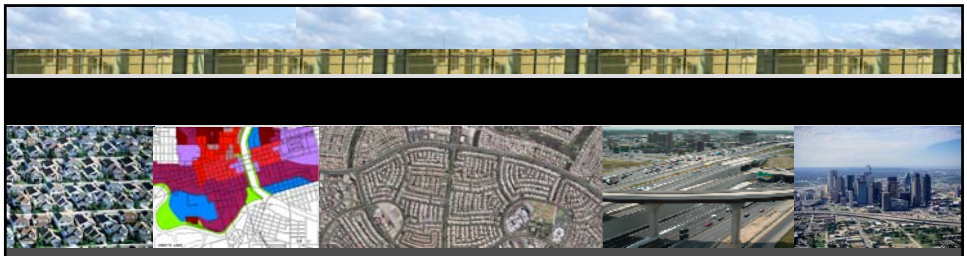
F. Multi Criteria Decision Analysis (MCDA)



Multi Criteria Decision Analysis (MCDA)

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Atlanta BeltLine Decision Support Tool Strategic Planning Session, Georgia Tech, : Atlanta, Georgia October 16, 2008

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INTRODUCTION

What is a Multi Criteria Decision Analysis (MCDA)?

- Conflicts between **criteria**
- Conflicts between different interpretations of the criteria and different sets of preferences among the **different actors**

The MCDA is a technique to help the decision makers **to choose, rank or sort alternatives** in situations of **multiple and conflicting criteria** (Peckham, 1997).

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INTRODUCTION

Basic Structure of Multi Criteria Decision Analysis

- A serial process of **defining objectives** — Vision & goals
- Arranging them into **criteria** — Setting DST Strategy
- Identifying all possible **alternatives**
- Measuring **consequences** — Analysis of Plan Scenarios
- **Aggregation** — Setting Priorities

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Process of the MCDA

(1) Decision Matrix

		Alternatives					
		A^1	A^2	...	A^i	...	A^n
Criteria	1						
	2						
	...						
	j				c_j^i		
	...						
	q						

- Preferences on consequences are captured as values: $v_j(A^i) = f_j(c_j^i)$

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Process of the MCDA

(2) Standardization of Consequences

Since the unit of each criterion is different, the consequence data of all criteria should be transformed **to unify the unit and sign**.

- Standardization (1)

For negative criteria: $v_j^i = \frac{min_{A^i \in A}(c_j^i)}{c_j^i}$

For positive preference criteria: $v_j^i = \frac{c_j^i}{max_{A^i \in A}(c_j^i)}$

- Standardization (2)

$$v_j^i = \frac{(c_j^i - \min(c_j^i))}{(\max(c_j^i) - \min(c_j^i))}$$

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Process of the MCDA

(3) Preferences on Criteria

- Expressions of the relative importance of criteria: $w_j > 0$ and $\sum w_j = 1$.
A weight vector is denoted as $w = (w_1, w_2, \ldots, w_j, \ldots w_q)$.

- A popular evaluation method is the simple additive weighting (SAW) method: $V(A^i) = \sum w_j \cdot v_j(A^i)$
Where $V(A^i)$ is the overall evaluation of alternative A^i.

- Sensitive analysis: the role of each criterion on the selection of alternatives can be understood by changing weights of different criteria.

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Process of the MCDA

(4) Other aggregation models in MCDA

- Maximin Criterion
- Maximax Criterion
- Hurwicz Criterion
- Bayes Criterion
- Concordance & Disconcordance Analysis

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Selecting Priority of the Individual Projects

(1) Consequence data

		Plan Scenarios for Economic Development			
Categories	**Criteria**	ALT1	ALT2	ALT3	ALT4
1. Population & Economic impacts	Density (POP/sq2) (+)	3161	5000	2000	1000
	Growth Rate (POP) (+)	0.05	0.2	0.15	0.1
	Retail Growth Rate (+)	0.15	0.3	0.25	0.2
	Income (Revenue) (million $) (+)	2	15	10	7
2. Transportation & Infrastructure impacts	Traffic (Commuting time) (-)	25	23	21	19
	Sewer capacity (M-gallon) (+)	4.2	6	3	2
3. Environmental impacts	Water Quality Index (+)	50	48	53	55
	Air Quality Index (+)	0.68	0.65	0.75	0.81
⋮	⋮	⋮	⋮	⋮	⋮

- Suppose that there are 4 plan scenarios (proposals) for the economic development.

