Computerized Support Tool for Participatory Flood Decision-Making in the Red River Basin

Taslima Akter

Department of Civil and Environmental Engineering
University of Western Ontario

Outline

- Introduction
- multi-criteria decision making(MCDM)
- Multiple stakeholders in the decision making process
- Ranking of alternatives
- Red River case study
- Conclusions

Introduction

1997 Flood

Introduction

Stages of Flood Management Decision Making:

- Planning
  - Selecting alternatives for future flood protection
- Emergency Management
  - Sand-bagging
  - floodway operation
- Post Flood Recovery
  - Compensation
  - Insurance claim assessment

Multi-criteria Decision Making

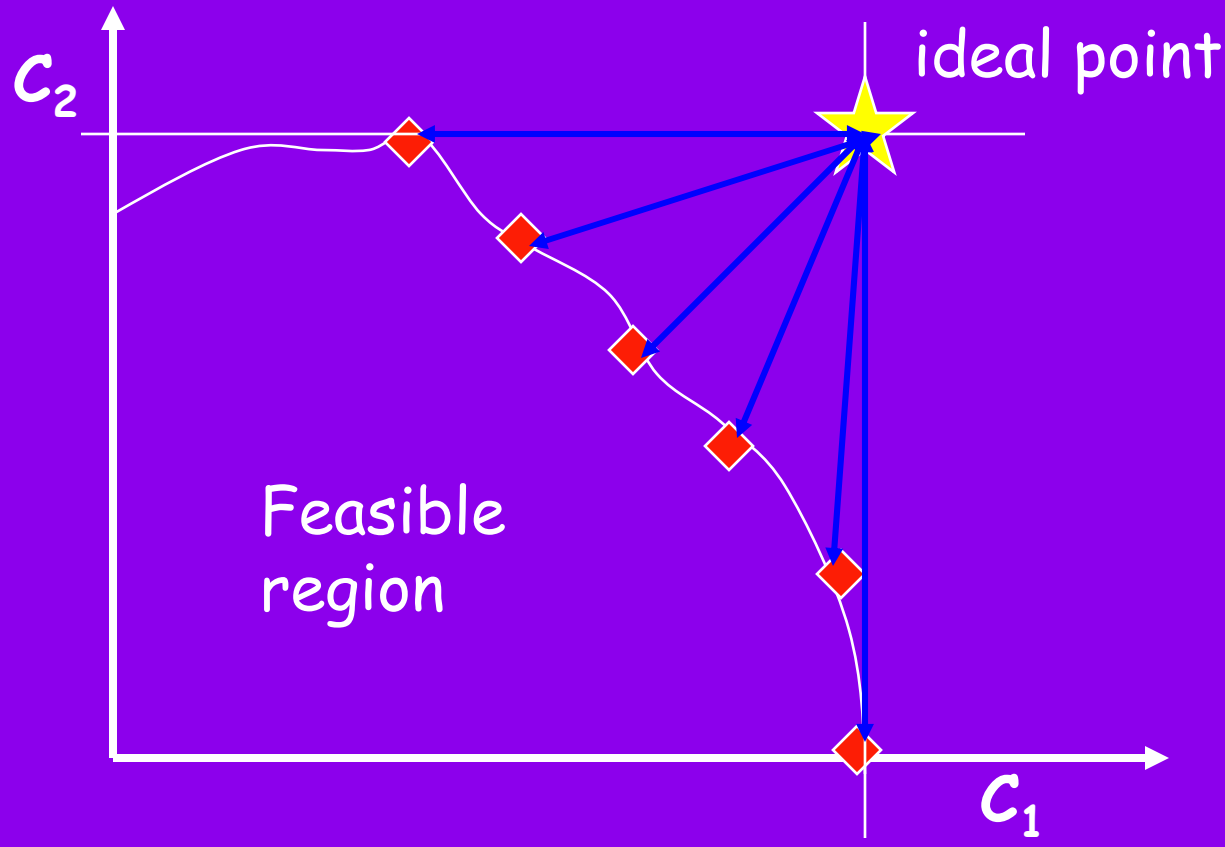
Components:

- Alternatives - Possible structural measure, nonstructural measure or operational strategy
- Criteria - Standard for evaluating the efficiency of an alternative
- Preference – Measure of importance of different criteria
- Stakeholder – A person or a group involved in flood decision making process
- A set of performance evaluations of alternatives for each objective or criteria

Multi-criteria Decision Making

	Criteria 1	**Criteria 2**	**Criteria 3**	**…**	**Criteria n**
Alternative 1	a_{11}	a_{12}	a_{13}		a_{1n}
Alternative 2	a_{21}	a_{22}	a_{23}		a_{2n}
……					
Alternative m	a_{m1}	a_{m2}	a_{m3}		a_{mn}
Weight w_n	w_1	w_2	w_3		w_n

