MULTI-CRITERIA DECISION ANALYSIS (MCDA) AND IWR PLANNING SUITE

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How familiar are you with the IWR Planning Suite? Please place a check/mark in one of the boxes below.

Novice	Some experience	Expert

What version of the software do you have experience with? Please place a check/mark in one of the boxes below.

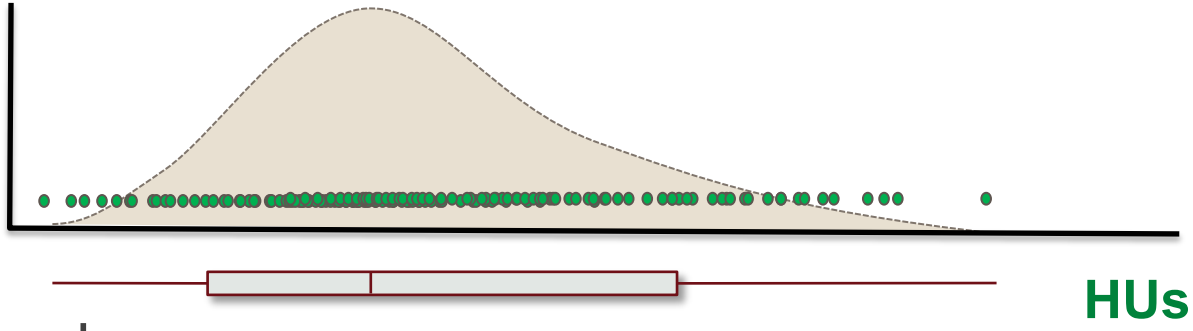
I haven't used any version of the software.	I've used a previous version of the software. (1.0.11, 2.0.6, 2.0.9)	I've used the latest version of the software. (2.0.9.34)

WEBINAR TOPICS

IWR Planning Suite II Basics

MCDA – what is it and why do we need it?

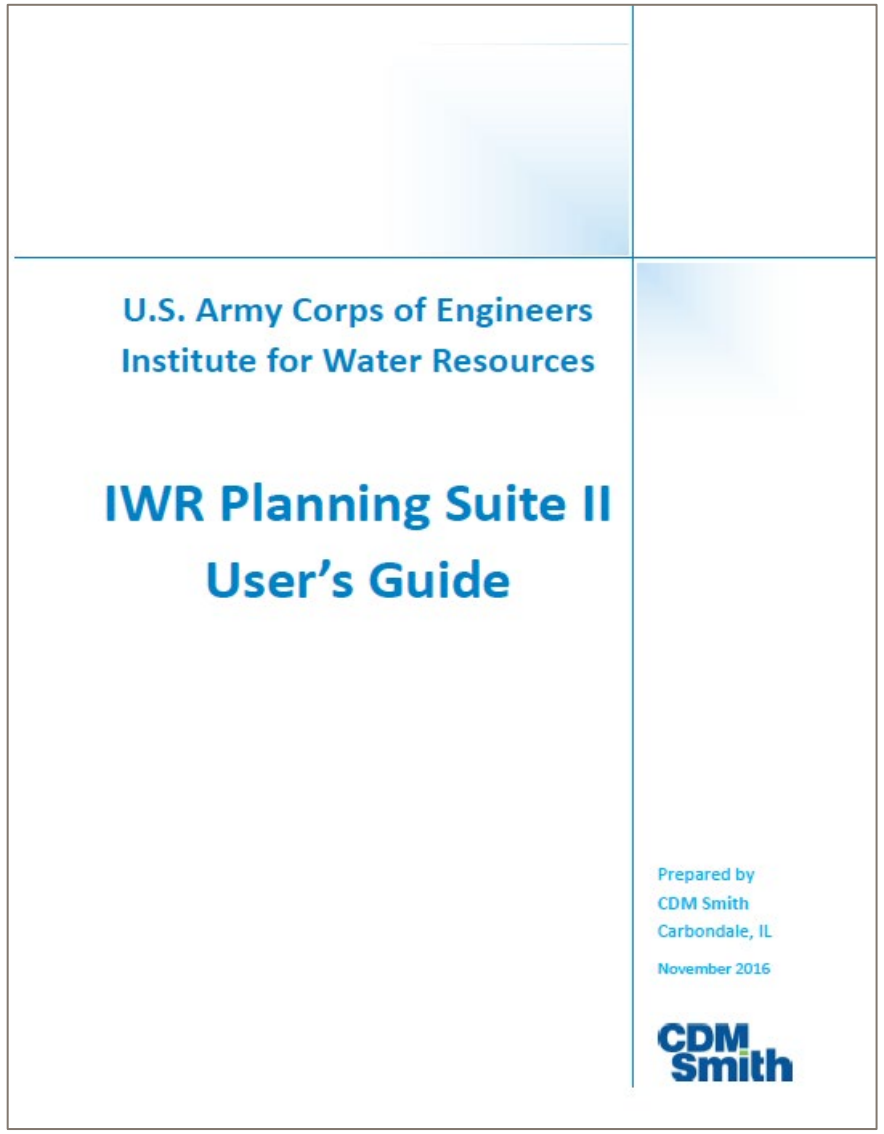
- MCDA 101
- Terminology
- Scoring & Ranking – 4 easy steps
  - Alternatives & Criteria
  - Weighting
  - Scoring & Ranking
  - Exploring Results
- Scoring & Ranking Methods – 4 methods
- Tips/Tricks/Gotchas



