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Expert Judgment Network: Bridging the Gap Between Scientific Uncertainty and Evidence-Based Decision Making

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Capturing complexity and enhancing implementation of one water paradigm: Innovative strategic planning aided by reference point approach

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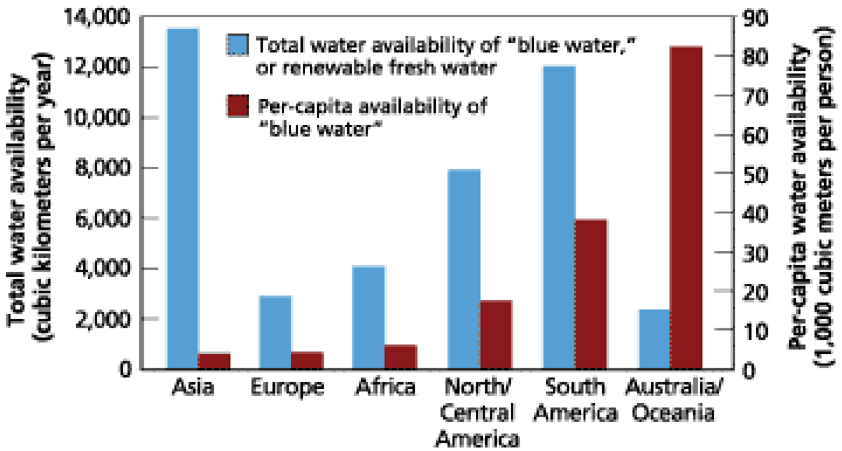
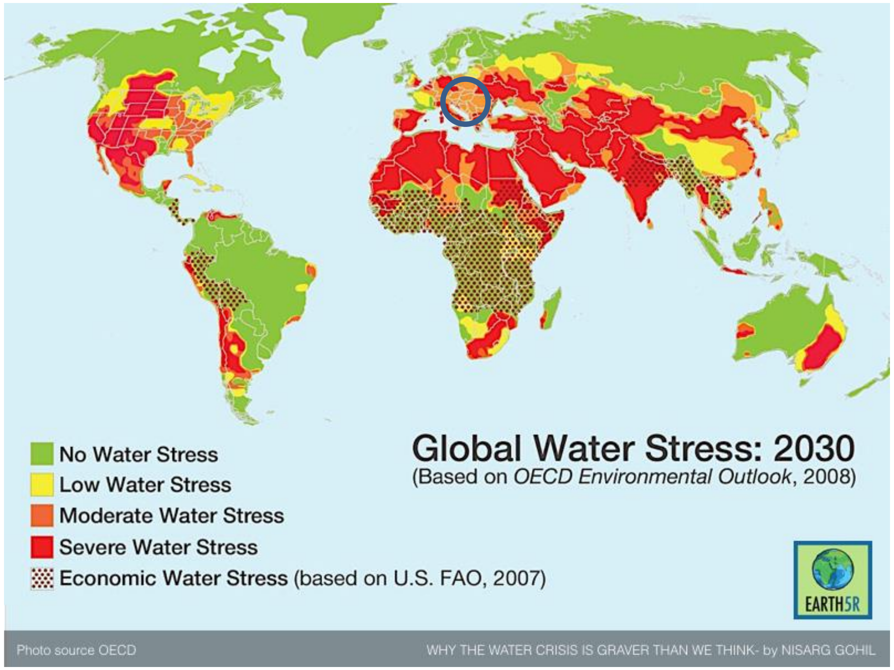
Serbia

Availability of water and water stress





SERBIA:
frequent summer water shortages and reductions in water supply to the customers

→

both management and public attitude towards water resources should urgently be changed.

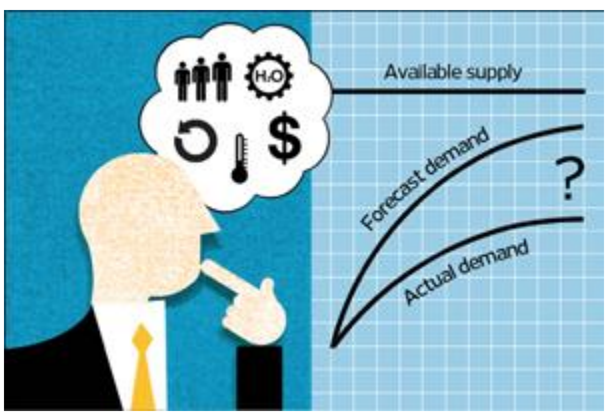
A Shift in How Water Resources are Managed

One Water is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs.