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(2) Standardization

		Plan Scenarios for Economic Development			
Categories	Criteria	ALT1	ALT2	ALT3	ALT4
1. Population & Economic impacts	• Density (+)	0.63	1.00	0.40	0.20
	• Growth (+)	0.25	1.00	0.75	0.50
	• Retail growth (+)	0.50	1.00	0.83	0.67
	• Income (Revenue) (+)	0.13	1.00	0.67	0.47
2. Transportation & Infrastructure impacts	• Traffic (+)	0.76	0.83	0.90	1.00
	• Sewer capacity (+)	0.70	1.00	0.50	0.33
3. Environmental impacts	• Water quality (+)	0.91	0.87	0.96	1.00
	• Air quality (+)	0.84	0.80	0.93	1.00
⋮	⋮	⋮	⋮	⋮	⋮

▶ The consequence data should be transformed to unify the unit and sign.

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(3) Setting weights

CRITERIA									
Density	Growth	Retail growth	Income (Revenue)	Traffic	Sewer capacity	Water quality	Air quality	...	Sum
0.06	0.10	0.12	0.20	0.16	0.12	0.14	0.10	...	1.00

▶ Assume that “Revenue” has the highest weight (0.20) and “Density” the lowest (0.06) according to the survey results.

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(4) Aggregation

			Plan Scenarios for Economic Development			
Categories	Criteria	W	ALT1	ALT2	ALT3	ALT4
1. Population & Economic impacts	• Density	0.06	0.038	0.060	0.024	0.012
	• Growth	0.10	0.025	0.100	0.075	0.050
	• Retail growth	0.12	0.060	0.120	0.100	0.080
	• Income (Revenue)	0.20	0.027	0.200	0.133	0.093
2. Transportation & Infrastructure impacts	• Traffic	0.16	0.122	0.132	0.145	0.160
	• Sewer capacity	0.12	0.084	0.120	0.060	0.040
3. Environmental impacts	• Water quality	0.14	0.127	0.122	0.135	0.140
	• Air quality	0.10	0.084	0.080	0.093	0.100
⋮	⋮	⋮	⋮	⋮	⋮	⋮
SUM ($V(A^i) = \sum w_j \cdot v_j(A^i)$)			0.566	**0.935**	0.765	0.675

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(5) Other aggregation methods

	Population & Economic Impacts				Transportation & Infrastructure Impacts		Environmental Impacts				
	Density	Growth	Retail Growth	Income	Traffic	Sewer Capacity	Water Quality	Air Quality	SUM	MAX	MIN
ALT1	0.038	0.025	0.060	0.027	0.122	0.084	0.127	0.084	0.566	0.127	0.025
ALT2	0.060	0.100	0.120	0.200	0.132	0.120	0.122	0.080	0.935	0.200	0.060
ALT3	0.024	0.075	0.100	0.133	0.145	0.060	0.135	0.093	0.765	0.145	0.024
ALT4	0.012	0.050	0.080	0.093	0.160	0.040	0.140	0.100	0.675	0.160	0.012

- Maxmin Criterion (conservative approach):
  ALT2 (0.060) > ALT1 (0.025) > ALT3 (0.024) > ALT4 (0.012)
- Maxmax Criterion:
  ALT2 (0.200) > ALT4 (0.160) > ALT3 (0.145) > ALT1 (0.127)

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- Hurwicz α Criterion:

  ALT2 (0.165) > ALT4 (0.123) > ALT3 (0.115) > ALT1 (0.102)

  Strategy = α(Min) + (1− α)(Max)

  If we assume that α=0.75,

  ALT1 = 0.75*(0.025)+0.25*(0.127)= 0.102

  ALT2 = 0.75*(0.060)+0.25*(0.200)= 0.165

  ALT3 = 0.75*(0.024)+0.25*(0.145)= 0.115

  ALT4 = 0.75*(0.012)+0.25*(0.160)= 0.123

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- Bayes Criterion:

  · If the decision maker supposes that each criteria has a same weight,

  $$V(A^i) = \frac{\sum v_j(A^i)}{N}$$

  ALT2 (0.938) > ALT3 (0.743) > ALT4 (0.646) > ALT1 (0.591)

  · If the decision maker consider the weights of all criteria,

  $$V(A^i) = \sum w_j \cdot v_j(A^i)$$

  ALT2 (0.935) > ALT3 (0.765) > ALT4 (0.675) > ALT1 (0.566)