Multi-criteria Decision Making



Multiple stakeholders in decision-making

	Criteria 1	Criteria 2	Criteria 3	…	Criteria n
Alternative 1	a_{11}	a_{12}	a_{13}		a_{1n}
Alternative 2	a_{21}	a_{22}	a_{23}		a_{2n}
……					
Alternative m	a_{m1}	a_{m2}	a_{m3}		a_{mn}
Weight w_n	w_1	w_2	w_3		w_n

Multiple stakeholders in decision-making

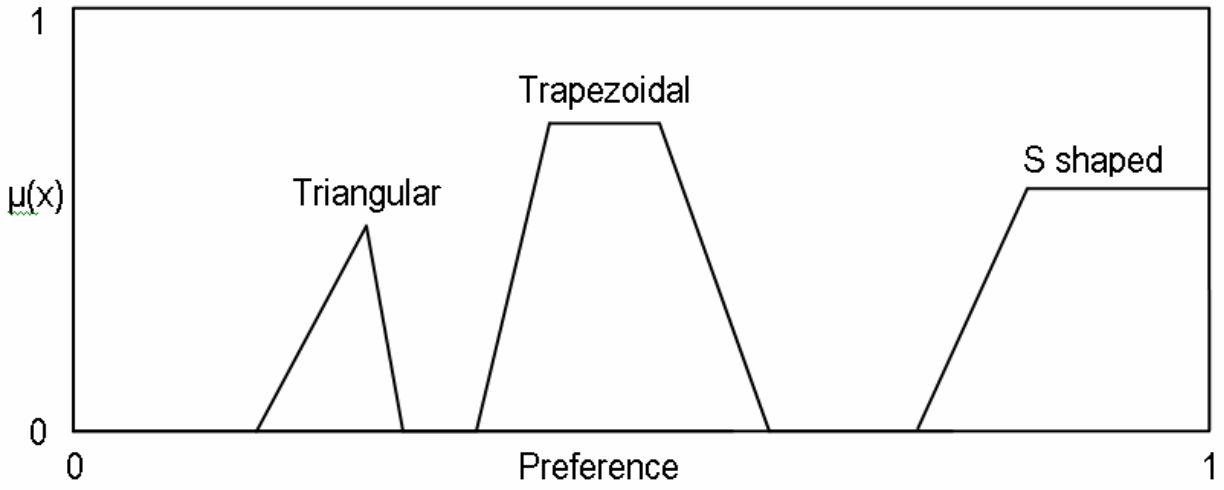
	Criteria 1	Criteria 2_1	Criteria 2_2	Criteria 2_3	Criteria 3	…	Criteria n
Alternative 1	a_{11}	a_{121}	a_{122}	a_{123}	a_{13}		a_{1n}
Alternative 2	a_{21}	a_{221}	a_{222}	a_{223}	a_{23}		a_{2n}
……							
Alternative M	a_{m1}	a_{m21}	a_{m22}	a_{m23}	a_{m3}		a_{mn}
Weight w_n	w_1	w_{21}	w_{22}	w_{23}	w_3		w_n

Uncertainty

- Natural hydrological processes
  - Inflow; Precipitation; Snowmelt; Temperature
- Data monitoring systems
  - Economic; Social; Health; Environmental
- Preferences (lack of knowledge)
  - Subjective; Multiple stakeholders

Uncertainty

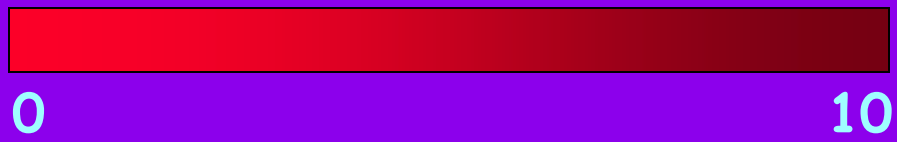
- Theory of fuzzy sets



$$A = \{(x, \mu_A(x) \mid x \in X\}$$

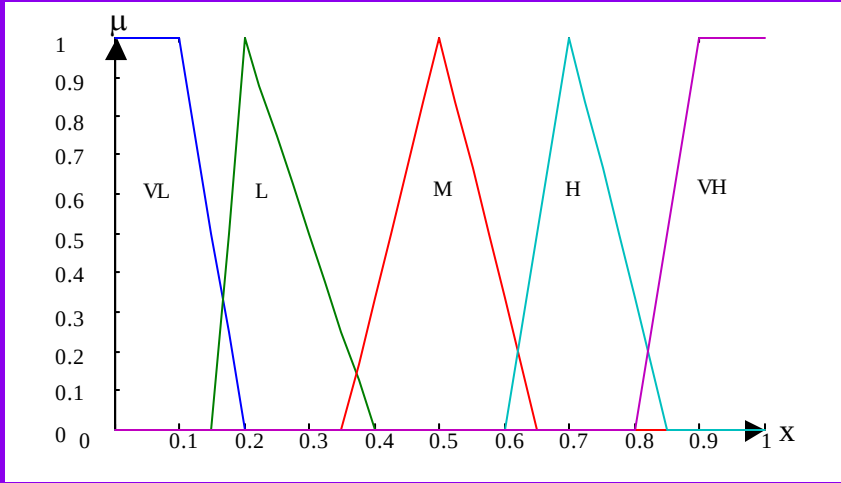
Multiple Stakeholders in Decision-Making

