Aalto University
School of Science

2 applications of portfolio decision analysis

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Presentation *8*
15.10.2021

MS-E2191 Graduate Seminar on Operations Research
Fall 2021

Content

1. Application 1: Improving European air traffic management

2. Application 2: Investment in natural capital and ecosystem services

Application 1: Improving European air traffic management

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Application 1: Overview

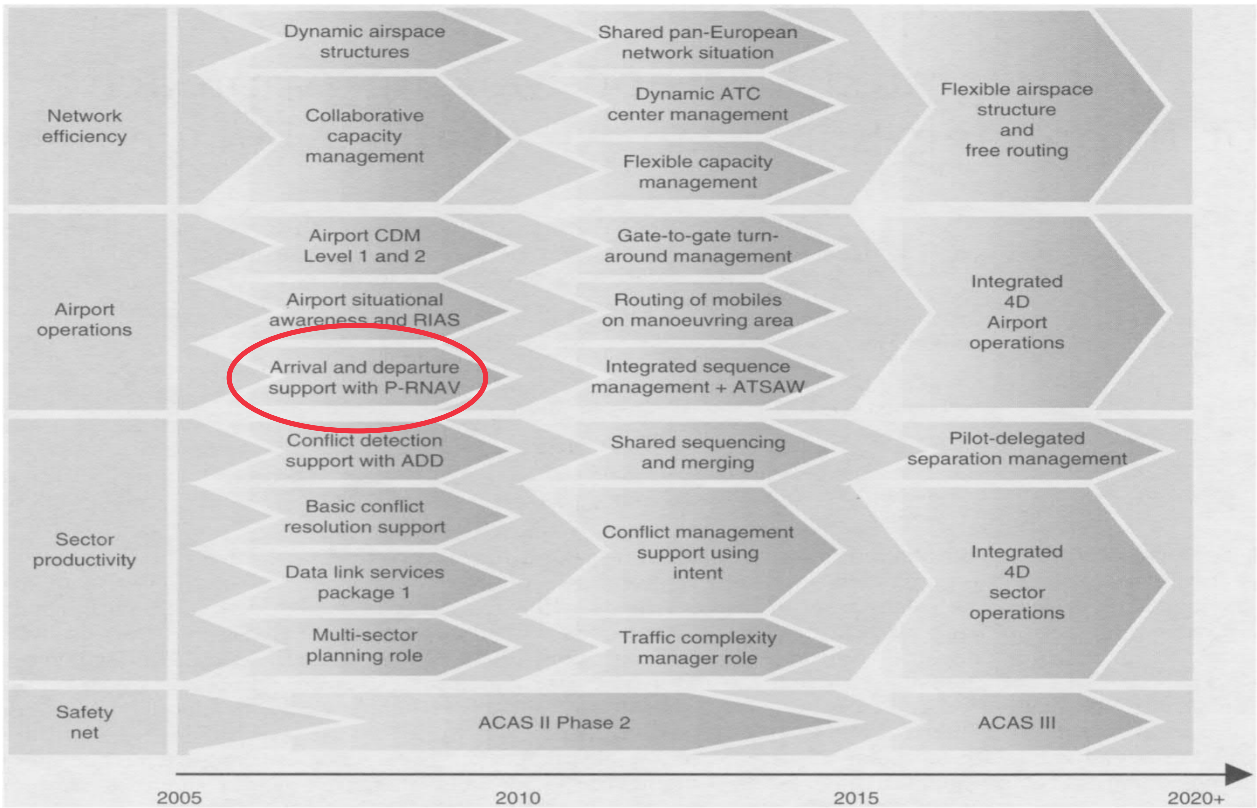
- **Problem: Airport and air traffic network capacity limits air transportation**
  - ATM system is outdated and not unified

- **Objective: Improve air traffic management (ATM)**
  - Capacity, safety, environmental effects, ATM costs etc.

