GROUP DECISION MAKING IN AGRICULTURE

Mathematical programming model + Group Decision Support System Approach

WP8: Agri-food supply chain decision-making under uncertainty

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How to support group decision making in horticulture: An approach based on the combination of a centralized mathematical model and a Group Decision Support System

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Introduction

- Planning of crops planting and harvest:
  - Balance between supply and demand
  - Objective → maximize profits
  - Volatility of prices → depend on supply-demand balance

- How can farmers decide which crops to cultivate each season to maximize their profits?
  - One solution:
    - Centrally plan the planting and harvest for all farmers
    - Maximize the profits of the region.
    - Problem: inequalities in profits obtained by farmers → unwillingness to cooperate

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Introduction

- Multi-objective mathematical programming model (MPM):
  - ε-constraint method → several Pareto optimal solutions
  - Need to chose one solution to be implemented
- Group Decision Support System:
  - MPM solutions as input data
  - Farmers of the region decide collaboratively between options
  - One selected solution to be implemented.
- Combination of two approaches to generate a satisfactory solution for a group

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2. Related work

- Group Decision Support Systems for agriculture or horticulture
  - Existing DSS for agriculture (Perini and Susi, 2004):
    - Single user (one decision maker)
    - No possibility to make group decisions
    - Focused on pest management

  - More than one decision-maker is involved in Agriculture decisions:
    - Farmers
    - Producers
    - Transporters
    - Sellers
    - ...

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2. Related work

- Collaborative planning for agriculture or horticulture
  - Research on coordination issues in agricultural supply chains is in its early development.
  - Research addressing coordination among actors in the same stage is even more scarce.
  - Collaboration mechanisms among the members of vegetable supply chains for:
    - Achieving sustainability
    - Increase revenues and customer satisfaction
    - Reduce the negative impact of uncertainty.

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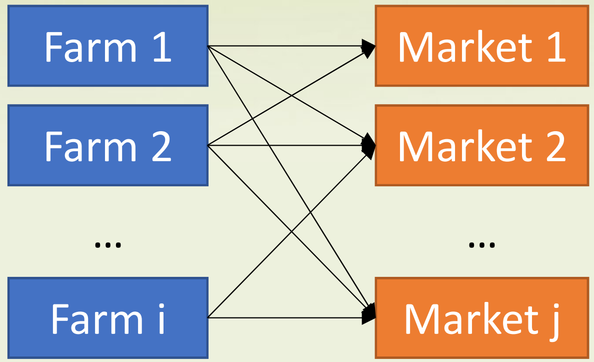
3. MPM for the tomato planning problem

- Centralized MPM
- Coordination among farmers.
  - **Planting** decisions: How many tomato plants of each type to plant per period and farmer?
  - **Harvesting** decisions: How many tomato of each type to harvest per period and farmer?
  - **Transport** decisions: How many tomato of each type to transport from each farmer to each market per period?



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3. MPM for the tomato planning problem

- Three objectives → three dimensions of sustainability:
  - **Economic:** maximize profits of the supply chain
    - Profits = sales incomes – production costs – distribution costs
  - **Environmental:** minimize the tomato wastes
    - Wastes before harvest = matured – harvested tomatoes
    - Wastes after harvest = harvested – transported tomatoes
    - Wastes at market = transported – sales tomatoes
  - **Social:** minimize the unfulfilled demand
    - Unfulfilled demand = demand – sales

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3. MPM for the tomato planning problem

- The model is subject to the following constraints:
  - **Planting constraints**:
    - The acreage for each type of tomato should not exceed the available planting area in each farm.
    - To ensure the flow of products:
      - All tomato types are planted in all planting periods.
      - All farmers plant tomatoes at all planting periods.
  - **Harvest constraints**:
    - The maximum quantity to be harvested at each period is fixed by the yield per unit area harvested.
  - **Transport constraints**:
    - The quantity of tomatoes to be transported can not exceed the quantity of harvested tomatoes at the same period.
  - **Market constraints**:
    - The quantity of tomatoes to be sold can not exceed the supply nor the demand.