(Water Research Foundation)

- Provide reliable, secure, clean water supplies
- Contribute to a livable city
- Protect human health
- Provide flood protection
- Minimize environmental pollution
- Use and reuse natural resources efficiently
- Provide resiliency to climate and economic changes
- Promote long-term sustainability, equity, and economic growth/ prosperity

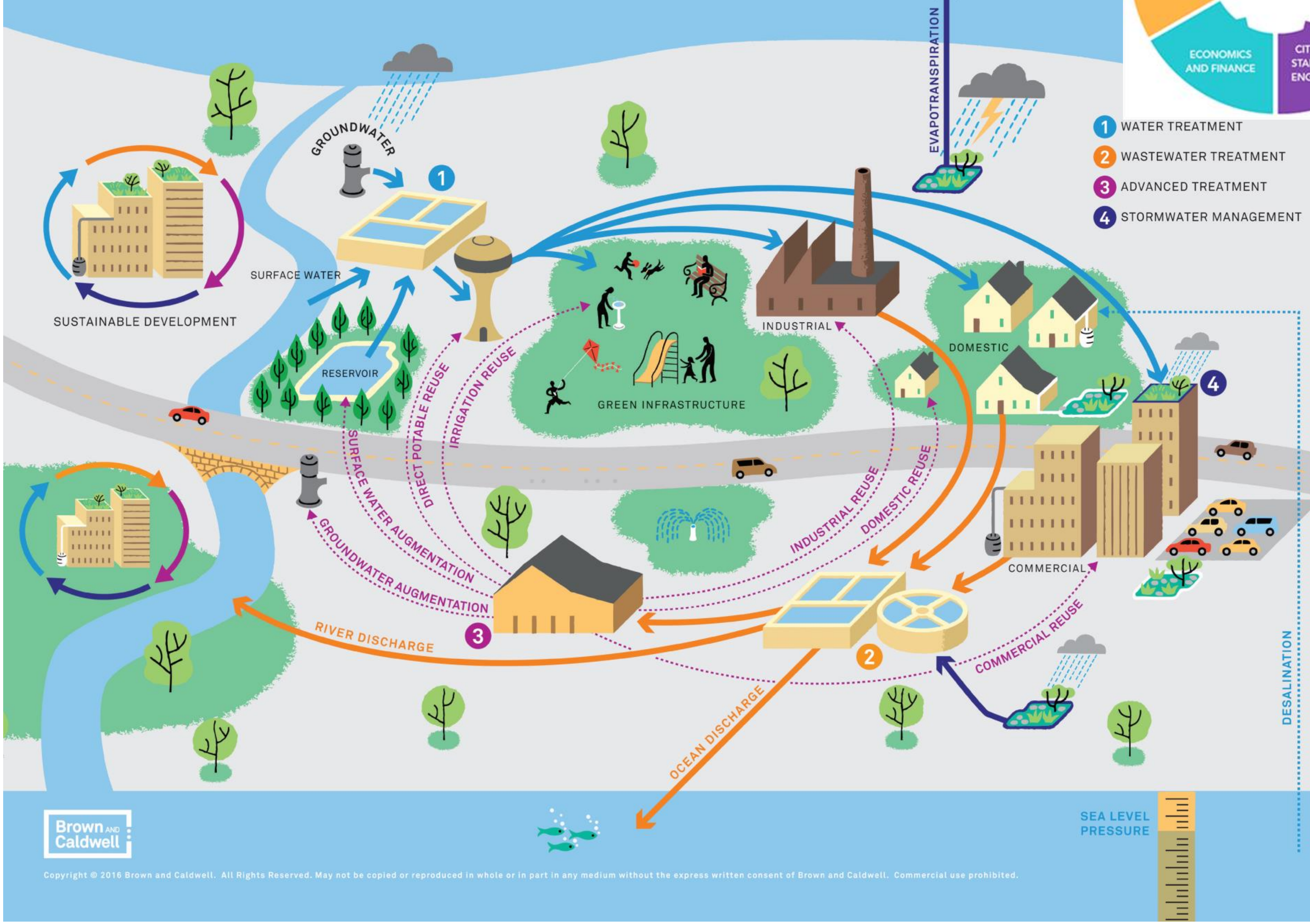
(Water Research Foundation, 2017)



