An integrated approach for allocating resources to projects

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Introduction

What is the problem?
How to choose a portfolio of projects from a set of candidate projects for funding when not enough resources exist for selecting them all?

Outline
• The integrated approach
• Some alternative portfolio selection approaches
• Commercial and non-commercial software implementations
• RAMS
• Future research

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The integrated approach

**Problem and model structuring**
- Value function building

**Assessment of the scores of the projects in each criterion**

**Assessment of criteria weights**

**Assessment of the overall benefits and costs of the projects**

**Portfolio analysis**

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Decision Conferencing Process

**Awareness of issue**
- Prepare objectives
- Participants
- Calling note

**Key Players**
- Compare: Gut⇔Model

**Build Model**
- Explore Issues

**Explore Model**
- Shared Understanding
- Commitment
- Actions

**Requisite decision model:**
- Sufficient in form and content to resolve the issues of concern

(Phillips, 2007)
**Premises for portfolio analysis**

For sake of simplicity we will start assuming that the only constrained resource is money, which is limited to the amount $C$.

Let’s say that each project $j$, from the set of candidate projects $J$ ($j=1,\ldots, n$), has a cost of $c_j$ and a (multi-criteria) benefit of $b_j$.

We will also start assuming that the benefit (respectively cost) of a portfolio are equal to the sum of the benefits (respectively costs) of its projects.

We should note that for $n$ projects there are $2^n$ possible portfolios.

**Approaches: the “benefit approach”**

Philips and Bana e Costa (2007) found that a frequent approach applied by both for-profit and not-for-profit organisations is:

1. Assess benefit and cost measures for each project $j$;
2. Rank the projects for decreasing order of benefit $b_j$;
3. Select the 1st, 2nd, 3rd, 4th, ..., ranked projects until their cumulative cost exhausts the amount of money available ($C$).

Despite being frequently used, this approach does not give the best use for the money, as we will see next.
The benefit-to-cost ratio approach obtains the set of convex efficient solutions. Its algorithm is as follows:

1. Assess benefit and cost measures for each project $j$;
2. Calculate the benefit-to-cost ratio ($b_j/c_j$) of each project;
3. Rank the projects for decreasing order of $b_j/c_j$;
4. Select the 1st, 2nd, 3rd, 4th,... ranked projects until their cumulative cost exhausts the amount of money available ($C$).

Example data table

<table>
<thead>
<tr>
<th>Project</th>
<th>Benefit</th>
<th>Cost (Mio €)</th>
<th>Project</th>
<th>Benefit</th>
<th>Cost (Mio €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj1</td>
<td>67,03</td>
<td>1,311</td>
<td>Proj12</td>
<td>32,09</td>
<td>0,322</td>
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<td>Proj2</td>
<td>54,77</td>
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<td>0,813</td>
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<td>0,421</td>
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<td>0,262</td>
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<td>2,969</td>
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<td>0,396</td>
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<td>1,340</td>
<td>Proj17</td>
<td>12,24</td>
<td>0,561</td>
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<tr>
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<td>0,292</td>
<td>Proj18</td>
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<td>0,359</td>
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<tr>
<td>Proj8</td>
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<td>1,129</td>
<td>Proj19</td>
<td>11,71</td>
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<tr>
<td>Proj9</td>
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<td>0,385</td>
<td>Proj20</td>
<td>10,15</td>
<td>0,886</td>
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<tr>
<td>Proj10</td>
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<td>0,733</td>
<td>Proj21</td>
<td>5,82</td>
<td>0,599</td>
</tr>
<tr>
<td>Proj11</td>
<td>40,63</td>
<td>0,493</td>
<td>Proj22</td>
<td>5,34</td>
<td>1,722</td>
</tr>
</tbody>
</table>
“Benefit approach” vs “benefit-to-cost approach”

Prioritisation of projects

Approaches: the “knapsack approach”

An operational researcher practitioner would address this problem using mathematical binary integer programming.

\[
\begin{align*}
\text{maximize} & \quad \sum_{j=1}^{n} b_j x_j \\
\text{subject to} & \quad \sum_{j=1}^{n} c_j x_j \leq C \\
& \quad x_j \in \{0,1\} \quad (j = 1, \ldots, n).
\end{align*}
\]

This approach would find the portfolio of projects that would give the maximum benefit for the given amount of money available \((C)\).
Software: Equity

Equity (version 3) is a software that:

1. Allows the assessment of the multi-criteria benefit and the multi-criteria cost for each project.
2. Uses the benefit-to-cost ratio approach to find efficient portfolios of projects.

