Aalto University
School of Science

MS-E2135
Decision Analysis
Lecture 10

- *Group techniques*
- *Voting*
- *MAVT for group decisions*

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Motivation

- Thus far we have assumed that:
  - The objectives, attributes/criteria, and decision alternatives are given
  - There is a single decision maker

- In this lecture, we consider
  - How a group of experts / DMs can generate objectives, attributes, and/or decision alternatives
  - How the views and preferences of the group members can be aggregated into a single decision recommendation

Idea generation and evaluation techniques

- Goals:
  - Generate topics / ideas / decision alternatives
  - Evaluate these topics / ideas / alternatives
  - Agree on a prioritization of the topics / ideas / alternatives

- Methods:
  - Brainstorming
  - Nominal group technique
  - Delphi method
  - ...and many variants of the above

Brainstorming

- **Goal:** to generate a large number of possible solutions for a problem

- **Participants:** Facilitator, recorder, and max 8-12 panel members
  - **Step 1** Prior notification: time for individual idea generation
  - **Step 2** Session for idea generation: all ideas are listed, spontaneous ideas are encouraged, no criticism is permitted
  - **Step 3** Review and evaluation: a list of ideas is sent to the panel members for further study

- **Principles:**
  - Focus on quantity
  - Withhold criticism
  - Welcome unusual ideas
  - Combine and improve ideas

Brainstorming

+ A large number of ideas can be generated in a short period of time
+ Simple – no expertise or knowledge required from the facilitator

- Blocking: During the process, participants may forget their ideas or not share them because they no longer find them relevant
- Collaborative fixation: Exchanging ideas in a group may decrease the novelty and variety of ideas

Nominal group technique

- **Goal:** To generate a large number of possible solutions to a problem and to decide on a solution

- **Participants:** Facilitator, recorder, and max 6-12 panel members
  - **Step 1:** Silent generation of ideas – group work not allowed
  - **Step 2:** Round-robin sharing of ideas. Facilitator lists all ideas on a flip chart, no comments at this point.
  - **Step 3:** Group discussion to facilitate common understanding of the presented ideas. No ideas are eliminated, judgment and criticism are avoided.
  - **Step 4:** Ranking of the ideas (by, e.g., voting)

Nominal group technique

+ A large number of ideas can be generated in a short period of time
+ Silent generation of ideas decreases blocking
+ Round-robin process ensures equal participation

- Not suitable for settings where consensus is required
- Can be time-consuming

Delphi technique

- **Goal:** To obtain quantitative estimates about the occurrence of future events (e.g., estimated probabilities, impacts, and time spans of negative trends for Finland)
- **Participants:** Facilitator and a panel of experts
- **Principles:**
  - Anonymous participation
  - Structured gathering of information through questionnaires: numerical estimates and arguments to support these estimates
  - Iterative process: participants comment on each other's estimates and are encouraged to revise their own estimates in light of such comments
  - Role of the facilitator: sends out the questionnaires, organizes the information, identifies common and conflicting viewpoints, works toward synthesis

Example: Decision analysis based real world conflict analysis tools

- Workshop organized by the Finnish Operations Research Society (FORS) Monday

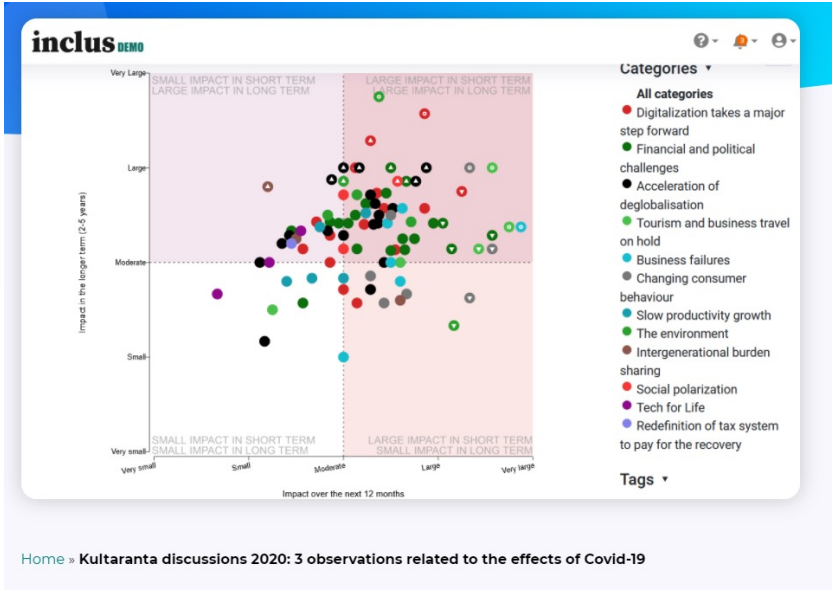
- Goal: to practice DA-based conflict analysis tools that Crisis Management Initiative (CMI) uses regularly in its operations:
  - Trend identification,
  - Data collection,
  - Visualization,
  - Root-cause analysis.

https://www.inclus.fi/

Identifying risks is one of the most challenging steps of risk management. Once you have collaboratively identified and assessed key risks, only then is it possible to effectively manage them and respond.

Inclus originated from complex and sensitive peace mediation processes conducted by Nobel Peace Prize laureate and President Martti Ahtisaari's Crisis Management Initiative (CMI).

Inclus specializes in building common understanding: our tools help to identify, understand, visualize and manage your risks across key organizational processes. Inclus' expertise stems from peace mediation, where we have constructed solutions in 15 of the world's most difficult conflict areas. The methodology behind Inclus has been developed in collaboration with Aalto University's Systems Analysis Laboratory.