To make more informed decisions, answers are needed to questions:

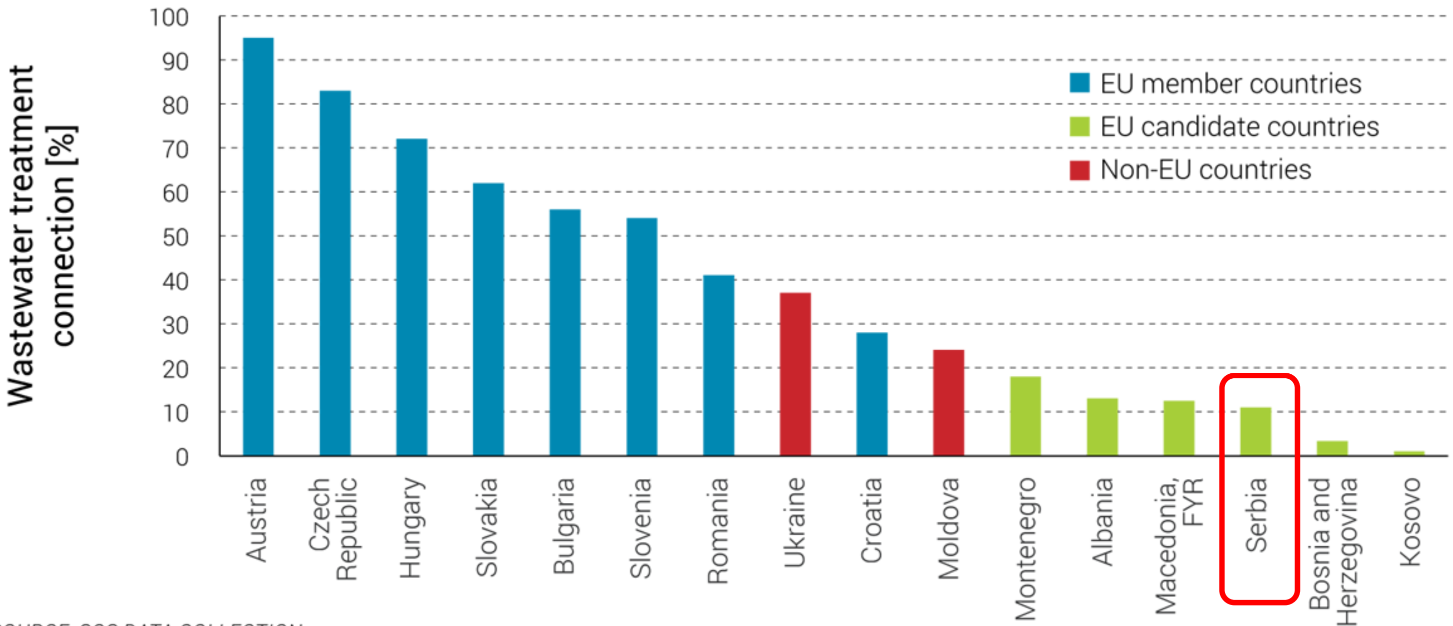
- what kinds of costs, benefits and risks?
- how are they distributed?
- how important are they for different stakeholders?

Complexity of **One Water** paradigm



Problem

FIGURE 31: WASTEWATER TREATMENT COVERAGE IN THE REGION, 2012



SOURCE: SOS DATA COLLECTION.

EU legislation requires that agglomerations over 2,000 inhabitants must have wastewater treatment plant.

There are 434 such settlements in Serbia, but less than 5% treat wastewater.

There is urgent need for investment in wastewater plants.

Financial sources are limited.

Transparent and justified prioritization of where investments should be placed is required.

