

# SSG Case Study



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**Company represented:** Universidad de los Andes (Bogotá, Colombia)

**Role:** Asset Management personnel of engineering laboratories

**Sector:** Education

**Asset owner:** Mechanical Engineering Department (Universidad de los Andes)

## Introduction

### Description of assets in study

The acquisition of laboratory equipment within a university department represents capital investment decision-making within a multi-category portfolio. The latter refers to a collection of assets under an organization's control that belong to different categories (Petchrompo & Parlikad, 2019). The cost of laboratory equipment can vary significantly, and these investments generate value for the organization by facilitating education and research activities, as well as providing services to companies.

The challenge in selecting equipment for acquisition arises from the competition among items of different categories, such as a lathe versus an oven. Furthermore, quantifying the generated value becomes non-operational in certain cases. For example, estimating the Net Present Value (NPV) of the services that the equipment would provide to companies could be challenging due to uncertainties and a lack of readily available information within the department's regular operation. Consequently, the decision-making approach needs to address intangible dimensions of value, such as the enhancement of the department's image through equipment acquisition, and operationalizing tangible dimensions that would be difficult to quantify, such as income generated through service provision. This case study showcases the developed value model designed to steer decision-making in strategic capital investments of this nature, aiming to inspire sectors beyond the realm of education.

### When was the activity carried out?

The activity was conducted over 16 weeks in the second semester of 2023.

### Why was the activity carried out?

At the Universidad de los Andes, the Faculty of Engineering allocates an annual budget for capital investments to each department. Within the Mechanical Engineering Department, professors are organized into research groups, and each group is tasked with submitting equipment proposals. These proposals must include the purchase cost and justifications for acquisition. Subsequently, a financial committee, comprising three professors and the department chair, reviews the submissions and selects the equipment for acquisition. However, past experiences with suboptimal investments prompted a re-evaluation of this decision-making process.

## Terminology

**Benefit:** Equipment capability to contribute to the achievement of departmental objectives through its use in teaching activities, research, and the provision of services, while enhancing the uniqueness of the equipment portfolio

**Cost Estimation:** Prediction of the future financial needs for both operational and maintenance costs. Assessment of the feasibility of estimating these expenses, taking into account the available information

**Risk:** Assessment aimed at reducing uncertainty regarding the equipment's ability to contribute to the department's objectives

**Equipment Uniqueness:** Equipment characteristic that, being the only one of its kind, contributes to improving the department's image and prevents the acquisition of redundant equipment

**Utilization:** Equipment capability to contribute to the achievement of departmental objectives through its use in teaching activities, research, and the provision of services

**Teaching:** Equipment capability to be used in teaching and learning activities in an academic environment

**Research:** Equipment capability to be used in research projects

**Service Provision:** Equipment capability to be used in the provision of services

**Supplier Representation:** Risk associated with the accessibility of after-sales services based on the geographical location of the supplier's technical service

**Equipment Obsolescence:** Risk related to the potential loss of utility of the equipment, evaluated based on the availability of after-sales services and the age of the model being considered for acquisition

**After-Sales Service:** Risk of not having after-sales services available or of the availability being limited in terms of duration

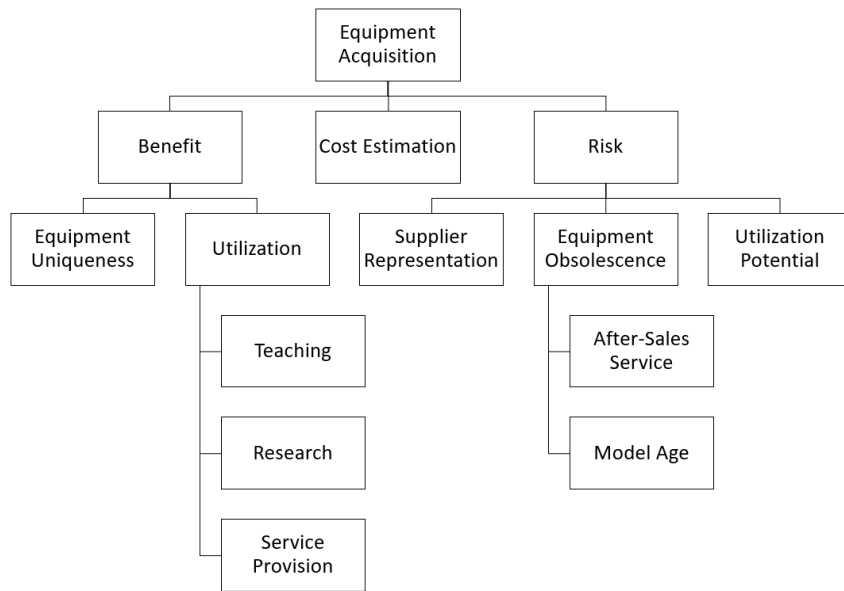
**Model Age:** Risk related to the technological obsolescence that the model may present due to its age in the market