Example cont'd

- Prior to the workshop, each participant was asked to
  - List 3-5 negative trends for Finland (title and brief description)
  - Provide time-spans for the impacts of these trends (<10 years, 10-20 years, >20 years)

Trend identification exercise: Negative trends for Finland

Negative trend is a, possibly escalating, course of events that would lead to harmful consequences. Please provide three to five negative trends that can have harmful impacts on the development of Finland. There are no limitations regarding the scope of the trend; it can be either broad or specific trend.

These trends can be related to
demographics,
economic situation,
welfare of citizens,
environment,
political situation
or other topics.

Give a short title for each trend and a longer explanation of why this trend can be harmful.

OBJECTIVES OF THE WORKSHOP. READING THIS MAY HELP YOU TO SUGGEST RELEVANT TRENDS:
The objective of this workshop is to evaluate and discuss these trends. This includes evaluation of (i) the probabilities that these trends cause significant harmful impacts, and (ii) the magnitudes of these impacts. The next step would be to use this information to design policy actions that can help to mitigate these trends and to adapt to them.

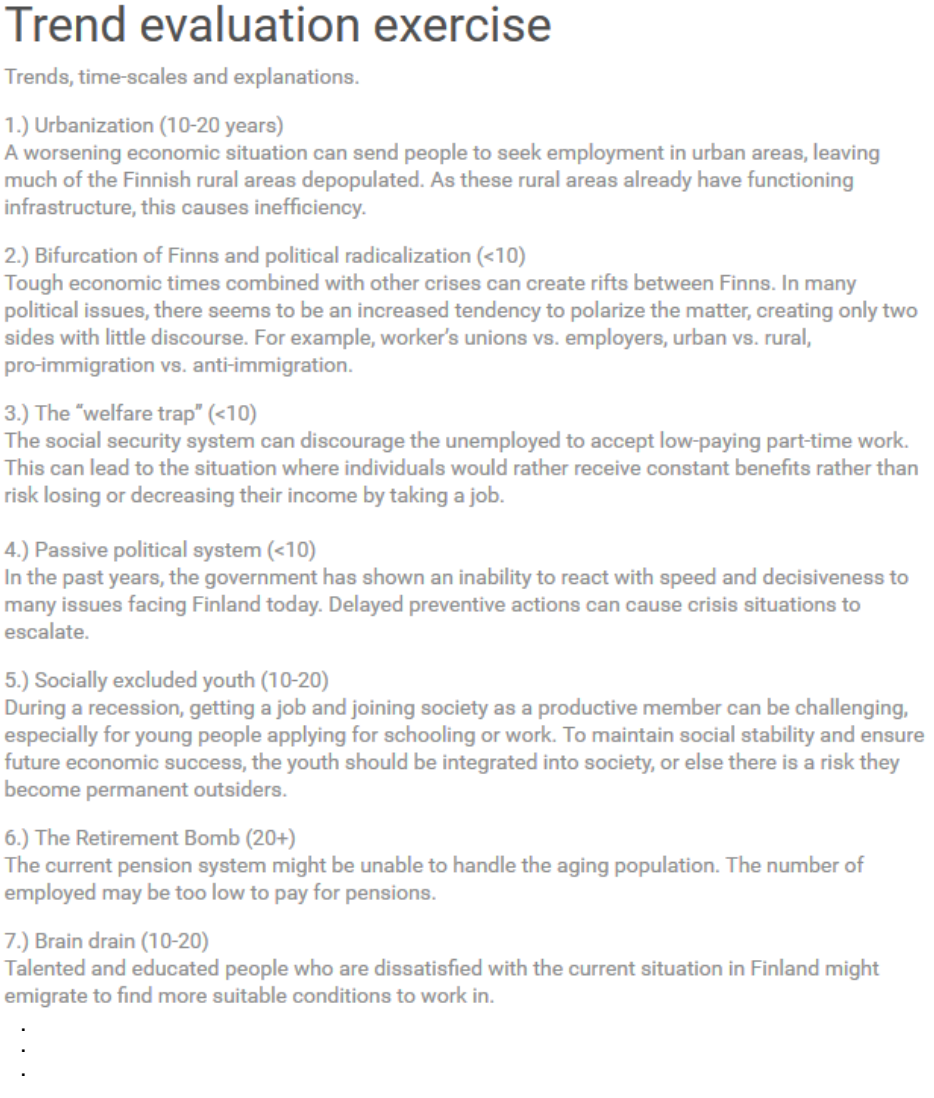
*Required

Trend 1 (title) *

Trend 1 (explanation) *

Example cont'd

- Trends listed by the participants were organized by the workshop facilitators
  - Similar trends combined
  - Marginal trends eliminated
- A final list of 21 trends was emailed to the participants prior to the workshop



Trend evaluation exercise

Trends, time-scales and explanations.

1.) Urbanization (10-20 years)
A worsening economic situation can send people to seek employment in urban areas, leaving much of the Finnish rural areas depopulated. As these rural areas already have functioning infrastructure, this causes inefficiency.

2.) Bifurcation of Finns and political radicalization (<10)
Tough economic times combined with other crises can create rifts between Finns. In many political issues, there seems to be an increased tendency to polarize the matter, creating only two sides with little discourse. For example, worker's unions vs. employers, urban vs. rural, pro-immigration vs. anti-immigration.

3.) The "welfare trap" (<10)
The social security system can discourage the unemployed to accept low-paying part-time work. This can lead to the situation where individuals would rather receive constant benefits rather than risk losing or decreasing their income by taking a job.

4.) Passive political system (<10)
In the past years, the government has shown an inability to react with speed and decisiveness to many issues facing Finland today. Delayed preventive actions can cause crisis situations to escalate.

5.) Socially excluded youth (10-20)
During a recession, getting a job and joining society as a productive member can be challenging, especially for young people applying for schooling or work. To maintain social stability and ensure future economic success, the youth should be integrated into society, or else there is a risk they become permanent outsiders.