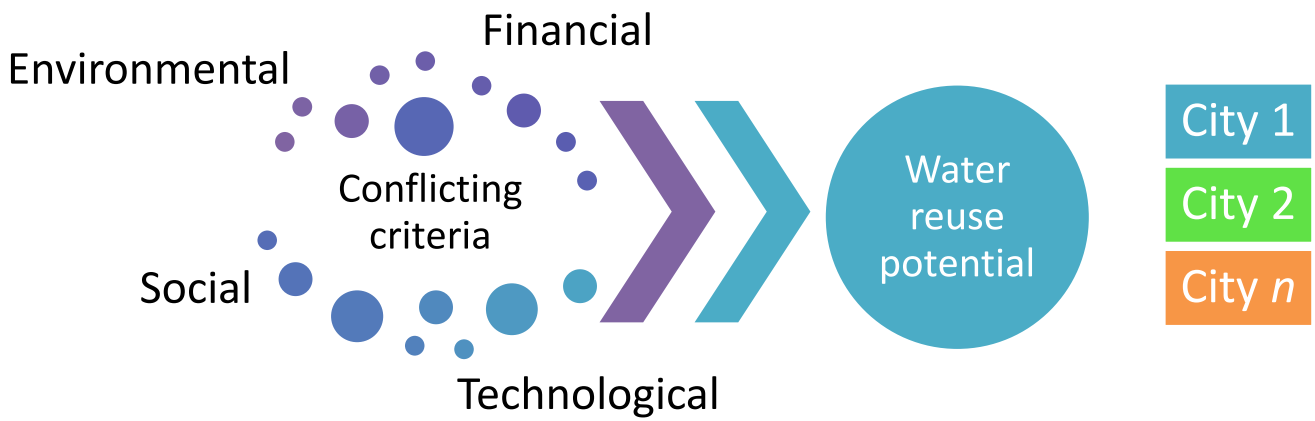
Innovative Approach

APPROACH: Embedding the **water reuse potential** of any particular site in the country into a planning and investing decision-making process.

Almost all most common water reuse types (agriculture, industrial, environmental purposes, urban use) can be applied in Serbia.

FOCUS: Urban use and Agricultural use.

Dimensions of evaluating criteria for water reuse potential assessment:



Urban use of reused water

Survey to check (*based on Jamrah et al., 2008*)

Accept new plumbing system in their homes
They think that it is economically beneficial
They think it is environmentally acceptable
They think it is not harmful to human health
They would use grey water for garden watering
They would use it for car washing
They would use it for toilet flushing
They think that grey water can be treated to the level of drinking water
They would allow researchers to install flow meters and measure flow rates from their homes

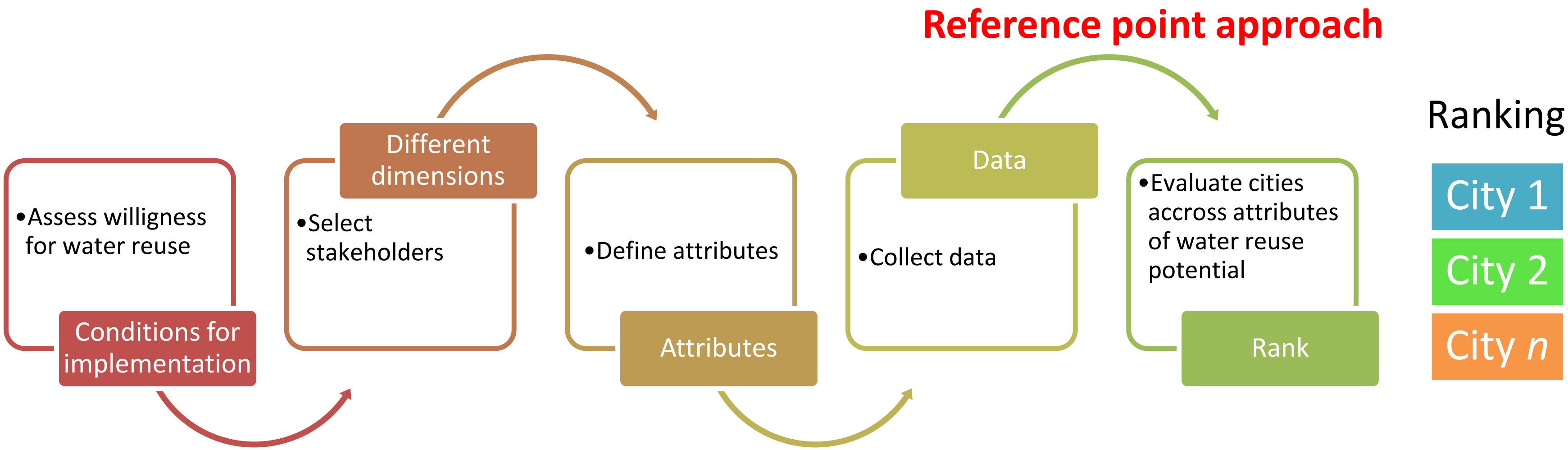
Agricultural use of reused water

Survey to check willigness to use and to pay – farmers
Survey to check social acceptability – consumers