- **Decision-makers**
  - E.g., Airlines, airports, air navigation service providers (ANSP)

→ **Multistakeholder, multicriteria decision-making problem**

Application 1: Operational improvement portfolios



Source: Grushka-Cockayne et al. (2008)

Application 1: Arrival and departure support with precision area navigation

- **Consists of five projects**

Components	Implementation modes				
P-RNAV	**A0** Stay with current	**A1** Implement during departure and arrival			
AMAN and DMAN	**B0** Stay with current	**B1** AMAN	**B2** DMAN	**B3** B1 and B2	**B4** B3 and sequencing tool
WV	**C0** Stay with current	**C1** Reduced WV minima	**C2** Improved onboard WV visualization	**C3** C1 & C2	**C4** Alternative procedures
TBS	**D0** Stay with current	**D1** Fixed-minimum TBS	**D2** Varying TBS		
B-CDA	**E0** Stay with current	**E1** Implement			

Source: Grushka-Cockayne et al. (2008)

Application 1: Selection of projects

- **Implementing project results in trade-offs in the objectives**
- **The projects are not independent**
- **Several ways to implement project**
- **Differences in the stakeholder priorities**
- **Qualitative assessment**
- **Performance targets**

Application 1: Formulation of the optimization problem

- **Objectives measured by 14 indicators**
  - Qualitative and quantitative
- **Indicators chosen so that they are preferentially independent**
  - Due to stakeholder disagreements each indicator has weight for each stakeholder

    -> Allows the use of overall performance score and the ranking of projects for each stakeholder separately
  - Optimal project combinations differ
  - Eurocontrol wants joint commitment by all stakeholders

    -> Overall objective is to maximize performance score over all stakeholders

Application 1: Formulation of the optimization problem

$$\max \sum_{m(1)=1}^{|I(1)|} \cdots \sum_{m(|O|)=1}^{|I(|0|)|} \sum_{k=1}^{|S|} \lambda^k \sum_{j=1}^{|P|} w_j^k \cdot v_j^k(h_j^k(e_{1,m(1),j}^k, \ldots, e_{|O|,m(|O|),j}^k)) \prod_{q=1}^{|O|} x_{q,m(q)}$$

- **Subject to**
    - Performance targets are achieved
    - The budget can not be exceeded for any stakeholder
    - Single implementation mode for each project
- **The model is nonlinear**

Application 1: Dependencies between projects

- **The joint effect of projects can either be**
  - Independent
    - The total performance is additive
  - Antagonistic
    - The joint effect is lower
  - Synergistic
    - The joint effect is higher

- **Heuristics was developed to estimate the joint effects**
  - No need to assess performance impact of each possible combination of implementation modes separately

Application 1: Dependencies between projects

- **Individual effect of projects**
  - DMAN (departure manager assist) = 25%, WV (wake vortex) = 15%