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4. GRoUp Support (GRUS) Decision

- GRUS system → web application
  - Developed on the GRAILS framework (open source planform)
  - Can be used by users:
    - At the same or different location
    - At the same or different time
    - One or several meeting simultaneously
  - Requirements:
    - Internet connection
    - Invitation to the meeting

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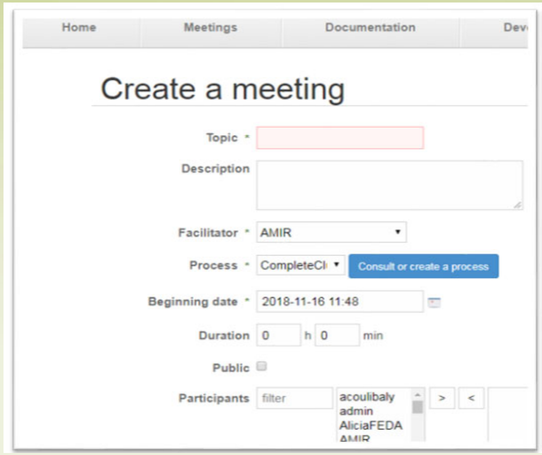
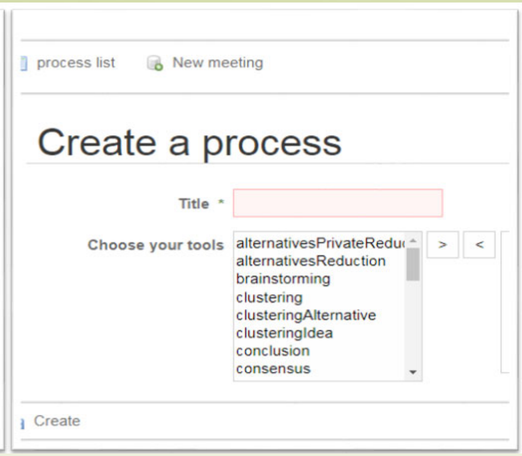
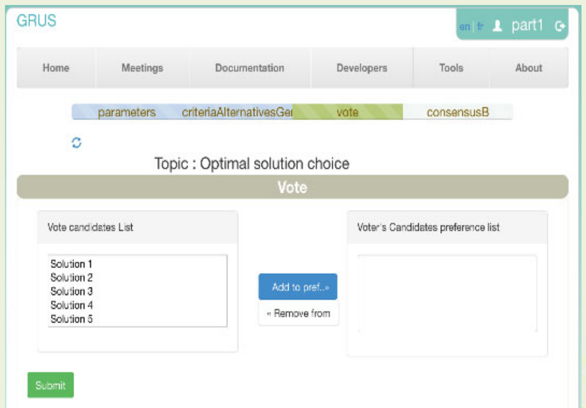
4. GRoUp Support (GRUS) Decision

- Two steps:
  - Meeting creation → definition of the process used to jointly make decisions





  - Meeting achievement → decision-makers follow the process to make decisions.



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5. Experiment: Case study

- Tomato planting and harvest in La Plata (Argentina):
  - One year horizon with monthly periods.
  - Five farmers with areas between 15 and 20 ha.
  - Three type of tomatoes to be planted: round, pear and cherry tomato.
  - Three planting seasons: July, October and January
  - Harvest dependent on planting:

	07	08	09	10	11	12	01	02	03	04	05	06
July					X	X	X	X				
October							X	X	X	X		
January									X	X	X	X

  - Yield per plant depends on planting, harvest and type of tomato
  - Limited workforce → planting and harvest activities

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5. Experiment: Case study

- Tomato planting and harvest in La Plata (Argentina):
  - Two types of customers: Central market and Restaurants
  - Transport costs depend on origin and destination
  - Known demand
  - Variation of price in function of the balance between supply and demand.
    - Price ↑ when supply is lower than demand
    - Price ↓ when supply is higher than demand
  - Penalizations for:
    - Wastes
    - Unmet demand

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5. Experiment: Results of MPM

- The ε-constraint method is used to solve the multi-objective model
  - One objective is fixed as the single objective of the model.
  - The rest of objectives are transformed into constraints.