Disgust over the concept
Use for which recycled water is intended
Perceptions of risk from recycled water
Sources of recycled water (e.g. is it rainwater or toilet water)
Choice between recycled and fresh water
Trust of authorities and knowledge
Attitudes towards the environment
Environmental justice issues
Cost of recycled water
Socio-demographic factors

(*Po et al., 2004*)

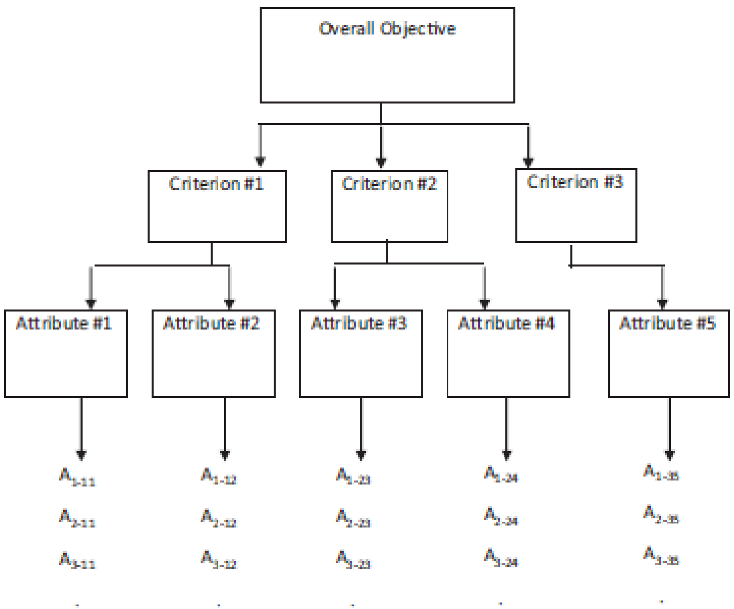
Framework for capturing complexity and enhancing implementation of one water paradigm



Pre-conditions:

- Legal framework adopted
- Awareness of water resources vulnerability raised
- Awareness of water reuse benefits raised
  (*personal* – lower prices; *common* - resources sustainability)

Reference Point Approach (RPA)



... finds compromise between a number of (sometimes) conflicting objectives.

- Applies to convex and nonconvex cases
- Can easily check Pareto-optimality of a given decision
- Can be easily supplemented by an a posteriori computation of weighting coefficients for the objectives
- Numerically well-conditioned and easy for implementation in cases with limited data and metadata
- Makes it possible to take into account the opinions of a decision maker directly, without necessarily asking him questions about his preferences

(Lewandowski, 1982)