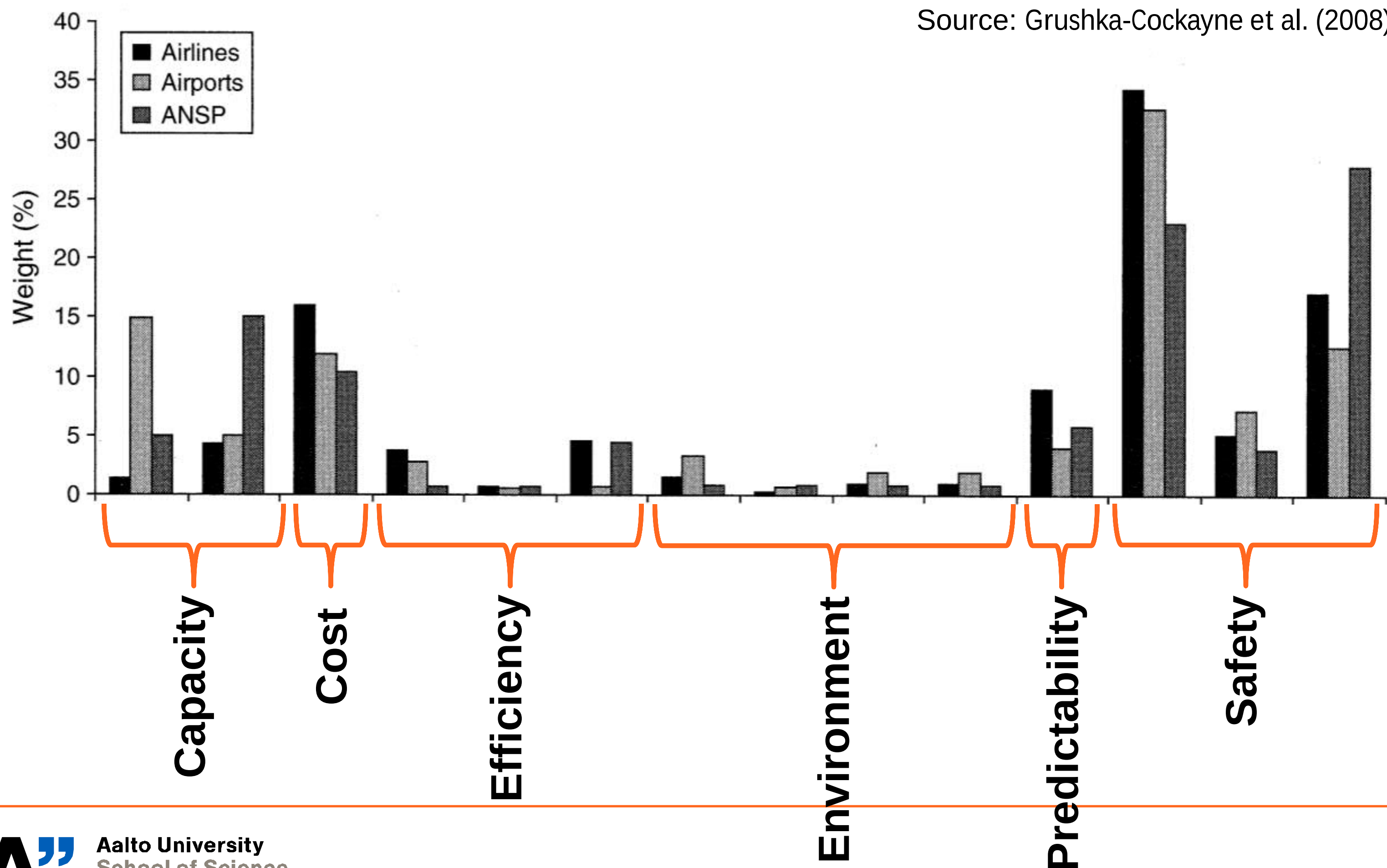
- **Joint effect: Antagonistic**
  - Let us consider increasing the capacity
  - $0.25+(1-0.25)^2 * 0.15 = 33\%$

- **Joint effect: Synergistic**
  - Let us consider enchantments on on-time arrivals
  - $(1.25 * 1.15) - 1 = 44\%$

Application 1: Linear model

- **Bundles of implementation modes are considered**
  - E.g. (AO, BO, CO, DO, EO) or (A1, B1, CO, DO, EO)
- **The objective:** $\max \sum_{i=1}^{|N|} \sum_{k=1}^{|S|} \lambda^k \sum_{j=1}^{|P|} w_j^k v_j^k (te_{i,j}^k) z_i$
- **For our problem there are only 300 different bundles**
  - Possible to compute value of the objective for each bundle
- **The number decision variables grows exponentially**

