Innovative Decision Support for Climate Change Risk Mitigation

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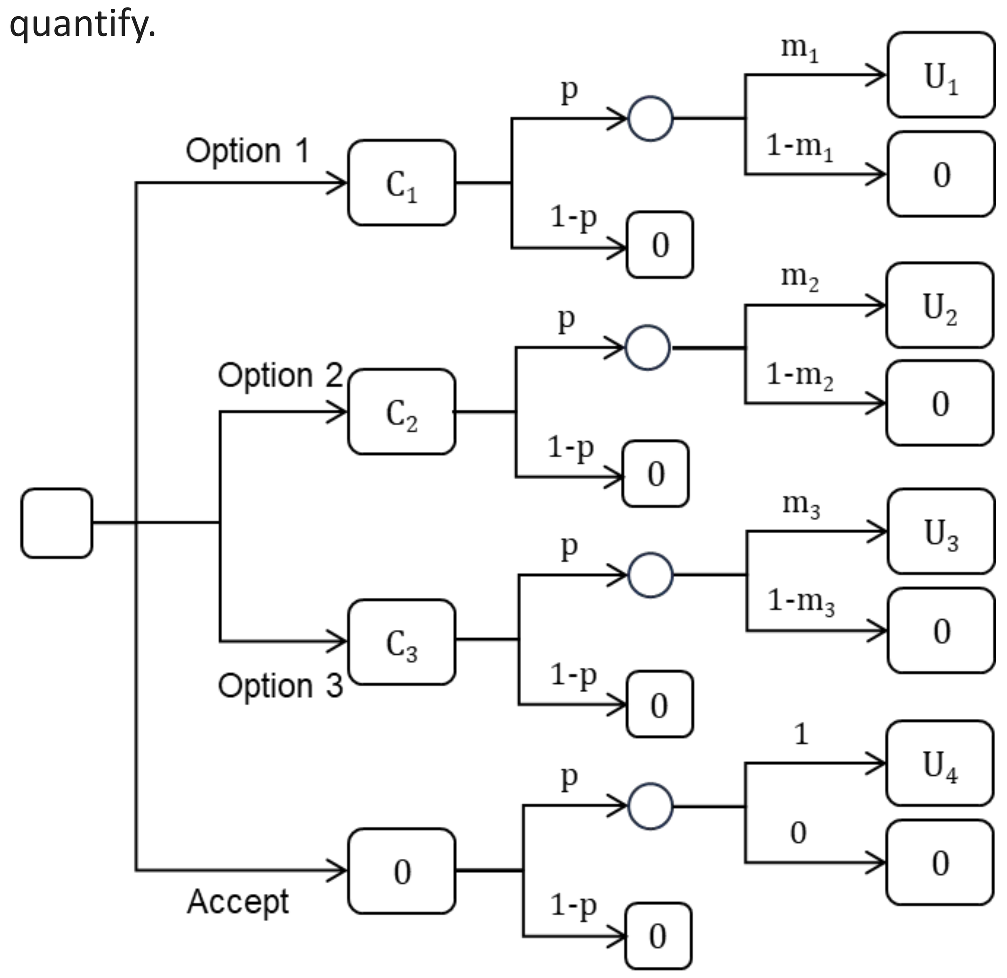
Introduction

This project aims to develop a decision support system (DSS) to assist a BU facility manager make risk mitigation decisions in response to severe weather events such as floods, high winds, heavy snow, and extreme heat. These events are expected to increase in frequency and intensity. The system utilizes indifference probabilities to quantify weather impacts and pairwise comparisons to facilitate unbiased decisions.

Decision Framework

A tree represents the decision that is affected by the probability of the climate risk event (p), and each risk response option's implementation cost (C_i), mitigation failure probability (m_i), and impact if the climate event affects the facility (U_i). This impact includes direct costs to repair damage and ripple effects within the University that the decision maker can anticipate but cannot quantify.



