

Fuzzy Criteria for Evaluation of Water Resources Systems Performance

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Banda Aceh - before





Flood Risk Management Workshop

Banda Aceh - after







New Orleans before





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New Orleans after





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New Orleans - flood







New Orleans –dike failure





Lake Pontchartrain pours through a breached levee into downtown New Orleans. After the city's defenses were damaged by Hurricane Katrina, local officials feared a steep death toll and planned to evacuate the thousands in shelters.





New Orleans – dike failure







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Katrina help





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Presentation outline

- Challenges
- Water resources systems performance
 - Change of paradigm
 - New performance measures
- A case study
 - London flood protection
- Conclusions





Challenges

- How to reduce the risk to water systems and in the same time obtain the social, environmental and economic benefits from the watershed areas under threat.
- How to improve our knowledge base
 - Prediction of hazardous events
 - Assessment of risk and vulnerability
 - Integrated use of structural and non-structural protection measures
 - Enhancement of preparedness





Risk definition

- Load and resistance concept
- Load /
 - a variable reflecting the behaviors of the system under certain external conditions of stress or loading
- Resistance r
 - a variable that describes the capacity of the system to overcome an external load





Risk definition

Failure or an incident

l > *r*

Safety or reliability

I≤ *r*





Risk definition

Set of performance measures

- Risk/reliability (how often?)
- Vulnerability (how much?)
- Resiliency (how long to recover?)
- Robustness (how able to adopt?)





Risk management confusion

- Inadequate distinction between three fundamental concepts of risk
 - Objective risk (real, physical)
 - Subjective risk (degree of belief)
 - Perceived risk (individual's feeling of fear)















Changing paradigm













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Fuzzy membership shapes









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New performance measures

New fuzzy measures for system performance evaluation

(*El-Baroudi and Simonovic, 2004-download from <u>www.slobodansimonovic.com</u>)*

- Combined fuzzy reliability-vulnerability
- Fuzzy robustness
- Fuzzy resiliency





New fuzzy performance measures



Western



New fuzzy performance measures





New fuzzy performance measures

Fuzzy membership function of a system state







Fuzzy reliability and vulnerability







Fuzzy reliability and vulnerability

The compatibility measure

$$CM_{S,L} = \frac{WOA_{S,L}}{WA_S}$$

- provides information about system reliability and vulnerability
- measure of proximity (overlap)





Fuzzy reliability and vulnerability

$\begin{aligned} \text{Reliability Index} = \frac{\max_{i \in K} \left\{ \text{CM}_1, \text{CM}_2, \dots, \text{CM}_i \right\} \times \text{LR}_{\max}}{\max_{i \in K} \left\{ \text{LR}_1, \text{LR}_2, \dots, \text{LR}_i \right\}} \end{aligned}$





Fuzzy robustness measure

Robustness Index = $\frac{1}{CM_1 - CM_2}$





Fuzzy resiliency measure







Fuzzy resiliency measure

$$\widetilde{T}(\alpha) = \left(\max_{j \in J} [t_{l_1}(\alpha), t_{l_2}(\alpha), \dots, t_{l_J}(\alpha)], \max_{j \in J} [t_{2_1}(\alpha), t_{2_2}(\alpha), \dots, t_{2_J}(\alpha)] \right)$$

Resilience Index =
$$\begin{bmatrix} \int_{t_1}^{t_2} t \ \widetilde{T}(t) \ dt \\ \int_{t_1}^{t_2} \widetilde{T}(t) \ dt \end{bmatrix}^{-1}$$





London flood protection case study

- Use of fuzzy performance measures
- Spatial extension of the concept
 - Calculation of measures at every point in space
 - Development of fuzzy performance maps
- City of London flood protection





London flood protection case study



Legend

Western

rel_id_land_u





ow: 0

W

Reliability Index





London flood protection case study





Resiliency Index

Western



London flood protection case study



Robustness Index





Conclusions

- Water resources systems are vulnerable to variety of hazards
- Main challenge diversity of uncertainty sources
- Probabilistic approach fails in case of human error, subjectivity, lack of history, etc.
- A fuzzy system reliability analysis offers an alternative approach