- Input
  - Scale



  - Linguistic

very low low medium high very high

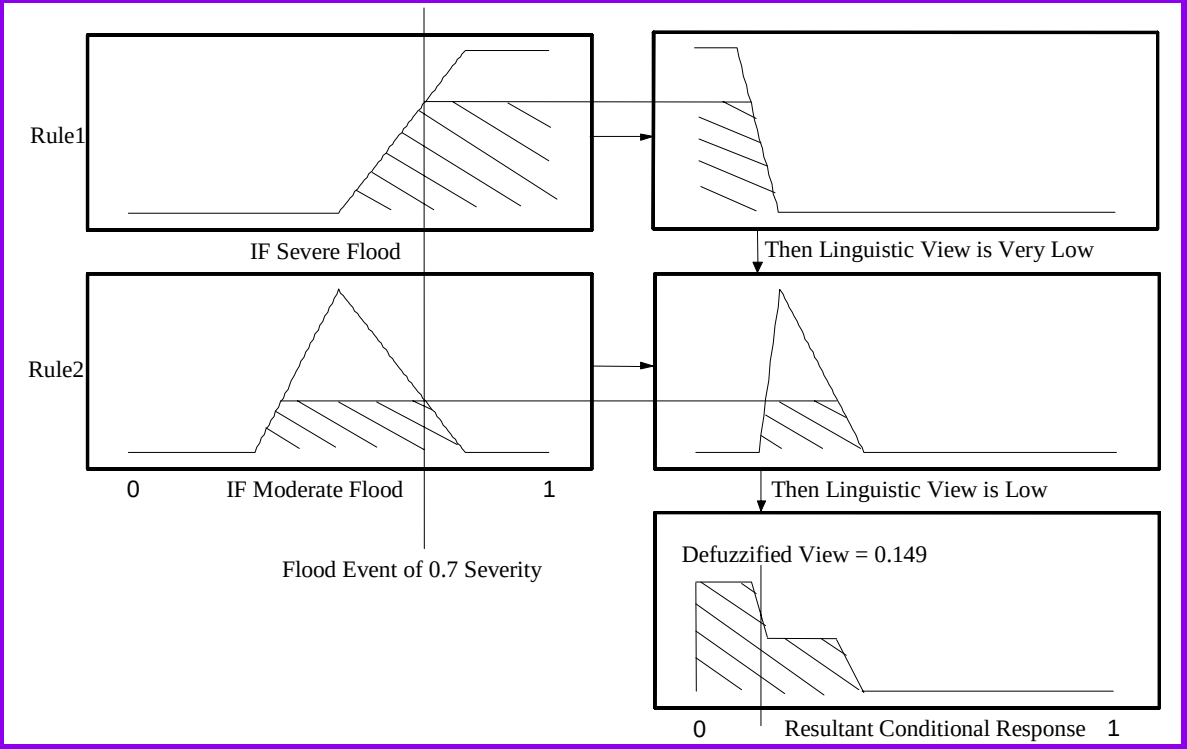


Multiple Stakeholders in Decision-Making

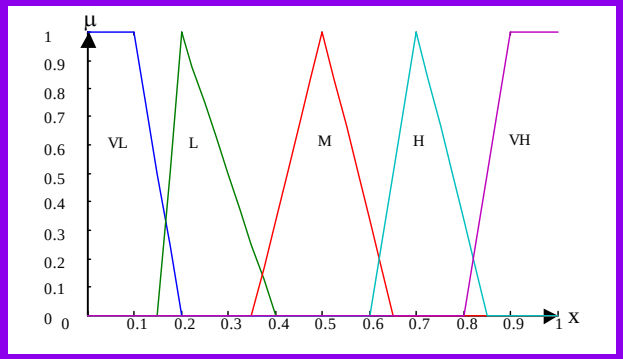
Western Engineering Science

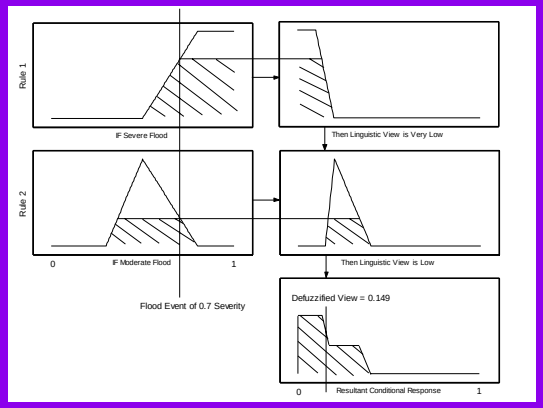
Conditional

IF severe flood expected THAN
IF moderate flood expected THAN
very low low medium high very high