Application 1: Results, Indicator weights



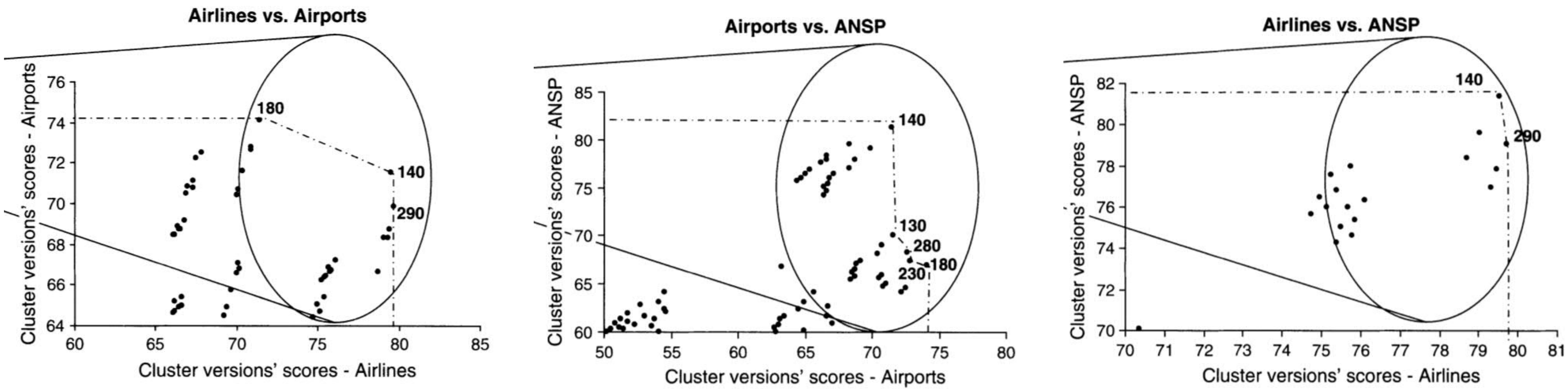
Application 1: Results, Cluster version

	Airlines		Airports		ANSP	
Rank	Cluster version	Components	Cluster version	Components	Cluster version	Components
1	290	A1 B4 C3 D2 E1	180	A1 B4 C2 D0 E1	140	A1 B4 C3 D2 E0
2	140	A1 B4 C3 D2 E0	230	A1 B4 C2 D1 E1	90	A1 B4 C3 D1 E0
3	240	A1 B4 C3 D1 E1	280	A1 B4 C2 D2 E1	290	A1 B4 C3 D2 E1

Source: Grushka-Cockayne et al. (2008)

- **Project implementations A1 and B4 are in the top-ranking clusters for all stakeholders**

Application 1: Results, Pairwise comparisons



Source: Grushka-Cockayne et al. (2008)

- **The nondominated clusters are on the dashed lines**

Application 1: Sensitivity analysis

- **Within stakeholders**
  - Weights assigned by stakeholders randomly generated
  - Expected performance impact considered as a range
    - Cluster 140 is the only top-ranking among all stakeholders
- **Across stakeholders**
  - Weights assigned to stakeholders
    - Robust portfolio modeling
    - A1 is recommended even if more information becomes available

Application 1: Implementation

- **The focus of Eurocontrol is on cluster 140 and 290**
- **Even though there is no single best cluster the does not mean that the analysis was worthless**
- **Analysis provided new information about the joint implementation of projects**

Application 2: Investment in natural capital and ecosystem services

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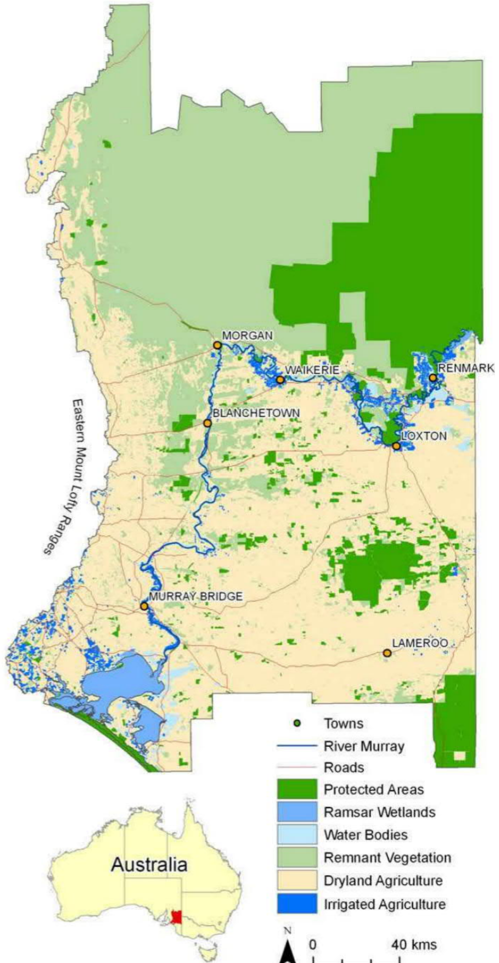
Application 2: Overview

- **Problem:**
  - Allocating budget to conservation, management and restoration projects that offer the highest return

- **Challenge:**
  - Uncertainty in the model parameters



Source: Bryan (2010)

Application 2: Preference information

- **32 capital assets and ecosystem services (objectives)**
- **46 targets (projects)**