**Utilization Potential:** Risk of not having the necessary resources or knowledge to fully utilize all the functionalities offered by the equipment, or not requiring them in their entirety

## **Description of activity**

### **Methodology**

The Mechanical Engineering Department of the Universidad de los Andes comprises 15 professors organized into five research groups. To define the objectives sought by decision-makers in addressing the decision, semi-structured interviews were conducted with the directors of the five research groups and the laboratory coordinator (representing key decision stakeholders), as well as with the department chair (representing the decision-makers; i.e. the financial committee). The primary aim was not only to identify the objectives but also to establish operational attributes capable of measuring their accomplishment. In this context, an 'operational attribute' refers to an attribute for which the information necessary to describe the consequences of the equipment over the objective can be obtained, allowing for a reasonable value trade-off. A hierarchy of objectives was constructed, as illustrated in the Figure 1.



**Figure 1: Hierarchy of objectives for the university asset acquisition decision problem.**

In accordance with the Asset Management definition of value (ISO55000), the fundamental objectives were identified as benefit, cost estimation, and risk. After identifying the objectives, a set of attributes was defined for both tangible and intangible objectives for their quantification. Constructed attributes are characterized by constructed scales with two or more distinct qualitative levels of objective achievement, with each level accompanied by a corresponding verbal judgement (Edwards et al., 2007). An example is illustrated in Figure 10. In this case study, constructed attributes were used to evaluate intangible objectives and to operationalize the assessment of tangible objectives.

Constructed Scale	Objective Achievement
1	Description of the first attribute level
2	Description of the second attribute level
...	...
n	Description of the n-th attribute level

**Figure 2: Template for a constructed attribute with 'n' constructed levels.**

In accordance with the Multi-Attribute Utility theory (Wallenius, et al., 2008), a utility function was defined for each attribute, followed by their weighting and aggregation to generate an overall value merit for each equipment. In this context, a weighted average was utilized. For an equipment characterized with attribute levels  $x_1, \dots, x_m$  on the  $m$  objectives, its value merit ( $V$ ) can be computed as:

$$V(x_1, \dots, x_m) = k_1 U_1(x_1) + \dots + k_m U_m(x_m)$$

where the weights are  $k_1, \dots, k_m$ , the utility functions for each attribute are  $U_1(x_1), \dots, U_m(x_m)$  and  $U(x)$  is a merit between 0 and 1.

Different approaches can be utilized to assess utility functions from constructed attributes (Keeney & Raiffa, 1993). A common method is to assign a merit of 0 to the worst level on the constructed scale and 1 to the best one. All the other levels are then rated between 0 and 1, reflecting the degree of preference for each constructed level relative to the lowest and highest ranked ones.

A workshop involving two research group directors and two professors from the financial committee was conducted to perform a pairwise comparison of objectives and determine their weights ( $k_i$ ) using the Analytic Hierarchy Process (AHP) method (Saaty, 1994). The resulting weights are presented in Figure 11. Subsequently, the utility functions for the constructed attributes were assessed, with specific merits assigned to each level on the constructed scale detailed in the 'Risk types' and 'Costing' sections.

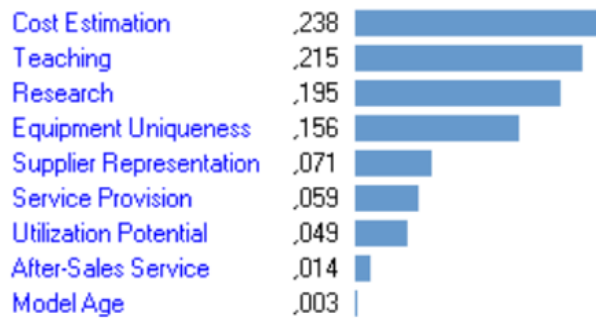


Figure 3: Weights obtained from the pairwise comparison of the objectives.