Multiple stakeholders in decision-making





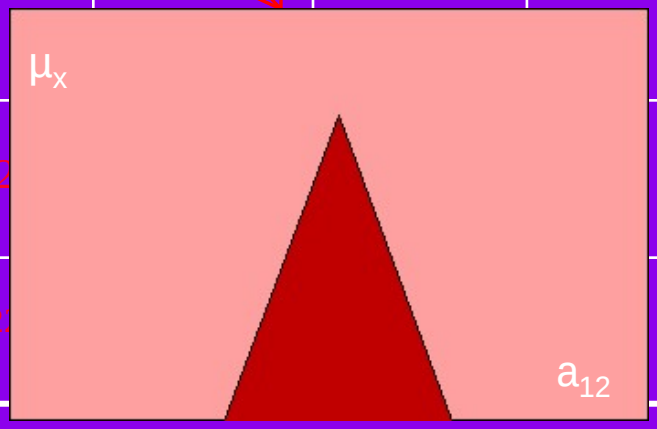
Response input

$$FEV(x_A) = \sup \{ \min [T, \mu(\xi_T)] \}$$
where $\xi_T = \{x \mid x_A(x) \geq T\}, \quad 0 \leq T \leq 1$
and $\mu\{x \mid x_A(x) \geq T\} = f_A(T)$

Aggregated output

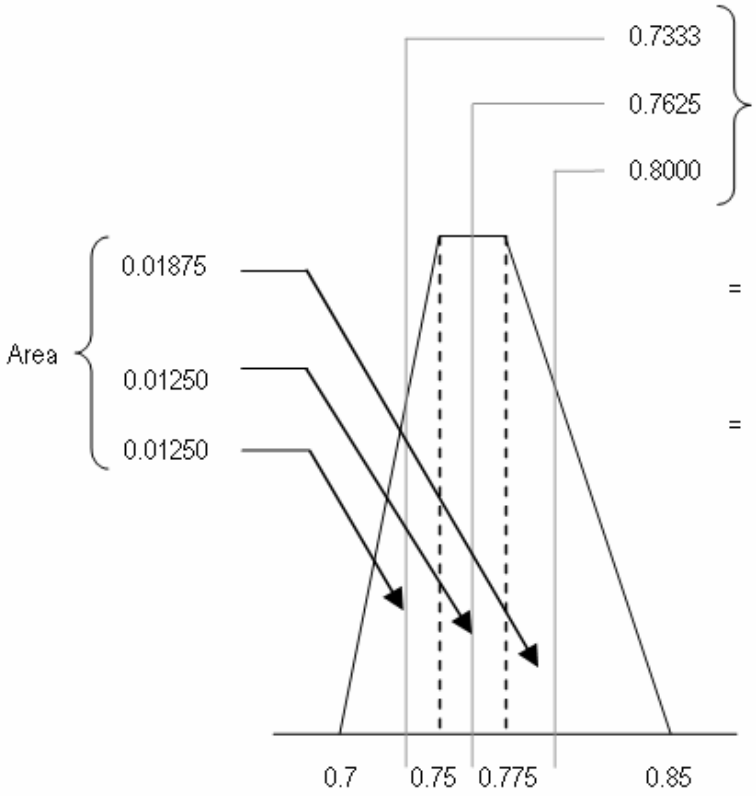
Multiple stakeholders in decision-making

	Criteria 1	Criteria 2_1	Criteria 2_2	Criteria 2_3	Criteria 3	…	Criteria n
Alternative 1	a_{11}	a_{121}	a_{122}	a_{123}	a_{13}		a_{1n}
Alternative 2	a_{21}	a_{221}	a_{222}	a_{223}	a_{23}		a_{2n}
……							
Alternative M	a_{m1}	a_{m21}	a_{m2}				a_{mn}
Weight w_n	w_1	w_{21}	w_2				w_n



Multiple stakeholders in decision-making

Defuzzify by centroid of area method



$$= \frac{0.7333(0.01250) + 0.7625(0.01250) + 0.8000(0.01875)}{(0.01250) + (0.01250) + (0.01875)}$$

$= 0.7702 \rightarrow$ Defuzzified FEV

Ranking of alternatives

- Method of Chang and Lee (1994)
  - Overall Existence Ranking Index (OERI)
  - Subjective weighting indicating neutral, optimistic and pessimistic preferences of the decision maker

$$OERI(A) = \int \omega(\alpha)\left[\chi_1(\alpha)\mu_{iL}^{-1}(\alpha) + \chi_2(\alpha)\mu_{iR}^{-1}(\alpha)\right]d\alpha$$