Where can I get the software?
Training resources & help

IWR PLANNING SUITE II: THE BASICS

- Provide for consideration of monetized and non-monetized costs and benefits
- Automate computations associated with Cost Effectiveness/Incremental Cost Analysis (CE/ICA)
- Facilitate documentation, visualization, reporting, and communication of CE/ICA
- Enable consideration of multiple variables, and support assessment of uncertainty on CE/ICA results
- Support risk-informed decision making



USACE-CERTIFIED VERSIONS

IWR Planning Suite Version 1.0.11.1

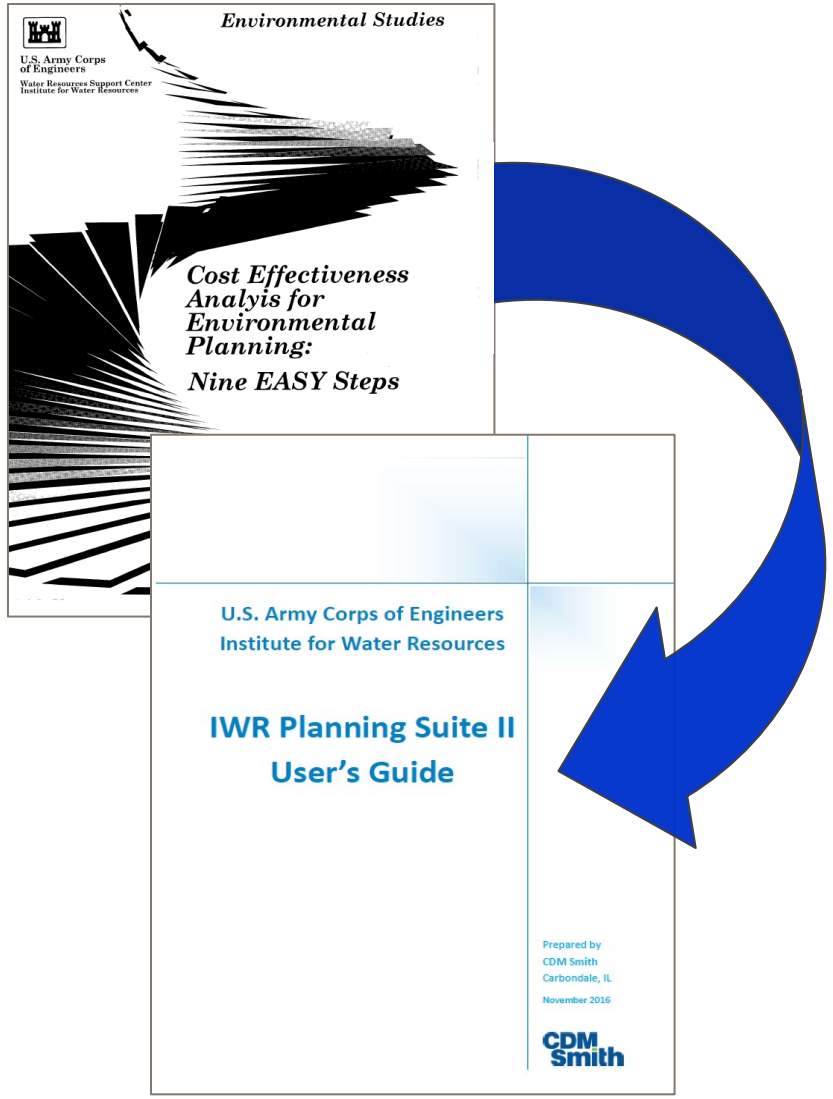
- Plan Generator and CE/ICA
- Derived Value Calculator/Module