## References

- Edwards, W., Miles, R., & Von Winterfeldt, D. (2007). *Advances in decision analysis*. Cambridge University Press.
- ISO55000. (2014). *Asset management — Overview, principles and terminology*. International Organization for Standardization.
- Keeney, R. L., & Raiffa, H. (1993). *Decisions with multiple objectives: preferences and value trade-offs*. Cambridge university press.
- Kim, W. C. (2005). Blue ocean strategy: from theory to practice. *California management review*, 47(3), 105-121.
- Petchrompo, S., & Parlikad, A. (2019). A review of asset management literature on multi-asset systems. *Reliability Engineering & System Safety*, 181, 181–201.
- Saaty, T. L. (1994). *Fundamentals of decision making and priority theory with the analytic hierarchy process*. RWS publications.
- Wallenius, J., Dyer, J. S., Fishburn, P. C., Steuer, R. E., Zionts, S., & Deb, K. (2008). Multiple criteria decision making, multiattribute utility theory: Recent accomplishments and what lies ahead. *Management science*, 54(7), 1336-1349.

## Risk types

As illustrated in Figure 1, the risk assessment focused solely on the risks related to the equipment's acquisition, since risks associated with its subsequent use, such as occupational health and safety risks, are evaluated in a separate process.

## Risk management process

Figure 4 illustrates the constructed attributes of risks associated with the acquisition of laboratory equipment, with the merit assigned to each level indicated in the third column. The assessment allowed for a comparison of competing equipment in terms of the risks associated with their acquisition.

Risk Category	Risk Subcategory	Merit	Description
Supplier representation	/	0,0	The supplier offers post-sales services outside the Americas
		0,4	The supplier offers post-sales services in the Americas
		0,8	The supplier offers post-sales services in Colombia
		1,0	The supplier offers post-sales services in Bogotá
Equipment Obsolescence	After-Sales Service	0,0	There is no availability of after-sales services
		0,3	After-sales services are available for 1-5 years after installation
		0,8	After-sales services are available for 6-10 years after installation
		1,0	After-sales services are available for more than 11 years after installation
	Model Age	0,0	The equipment model has been on the market for more than 11 years
		0,3	The equipment model has been on the market for 6 to 10 years
		0,6	The equipment model has been on the market for 3 to 5 years
		1,0	The equipment model has been on the market for less than 2 years
Utilization Potential	/	0,0	Only some of the equipment's features will be used
		0,7	Most of the equipment's features will be used
		1,0	All of the equipment's features will be used

Figure 4: Constructed attributes for the risks related to the acquisition of a laboratory equipment.

## Tools used

Expert Choice software was used to implement the Analytic Hierarchy Process (AHP) method for calculating weights via pairwise comparisons of objectives. While, Microsoft Excel worksheets were employed to compute the value merit of each equipment using the weighted average equation and to present the results graphically.

## Costing

The purchasing cost was deliberately excluded from this process, as it is considered in a subsequent stage where the final decision is based on the merit assigned by the value model to different equipment and their purchasing costs. The equipment uniqueness criterion assessed the strategic value equipment, because it is operationally determined that another one is needed, does not fit into this process. Moreover, attempting to estimate the monetary benefits of acquiring equipment would not be operational. Hence, constructed attributes, as illustrated in Figure 5, were employed.

Benefit Category	Benefit Subcategory	Merit	Description
<i>Equipment Uniqueness</i>	/	0,0	The department already has other equipment of this type
		0,1	The university already has other equipment of this type
		0,7	There are no equipment of this type at the university
		0,9	There are no equipment of this type in Bogotá
		1,0	There are no equipment of this type in Colombia
<i>Utilization</i>	Teaching	0,0	The equipment will not be used within any course
		0,2	The equipment will be used exclusively in one course
		0,8	The equipment will be used in multiple courses within one research area
		1,0	The equipment will be used in courses across multiple research areas
	Research	0,0	The equipment will not be used in any research projects
		0,4	The equipment will be primarily used in the research of a professor
		0,8	The equipment will be used in multiple projects within a single research areas
		1,0	The equipment will be used in projects spanning multiple research areas
	Service Provision	0,0	The equipment will not be utilized for service provision
		0,5	The equipment will provide services within the university
		1,0	The equipment will provide services outside the university

Figure 5: Constructed attributes for the benefits related to the acquisition of a laboratory equipment.

Finally, the cost dimension of value was incorporated by assessing the ability to estimate equipment costs for maintenance and operations, as depicted in Figure 6.

Merit	Description
0,0	Maintenance and operation costs cannot be estimated
0,4	Only operation costs can be estimated
0,7	Operation costs can be estimated, and maintenance costs can be estimated partially
1,0	Both operation and maintenance costs can be estimated

Figure 6: Constructed attribute for the cost estimation related to the acquisition of a laboratory equipment.