Reference point approach

Performance matrix

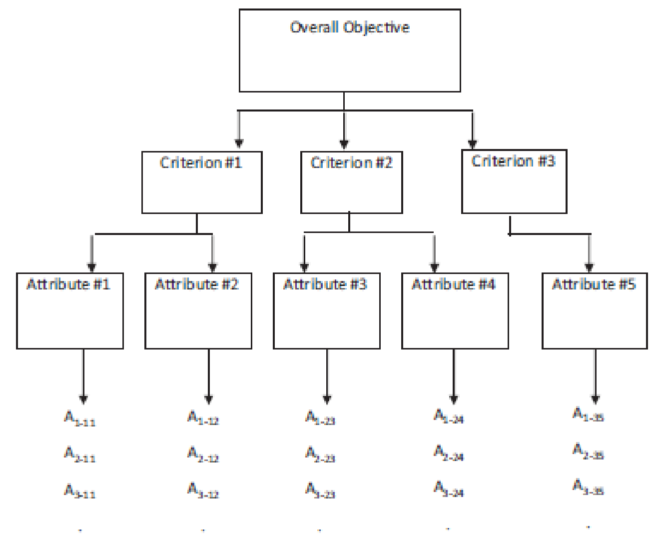
Alternatives	Criterion 1			Criterion 2			…	Criterion *nc*		
	Attribute 1^{1}	Attribute 2^{1}	Attribute $natt^{1}$	Attribute 1^{2}	Attribute 2^{2}	Attribute $natt^{2}$	…	Attribute 1^{nc}	Attribute 2^{nc}	Attribute $natt^{nc}$
A 1	$a_{11}^{(1)}$	$a_{12}^{(1)}$	$a_{1natt^{1}}^{(1)}$	$a_{11}^{(2)}$	$a_{12}^{(2)}$	$a_{1natt^{2}}^{(2)}$	…	$a_{11}^{(nc)}$	$a_{12}^{(nc)}$	$a_{1natt^{nc}}^{(nc)}$
A 2	$a_{21}^{(1)}$	$a_{22}^{(1)}$	$a_{2natt^{1}}^{(1)}$	$a_{21}^{(2)}$	$a_{22}^{(2)}$	$a_{2natt^{2}}^{(2)}$	…	$a_{21}^{(nc)}$	$a_{22}^{(nc)}$	$a_{2natt^{nc}}^{(nc)}$
.	.	.	.	.	.	.	…	.	.	.
.	.	.	.	.	.	.	…	.	.	.
.	.	.	.	.	.	.	…	.	.	.
A *nalt*	$a_{natt\,1}^{(1)}$	$a_{nal\,2}^{(1)}$	$a_{nalt\,natt^{1}}^{(1)}$	$a_{nalt\,1}^{(2)}$	$a_{nal\,2}^{(2)}$	$a_{nalt\,natt^{2}}^{(2)}$	…	$a_{nalt\,1}^{(nc)}$	$a_{nal\,2}^{(nc)}$	$a_{nalt\,natt^{nc}}^{(nc)}$

Box – Cox transformation + probability integral transformation theorem = **uniform distribution of attribute values in the interval [0,1]**

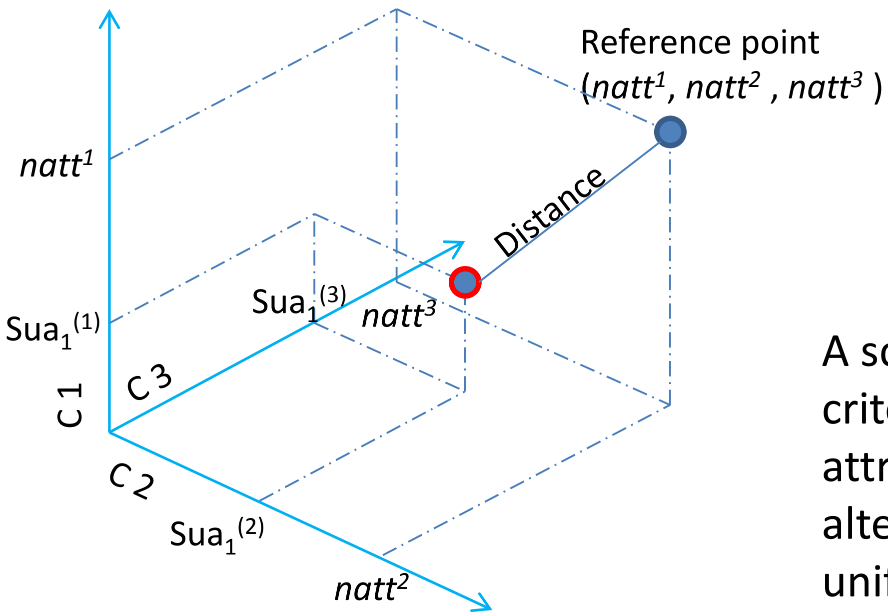
In contrast to other ideal point methods, such as CP or TOPSIS, RPA does not use a virtual utopia point (in the case of CP) or ideal positive or negative point (in the case of TOPSIS).

Instead, RPA uses as a reference objective the realistic point in the *nc*-decision space, defined by a decision-maker as desired value or set as a highest (lowest) value of any criterion.

The minimization (or maximization) norm in RPA is replaced with the optimization of achievement scalarization functions.



Reference Point Approach



Normalization and uniformization processes =>

the attributes have values between 0 and 1 and have no units so that the sum of the attributes is easy to obtain.