IWR Planning Suite Version 2.0.6.1

- Plan Generator and CE/ICA
- Derived Value Calculator/Module
- Added the Annualizer Module

Version 2.0.9 aka IWR Planning Suite II

- Updated Interface
- Added MCDA Module
- Added Uncertainty Module
- Added Watershed Module
- Added Report Generator



IWR PLANNING SUITE II: STATUS

- **CERTIFIED**

- 31-MAY-2018 CECW-P Memorandum
  - Review plans approved after 31-MAY-2018 must use latest software
  - Studies engaging in multiple criteria decision analysis (MCDA) should engage the ECO-PCX to develop a strategy for appropriate and policy compliant use

- ER 1105-2-100 (Planning Guidance Notebook)
  - Provides instruction for NED and NER methods
  - Provides instruction on use of CE/ICA during selection of NER plan and for all recommended mitigation plans

- IWR Planning Suite User's Guide https://publibrary.planusace.us/document/5641c105-449e-4b7f-c52f-af91a15a99e2

IWR PLANNING SUITE'S ROLE IN PLANNING

- IWR Planning suite should be used as a tool to support plan formulation process
  - Ecosystem Restoration (NER), Mitigation, Other Business Lines
  - Helps clarify tradeoffs across multiple (often conflicting) criteria
  - Consistent framework that provides clarity and transparency in the decision-making process

- Need to employ well-specified planning objectives in concert with plan generation

- Recommend starting with alternatives (or at least a suite of management measures) that work together within a reach/area/sub-basin to meet planning objectives

How familiar are you with MCDA?
Please place a check/mark in one of the boxes below.

Novice	Some experience	Expert

MCDA 101

What is MCDA?

- Technique to assist with decision making
- Helps clarify tradeoffs across multiple (and often conflicting) criteria
- Logical, consistent framework that provides clarity and transparency in the decision-making process

Why use MCDA?

- Technically defensible, easily understandable, and repeatable
- Improves quality and consistency of individual judgments/decisions
- Delivers transparency and conveys rationale behind a decision
- Framework for stakeholder engagement
- Benefits, benefits, benefits, benefits

CONSIDERATIONS

- MCDA is a complex process that cannot be simplified to a ‘push a button’ approach
- There are tools that can assist in the analysis like IWR Planning Suite (IWRPS)
- Follow the steps carefully. Choices made in those steps can affect the final rankings/choices
- MCDA is not a linear process that results in a single best answer
- Timing: When do you use MCDA in your study?

TRADE-OFFS

- "…you can't always get what you want" (Mick Jagger)
- Giving up one thing to gain another; competing and mutually exclusive trade-offs
- You can't have it all
  - Explicit – terms of trade fixed by laws of universe
  - Implicit – terms of trade fixed by the value system and preferences of an individual
- Value trade-offs have divergent and incommensurable values

MULTI-CRITERIA DECISION ANALYSIS (MCDA)

- Formal approaches to assist in exploring decisions when multiple criteria are present
- Incommensurable units (apples and oranges)
- Identifies conflicts and tradeoffs
- Much studied, complex problem

WHY DO WE NEED MCDA?

