Centre for Traffic and Transport

Decision Modelling Group

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The COSIMA Approach to Transport Decision Making: Combining Cost-benefit and Multi-criteria Analysis for Comprehensive Project Appraisal

Presentation by:

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Overview of presentation

- Some basic principles about transport decision making and cost-benefit analysis
- Combining cost-benefit analysis (CBA) and multi-criteria analysis (MCA) in a composite model for assessment (COSIMA)
- Two demo-cases concerning road infrastructure project alternatives
- Decision conference as an element of COSIMA
- Conclusions and perspective

Transport Decision Making

- A transport project often has significant impacts on society for which reason appraisal methodology is of high importance

- Benefits can be both monetary and non-monetary – Could these be brought together in a comprehensive type of analysis?

- If yes, what should characterise such a type of appraisal?
  - Comprehensiveness: All important impacts must be included
  - Effectiveness: The results must be easy to interpret and make use of in order to make a decision
  - Transparency: The choices made by decision-makers must be understood by the public. However, consensus is not necessary

Cost-benefit analysis

- The cost-benefit analysis (CBA) has been used in most countries to assess transport infrastructure projects

- General decision criteria are:
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
  - Benefit/cost-rate (B/C-rate)

- In the comprehensive type of appraisal to be presented B/C-rate information is extended with MCA information to produce a total rate of return (TRR) weighing monetary socio-economic value and non-monetary attractiveness together

Principles for composite modeling assessment I

- In the following the Danish manual for socio-economic analysis from 2003 is applied as the guidelines for CBA

- The composite model for assessment (COSIMA):
  - Consists of a CBA-part and a MCA-part $TV(A_k) = CBA(A_k) + MCA(A_k)$, with $TV(A_k)$ indicating total value of alternative A_k
  - Assumes that MCA can be made truly additive to CBA

    (so issues of double-counting are avoided)
  - Sheds light on the situation where the investment in alternative A_k equal to the investment cost C_k is not feasible seen from CBA, i.e. gross value $CBA(A_k)<C_k$. In this situation the investment can be justified by the wider COSIMA examination if $TV(A_k)>C_k$ or, if expressed as a total rate of return, $TRR(A_k)>1$

Principles for composite modeling assessment II

- It is convenient to express the feasibility by the total rate of return TRR(A_k) from the investment cost C_k

$$TRR(A_k) = \frac{1}{C_k} \cdot \left(\sum_{i=1}^{I} V_{CBA}(X_{ik}) + \alpha \cdot \left[\sum_{j=1}^{J} w(j) \cdot V_{MCA}(X_{jk}) \right] \right)$$

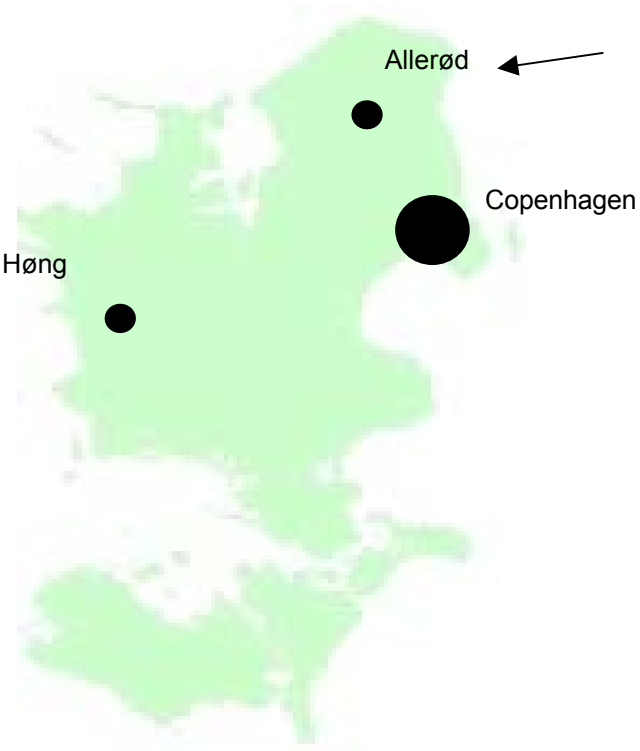
  - $V_{CBA}(X_{ik})$: Value in monetary units for the CBA effect i for alternative k for altogether I CBA effects
  - $V_{MCA}(X_{jk})$: Value function for MCA criterion j for alternative k for altogether J MCA criteria
  - α: Calibration factor that expresses the specific model set-up's trade-off between the CBA and the MCA part
  - w(j): A weight that expresses the importance of criterion j