- **Impacts were scored on scale a scale from -10 to 10**

Target ID	(NC1) Water	(NC2) Land	(NC3) Biota	(NC4) Atmosphere	(BC1) Built Environs	(BC2) Zoning & Planning
A1.1	0	0	0	7	5	1
A1.2	1	3	3	3	2	0
A1.3	0	0	0	3	3	0
A1.4	1	4	6	8	0	1
A2.1	3	4	1	1	2	1
B1.1	3	3	8	1	0	1
B1.2	2	5	10	5	1	0
B1.3	1	3	10	1	0	0
B1.4	2	3	5	3	2	2
B2.1	10	7	10	1	1	1
B2.2	7	5	8	1	0	0
B2.3	4	2	9	1	0	0
B2.4	0	3	8	0	0	0
B3.1	0	0	10	0	0	2
B3.2	2	4	10	1	0	1

Source: Bryan (2010)

Application 2: Uncertainty

- **Uncertainty in many key parameters**
  - Costs
  - Benefits
  - Background level of target
  - Available budget

- **Incomplete information is presented with three values**
  - Most likely (ml), minimum and maximum value

Application 2: Robust portfolio selection

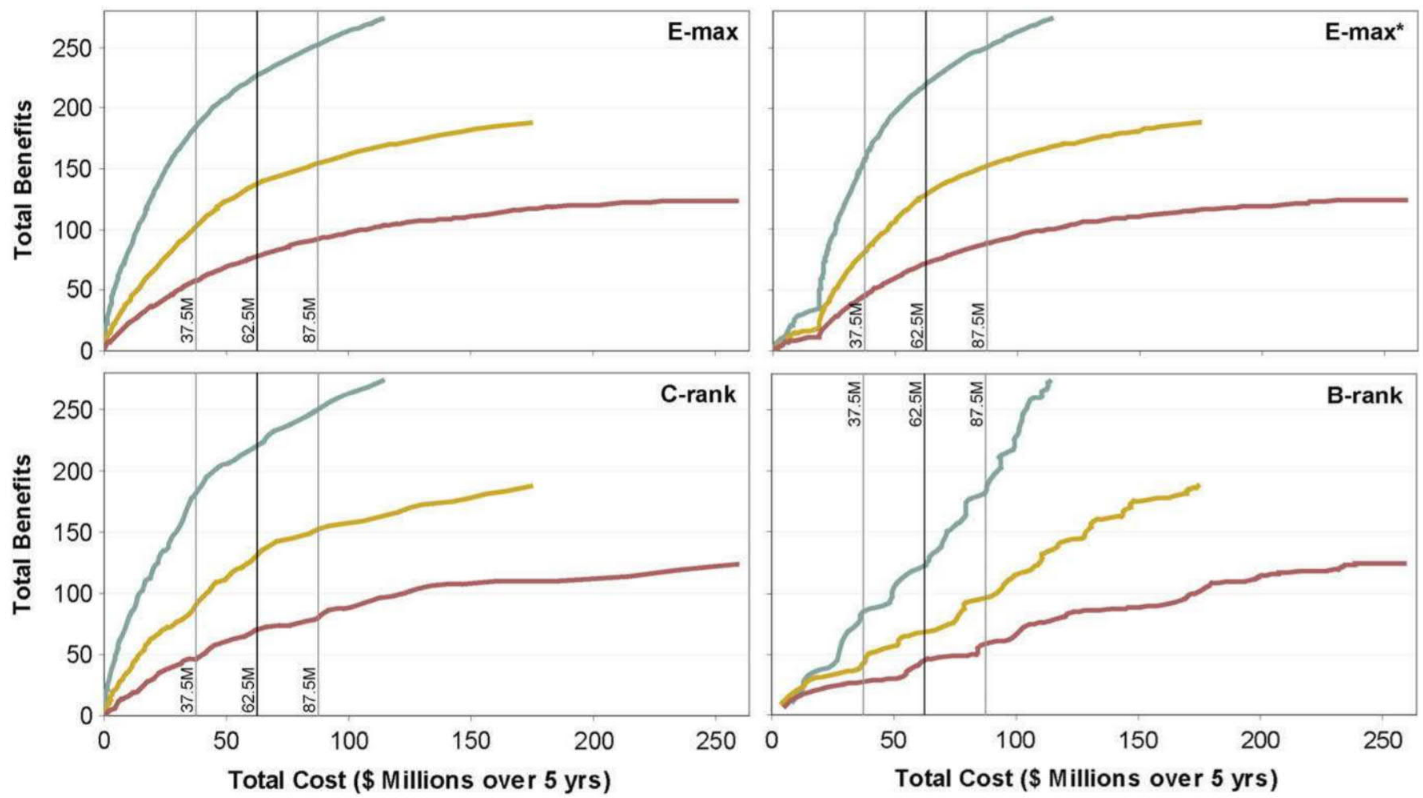
- **Robustness is achieved by solving the model with different parameters**
  - Three different decision rules
    - Optimistic (c_k^{min}, b_k^{max} and T_k^{min}) , most likely, pessimistic
  - Three different budgets
  - Four different investment strategies