6.) The Retirement Bomb (20+)
The current pension system might be unable to handle the aging population. The number of employed may be too low to pay for pensions.

7.) Brain drain (10-20)
Talented and educated people who are dissatisfied with the current situation in Finland might emigrate to find more suitable conditions to work in.

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Example cont'd

- At the workshop, each participant was asked to evaluate
  - The probability of each trend being realized (scale 0-5)
  - The impact that the trends would have upon realization (scale 0-5)

Prioritization

You are asked to evaluate each trend with respect to (1) the probability of the trend realizing in significant negative consequences and (2) the impact the trend would have upon realization.

In both dimensions we use a scale of 0 to 5. For the probabilities, 0 means close to impossible and 5 means next to certain. For the impacts, 0 means close to no significant negative impact and 5 means a very significant negative impact.

Probability of each trend realizing in significant negative consequences *

Tick your best guess for each. 0 means close to impossible and 5 means next to certain.

	0	1	2	3	4	5
1.) Urbanization	○	○	○	○	○	○
2.) Bifurcation of Finns and political radicalization	○	○	○	○	○	○
3.) The "welfare trap"	○	○	○	○	○	○

.
.
.

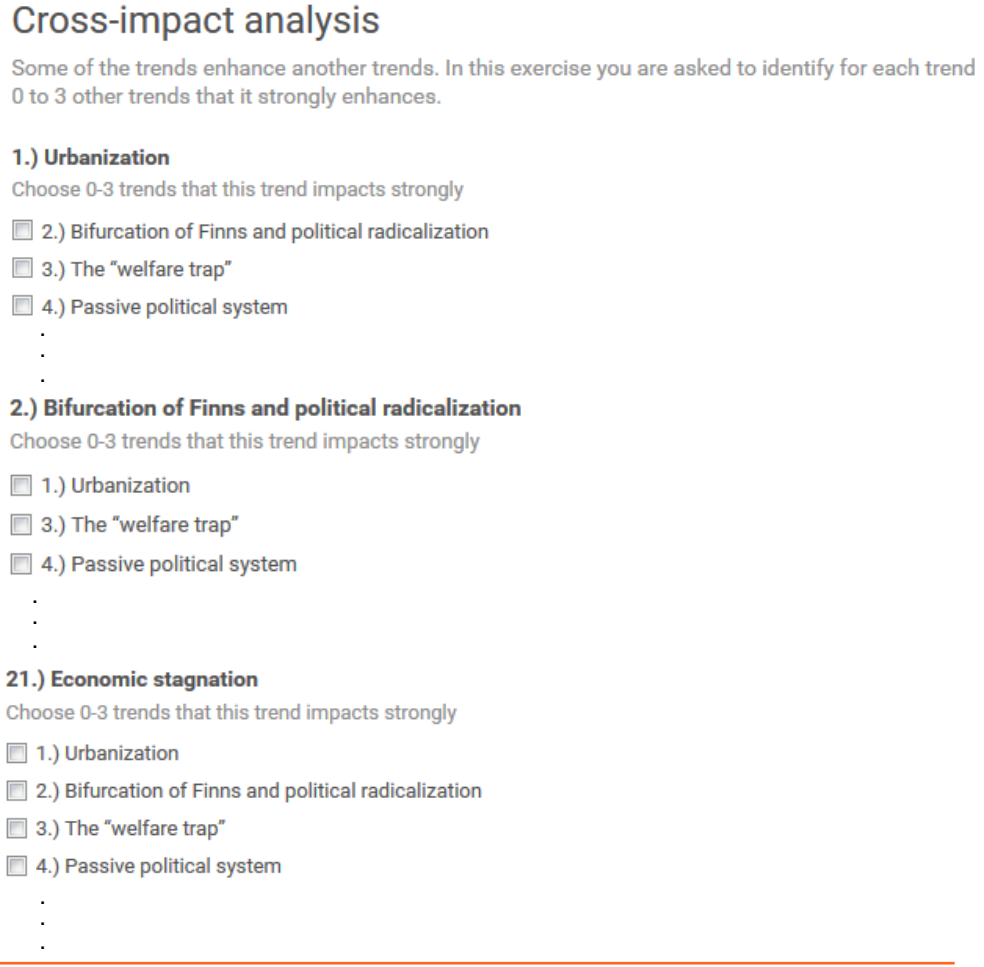
Impacts that the trends would have upon realization *

Tick your best guess for each. 0 means close to no significant negative impact and 5 means a very significant negative impact.

	0	1	2	3	4	5
1.) Urbanization	○	○	○	○	○	○
2.) Bifurcation of Finns and political radicalization	○	○	○	○	○	○
3.) The "welfare trap"	○	○	○	○	○	○
4.) Passive political system	○	○	○	○	○	○