- In order to calculate TRR, α and w(j) have to be determined

Presentation of cases

Two COSIMA cases concerning road infrastructure project alternatives

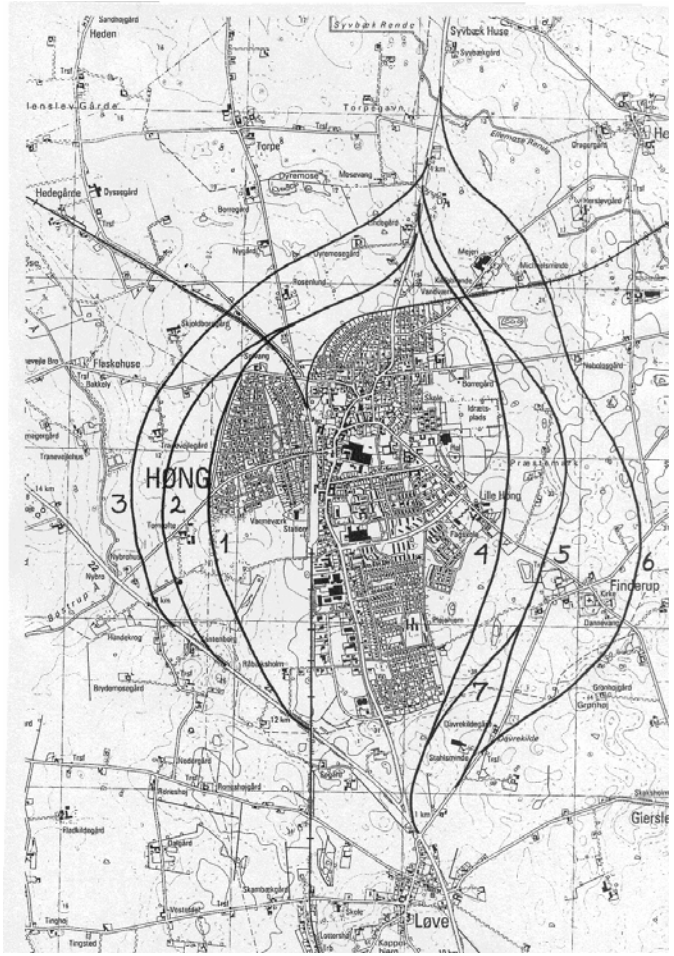
Case 1:
COSIMA with
a point scale



Case 2:
COSIMA with
AHP impacts

COSIMA with a point scale I

- Case example dealing with seven alternatives for a bypass road around the city of Høng
- Decision-makers assign point scores between -5 and 5 to the MCA impacts



COSIMA with a point scale II

- The point scores are translated into ratings between 0 and 100

Alternative	Cost in m Dkr.	FYB in k Dkr.	Network access.	Urban planning	Land-scape
Alternative 1	16.7	1310	71	50	0
Alternative 2	15.3	790	57	50	100
Alternative 3	16.9	350	29	83	67
Alternative 4	18.0	2900	100	0	67
Alternative 5	17.2	2460	86	67	83
Alternative 6	20.8	1790	0	100	33
Alternative 7	19.9	2330	86	50	83

Rank Order Distribution (ROD) weights

- Determination of w(j) – the importance of the criteria
  - Includes decision-maker interaction via criteria ranking
  - The SMARTER technique is applied based on value functions (VF) and ROD-weights

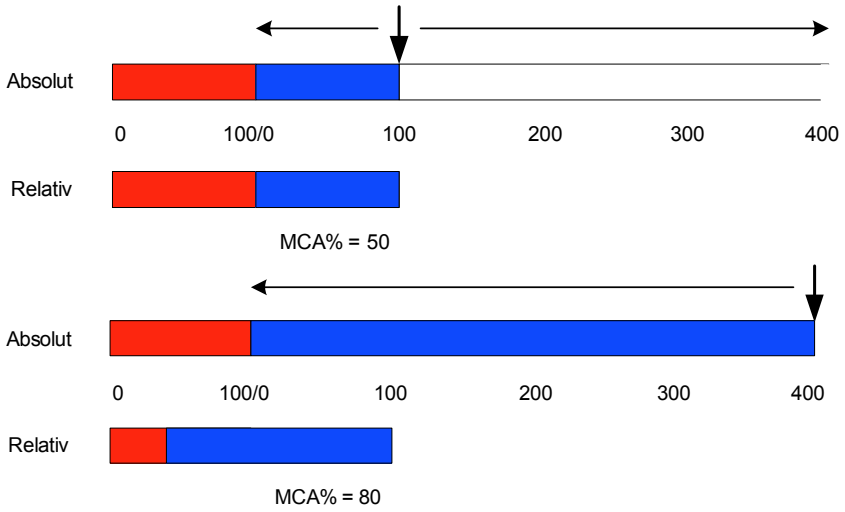
Criteria									
Priority	2	3	4	5	6	7	8	9	10
1	0.6932	0.5232	0.4180	0.3471	0.2966	0.2590	0.2292	0.2058	0.1867
2	0.3068	0.3240	0.2986	0.2686	0.2410	0.2174	0.1977	0.1808	0.1667
3		0.1528	0.1912	0.1955	0.1884	0.1781	0.1672	0.1565	0.1466
4			0.0922	0.1269	0.1387	0.1406	0.1375	0.1332	0.1271
5				0.0619	0.0908	0.1038	0.1084	0.1095	0.1081
6					0.0445	0.0679	0.0805	0.0867	0.0893
7						0.0334	0.0531	0.0644	0.0709
8							0.0263	0.0425	0.0527
9								0.0211	0.0349
10									0.0173