Methodology

The best choice is the decision option with the lowest expected value, which cannot be calculated until the U_i values are estimated precisely:

$$E_i = C_i + pm_iU_i;\ i = 1,2,\dots,n$$

The values of U_i are determined in a pairwise manner. By equating each pair of options ($E_i = E_j$), indifference probabilities (q_{ij}) can be determined:

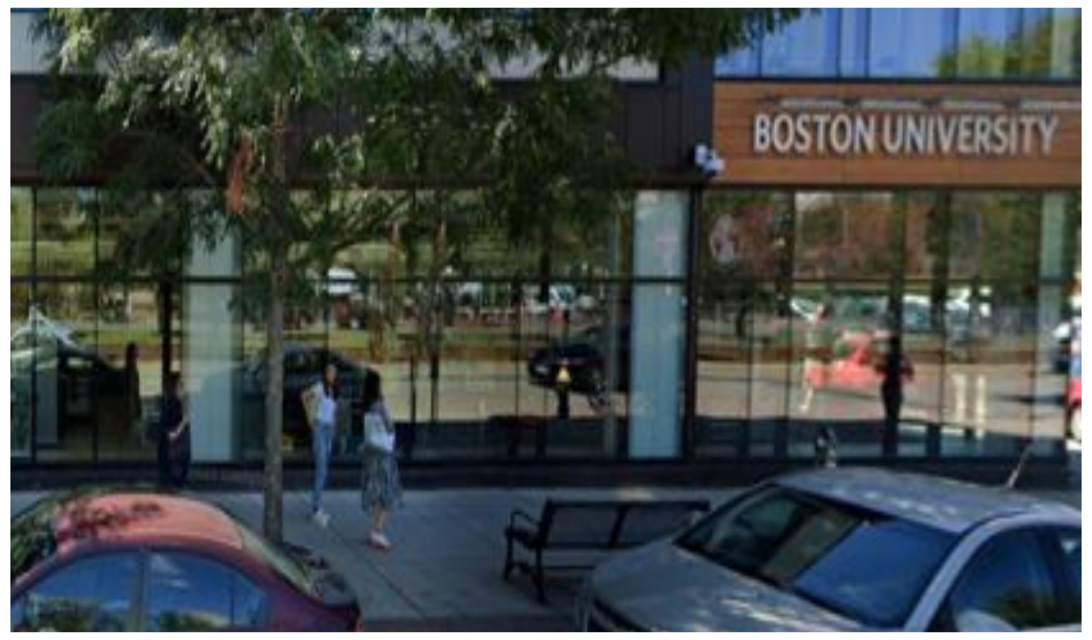
$$q_{ij} = \frac{C_j - C_i}{m_iU_i - m_jU_j};\ i = 1,2,\dots,n-1; j = i+1,\dots,n$$

After determining each q_{ij} value, differences in expected values (E_{ij}) for each pair of risk response options are calculated:

$$E_j - E_i = (C_j - C_i)\left(1 - \frac{p}{q_{ij}}\right);\ i = 1,2,\dots,n-1; j = i+1,\dots,n$$

A binary search, aided by a color-coded matrix displaying uncertainty, is used to identify the indifference probabilities.

