Allocation of corrective measures for risk reduction in research laboratories (semester project)

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1 Description

Many research and teaching laboratories are associated with physical hazards. Those can potentially cause harm to people, damage facilities, pollute the environment and ruin the university reputation. The examples are toxic chemicals, flammable liquids, noise, exposition to high or low temperatures, laser waves and radiation. In order to assure safety in a lab it is crucial to asses the risks and choose adequate corrective measures to minimize them.

A tool aiming at this task, developed at EPFL, is called Laboratory Assessment and Risk Analysis (LARA) [1]. LARA provides a web interface with the following functionalities:

1. Identification of the set of hazards in a lab and the set of available corrective measures.
2. Quantification of the risk for each hazard with the Laboratory Criticality Index (LCI), which is a rational value in a specified domain.
3. Estimation of the risk reduction ΔLCI for a given hazard under the assumption that a given corrective measure has been applied.

The goal of this project is to complement LARA with a decision aiding tool. Given the set of available corrective measures, we would like to choose a subset of them which will minimize the risk for all the hazards. One natural assumption is that not all measures can be undertaken, since each of them has an implementation cost and there is a limited budget available to each lab at EPFL. Besides the financial aspect, there is a set of criteria to be considered during the decision process. E.g., it is important that the selected measures are acceptable for people working in the lab and simple to implement.

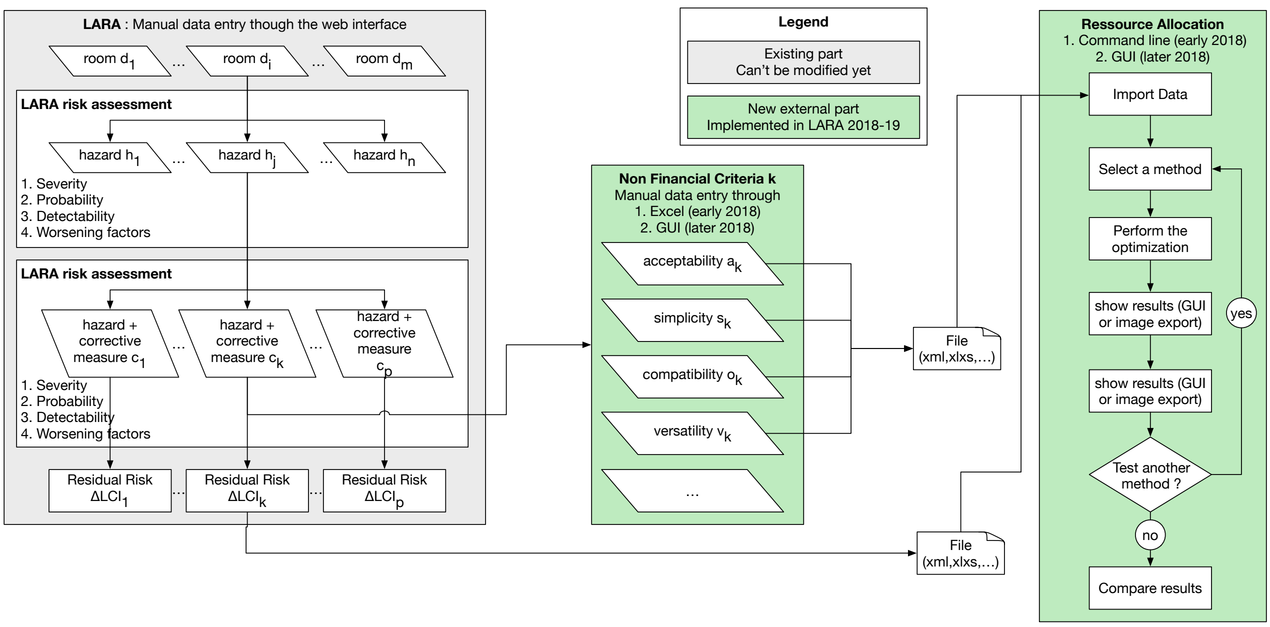

Figure 1: The intended work flow of the project. The part in grey shows the existing functionality of LARA.

2 Mathematical modeling

The problem can be formally defined with a set of m hazards, n corrective measures, $c_i \in \mathbb{R}_+$ being the cost of implementing a corrective measure $i \in [n]$, $b \in \mathbb{R}_+$ being the budget, and $\Delta LCI_{i,j} \in [0; 10]$ being the risk reduction of applying i to a hazard $j \in [m]$.

Furthermore, one can set $p_i = \sum_{j \in [m]} \Delta LCI_{i,j}$ to be the total risk reduction for $i \in [n]$ and obtain a simple integer programming model for our problem

$$\max\{p^\top x : \; c^\top x \leq b, \; x \in \{0,1\}^n\}. \tag{1}$$

This formulation corresponds to the Knapsack problem which is well-studied in the literature and can be efficiently solved in practice [2].

A drawback of the above approach is that it does not adequately reflect the situation when several corrective measures reduce the risk of the same hazard. Let $\bar{x}$ be an optimal solution of (1), thus suggesting the set of measures $S = \{i \in [n] : \; \bar{x}_i = 1\}$. The risk reduction for a hazard j reflected by S in $p^\top \bar{x}$ would be $\sum_{i \in S} \Delta LCI_{i,j}$, while the effective risk reduction in a real-life situation would be closer to $\max_{i \in S} \Delta LCI_{i,j}$.

We observe here the issue of appropriately aggregating the risk reduction values of different hazards into a common objective function. Additionally, besides the risk reduction and satisfying the budget constraint, there is a set of important non-financial criteria (acceptability, simplicity, compatibility) to be met when making the decision on the "best" set of corrective measures. Thus we would like to investigate and enhance the techniques existing in the field of Multiple Criteria Decision Analysis (MCDA) [4].

Our tentative plan of the project can be summarized in the following phases:

1. Selecting the most adequate models and algorithms among the state of art techniques in MCDA [3], [4] and portfolio decision analysis [5].

2. Adopting the selected methods and their software implementation.

3. Assessing the quality of the obtained solutions on a set of use cases.

References

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[3] R. Bisdorff, L. C. Dias, P. Meyer, V. Mousseau, M. Pirlot (Eds.). *Evaluation and Decision Models with Multiple Criteria: Case Studies.* Springer, 2015. 643 pp.

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[5] A. Salo, J. Keisler, A. Morton (Eds.). *Portfolio Decision Analysis: Improved Methods for Resource Allocation.* Springer, 2011. 409 pp.