  - It is assumed that it is possible to apply individual linear functions and thereby obtain the actual score
  - The decision-makers only have to rank the J MCA criteria, which is assumed to be more simple than a direct weighting

CBA/MCA trade-off

The last step is to determine the trade-off between CBA and MCA (the α-value or MCA-percent)

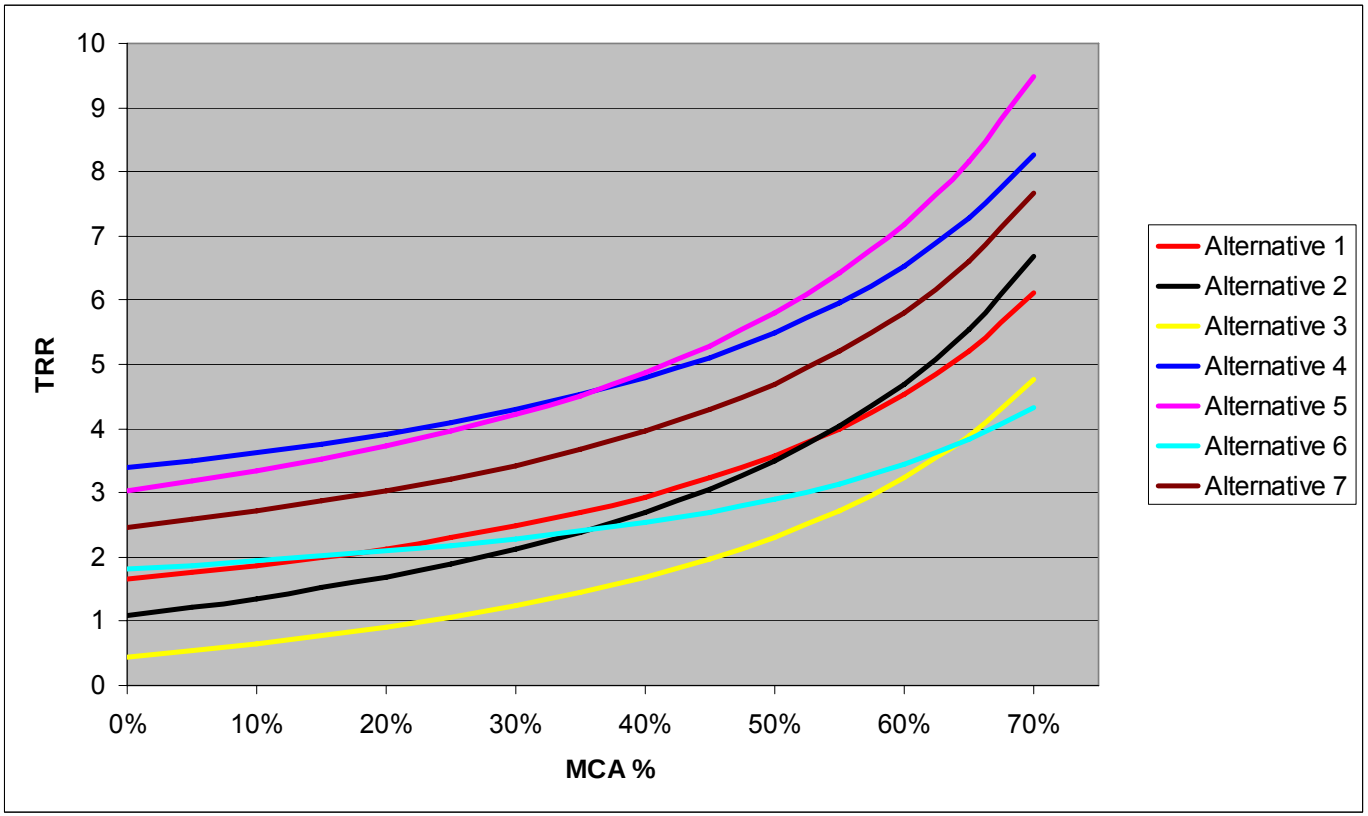
Example:



If the decision-maker(s) cannot agree upon a specific CBA/MCA trade-off, different values (MCA-percents) can be tested. Furthermore, it can be of great value for the decision-makers to know at which MCA-percents the ranking of the alternatives may change.