Red River Case Study

	Economic Criteria			Environmental Criteria			Social Criteria	
	Cost	Damage	Benefit	Chemical Contami-nation	Alien Species	Environ-ment	Community Involvement	Personal Loss
Structural Alternative	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}	e_{16}	e_{17}	e_{18}
Non-Structural Alternative	e_{21}	e_{22}	e_{23}	e_{24}	e_{25}	e_{26}	e_{27}	e_{28}
Combination Alternative	e_{31}	e_{32}	e_{33}	e_{34}	e_{35}	e_{36}	e_{37}	e_{38}
Weight Coefficient	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8

*Stakeholder preference, e_{mn}

Flood management pay-off (decision) matrix

Red River Case Study

- Experiment
  - Two criteria
    - Maximize community involvement
    - Minimize personal losses
  - Three alternatives
    - Structural alternative
    - Non-structural alternative
    - Combined alternative
  - Around 40 stakeholders

Red River Case Study

- Criterion 1 – Community involvement
  1. Rate the level of opportunity provided by each alternative to get involved during the planning stage of flood protection.
  2. Rate the level of opportunity provided by each alternative to get involved during time of flooding.
  3. To what degree would you think each alternative induces this sense of complacency?
  4. For each alternative, indicate the level of technical contribution that you would be able to provide through knowledge and experience.
  5. Rate the alternatives according to the level of training required to be actively involved in flood management activities.
  6. Rate your willingness to participate
  7. Rate the importance of the role of leadership to the successful execution and implementation of each alternative.
  8. Rate the alternatives according to the degree to which they promote local leadership and community tightness.

Red River Case Study

- Criterion 2 – Personal loss
  1. Rate the severity of an economic loss
  2. Rate the degree of impact on personal health each alternative would expose the public to during a flood.
  3. Rate the level of stress induced in the daily lives of the public by each alternative
  4. Rate the alternatives according to the level of safety they would provide.
  5. Rate the level of control an individual and/or a community have over the flood protection measures implemented