The initial evaluation of benefits and costs of the projects can be done separately by areas.

Because different areas usually have different swings (worst-to-best) with the same score (100) in the same criterion, Equity uses within-criterion weights information to generate a common scale for each criterion.

Across-criteria weights are used to assess the overall benefit (or overall cost) score for each project.
With this information the software generates a chart showing the convex envelope of the portfolios using the benefit-to-cost ratio approach to draw the upper line.

If the user decide to choose a portfolio (P) that is not on the convex frontier, Equity will propose two alternative portfolios (“packages”) on the frontier:

- (B) a portfolio that gives a greater benefit than P;
- (C) a portfolio that costs less than P.
HiPriority allows to create projects (“Options”) and evaluate them in terms of their multi-criteria benefit and multi-criteria cost.

With the required information inserted HiPriority draws the convex envelope of the portfolio solutions. Its upper line (the “Golden Frontier”) is obtained by the benefit-to-cost ratio approach.
If requested HiPriority also draws the efficient frontier (the “Full Frontier”), that is, the line that connects all non-dominated solutions.

HiPriority also handles mutually exclusive projects (throughout “Exclusions”), mutually inclusive projects (throughout “Dependencies”), and synergies between projects (throughout “Modifiers”).
Logical Decisions Portfolio (LDP) is a separate piece of software that runs as an Excel add-in.

LDP takes as input the overall benefit scores of the projects ("alternatives") of a Logical Decisions for Windows (LDW) model. It also can import the cost and resource usage information for each project from LDW.
Software: Logical Decisions Portfolio

LDP uses the benefits score and the resource usage information for each project, together with a defined budget and other possible constraints to run a mathematical binary integer programming model to find the best portfolio that meets the constraints.

Other software

- **Expert Choice** is a commercial software from Expert Choice Inc. that implements AHP. Expert Choice Resource Aligner is its add-in for resource allocation. -- It has to be analysed --

- **Robust Portfolio Modeling (RPM)** (Liesiö et al. 2007, Liesiö et al. *to appear*) is a non-commercial software suited to help decision-makers when in face of incomplete information about: project performances, projects costs, criteria weights, budget availability and project interdependencies.
RAMS

- Resource Allocation for Management and Support (RAMS) is a tool that, in its current version, uses two approaches: ratio benefit-to-cost and knapsack.

With a budget constraint of 10 Mio €

The DM has a portfolio that gives a benefit score of 55.8 per each Mio € spent.

If the DM was able to add more 0.085 Mio € to his initial budget

The DM would obtain a portfolio that gives a benefit score of 56.4 per each Mio € spent.
The 10 Mio € budget are assigned to 3 areas (A, B and C) according with the percentages 35%, 35% and 30%.

<table>
<thead>
<tr>
<th>Project</th>
<th>Area</th>
<th>Project</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proj1</td>
<td>B</td>
<td>Proj12</td>
<td>A</td>
</tr>
<tr>
<td>Proj2</td>
<td>C</td>
<td>Proj13</td>
<td>C</td>
</tr>
<tr>
<td>Proj3</td>
<td>C</td>
<td>Proj14</td>
<td>B</td>
</tr>
<tr>
<td>Proj4</td>
<td>B</td>
<td>Proj15</td>
<td>B</td>
</tr>
<tr>
<td>Proj5</td>
<td>A</td>
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<tr>
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<td>Proj10</td>
<td>B</td>
<td>Proj21</td>
<td>C</td>
</tr>
<tr>
<td>Proj11</td>
<td>C</td>
<td>Proj22</td>
<td>B</td>
</tr>
</tbody>
</table>

Convex envelope with no constraints and the efficient frontier with budget constraints of 3.5 Mio €, 3.5 Mio € and 3 Mio € for areas A, B and C, respectively.
Future research: concerns to address

Concerns to address:

- How to deal with project dependencies and with the (positive or negative) synergies between them
- How to help decision-makers (DMs) to be aware of the “hidden trade-offs” of adding additional constraints to their problem
- How to help DMs to make robust decisions
Acknowledgements

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References


References


Thank you!