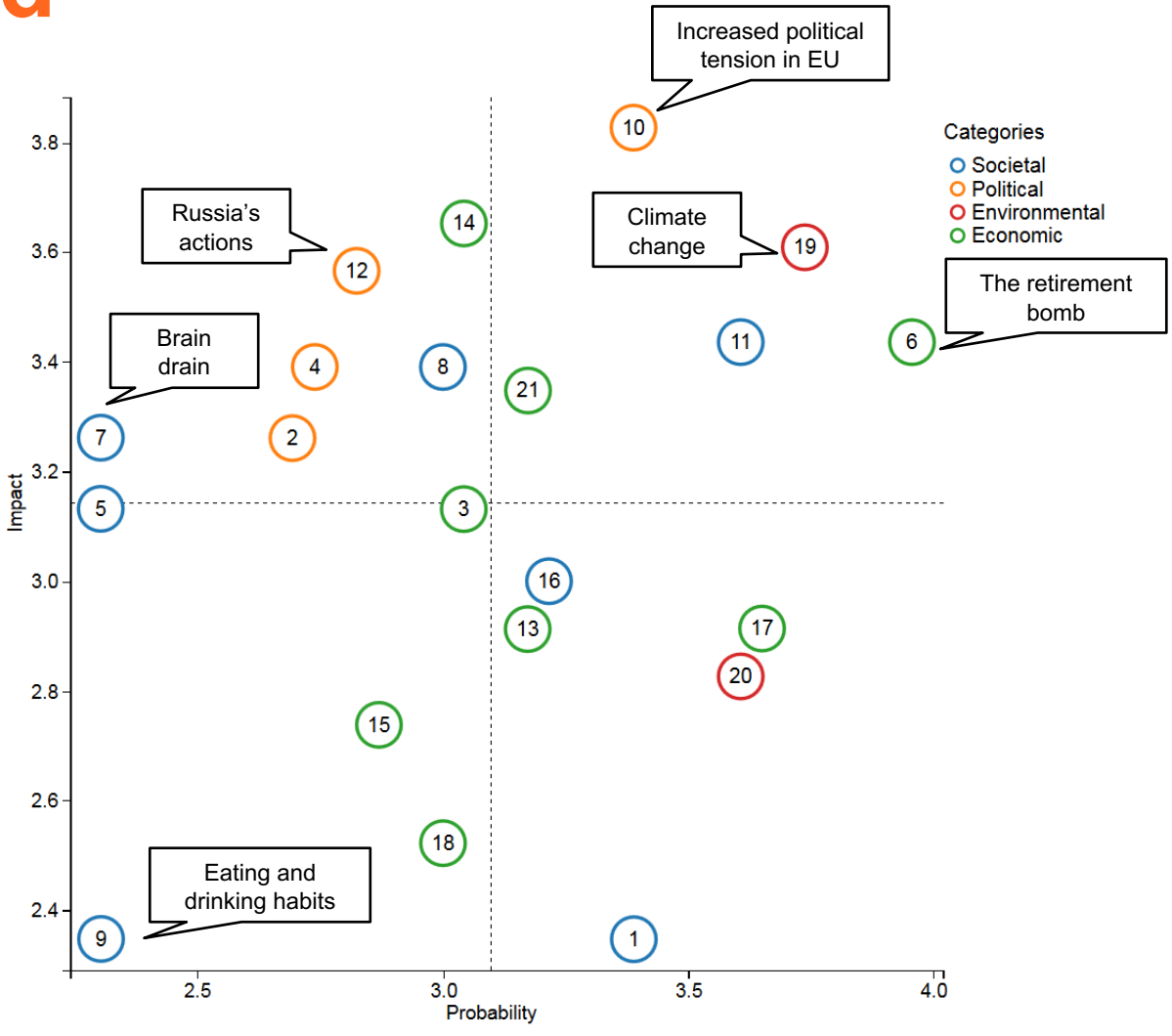
Example cont'd

- The participants were also asked to assess *cross-impacts* among trends
  - Which other trends does this trend enhance?