- We value more than money (e.g., comprehensive benefits analysis)
- Not all criteria for selection are easy to quantify
- Sometimes we need to quantify the qualitative
- Integrate objective measurement with value judgments
- Help stakeholders articulate and apply their values to the problem rationally and consistently
- Display how alternatives perform on the various criteria
- Facilitate compromise

RECOGNIZE DIFFICULTIES / LIMITATIONS

- Decisions are Difficult
- Complex / Inherent uncertainty / Differences in perspectives
- Conflicting objectives
- Fundamentally a political process - Not “science”
- Does not give “right” answer
- Not objective
- Does not take pain out of decision process

LET'S GET THE LANGUAGE DOWN FIRST

- Alternatives
- Criteria
- Decision Matrix
- Weights
- Scores and Ranks

ALTERNATIVES

- Alternative ways of solving problems and meeting objectives
- Discrete and distinct options/plans for the problem being studied
- Assumption: Dealing with a finite (possibly large) number of pre-defined alternatives

CRITERIA

- A test, principle, rule, canon, or standard, by which anything is judged or estimated

- Dimensions on which an alternative is measured such as a cost, benefit, or environmental impact

- Examples:
  - Costs
  - Habitat Units
  - Forested Acreage

IF YOU COULD HAVE ANY CAR, WHAT WOULD IT BE? (LIST BELOW)

WHAT FACTORS ARE IMPORTANT TO YOU IN BUYING A CAR? (LIST BELOW)

DECISION MATRIX

- Rating
  - The value of a particular criterion for a particular alternative
  - At this stage, use familiar units, preferably not transformed by normalization
- Decision Matrix
  - Matrix of Ratings (all criteria, all alternatives)
  - Alternatives = Rows
  - Criteria = Columns

Alternative	Cost	Reliability	Gas Efficiency	Overall Customer Satisfaction
Without New Car Conditions	$20,000	.5	18 mpg	2.1
Chevrolet Equinox	$30,320	4.6	22 mpg	4.5
Hyundai Santa Fe	$30,845	4.3	20 mpg	4.1
Nissan Murano	$39,630	4.8	18 mpg	4.8
Toyota Highlander	$36,495	4.6	20 mpg	4.8

WEIGHTS

- All criteria are not equally important
- Someone or a group must decide which are more important and by how much
- Weights measure the relative importance given a criterion by decision makers
- Developing weights is not a simple task
  - Differences of opinion
  - Consistency of opinion

SCORES & RANKS

- Results of an MCDA model

- Score
  - Aggregate single numerical measure for an alternative on a given criterion (e.g., Alternative A = 170, Alternative D = 220)
  - Expresses degree of preference for an alternative

- Rank
  - Ordering of the alternatives, with no expression of degree of preference (good, better, best) (1st, 2nd, 3rd)

SIMPLE 4-STEP PROCESS

1) Create Decision Matrix

2) Develop Weights

3) Score and Rank Alternatives

4) Analyze Results

STEP 1 – CREATE DECISION MATRIX

- Assemble alternatives
- Select criteria
- Rate alternatives against each of the criteria

Alternative	Cost	Reliability	Gas Efficiency	Overall Customer Satisfaction
Without New Car Conditions	$20,000	.5	18 mpg	2.1
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STEP 2 – DEVELOP WEIGHTS

- Weights are needed because all criteria may not be equally important to the decision
- Weighting reflects relative importance
- Different decision makers/constituencies may have different criterion weights

STEP 2 – DEVELOP WEIGHTS – TWO METHODS

MANUAL WEIGHTING

- Direct user assignment
  - Reliability = .75 and Fuel Efficiency = .25
    - Reliability is 3 times as important as fuel efficiency
    - Could express as fuel efficiency = 1 and reliability = 3
    - Normalization is handled internally in IWPS software
- Rating (example: scale 1 to 10)
  - Fuel Efficiency = 2 | Reliability = 6 | Cost = 9
  - Develop your own rating and scale
- Expression of relative importance of criterion

ANALYTICAL HIERARCHY PROCESS (AHP)

- Decision-maker fills in matrix of relative importance
- 9-point scale of relative importance of criteria
- Pair-wise comparison of criteria
- Measures of consistency in rating are determined
- Weights are derived from relative importance matrix

AHP USES SAATY'S SCALE

Absolutely Less Important	1/9
Demonstrably Less Important	1/7
Strongly Less Important	1/5
Slightly Less Important	1/3
Equally Important	1
Slightly More Important	3
Strongly More Important	5
Demonstrably More Important	7
Absolutely More Important	9

- Matrix of relative criterion importance
- Decision makers use natural language to describe how they feel about one criterion over another (all criterion pairs)
- Software provides weights automatically
- Helps to uncover inconsistencies in preferences