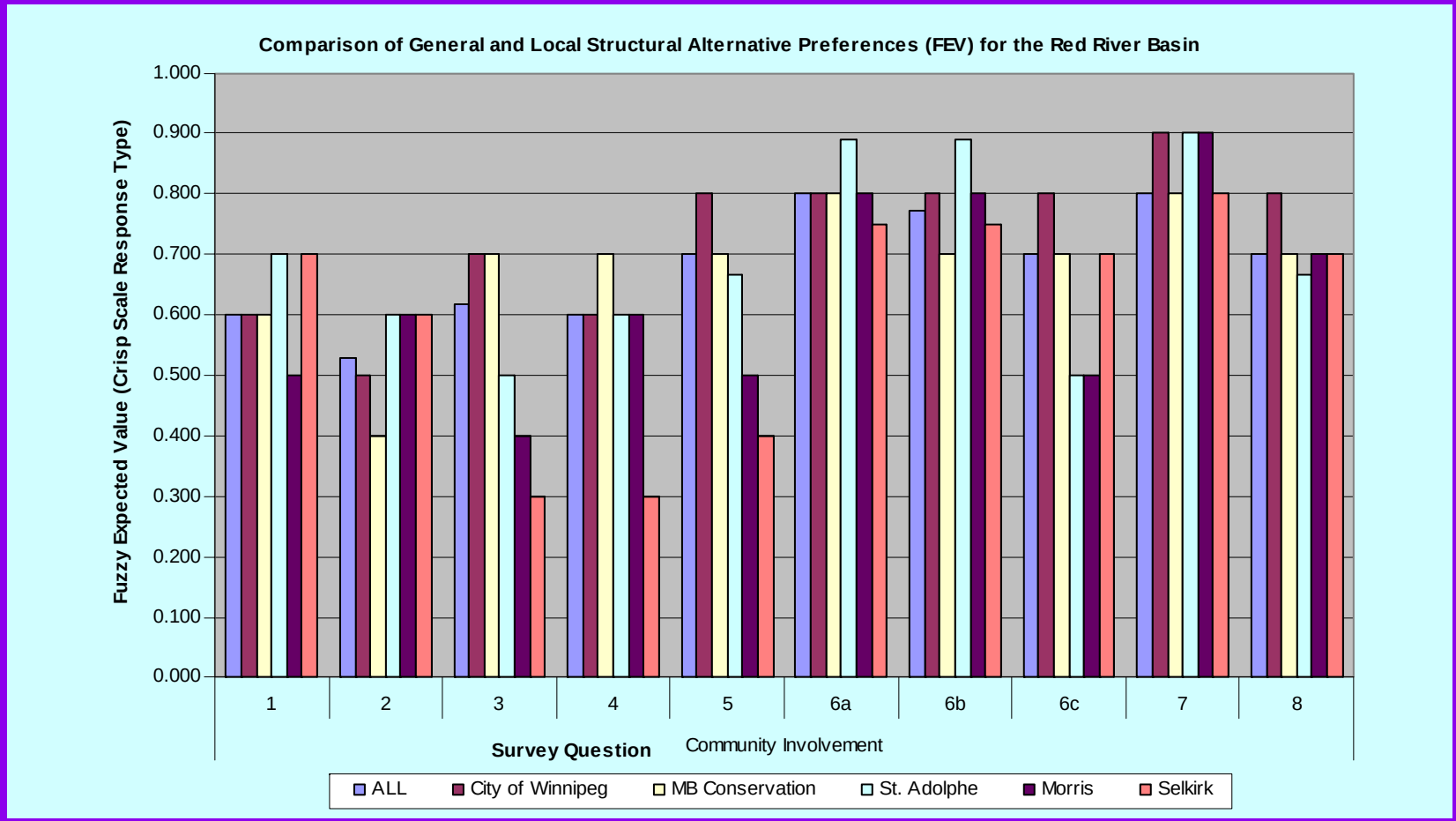
Red River Case Study

- Data sources by location
  - Manitoba Conservation
  - City of Winnipeg
  - St. Adolphe
  - Morris
  - Selkirk
- Data sources by domain knowledge
  - Technical
  - Non-technical