Case Study: BU Innovation Center

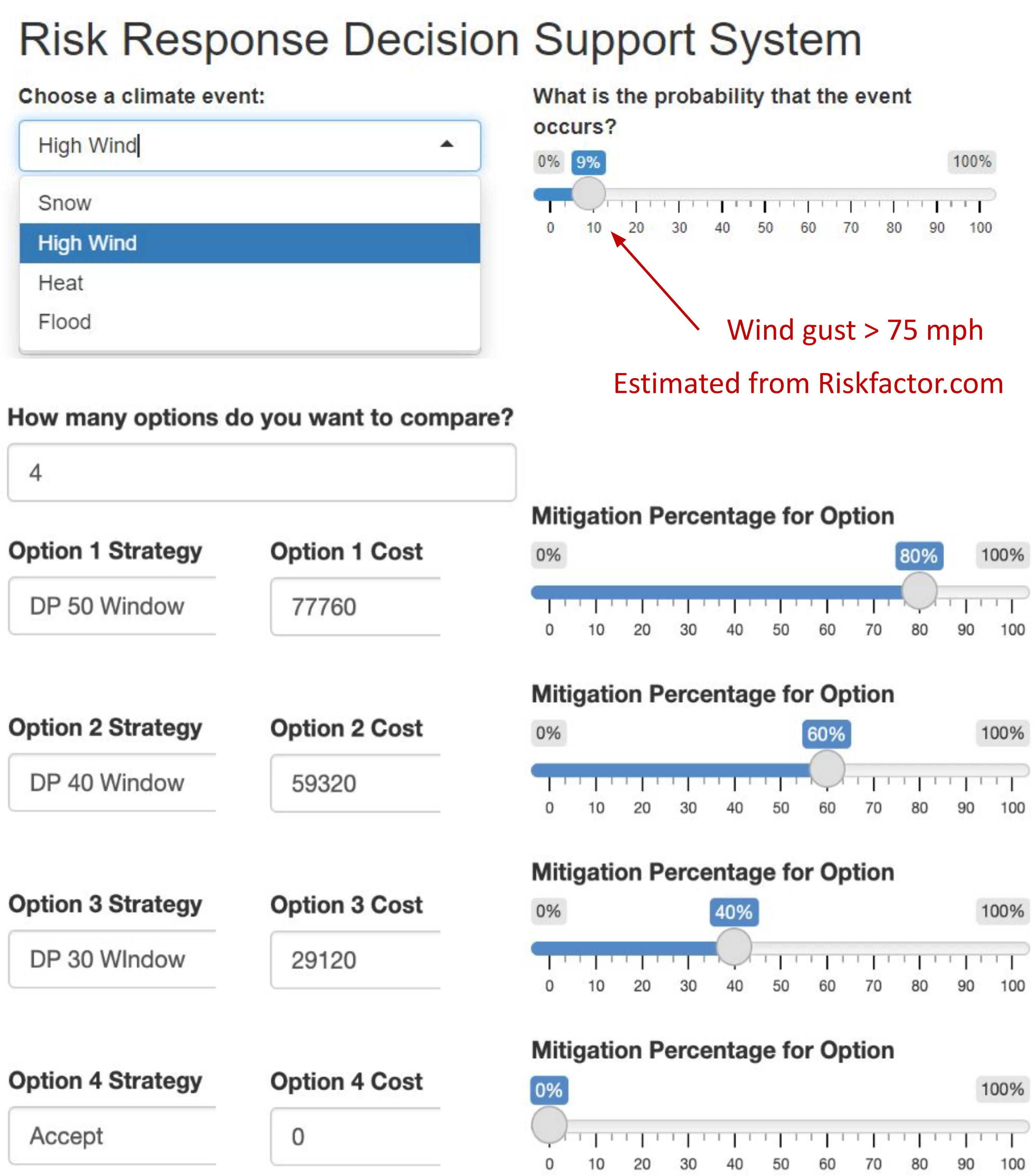


The BU Innovation Center, originally a car dealership, is used for events, classes, and research. It includes equipment worth $5 million. It sits on windy Commonwealth Avenue, and the windows risk implosion during strong wind events. Some wind risk mitigations include (DP = Design Pressure):