SOFTWARE-ASSISTED DEVELOPMENT OF WEIGHTS BY PAIRWISE PREFERENCES

AHP Weights

	PortProximity	IntermodalConnections	UplandSupport	WaterDepth	NavigationAccessibility
PortProximity	N/A	(3) Slightly More Important	(1) Equally Important	(1) Equally Important	(1) Equally Important
IntermodalConnections	(-3) Slightly Less Important		(1) Equally Important	(1) Equally Important	(1) Equally Important
UplandSupport	(1) Equally Important		N/A	(1) Equally Important	(1) Equally Important
WaterDepth	(1) Equally Important		(1) Equally Important	N/A	(1) Equally Important
NavigationAccessibility	(1) Equally Important		(1) Equally Important	(1) Equally Important	N/A
Weight	25.663		19.415	19.415	19.415

(-9) Absolutely Less Important
(-7) Demonstrably Less Important
(-5) Strongly Less Important
(-3) Slightly Less Important
(1) Equally Important
(3) Slightly More Important
(5) Strongly More Important
(7) Demonstrably More Important
(9) Absolutely More Important

AHP Weights

	PortProximity	IntermodalConnections	UplandSupport	WaterDepth	NavigationAccessibility
PortProximity	N/A	(3) Slightly More Important	(-3) Slightly Less Important	(1) Equally Important	(1) Equally Important
IntermodalConnections	(-3) Slightly Less Important	N/A	(1) Equally Important	(1) Equally Important	(1) Equally Important
UplandSupport	(3) Slightly More Important	(1) Equally Important	N/A	(1) Equally Important	(1) Equally Important
WaterDepth	(1) Equally Important	(1) Equally Important	(1) Equally Important	N/A	(1) Equally Important
NavigationAccessibility	(1) Equally Important	(1) Equally Important	(1) Equally Important	(1) Equally Important	N/A
Weight	21.063	15.85	26.207	18.44	18.44

STEP 3 – SCORE AND RANK ALTERNATIVES

- Score is developed for each alternative
  - Based on weights assigned to criteria
- Rank is based on score
  - Highest score gets rank #1, etc.
- Multiple ranking methods to choose from in IWRPS
  - Efficient Frontier
  - Weighted scoring
  - Compromise Programming
  - Outranking