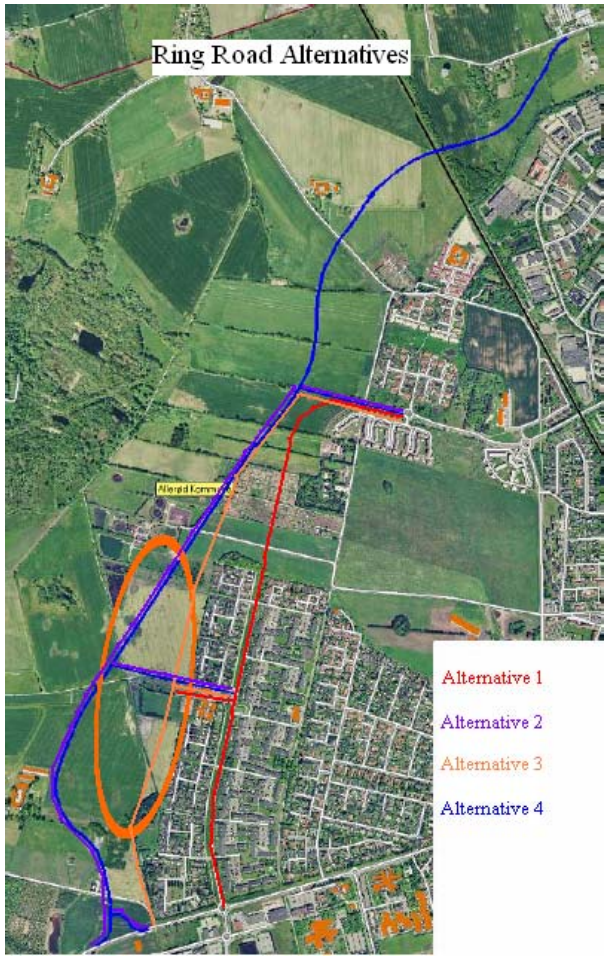
COSIMA with a point scale III

- The total rate of return (TRR) is calculated for a range of trade-offs (MCA percents) for the seven bypass alternatives



COSIMA with AHP impacts I

- The case example deals with a new ring road around the city of Allerød in conjunction with a new residential area



COSIMA with AHP impacts II

- The MCA assessment is carried out by use of the AHP (Analytical Hierarchy Process) method
- The alternatives are assessed by use of pair-wise comparisons and assigned a weight according to the AHP-scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit

Table 1 The fundamental scale for pair-wise comparisons (Saaty, 1996)