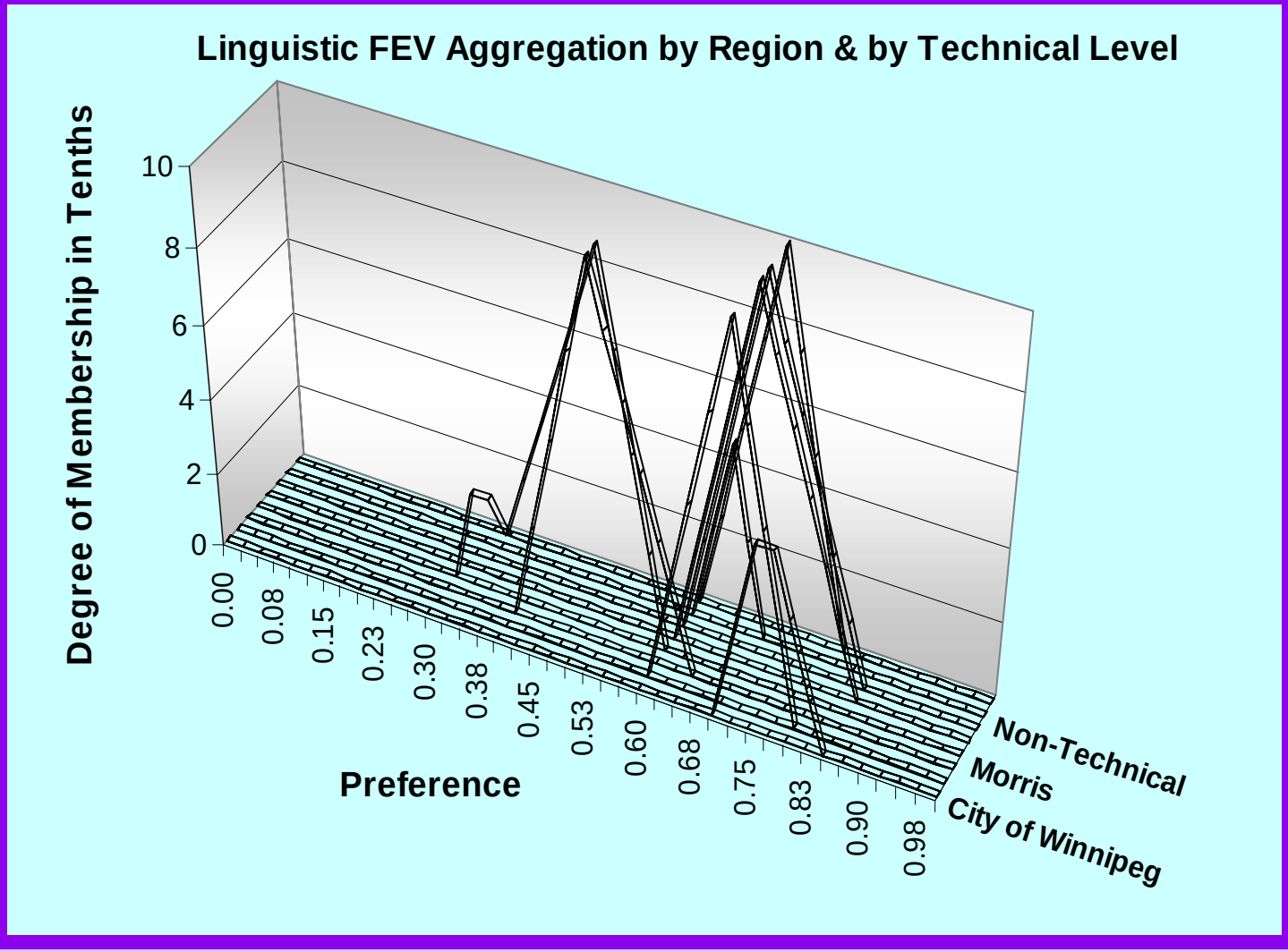
Red River Case Study

	Alternative	Structural			Non-Structural			Combination		
	Type	A	B	C	A	B	C	A	B	C
	Question No.	FEV	FEV	FEV	FEV	FEV	FEV	FEV	FEV	FEV
Community Involvement	1	0.600	0.650	0.544	0.647	0.650	0.544	0.600	0.625	0.544
	2	0.529	0.517	0.500	0.500	0.517	0.491	0.500	0.570	0.544
	3	0.618	0.700	0.529	0.559	0.625	0.529	0.600	0.625	0.544
	4	0.600	0.650	0.544	0.657	0.650	0.559	0.686	0.650	0.544
	5	0.700	0.700	0.559	0.629	0.650	0.544	0.700	0.650	0.544
	6a	0.800	0.825	0.677	0.704	0.770	0.588	0.800	0.825	0.647
	6b	0.771	0.770	0.588	0.714	0.717	0.574	0.743	0.770	0.574
	6c	0.700	0.700	0.574	0.629	0.650	0.574	0.686	0.700	0.574
	7	0.800	0.825	0.735	0.829	0.850	0.718	0.857	0.825	0.718
	8	0.700	0.717	0.574	0.700	0.650	0.574	0.700	0.700	0.574
Personal Loss	1	0.800	0.770	0.718	0.700	0.700	0.574	0.700	0.717	0.671
	2	0.588	0.570	0.544	0.600	0.650	0.544	0.600	0.625	0.574
	3a	0.500	0.570	0.574	0.559	0.625	0.574	0.559	0.570	0.574
	3b	0.700	0.717	0.625	0.700	0.717	0.588	0.706	0.717	0.588
	4	0.771	0.770	0.574	0.700	0.650	0.574	0.700	0.717	0.544
	5	0.500	0.570	0.529	0.700	0.570	0.544	0.571	0.570	0.544

Results Red River Case Study



FEV Aggregation (Linguistic)

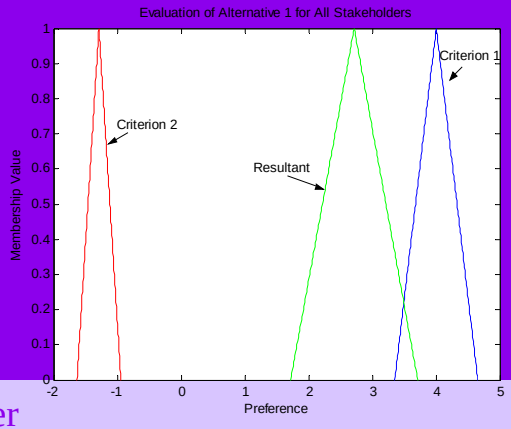


Red River Case Study

- Ranking
  - 3 generic alternatives
  - 2 social criteria
  - Equal weights
  - All participants
  - Winnipeg
  - Morris
  - Selkirk

Red River Case Study

		Criterion 1										Criterion 2					
	Question #	1	2	3	4	5	6a	6b	6c	7	8	1	2	3a	3b	4	5
Alt 1	Left X	0.392	0.600	0.625	0.600	-0.829	0.726	0.600	0.821	-0.842	0.000	-0.614	-0.614	-0.842	-0.814	0.526	0.000
	Centre X	0.517	0.700	0.650	0.700	-0.825	0.770	0.700	0.825	-0.717	0.000	-0.570	-0.570	-0.717	-0.770	0.570	0.000
	Right X	0.642	0.800	0.675	0.800	-0.821	0.814	0.800	0.829	-0.592	0.000	-0.526	-0.526	-0.592	-0.726	0.614	0.000
Alt 2	Left X	0.392	0.621	0.625	0.625	-0.814	0.592	0.625	0.825	-0.675	0.000	-0.675	-0.629	-0.842	-0.675	0.526	0.000
	Centre X	0.517	0.625	0.650	0.650	-0.770	0.717	0.650	0.850	-0.650	0.000	-0.650	-0.625	-0.717	-0.650	0.570	0.000
	Right X	0.642	0.629	0.675	0.675	-0.726	0.842	0.675	0.875	-0.625	0.000	-0.625	-0.621	-0.592	-0.625	0.614	0.000
Alt 3	Left X	0.526	0.621	0.625	0.625	-0.829	0.726	0.600	0.821	-0.800	0.000	-0.629	-0.614	-0.842	-0.842	0.526	0.000
	Centre X	0.570	0.625	0.650	0.650	-0.825	0.770	0.700	0.825	-0.700	0.000	-0.625	-0.570	-0.717	-0.717	0.570	0.000
	Right X	0.614	0.629	0.675	0.675	-0.821	0.814	0.800	0.829	-0.600	0.000	-0.621	-0.526	-0.592	-0.592	0.614	0.000

