**RIAM Design Requirements**

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The scope of this document is to provide guidelines on the design of the optimization methods for the RIAM projects.

1. **Optimization Requirements:**
   1. **Single Knapsack Problem (SKP)**

The objects considered for optimization will generally called *investments* and their number be indicated by . The profits and consumption of resources associated with the *ith* investments will be called *net\_present\_values* and *costs*,respectively, and denoted by and . The problems considered in following 1-2 are *single knapsack* problems, where one knapsack (or *available\_capitals*) must be filled with an optimal subset of investments. The capacity of such a knapsack will be denoted by .

1. Shall be able to solve 0-1 single Knapsack problem, defined by
2. Shall be able to solve Bounded single Knapsack problem, defined by
3. Shall be able to solve above single Knapsack problems (1-2) with uncertainty parameters (stochastic programming) for project prioritization. **By introducing binary variables , taking value 1 if project has no lower priority than project , 0 otherwise.**
   1. **Multi-dimensional knapsack problem or D-dimensional knapsack problem (D-KP)**

If there is more than one constraint (for example, both capital limit and depreciation limit, where the capital and depreciation of each item are not related), we get the multiple-constrained knapsack problem, multi-dimensional or d-dimensional knapsack problem. This has 0-1, bounded and unbounded variants; the bounded one is shown below:

For example, consider a D-KP problem in which the costs of each investment and the available capitals vary according to time period . By defining as the cost of investment at time period , and as the available capital at time period , we get:

1. Shall be able to solve above **D-KP**with time-dependent costs and capacities
2. Shall be able to solve above d-KP problem (4) with uncertainty parameters (stochastic programming) for project prioritization:
   1. **Multiple Knapsack Problem (MKP)**

An important generalization of the above knapsack problem is the 0-1 Multiple Knapsack problem, arising when knapsacks, of given capacities are available. **By introducing binary variables , taking value 1 if investment is selected for knapsack , 0 otherwise.**

Examples: parallel maintenance of multi-units

1. Shall be able to solve 0-1 multiple Knapsack problem defined by
2. Shall be able to solve above multiple Knapsack problems (6) with uncertainty parameters (stochastic programming) for project prioritization, i.e.
   1. **Multiple-choice knapsack problem (MCKP)**

If the investments/projects are subdivided into options denoted , and exactly one option must be taken from each investment/project, we get the multiple-choice knapsack problem (MCKP). Using the decision variable to denote whether option was chosen from the set . In addition, will be used to denote the option of non-selection of investment/project . The following model appears:

1. Shall be able to solve MCKP problem in which the profits and costs of each investment/project vary according to the option for which they are selected. By defining (resp. ) as the profit (resp. the cost) of investment/project with selected option , we get
2. Shall be able to solve above MCKP (8) with uncertainty parameters (stochastic programming) for project prioritization, i.e.
   1. **Extension of MCKP: MCKP with D-Dimensional Knapsack problem (D-MCKP):**
3. Shall be able to solve MCKP with multiple constraints:

If the available budgets are depending on the time period or depending on both type of resources and time period , the MCKP would be:

Or

1. Shall be able to solve above MCKP (10) with uncertainty parameters (stochastic programming) for project prioritization, i.e.

Or

* 1. **Extension of MKP: MKP with D-Dimensional Knapsack problem (Options, do not have any use cases)**

To be discussed

* 1. **Additional constraints**

1. Precedence Constraint Knapsack Problem

Piggybacking constraint captures situations in which option for project (which may have cheaper costs) may be selected only if project-option pair is also selected.

1. Other resource constraints limiting project selection due to multiple projects competing for time, space, personnel, equipment, dependencies/synergies, and depreciation limit.
2. **Other Requirements** 
   1. Shall be able to handle managerially required/mandated investments/projects
   2. Shall be able to compute net present values from provided cash flows

Where is net cash inflow-outflows during a single period , is discount rate or return that could be earned in alternative investments, and is number of time periods.

* 1. Optional to perform repeated analysis for single perturbed parameter

1. User Cases:

To be discussed …

1. Input Requirements:

To be discussed …

1. Output Requirements:

To be discussed …

1. Net Present Value (NPV), Internal Rate of Return (IRR) and Profitability Index (PI)
2. Internal Rate of Return: similar to NPV except that the discount rate is the rate that reduces the NPV of an investment to zero. This method is used to compare projects with different lifespans or amount of required capital
3. Profitability Index
4. Payback period: calculates how long it will take for the original investment to be repaid.