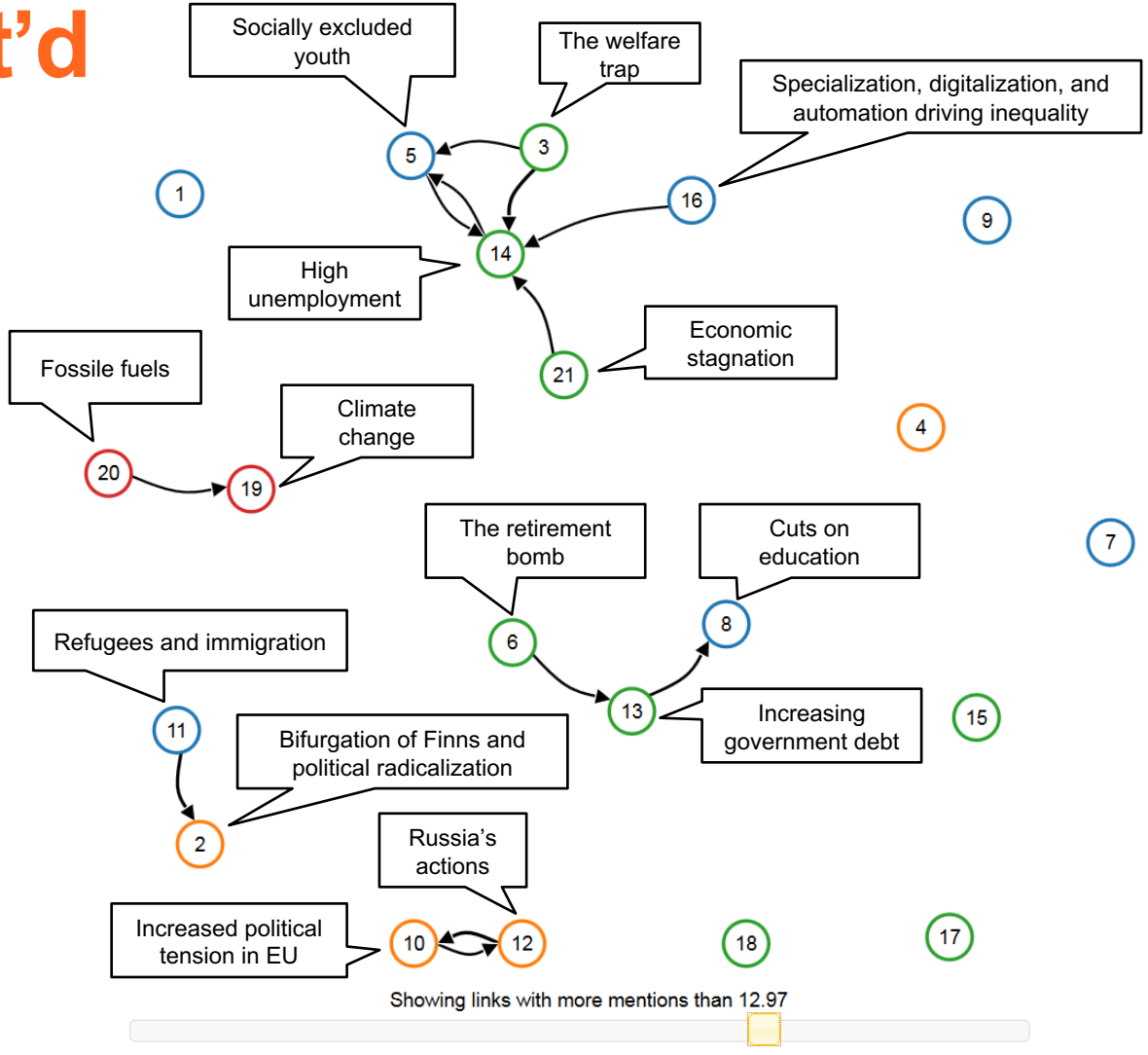
Example cont'd

- Visualizations on the probability and impact assessments were shown to the participants to facilitate discussion



Example cont'd

- Cross-impacts were visualized, too



Example cont'd

- Goal of such analysis:
  - To create a shared understanding of the problem
  - To identify possible points of disagreement

- Next steps:
  - Possible revision of estimates in light of the discussion
  - The determination of policy actions to help mitigate / adapt to the most important negative trends
  - Agreement on which policy actions to pursue
  - The implementation of these policy actions

Aggregation of preferences

- Consider N alternatives $x_1,\ldots, x_N$
- Consider K decision makers $DM_1,\ldots DM_K$ with different preferences about the alternatives
- How to aggregate the DMs' preferences into a group choice?
  - Voting
  - MAVT

Plurality voting

- Each voter casts one vote to his/her most preferred candidate
- The candidate with the most votes wins
- Plurality voting with runoff:
  - The winner must get over 50% of the votes
  - If this condition is not met, alternatives with the least votes are eliminated
  - Voting is continued until the condition is met
  - E.g., Finnish presidential election: in the second round only two candidates remain

Plurality voting

- Suppose, there are three alternatives A, B, C, and 9 voters
  - 4 think that A > B > C
  - 3 think that B > C > A
  - 2 think that C > B > A

Plurality voting

4 votes for A
3 votes for B
2 votes for C

⇒ A is the winner

Run-off

C eliminated

4 votes for A
3+2 = 5 votes for B

⇒ B is the winner

Condorcet

- All voters rank-order the alternatives
- Each pair of alternatives is compared - the one with more votes is the winner
- If an alternative wins all its one-to-one comparisons, it is the Condorcet winner
- There might not be a Condorcet winner – some other rule must be applied, e.g.,
  - Copeland's method: the winner is the alternative with the most wins in one-to-one comparisons
  - Eliminate the alternative(s) with the least votes and recompute

Condorcet - example

- 33 voters and alternatives A, B, C
  - 17 voters: A>B>C
  - 1 voter: A>C>B
  - 15 voters: B>C>A
  - 0 voters: C>B>A, C>A>B, B>A>C
- A is the Condorcet winner, because it wins both B and C in one-on-one comparisons
  - 17+1=18>15 out of 33 favor A over B
  - 17+1=18 favor A over C

Condorcet completion

- There might not be a Condorcet winner
  - Copeland's ***completion*** method: the winner is the alternative with the most wins in one-to-one comparisons

5 voters and 5 alternatives A, B, C, D, E

- 1 voter: A>B>C>D>E
- 1 voter: A>D>E>C>B
- 2 voters: D>E>B>C>A
- 1 voter: C>B>A>D>E

D wins more one-on-one comparisons than other alternatives

	A	B	C	D	E	wins
A		2	2	3	3	2
2+1=	3		3	2	2	2
C	3	2		2	2	1
D	2	3	3		5	3
E	2	3	3	0		2

Condorcet completion

- Another possibility for Condorcet completion: Eliminate the one with least wins and recompute results

- First C is eliminated
  - B,D,E “lose” one win

- B and E with one win are elimitated
  - A and D remain

- A wins D by 3 votes to 2

	A	B	C	D	E	wins
A		2	2	3	3	2
B	3		3	2	2	~~2~~ 1
~~C~~	~~3~~	~~2~~		~~2~~	~~2~~	~~1~~
D	2	3	3		5	~~3~~ 2
E	2	3	3	0		~~2~~ 1

Borda

- Each voter gives
  - n-1 points to the most preferred alternative,
  - n-2 points to the second most preferred,
  - …
  - 0 points to the least preferred alternative

- The alternative with the highest total number of points wins

4 state that A > B > C	A : 4·2 + 3·0 + 2·0 = 8 points
3 state that B > C > A	B : 4·1 + 3·2 + 2·1 = 12 points
2 state that C > B > A	C : 4·0 + 3·1 + 2·2 = 7 points

Approval voting

- Each voter casts one vote for each alternative he/she approves
- The alternative with the highest number of votes is the winner

	DM_1	DM_2	DM_3	DM_4	DM_5	DM_6	DM_7	DM_8	DM_9	total
A	X	-	-	X	-	X	-	X	-	4
B	**X**	**X**	**X**	**X**	**X**	**X**	**-**	**X**	**-**	(7)
C	-	-	-	-	-	-	X	-	X	2

the winner!