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- Concordance Analysis

	1. Density	2. Growth	3. Retail growth	4. Income	5. Traffic	6. Sewer capacity	7. Water quality	8. Air quality
ALT 1	0.038	0.025	0.060	0.027	0.122	0.084	0.127	0.084
ALT 2	0.060	0.100	0.120	0.200	0.132	0.120	0.122	0.080
ALT 3	0.024	0.075	0.100	0.133	0.145	0.060	0.135	0.093
ALT 4	0.012	0.050	0.080	0.093	0.160	0.040	0.140	0.100

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- Concordance Analysis

$K_{ii'} = \{j \mid V_{ij} \geq V_{i'j}\}$ Concordance Set

$K_{12} = \{ 7, 8 \}$
$K_{13} = \{ 1, 6 \}$
$K_{14} = \{ 1, 6 \}$
$K_{21} = \{ 1, 2, 3, 4, 5, 6 \}$
$K_{23} = \{ 1, 2, 3, 4, 6 \}$
$K_{24} = \{ 1, 2, 3, 4, 6 \}$
$K_{31} = \{ 2, 3, 4, 5, 7, 8 \}$
$K_{32} = \{ 5, 7, 8 \}$
$K_{34} = \{ 1, 2, 3, 4, 6 \}$
$K_{41} = \{ 2, 3, 4, 5, 7, 8 \}$
$K_{42} = \{ 5, 7, 8 \}$
$K_{43} = \{ 5, 8 \}$

$C_{ii'} = \{\#$ of $K_{ii'}$ element$\}$ Concordance Index

$C_{12} = 2$
$C_{13} = 2$
$C_{14} = 2$
$C_{21} = 6$
$C_{23} = 5$
$C_{24} = 5$
$C_{31} = 6$
$C_{32} = 3$
$C_{34} = 5$
$C_{41} = 6$
$C_{42} = 3$
$C_{43} = 2$

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- Concordance Analysis

$ALT_i = \Sigma C_{ii'} - \Sigma C_{i'I}$

$ALT1 = (C_{12}+C_{13}+C_{14})-(C_{21}+C_{31}+C_{41})=6-(6+6+6)=-12$

$ALT2 = (C_{21}+C_{23}+C_{24})-(C_{12}+C_{32}+C_{42})=16-(2+3+3)=8$

$ALT3 = (C_{31}+C_{32}+C_{34})-(C_{13}+C_{23}+C_{43})=14-(2+5+2)=5$

$ALT4 = (C_{41}+C_{42}+C_{43})-(C_{14}+C_{24}+C_{34})=11-(2+5+5)=-1$

ALT2(8) > ALT3(5) > ALT4(-1) > ALT1(-12)

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SUMMARY

- Maxmin Criterion (conservative approach):
  ALT2 (0.060) > ALT1 (0.025) > ALT3 (0.024) > ALT4 (0.012)
- Maxmax Criterion:
  ALT2 (0.200) > ALT4 (0.160) > ALT3 (0.145) > ALT1 (0.127)
- Hurwicz α Criterion:
  ALT2 (0.165) > ALT4 (0.123) > ALT3 (0.115) > ALT1 (0.102)
- Bayes Criterion:
  ALT2 (0.938) > ALT3 (0.743) > ALT4 (0.646) > ALT1 (0.591)
  ALT2 (0.935) > ALT3 (0.765) > ALT4 (0.675) > ALT1 (0.566)
- Concordance Analysis:
  ALT2 (8) > ALT3 (5) > ALT4 (–1) > ALT1 (–12)

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Conclusions

A Multi Criteria Decision Analysis (MCDA) provides

- a structured and documented information on the problem
- a focus for discussion
- and a means for resolving conflicts

Finding a solution with MCDA implies a process of generating solutions with information on why certain solutions are better.

The information generated can provide a basis for negotiation between the different actors.

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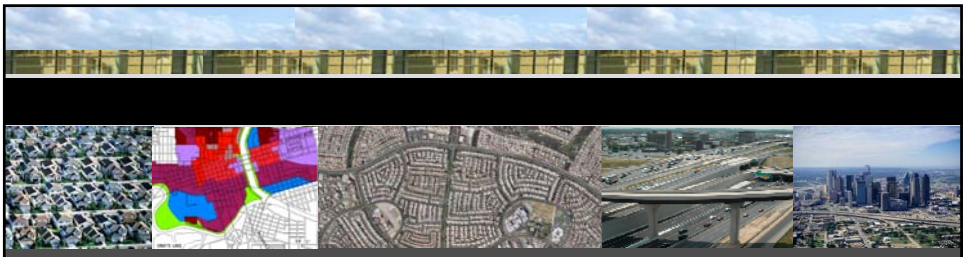

THANK YOU!

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