- Several non-dominated solutions are obtained
  - Decision-makers are provided with the following information per solution:
    - Profits per farmer and for the entire SC.
    - Wastes
    - Unmet demand
    - Acreage per tomato type

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5. Experiment: GRUS for solution selection

- Context:
  - Ten alternatives (non-dominated solutions)
  - Five decision-makers with same importance (represent five farmers)
  - Three step process:
    - Alternative generation → made by facilitator
    - Vote → made by decision-makers
    - Final ranking → made by GRUS system

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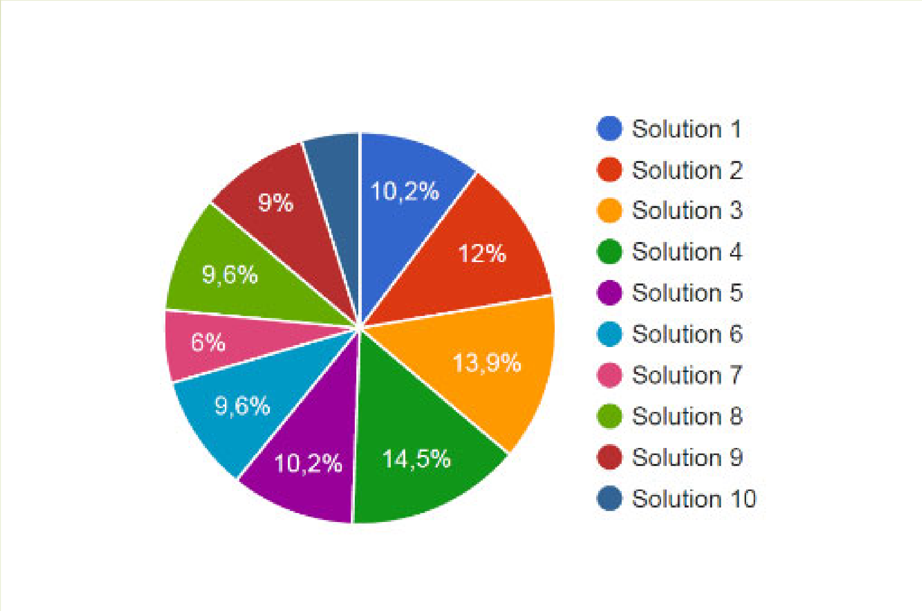
5. Experiment: GRUS for solution selection

- Results:
  - Solution 4: 24 points
  - Solution 3: 23 points
  - Solution 2: 20 points
  - Solutions 1 and 5: 17 points
  - Solutions 6 and 8: 16 points
  - Solution 9: 15 points
  - Solution 7: 10 points
  - Solution 10: 8 points



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5. Experiment: GRUS for solution selection

- Best solution for the group: Solution 4
  - Five farmers have benefits
  - The three types of tomatoes are planted.
  - It is not the solution that generates the best profits for the entire SC.

- Best solution in terms of SC profits: Solution 1
  - The solution with higher profits is not necessarily the best one for the group of decision makers.

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6. Conclusions

- Combination of two approaches (MPM and GDSS) for agriculture
  - MPM to generate ten optimal solutions
  - GDSS to select the solution in a group of five farmers
- The use of GDSS reduces conflicts between farmers → consensus
- Limitations
  - Group of researches have acted like the real farmers

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7. Future work

- GRUS + Multi-objective centralized model (weighted sum method)
  - Use GRUS for the objectives definition and weights assigned to objectives.
  - Use MO model to obtain an optimal solution for the objectives and weights defined.
- Multi-objective centralized model (ε-constraint method) + GRUS
  - Use MO model to obtain several optimal solutions.
  - Use GRUS with real farmers to decide which solution to implement.
- Comparation of both approaches

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References

- Pascale Zaraté, MME Alemany, Mariana del Pino, Ana Esteso, Guy Camilleri (2019). "How to Support Group Decision Making in Horticulture: An Approach based on the Combination of a Centralized Mathematical Model and a Group Decision Support System". Decision Support Systems IX: Main Developments and Future Trends, 83-94

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