STEP 4 – ANALYZE RESULTS USING REPORTS/GRAPHS

Explore Trade-Offs

Ranking Reports

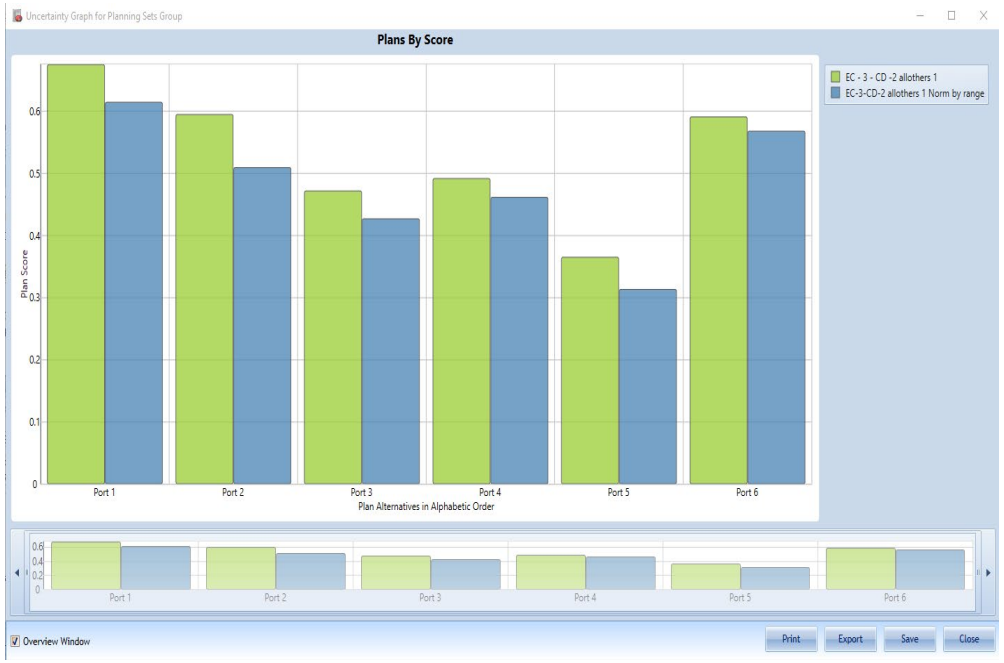
– Scenario Comparison Reports

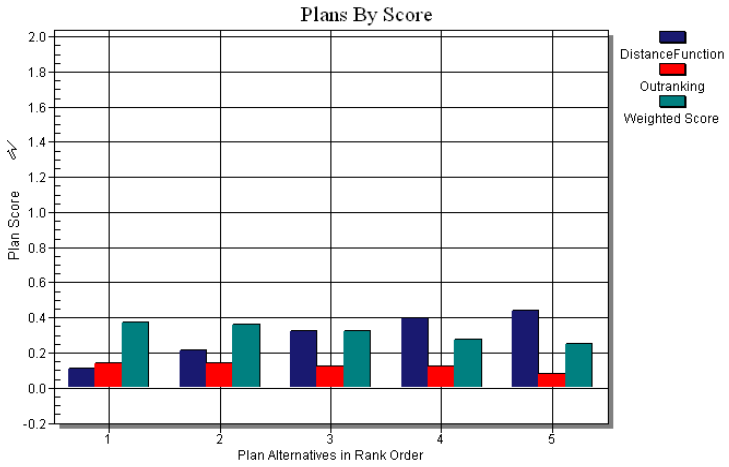
– Alternative Rank/Score Graphs

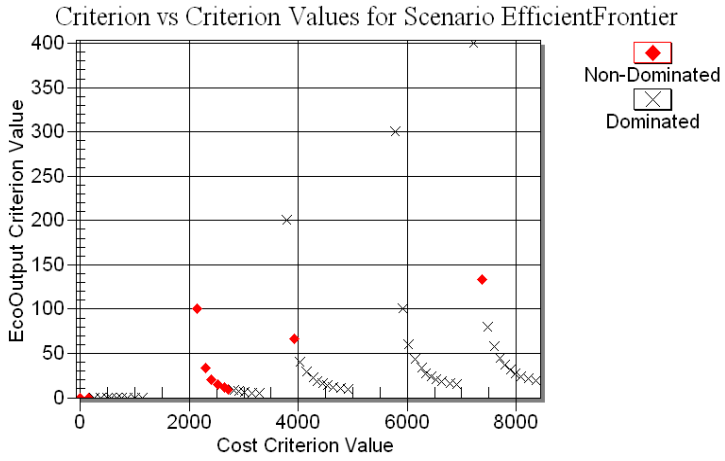
– Criterion contribution to Scores

– Criterion vs. criterion plots

Export to MS Excel







RANKING METHODS IN IWRPS, SUMMARIZED

- Efficient Frontier
  - Find non-dominated alternatives in a multi-objective setting
- Weighted scoring
  - Simple, Intuitively appealing
- Compromise Programming
  - Utilizes distance functions, find closet to “ideal” alternative
- Outranking
  - Utilizes preference functions
  - Can handle problems of ‘indifference’ to small changes in criteria

EFFICIENT FRONTIER

- Non-Dominated Solution = A solution in which no other solution exists that is clearly better than that solution

- Remove alternatives that are worse, in all criteria, than other alternatives

- Searches for the “efficient frontier”
  - No plan outside the frontier gives more of any output without increasing any input

- Technically not a ranking algorithm, although all alternatives are ranked either #1 (non-dominated) or #2 (dominated)

Alternative	Cost -	Reliability	Gas Efficiency	Overall Customer Satisfaction
Chevrolet Equinox	$30,320	4.6	22 mpg	4.5
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WEIGHTED SCORING