- "If you want to vote against some, cast your votes to all others"

Problems with voting: The Condorcet paradox (1/2)

- Consider the following rank-orderings of three alternatives

	DM1	DM2	DM3
A	1	3	2
B	2	1	3
C	3	2	1

- Paired comparisons:
  - A is preferred to B by 2 out of 3 voters
  - B is preferred to C by 2 out of 3 voters
  - C is preferred to A by 2 out of 3 voters

Problems with voting: The Condorcet paradox (2/2)

- Three voting orders:
  1. (A-B) → A wins, (A-C) → **C is the winner**
  2. (B-C) → B wins, (B-A) → **A is the winner**
  3. (A-C) → C wins, (C-B) → **B is the winner**

	DM1	DM2	DM3
A	1	3	2
B	2	1	3
C	3	2	1

The outcome depends on the order in which votes are cast!

- No matter what the outcome is, the majority of voters would prefer some other alternative:
  - If C wins, 2 out of 3 voters would change it to B
  - ...But B would be changed to A by 2 out of 3 voters
  - ...And then A would be changed to C by 2 out of 3 voters...

Problems with voting: tactical voting

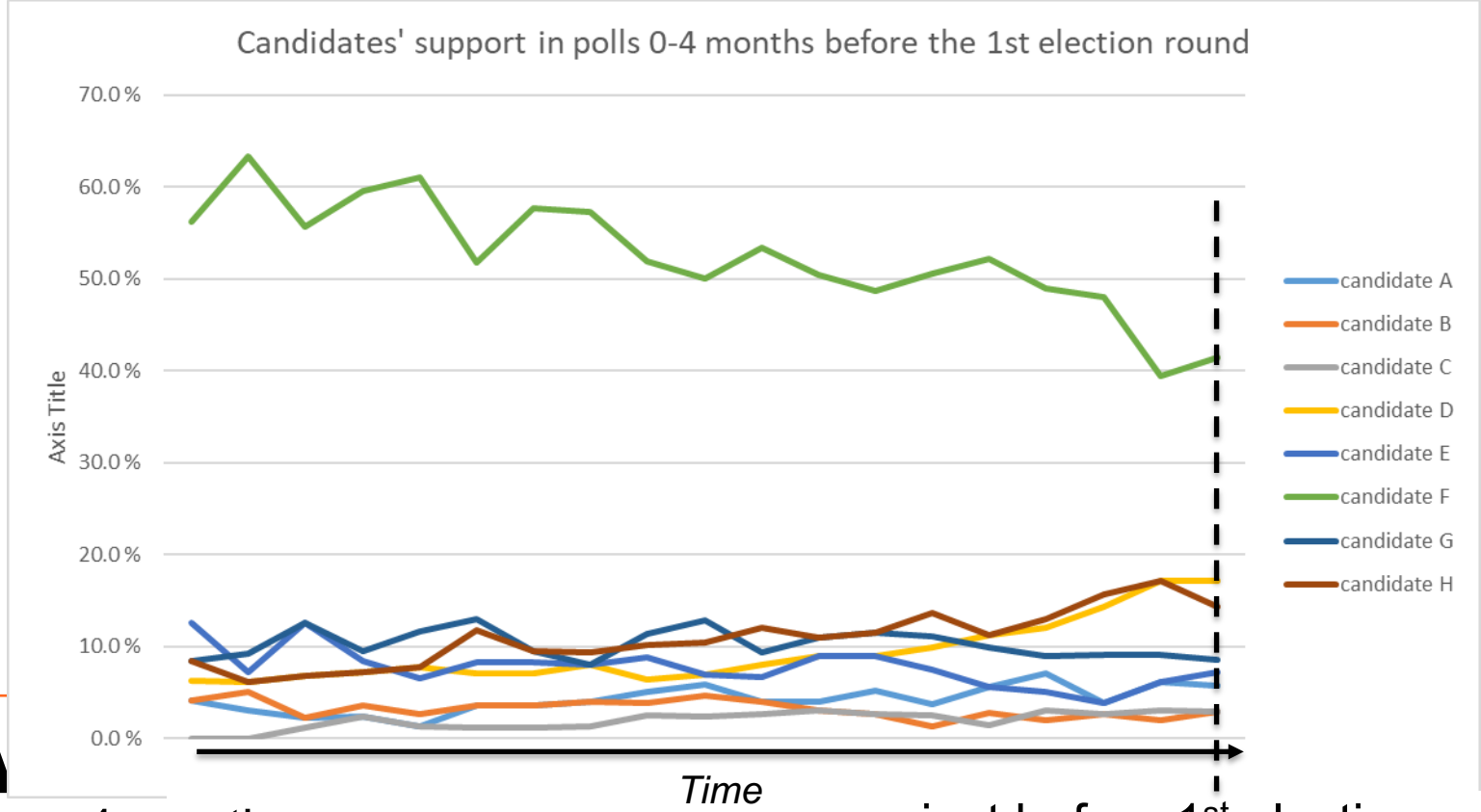
- DM_1 knows the preferences of the other voters and the voting order (A-B, winner-C)
- If DM_2 and DM_3 vote according to their true preferences, then the favourite of DM_1 (A) cannot win:
  - 1st round: *A* gets 2 votes
  - 2nd round: *A* loses to *C*
- Could DM_1 avoid the selection of C, her worst outcome?
  - 1st round: vote for *B; B* wins 2-1
  - 2nd round: vote for *B*; *B* wins 2-1

	DM1	DM2	DM3
A	1	3	2
B	2	1	3
C	3	2	1

Example: Finnish Presidential elections

- **Organized every 6 six years**
- **Plurality voting with runoff**
  - 2 most voted candidates to the 2nd round, unless some candidate receives over 50 % of votes already on the 1st round
- **7-11 candidates in 1994-2018**
  - Some candidates can have moderate support, but strong opposition
    - I.e., they are ranked 1st by some, but last or close to last by many other voters

Polls just before the 1st election round suggest that candidate F is the strongest, but a 2nd round will be needed. Tight battle for the 2nd position