- **Robustness quantified by a core index**
  - Core targets are fully invested with every combination of parameters and budgets

Application 2: Investment strategies

- **E-max**
  - Investments with highest benefit to cost ratio
- **E-max***
  - Considers also the obligations and prior commitment
- **B-rank**
  - Investments with the highest benefit
- **C-rank**
  - Investments with lowest cost

Application 2: Results

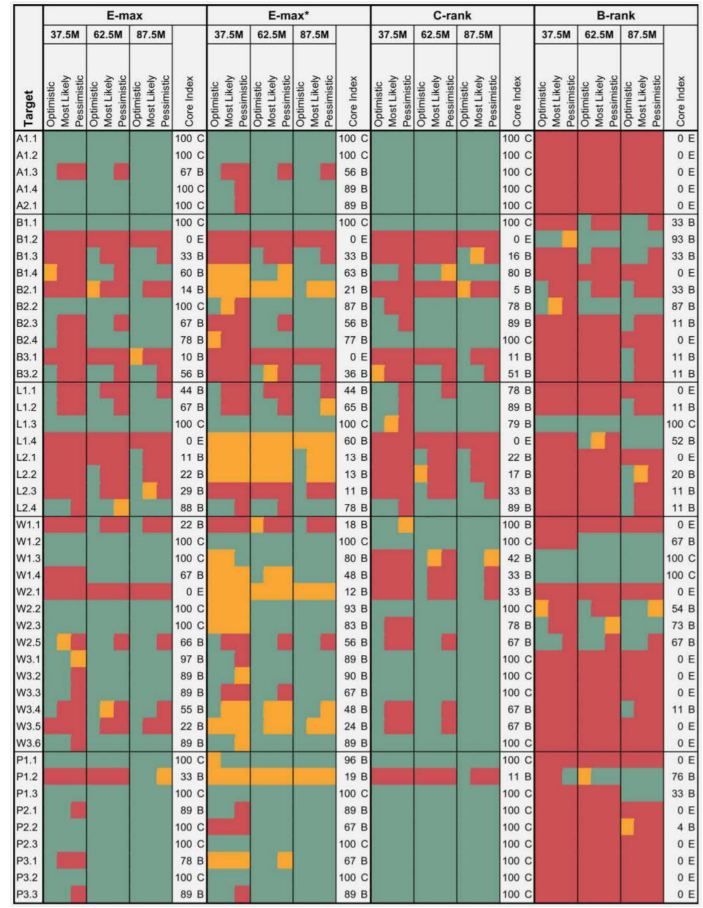


Source: Bryan (2010)

Application 2: Results, Core indices

- **Investment classification:**
  - Core
  - Borderline
  - External

- **E-max, E-max* and C-rank have similar portfolio compositions**



Source: Bryan (2010)

Application 2: Conclusions

- **The effect of uncertainty in costs and benefits in the performance and composition of portfolios was significant**
- **DM should adopt single strategy to reduce the complexity of the decision making**
- **Framework is directly transferable to other environmental investment problems**
- **Analysis was used to guide the investments towards the projects that are selected more often in the optimal portfolios**

References

- Grushka-Cockayne, Y., De Reyck, B., Degraeve, Z., 2008: An Integrated Decision-Making Approach for Improving European Air Traffic Management, Management Science 54/8, s. 1395-1409.
- Bryan, B. A., 2010: Development and Application of a Model for Robust, Cost-Effective Investment in Natural Capital and Ecosystem Services, Biological Conservation 143/7, s. 1737-1750.

Homework

Task 1: Come up with a multistakeholder decision-making problem where the stakeholders have conflicting objectives and different perspectives. How would you determine the weights for each of the stakeholders so that each of them is satisfied?

Task 2: Discuss briefly about the advantages and limitations of the methods used in application 2.

Send your solution to *antti.korkealaakso@aalto.fi*