- Each alternative gets a score, based on weights assigned to criteria
- Score = Sum [(weight criterion 1∗ criterion 1 value) + (weight criterion 2 * criterion 2 value) + …]
- Uses normalized weights and criterion values
- Maximize or Minimize for each criterion
  - Maximize Sediment Reduction but Minimize Cost
  - Minimize = maximize (- value)
- Ranking based on score
- Simple and intuitive, most commonly used method

$$\sum (w_i * v_i)$$

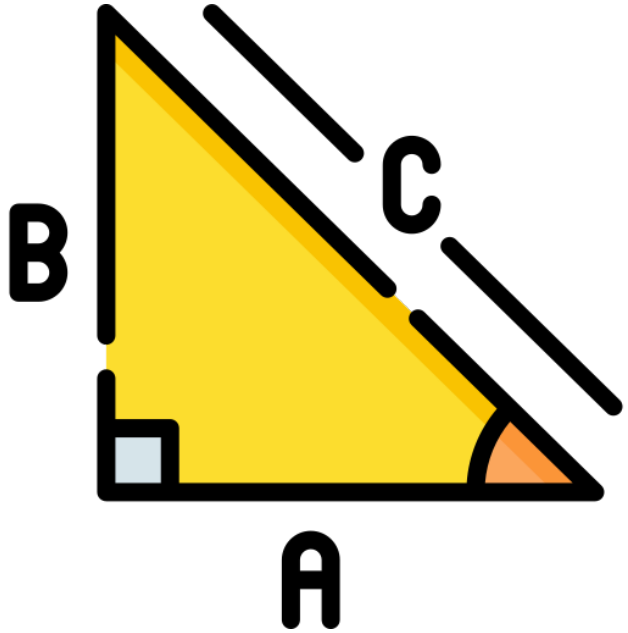
Where:

w_i = weight

v_i = normalized value

COMPROMISE PROGRAMMING

- Determination of “Ideal” alternative built from best of the best
- Find distance between each alternative and “ideal” alternative
- Rank plans based on distance (closest to “ideal” gets ranked #1)
- Calculates the distance from the “ideal” work package using n-dimensional Euclidean distance (Pythagoras’ Theorem)
- Better than traditional methods for finding “best overall” or “robust” alternatives



WEIGHTS – GOTCHAS & TIPS

- When using weights, be mindful of the multiplying effect of the weights
- Example: If the weight for A=10 and B=1, A is 10 times more important than B
- The AHP algorithm using Saaty's scale is included in IWRPS. A benefit to using this over direct weight assignment is that the tool will warn you when your choices are inconsistent

SCORING/RANKING – GOTCHAS & TIPS

- Start with Weighted Scoring – it's simple and easy to understand
- You can produce alternative scenarios easily in IWRPS and explore how different algorithms reflect the decision maker's preferences
- Use Compromise Programming to explore how results differ when searching for the most "robust" alternatives
- Explore outranking if dealing with issue of indifference. If alternatives are scored higher based on minuscule differences, and this is a concern, then Outranking can help

CRITERIA/NORMALIZATION – GOTCHAS & TIPS

- You do not want to have criteria that are highly correlated
- Recommend running a statistical package on the dataset to determine correlation issues
- Normalization can make a difference in results. IWRPS normalizes the decision matrix when using weighted scoring to put all criteria on the same scale
- Select the normalization method that makes sense for your data – by range, by total, or by percent of maximum

OUTRANKING

- The problem of indifference

- Example: If alternative A provides 100 acres of forested habitat and alternative B provides 101 acres of forested habitat
  - Based on the information I have, is Alternative B always better?
  - What if the cost of plan B was $1 more than plan A – is that enough information to decide that plan B is a better choice? than alternative B is plan A always better?

- Outranking utilizes “preference functions” to provide a means of addressing problems of indifference or “fuzziness” around preferences

- Pairwise Comparison of Alternatives Against Criteria
  - For how many criteria is Plan A better than Plan B?
  - For how many criteria is Plan A worse than Plan B?

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TRAINING RESOURCES & HELP

- Links to the software, certification memo, and other related resources can be found at: http://www.iwr.usace.army.mil/Missions/Economics/IWR-Planning-Suite/

- Training materials that highlight IWR Planning Suite's capabilities, improvements and case study applications are available online at the IWR Planning Assistance Library

- Customized or study-specific training is also available upon request. For support please contact:
  - IWR Planning Suite Development Team at: **DLL-CEIWR_IWR-PLAN**
  - ECO-PCX
  - Collaboration and Public Participation Center (CPCX)

THANK YOU!

QUESTIONS / DISCUSSION

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