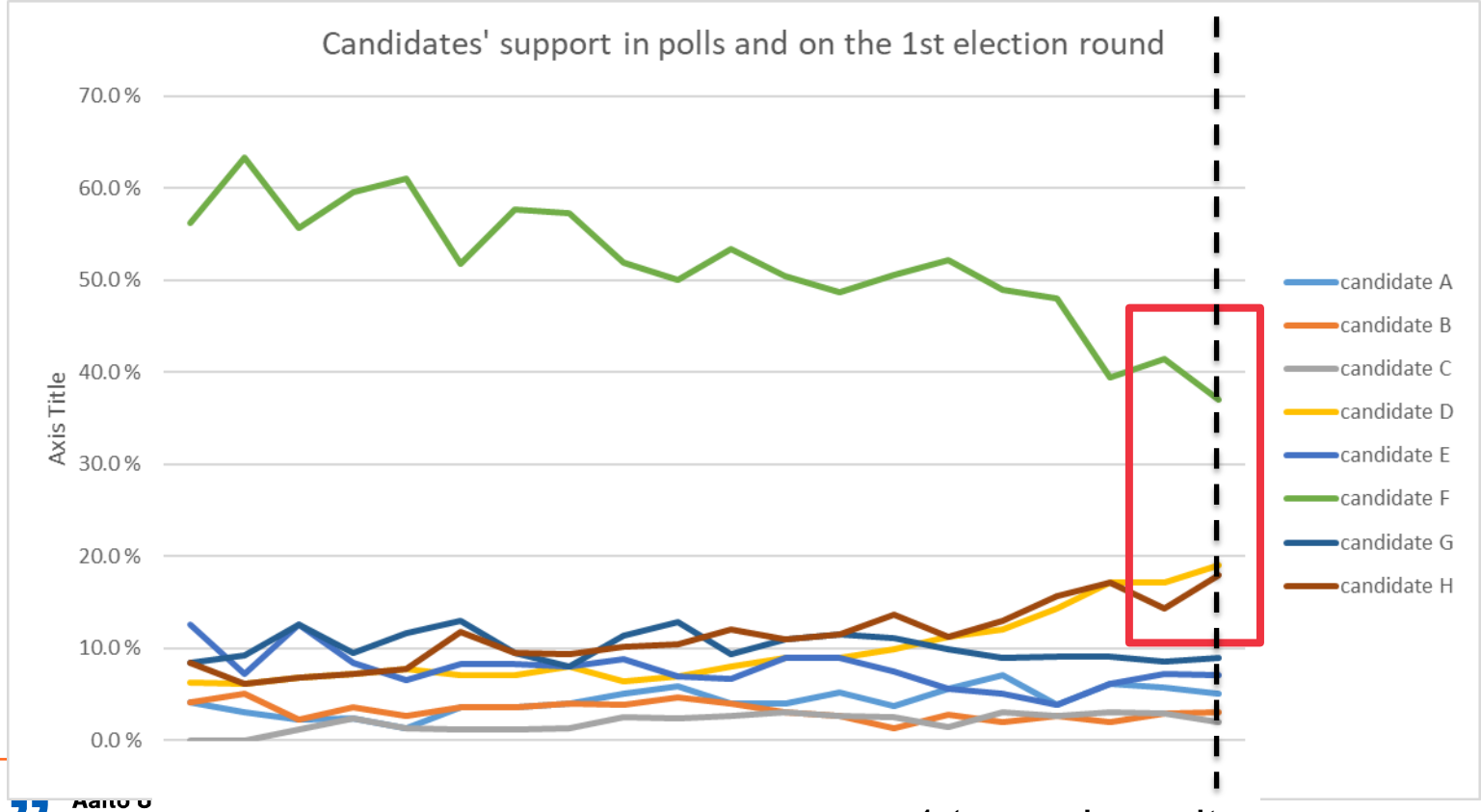


A

-4 months

just before 1st election round

Do voters actually vote tactically?



Social choice function

- Assume that the preferences of DM_i are represented by a complete and transitive *weak preference order* R_i:

$$DM_i \text{ thinks that x is at least as good as y} \Leftrightarrow x \, R_i \, y$$

- What is the *social choice function f* that determines the collective preference $R=f(R_1,\ldots,R_K)$ of a group of K decision-makers?
  - Voting procedures are examples of social choice functions

Requirements on the social choice function

1. **Universality:** For any set of R_i, the social choice function yields a unique and complete preference ordering R for the group

2. **Independence of irrelevant alternatives:** The group's preference between two alternatives (x and y) does not change if we remove an alternative from the analysis or add an alternative to the analysis.

3. **Pareto principle**: If all group members prefer x to y, the group prefers x to y

4. **Non-dictatorship:** There is no DM_i such that $x \, R_i \, y \Rightarrow x \, R \, y$

The big problem with voting: Arrow's theorem

There is no complete and transitive social choice function *f* such that conditions 1-4 are always satisfied.

Arrow's theorem – an example

- Borda criterion:

	DM_1	DM_2	DM_3	DM_4	DM_5	Total
x_1	3	3	1	2	1	10
x_2	2	2	3	1	3	**11**
x_3	1	1	2	0	0	4
x_4	0	0	0	3	2	5

Alternative x_2 is the winner!

- Suppose that the DMs' preferences do not change. A ballot between alternatives 1 and 2 gives

	DM_1	DM_2	DM_3	DM_4	DM_5	Total
x_1	1	1	0	1	0	**3**
x_2	0	0	1	0	1	2

Alternative x_1 is the winner!