1. Install DP 50 windows
2. Install DP 40 windows
3. Install DP 30 windows
4. Accept the risk

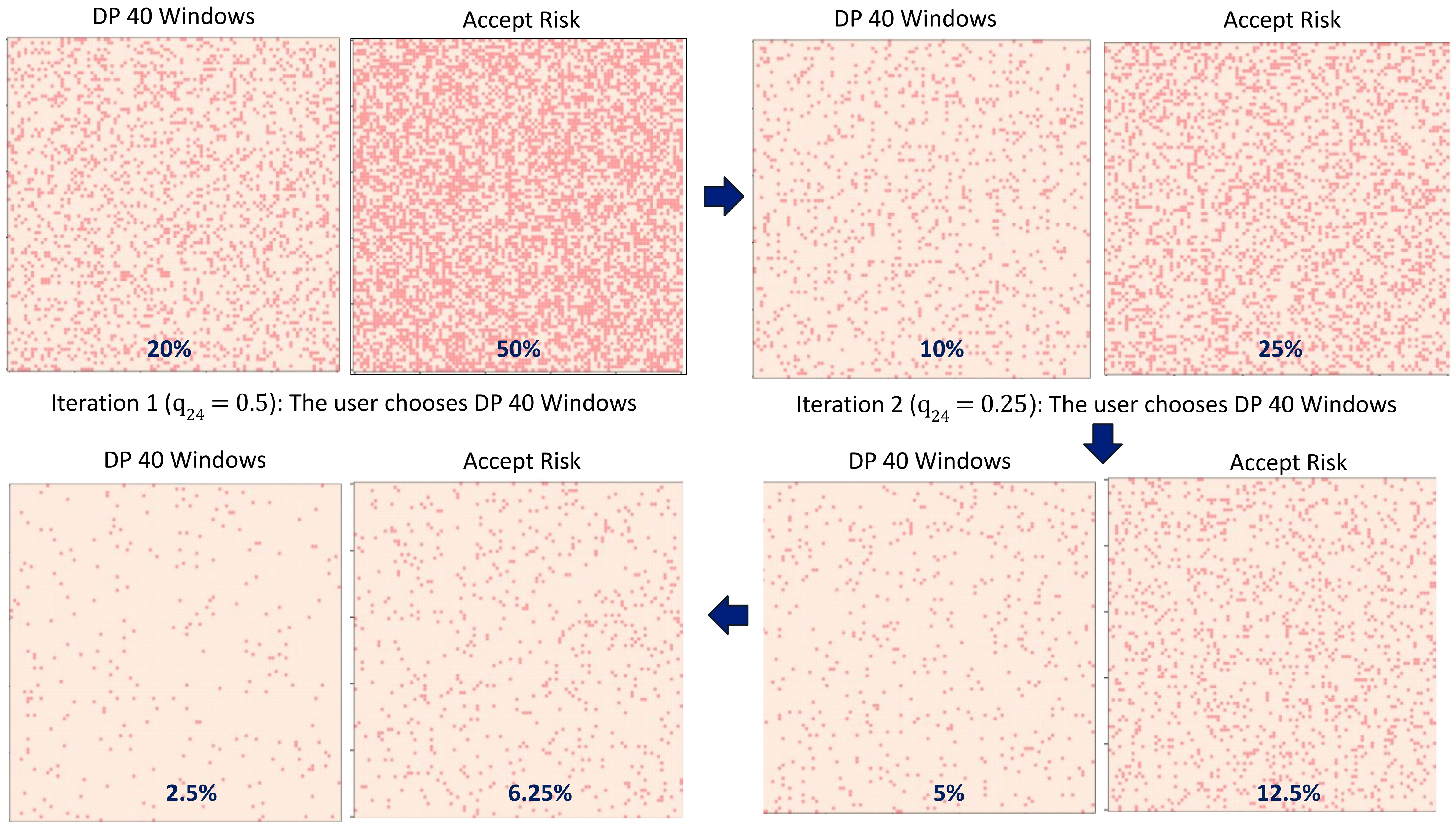
Decision Support System: Inputs

The DSS was developed in R-Shiny, a package that supports building a web application. Inputs for the BU Innovation Center example are shown below:



User Interface: Indifference Probability Determination

The procedure for applying a binary search to determine the indifference probability for each option pair is illustrated below. For example, the comparison of DP 40 windows and accepting the risk resulted in an indifference probability of 6.25%.



Iteration 1 ($q_{24} = 0.5$): The user chooses DP 40 Windows

Iteration 2 ($q_{24} = 0.25$): The user chooses DP 40 Windows

Iteration 3 ($q_{24} = 0.125$): The user chooses DP 40 Windows

Iteration 4 ($q_{24} = 0.0625$): The user chooses Indifferent

Computations and Conversion to AHP Matrix

The differences in the expected values for each risk response option are calculated using the indifference probabilities. These values become the input to the AHP matrix that requires a 1-9 scale (1 indicates that the two options have similar preference, while 9 implies the highest difference in preference), where E^* is the maximum absolute difference.

i	j	qij	Ej-Ei
1 (DP 50)	2 (DP 40)	0.3359	-$13,499.80
1 (DP 50)	3 (DP 30)	0.1094	-$8,616.23
1 (DP 50)	4 (Accept)	0.0625	$34,214.40
2 (DP 40)	3 (DP 30)	0.0898	$52.52
2 (DP 40)	4 (Accept)	0.0625	$26,100.80
3 (DP 30)	4 (Accept)	0.1172	-$6,755.84

$$a_{ij} = \begin{cases} \frac{8|E_{ij}| + E^*}{E^*}, & E_{ij} < 0 \\ \frac{E^*}{8|E_{ij}| + E^*}, & E_{ij} \geq 0 \end{cases}$$

$$a_{ii} = 1 \qquad a_{ji} = a_{ij}^{-1}$$

	DP 50	DP 40	DP 30	Accept
DP 50	1.0	0.2	0.3	9.0
DP 40	4.2	1.0	1.0	7.1
DP 30	3.0	1.0	1.0	0.4
Accept	0.1	0.1	2.6	1.0

The final rankings (r_i) are determined using the AHP methodology, where option scores sum to 1. For the BU Innovation Center example, DP 40 windows would be the best option.

$$r_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{a_{\cdot j}};\ i = 1,2,\dots,n$$

DP 50	DP 40	DP 30	Accept
0.201	0.384	0.252	0.163

Acknowledgements

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