## People

The activity involved an employee working nine hours per week. Additionally, three asset management personnel supervised the employee for one hour per week, and semi-structured interviews and workshops were conducted with selected stakeholders.

## Evaluation

### What was the main output of the activity?

A hierarchy of equipment, ranked according to their respective value merit, was established (Figure 7), serving as a crucial tool for assessing the most favourable choices among the options.

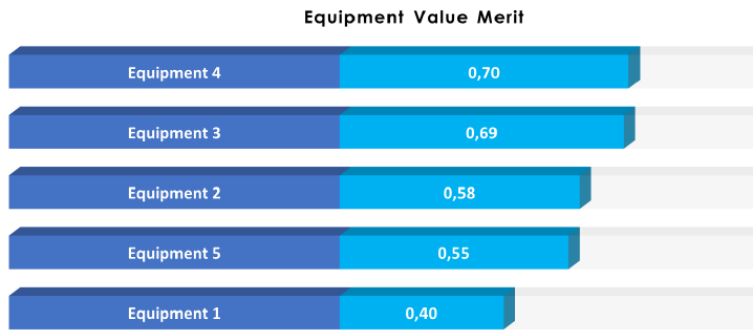


Figure 7: Hierarchy of equipment ranked according to the merit assigned from the value model.

However, the hierarchy was generated using the weighted average. This function allows the compensation between good and bad scores across objectives while also foregoing specific information that may be important when ranking the equipment. For this reason, two additional visualizations were provided. The histogram in Figure 8 illustrates the performance of the equipment across the fundamental objectives (i.e., dimensions of value), providing decision-makers with a visual representation that aids in understanding the strengths and weaknesses of each equipment. Additionally, the value curve shown in Figure 9 offers an insightful overview of the performance of each equipment on the evaluated objectives, allowing the financial committee to assess the overall suitability of each equipment. The value curve is a graphic depiction of a organization's relative performance across its industry's factors of competition and has been utilized as a diagnostic and an action framework for building compelling organizational strategies (Kim, 2005). In this case study, the value curve is adopted for a point-to-point comparison of alternatives.

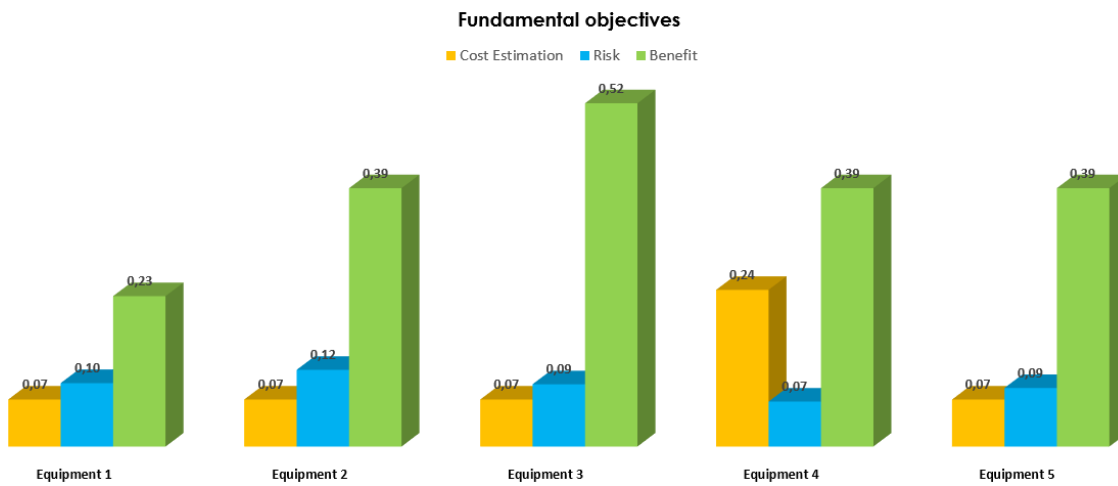


Figure 8: Merit of each equipment across the fundamental objectives.