A score of alternative ($Sua_i^{(k)}$) for the *k*th criterion associated with $natt^k$ number of attributes can be obtained for the *i*th alternative as summation of normalized and uniformized *j*th attribute values (ua_{ij}):

$$Sua_i^{(k)} = \sum_{j=1}^{natt^k} ua_{ij}$$

The reference level for the *k*th criterion is equal to the number of the attributes associated (all attributes have normalized and uniformized values; max value can be 1)

Best alternative for the *k*th criterion has the $Sua_i^{(k)}$ value of $natt^k$.

Objectiveness - the RPA does not need to elicit any weights to the attributes or the criteria in the sum model employed.

Setting up objectives, criteria and attributes

The overall objective: performance assessment of Cities as investment sites in terms of criteria: (1) Potental of urban use of reused water and (2) Potential of agricultural use of reused water.

Attributes

Urban use of reused water	Agricultural use of reused water
Irrigation facilities	Drought index
Cost of new infrastructure	Financial benefits of farmers
Cost of treatment	Cost of treatment
Environmental benefits	Crop tolerancy
Restoring scenic beauty	
. . .	. . .

Will be defined by stakeholders

Alternatives: City 1, City 2, City n

Assessment of performance of alternatives

Sum normalized and uniformized attribute values ua_{ij} for *ith* alternative (j=1,.., $natt^k$) for each criterion (k=1,.., nc)

$$Sua_i^{(k)} = \sum_{j=1}^{natt^k} ua_{ij}$$

and present *ith* alternative as a point in *nc* space with coordinates
$(Sua_i^{(1)}, Sua_i^{(2)}, \ldots, Sua_i^{(nc)})$

Urban use of reused water	Agricultural use of reused water
Irrigation facilities	Drought index
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Restoring scenic beauty	
. . .	. . .

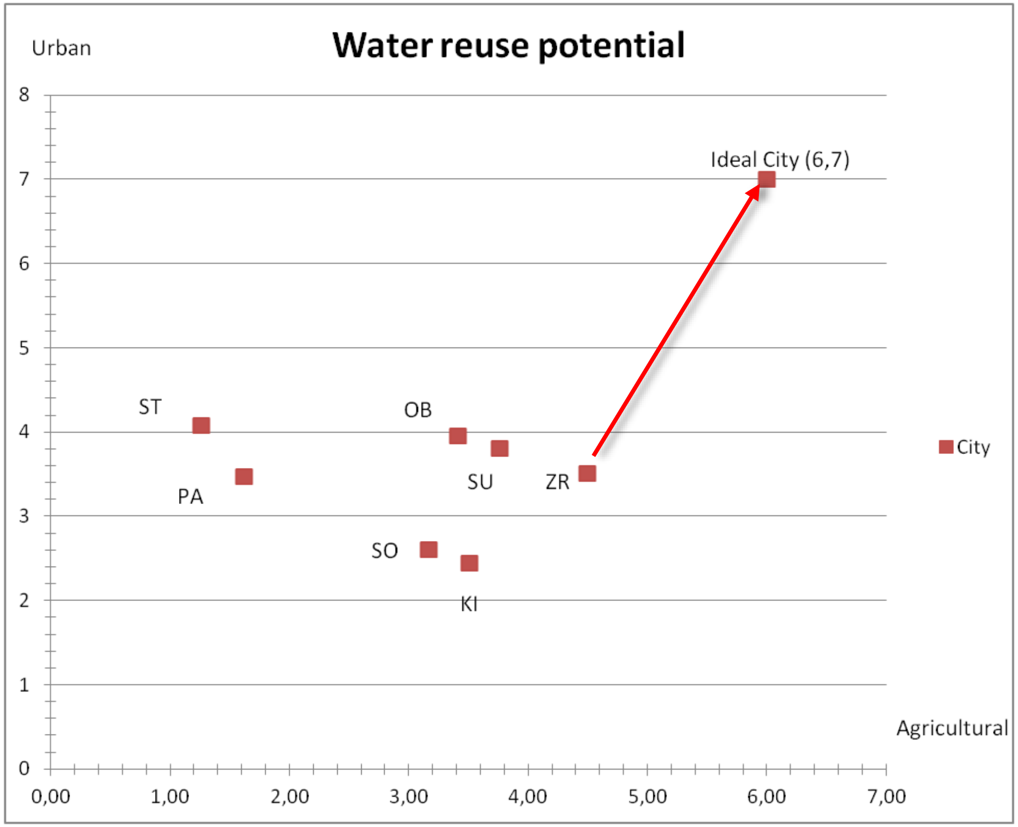
Alternatives: City 1, City 2, City n

Calculate the Euclidean distance ED_i of *ith* alternative from the reference point.

$$ED_i = \sqrt[nc]{\sum_{k=1}^{nc} \left(q_k - Sua_i^{(k)}\right)^2}$$

Alternative with smalest distance from the reference point is considered as the best one.