- **The independence of irrelevant alternatives does not hold!**

Aggregation of values

Theorem (Harsanyi 1955, Keeney 1975):
Let $v_k(\cdot)$ be a cardinal value function describing the preferences of DM_k. There then exists a *K*-dimensional differentiable (ordinal) function $V^G()$ with positive partial derivatives describing group preferences $\succ_g$ in the definition space such that

$$a \succ_g b \Leftrightarrow V^G[v_1(a),\ldots,v_K(a)] \geq V^G[v_1(b),\ldots,v_K(b)]$$

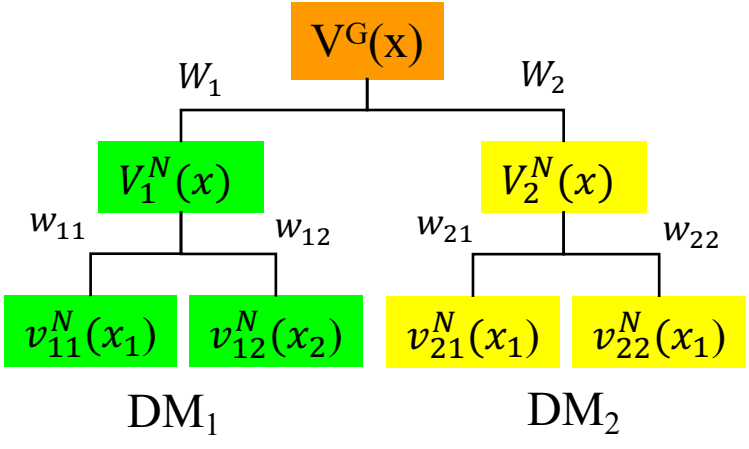
and conditions 1-4 are satisfied.

Note: Voting procedures use only ordinal information (i.e., rank ordering) about the DMs' preferences – the strength of preference should be considered, too

MAVT in group decision support

- From MAVT, we already know how to combine cardinal value functions into an overall value function:

$$V^G(x)=\sum_{k=1}^{K} W_k V_k^N(x)\,, W_k \geq 0, \sum_{k=1}^{K} W_k = 1.$$

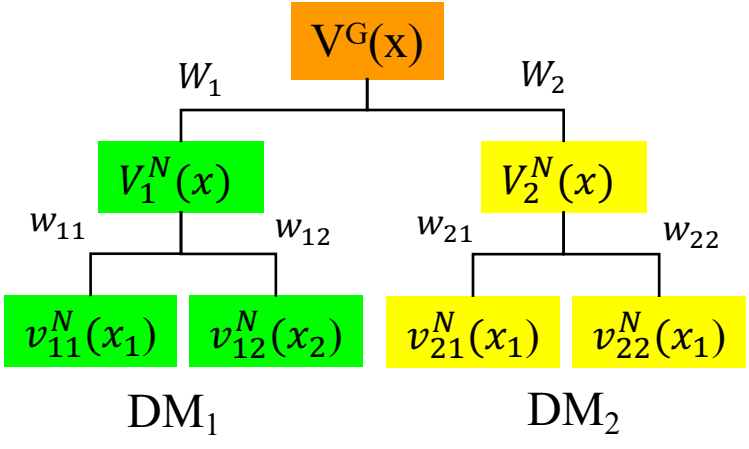


- This can be done for multiattribute cardinal value functions as well:

$$V^G(x)=\sum_{k=1}^{K} W_k \sum_{i=1}^{n} w_{ki} v_{ki}^N(x_i)$$

MAVT in group decision support

- Weights W_1, W_2 measure the value difference between the worst and best achievement levels x^0, x^* for DM_1 and DM_2, respectively
- How to compare these value differences – i.e., how to make trade-offs **between people**?
  - *"Compared to my preference for apples over oranges, how strong is yours?"*
- Group weights $W_1 = W_2 = 0.5$ would mean that the value differences are equally valuable, but…
- Who gets to define x^0 and x^*?



MAVT for group decision support

- Example: for both DMs, v_i's are linear, DM_1 has preferences (1,0)~(0,2) and DM_2 (2,0)~(0,1)
- Let $x^0=(0,0)$, $x^*=(2,4)$ for both DMs, and $W_1=W_2=0.5$
  - Then $v_{k1}^N=0.5x_1$, $v_{k2}^N=0.25x_2$ for both $k=1,2$

DM_1
- $(1,0)\sim(0,2) \Rightarrow V_1^N(1,0)=V_1^N(0,2) \Rightarrow 0.5w_{11}=0.5w_{12} \Rightarrow w_{11}=w_{12}=0.5$
- $V_1^N(1,0)=0.25$, $V_1^N(0,1)=0.125$

DM_2
- $(2,0)\sim(0,1) \Rightarrow V_2^N(2,0)=V_2^N(0,1) \Rightarrow w_{21}=0.25w_{22} \Rightarrow w_{21}=0.2$, $w_{22}=0.8$
- $V_2^N(1,0)=0.1$, $V_2^N(0,1)=0.2$

- **$V^G(1,0)=0.5*0.25+0.5*0.1=0.175 > V^G(0,1)=0.1625$**

MAVT for group decision support

- Interpretation of the result
  - For DM_1 (1,0)←(0,1) is an improvement. The "group" values this more than the value of change (0,1)←(1,0) for DM_2

- Let x^0=(0,0), x*=(4,2) for both DMs, and W_1=W_2 =0.5
  - V^G(1,0)=0.1625 < V^G(0,1)=0.175

- Interpretation of the result
  - (0,1)←(1,0) - which is an improvement for DM_2 - is now more valuable for the group than change (1,0)←(0,1)

Summary

- Techniques for involving a group of experts or DMs can be helpful for
  - Problem identification and definition,
  - Generating objectives, attributes, and alternatives,
  - Defining common terminology

- Individual preferences can be easily aggregated into a group preference through voting procedures, but…
  - Arrow's impossibility theorem states that no "good" voting procedure exists

- MAVT provides a sound method for aggregating preferences, but…
  - The determination of group weights = interpersonal comparisons can be difficult

  → It may be pertinent to develop a joint model with incomplete preference information