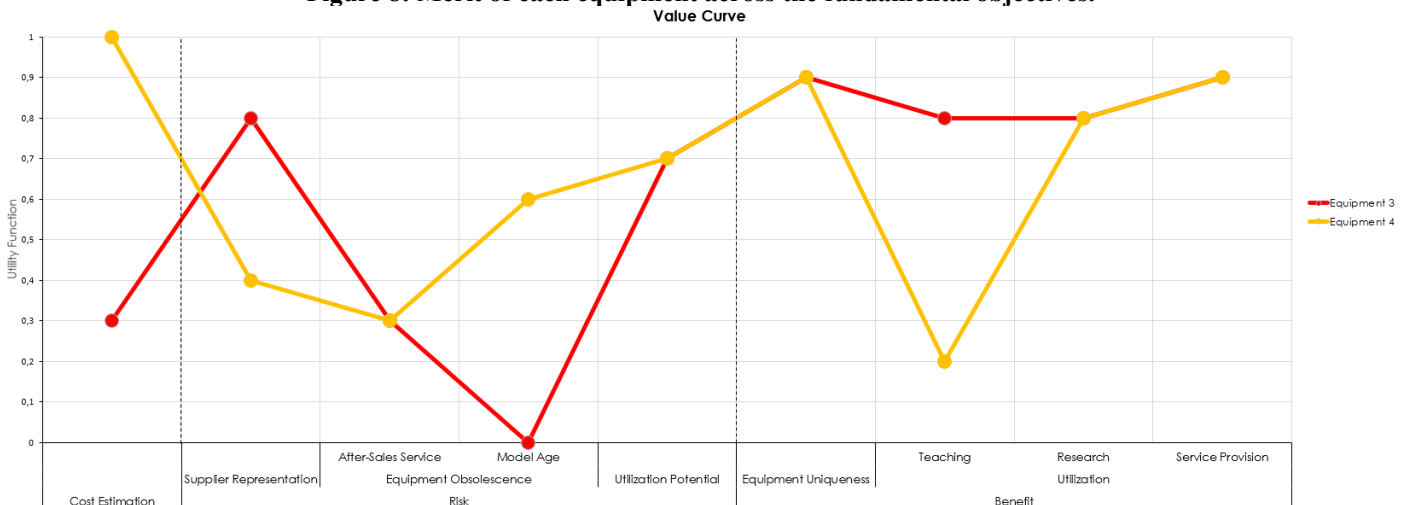


Figure 9: Value curve for the point-to-point comparison between equipment 3 and 4.

## Validation

The developed value model was utilized to compare three equipment items of different categories, each with diverse price ranges and characteristics. The assessment process was overseen by the laboratory coordinator without imposing an extensive burden on normal operations. Additionally, the obtained visualizations were reviewed with two professors from the financial committee. The professors acknowledged that the model facilitated the ranking of alternatives and provided a better understanding of their strengths and weaknesses, thereby enabling informed value-based decisions.

## Outcome

The proposed approach presents the following strengths:

- **Clear values and trade-offs:** a robust decision-making framework was established for guiding the equipment acquisition. Firstly, the model identifies clear objectives based on asset management principles, ensuring a thorough consideration of each aspect of the decision. By organizing the objectives hierarchically, the model provides a clear delineation of priorities. Additionally, to manage trade-offs effectively, the model assigns specific weights to each objective and utilizes constructed attributes in evaluating the varying levels of achievement for each objective across different alternatives.
- **Meaningful and reliable information:** clear guidelines were established for the quantification of the achievement of the objectives through constructed attributes. These guidelines make it evident what specific information should be included in each alternative's proposal, thus facilitating a comprehensive and standardized evaluation process.
- **Suitable decision model:** the value model empowers the decision-makers to transcend common-sense-based approaches and make analytically sound choices by providing the robust visual representations and comprehensive insights. Even though the methodology has proven to be effective in the case study, various areas for improvement can be identified. The primary limitations are observed in the analytical approach, which could be enhanced if more quantitative methods are needed. For instance, different approaches can be utilized to construct individual utility functions by formally modelling uncertainty and decision makers' attitudes towards risk. Alternatively, quantitative tools can be adopted to assess the achievement of objectives within constructed attributes, such as demand analysis or simulation, among others. Therefore, the analytical approach proposed in this work may serve as a baseline that can be improved based on the complexity and importance of the decision at hand. Finally, the value model was constructed based on expert judgment. Like any subjective process, some objectives may have been neglected or may not be fully aligned with the organizational strategy. In this regard, the utilization of value frameworks could be beneficial, as they describe what constitutes value for an organization in relation to achieving its organizational objectives, while also considering the needs and expectations of its stakeholders.

This case study was kindly submitted by Giacomo Barbieri, Juliana Laserna and Luis Mario Mateus from the Mechanical Engineering Department of the Universidad de los Andes, Bogotá, Colombia.