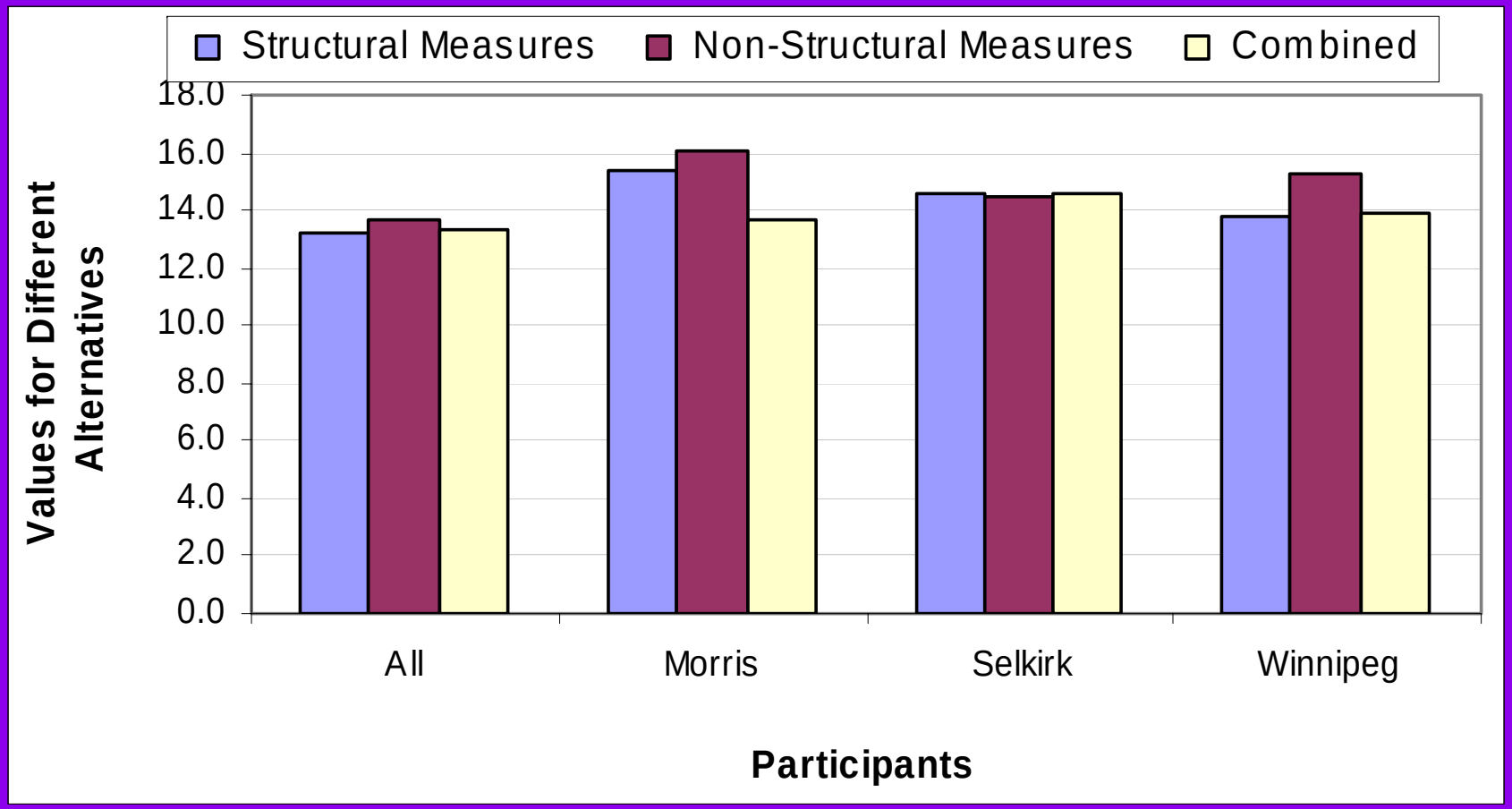


all

Red River Case Study

Participants	Alternative 1	Alternative 2	Alternative 3
All stakeholders	13.22 (1)	13.72 (3)	13.29 (2)
Morris	15.43 (2)	16.09 (3)	13.63 (1)
Selkirk	14.63 (3)	14.42 (1)	14.58 (2)
Winnipeg	13.74 (1)	15.25 (3)	13.92 (2)

Red River Case Study



Conclusions

- Tool for supporting flood decision making
  - Multiple criteria
  - Multiple stakeholders
  - Uncertainty
- Red River Case Study
  - 3 generic alternatives
  - 2 social criteria
- Observations
  - Variability in regional data comparison (FEV)
  - Final rank dependent on the input data