Optimal strategies for selecting project portfolios using uncertain value estimates

E. Vilkkumaa, J. Liesiö, A. Salo

University of Vienna, November 6th 2013
Post-decision disappointment in portfolio selection

- Project portfolio selection is important
- Decisions are typically based on uncertain value estimates $v^E$ about true value $v$
- If the value of a project is overestimated, this project is more likely to be selected
- Disappointments are therefore likely

Underestimation of costs in public work projects (1/2)

- Flyvbjerg et al. 2002 found statistically significant escalation \( (p<0.001) \) of costs in public infrastructure projects.

- This escalation was attributed to strategic misrepresentation by project promoters.

Underestimation of costs in public work projects (2/2)

- If projects with the lowest cost estimates are selected, the realized costs tend to be higher even if cost estimates are unbiased \textit{a priori}

- Cost escalation could therefore be attributed to ‘post-decision disappointment’ as well
Bayesian revision of value estimates (1/2)

- Assume that the prior $f(v)$ and the likelihood $f(v^E|v)$ are known such that $E[V_i^E | V = v] = \int_{-\infty}^{\infty} v_i^E f(v_i^E | v) dv_i^E = v_i$

- By Bayes’ rule we have $f(v|v^E) \propto f(v) \cdot f(v^E|v)$

- Use the Bayes estimates $v_i^B$ for selection

$$v_i^B = E[V_i | V^E = v^E] = \int_{-\infty}^{\infty} v_i f(v_i | v^E) dv_i$$

- If $V_i \sim N(\mu_i, \sigma_i^2)$, $V_i^E = v_i + \epsilon_i$, $\epsilon_i \sim N(0, \tau_i^2)$, then $V_i | V_i^E \sim N(v_i^B, \rho_i^2)$, where

$$v_i^B = \frac{\sigma_i^2}{\sigma_i^2 + \tau_i^2} v_i^E + \frac{\tau_i^2}{\sigma_i^2 + \tau_i^2} \mu_i, \quad \rho_i^2 = \frac{\sigma_i^4}{\sigma_i^2 + \tau_i^2}.$$
Bayesian revision of value estimates (2/2)

- Portfolio selection based on the revised estimates $v_i^B$
  - Eliminates post-decision disappointment
  - Maximizes the expected portfolio value given the estimates $v_i^E$

- Using $f(v/v^E)$, we show how to:
  1. Determine the expected value of acquiring additional estimates $v_i^E$
  2. Determine the probability that project $i$ belongs to the truly optimal portfolio (= portfolio that would be selected if the true values $v$ were known)
Example (1/2)

- 10 projects ($A, \ldots, J$) with costs from $1M$ to $12M$
- Budget $25M$
- Projects’ true values $V_i \sim N(10,3^2)$
- $A, \ldots, D$ conventional projects
  - Estimation error $\varepsilon_i \sim N(0,1^2)$
  - Two interdependent projects: $B$ can be selected only if $A$ is selected
- $E, \ldots, J$ novel, radical projects
  - These are more difficult to estimate: $\varepsilon_i \sim N(0, 2.8^2)$
Example (2/2)

True value = 52$M
Estimated value = 62$M

True value = 55$M
Estimated value = 58$M

\(v^E / v^B\) = Optimal project based on \(v\)

Size proportional to cost

Prior mean

Bayes estimate \(v^B\) ($M)

Prior mean

True value \(v\) ($M)

True value \(v\) ($M)
Value of additional information (1/2)

- Knowing \( f(v|v^E) \), we can determine
  - The expected value (EVI) of additional value estimates \( V^E \) prior to acquiring \( v^E \)
  - The probability that project \( i \) belongs to the truly optimal portfolio

The probability that the project belongs to the truly optimal portfolio is here close to 0 or 1
Value of additional information (2/2)

- Select 20 out of 100 projects
- Evaluation cost 3% of a project’s cost
- Re-evaluation strategies
  1. All 100 projects
  2. 30 projects with the highest EVI
  3. ‘Short list’ approach (Best 30)
  4. 30 randomly selected projects
Conclusions

- Uncertainties in cost and value estimates should be explicitly accounted for.
- Bayesian revision of the uncertain estimates helps
  - Increase the expected value of the selected portfolio
  - Alleviate post-decision disappointment
- Bayesian modeling of uncertainties guides the cost-efficient acquisition of additional estimates as well.