Illustrative example:
Assessment of water reuse potential of 7 cities in Vojvodina Province (Serbia)



	Dist from (6,7)
KI	5,18
SU	3,90
ZR	3,80
SO	5,22
OB	3,99
ST	5,56
PA	5,62

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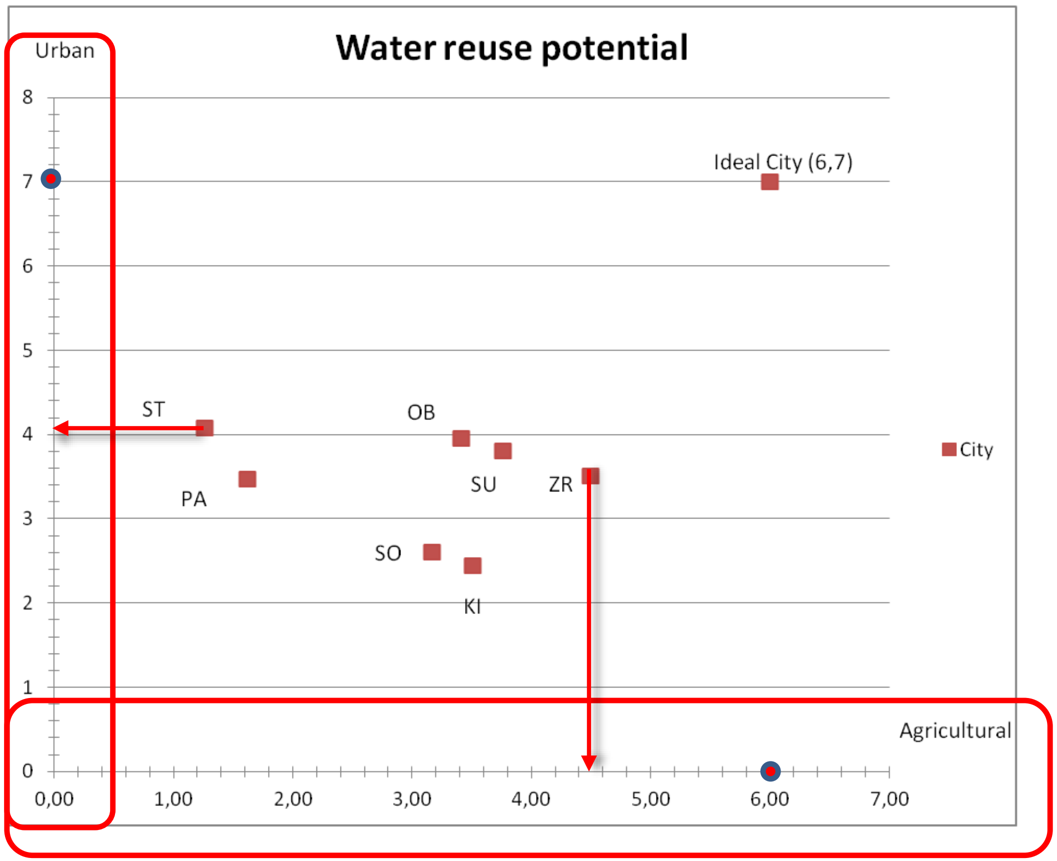

Conclusions

Although water reuse is complex, expensive and difficult for implementation, it is unavoidable necessity in reality characterized by population growth, climate change, increased demand of customers in different sectors and environmental protection requirements.

Proposed strategic planning framework capture complexity of one water paradigm in Serbia by

(1) involving different stakeholders and sectors in DM process
(2) evaluating water reuse potential of investment alternatives
(3) introducing water reuse potential as criterion for planning and investing decision making process.

Objectiveness of the evaluation is ensured by reference point approach.

The visual representation of the alternatives' performance in the form of a 2D scatter plot of urban vs. agricultural water resuse potential is convenient for communicating the results to the decision-makers &/or stakeholders.