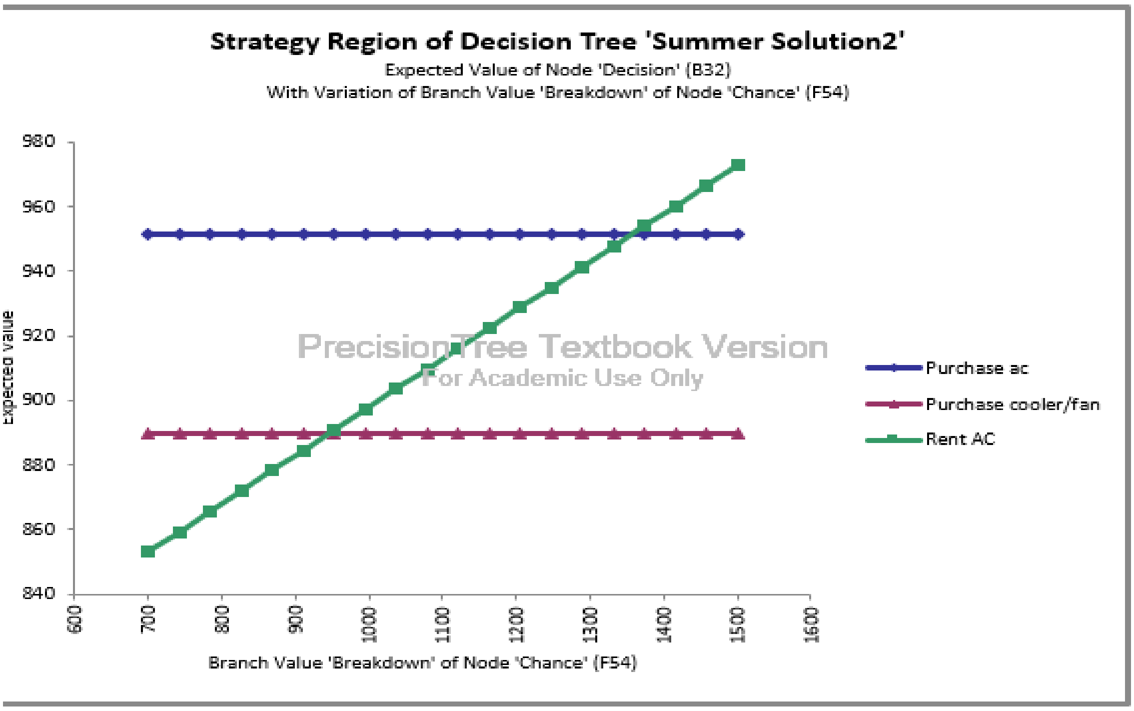


4.3. Sensitivity Analysis:

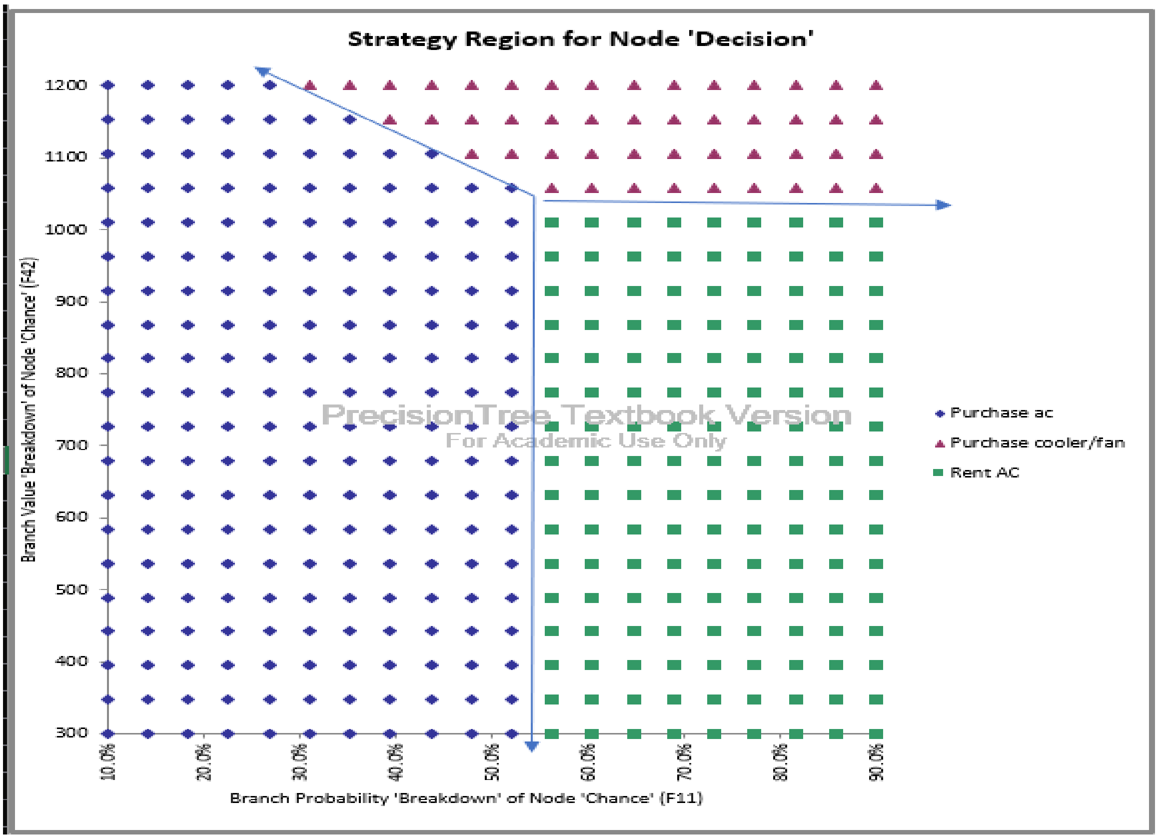
1. One-way sensitivity: Evaluating Probability of breakdown during harsh summer under Purchase of AC decision across a range of 10% - 90%



2. One-way sensitivity: Examining the payoff amount during breakdown in harsh summer under Rent of AC decision across a range of $700-$1500



3. Two-way sensitivity: Investigating the scenario in the event of changing probability of breakdown during harsh summer under Purchase of AC decision across a range of 10% - 90% along with change in the payoff cost due to breakdown in a regular summer under Purchase of cooler decision across a range of $300-$1200



5. Conclusion:

We can conclude from the decision analysis that the optimal solution for our analysis is purchasing an AC. We observe from the sensitivity analysis as well that the optimal decision is to purchase an AC because of the consecutive extreme summer temperatures in pacific northwest region.

6. Next Steps:

- More research on data to arrive at a conclusive sensitivity analysis considering the fact that the payoff values and cost values are the probable estimated values based on average usage of customers.

- More accurate data on charges to build a robust model because with accurate data we might be able to build a solution based on the real-time values of average usage of customers.

7. References:

1. To Analyse the cost/payoff of buying an AC vs Cooler by understanding the electricity consumption and efficiency by referencing on a private website: https://hvacdirect.com/seer-efficiency-savings-calculator.html,
2. AC/ cooler information :Window, Wall & Portable Air Conditioners | HVACDirect.com
3. Fan information Trending Ceiling Fans at Build.com ,
4. Fan repair: 2022 Attic Fan Replacement & Repair Costs (Vents, Fans, Motors) - HomeAdvisor
5. Maintenance costs 2022 Costs of AC Service & Maintenance – HomeAdvisor
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7. Climate data collected from National Weather Service: https://www.weather.gov