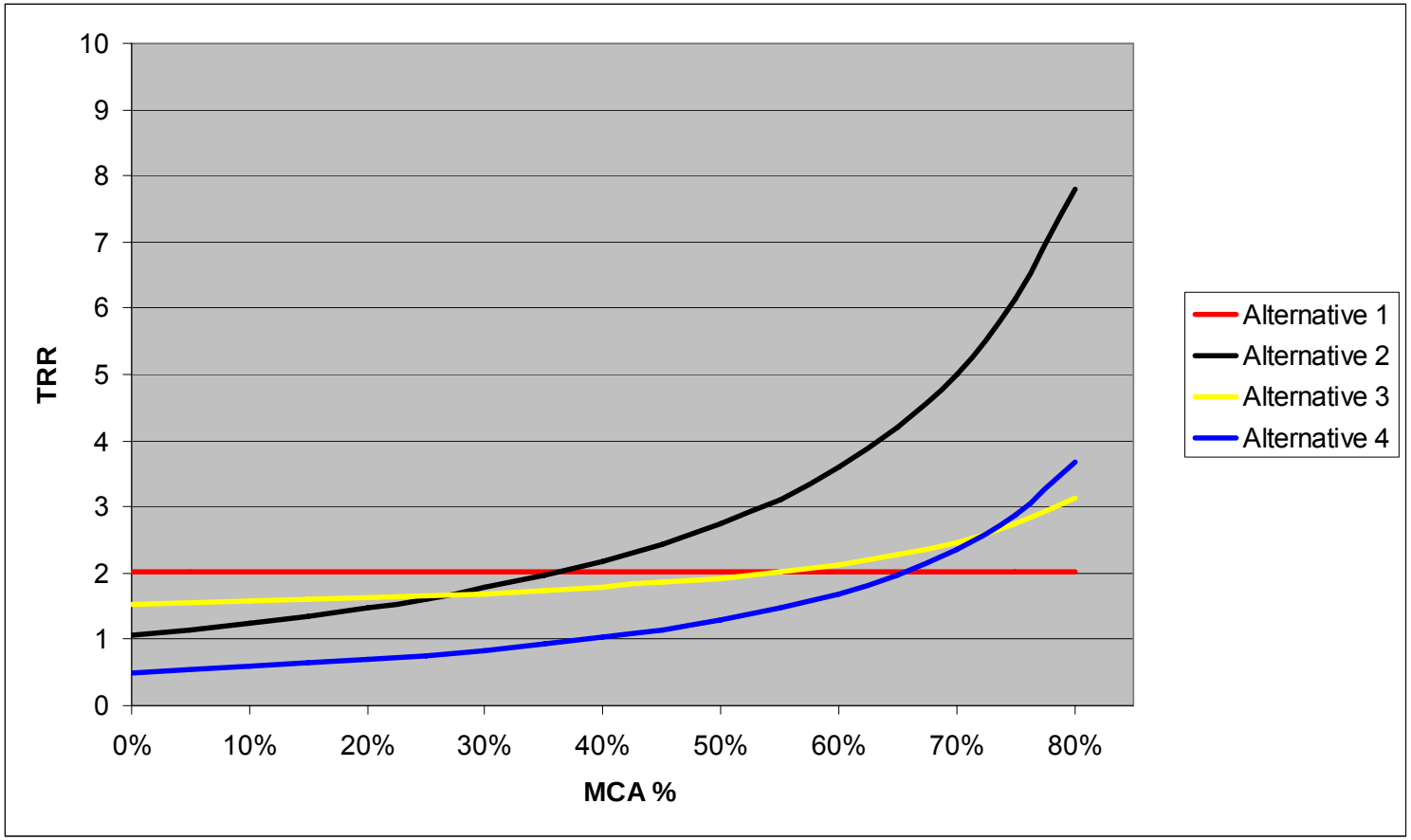
COSIMA with AHP impacts III

- The scores obtained by the AHP assessments are transformed into a linear value function applying a local scale between 0 and 100

Alternative	Cost in m Dkr.	Accessibility	Local land use	Regional network
Alternative 1	19.2	0	0	0
Alternative 2	54.9	46	100	23
Alternative 3	48.6	19	7	3
Alternative 4	194.9	100	100	100

COSIMA with AHP impacts IV

- Total rates of return (TRR) for the four ring road alternatives



Decision conference I

- A decision conference can be seen as a strategic tool that can be used for long-term complex decisions
- Highlights the concepts of:
  - Decision analysis, group processes and information technology
- A group of persons involved in the decision making are brought together under the control of a facilitator (F) who – assisted by a decision analyst (DA) – collects input for the decision model
- The group should be composed in such a way that all principal perspectives on the issue are covered
- The purpose is to create a synthesis of F and DA's techniques with the qualities and dynamics obtained by decision making in groups

Decision conference II

For the two case-examples a decision conference could be built upon the following five questions:

1. Do you agree with the result of the CBA?
2. What other criteria should by included in the assessment (MCA)?
3. Have the alternatives been scored in a satisfactory way?
4. How should the criteria be ranked/prioritised?
5. How should the MCA-part and the CBA-part influence the appraisal?

The questions can be formulated in different ways depending on the individual study scope. It is the responsibility of the facilitator to structure the decision conference so a search-learn-debate process can take place.

Summing up

- Main characteristics of the COSIMA approach:
  - Comprehensiveness: The COSIMA method can include all important impacts determined by the decision-makers
  - Effectiveness: The results of the COSIMA method are relatively easy to interpret and make use of
  - Transparency: The process and findings of COSIMA are transparent when the choices to be made by the decision-makers are well presented and motivated
- The paper provides further technical details

Conclusions and perspective

- COSIMA makes it possible to include all important impacts in one comprehensive analysis
- COSIMA does not change or hide CBA information; it only adds new information
- Using COSIMA, it is possible to customise the analysis to consider special study conditions
- Unlike a traditional multi-criteria analysis COSIMA also accounts for the economic feasibility of a project
- The concept of customised decision support systems (C-DSS) is currently developed by CTT-DTU based on appraisal studies of different European infrastructure projects