Economic evaluation of industrial projects

Elio Padoano

Introduction

- The focus of this module is *industrial companies* (ICs), which create products and/or services for individuals or organisations (customers or clients).
- Customers find *value* in the output of an IC, so they are *willing to pay* for it.
- A primary characteristic of ICs is that a company's income is derived from selling products or services.
- In the case of manufacturing companies, products can be sold as semi-finished or finished goods.

- More generally, ICs provide “value propositions” for target customers through different kinds of activities.

- An *activity* is a collection of related tasks that together contribute to achieving a specific result.
- Example: processing a purchase order for materials.
- A *process* is a structured set of activities designed to achieve a specific business or operational objective.
- Example: the *procurement process,* which includes activities such as supplier selection, order placement, goods receipt, and payment processing.

- A *task* can be considered as the smallest unit of work within a workflow or process. It is a single action, or a set of simple actions, required to achieve a simple objective.
- Example: entering data related to a customer into a database.
- Activities can be classified into two broad categories:
  - project activities (*projects*)
  - routine activities (*operations*).
- Common aspects:
  - they are carried out by individuals
  - they are constrained by limited resources
  - they are planned, executed and controlled.

What is a project?

- A simple and effective definition of project is given by the *Project Management Institute*:

  a project is a temporary endeavour undertaken to create a unique product, service, or result

- Therefore, a project
  - is an organised set of activities
  - has a clearly defined objective (in business, it is often the creation of *unique* products, services or results)
  - is carried out within a *limited time* (*life cycle*)
  - uses a predetermined number of resources.

- Routine activities do not have a precise beginning and end, and they can be repeated systematically and (practically) always in the same conditions.
- A project is carried out in a “specific” situation, so high variation in implementing the project activities is usually required (*low standardisation*).
- Conversely, a routine activity is designed and performed to obtain systematically the same result (*high standardisation*).
- In manufacturing, processes are executed repeatedly and follow predefined rules.

Feature	Process	Project
Nature	Ongoing and repetitive	Temporary and unique
Objective	Efficiency and consistency	Achieving a specific goal
Duration	Continuous or cyclical	Defined start and end date
Output	Standardised, predictable results	Unique (final) deliverable
Flexibility	Follows predefined workflows	Adapts to changes in scope and requirements

- Relationship between process and project:
  - a project may create a new process (e.g. a project to develop a new assembly process)
  - a process may include projects (e.g. a product development process may involve several R&D projects).

- Projects are typical of *production to order* companies.
- These are focused on each specific customer order, which entail *customised* solutions. For example:
  - design and manufacturing of ships, industrial facilities, buildings etc.
  - development of new technology
  - design and implementation of manufacturing execution system.
- However, projects are carried out in other companies too:
  - launch of a new product
  - design and testing of a prototype
  - renovation of a manufacturing facility.

Key characteristics of projects

- The effort is finalised to achieving a result.
- The objectives are defined.
- Projects are temporary.
- The overall process and the result are unique.
- There is a multiplicity of activities and skills (complexity)
- Resources available for the project are limited.

Effort and objectives

- The effort made is aimed at achieving a goal
  $\Rightarrow$ mobilising resources and managing them to carry out *coordinated* and *goal-oriented* actions.
- The main output is a product or service: the emphasis is put on the satisfaction of certain needs.
- If the focus is the satisfaction of needs, the output (product and/or service) is less bound to standard solutions.
- The objectives must be established in advance and clearly.

Projects are temporary

- A project has a definite beginning and end.
- Therefore, the duration of a project is finite, even if not necessarily short.
- This does not generally apply to the result or results of the project. There may also be consequences that can escape even careful planning.

- A project generally begins when an official document establishes its start (*project charter*)
- The end of a project is determined when one of the following conditions is met:
  - the objectives of the project are achieved
  - it becomes clear that the objectives cannot be achieved
  - the need for the project no longer exists.

The overall process and the result are unique

- The product/service (P/S) that is the main result of the project has aspects and/or features that are different from those of previously produced products/services (of the same type).
- *Example*: a biogas production facility with a new technology.
- The project is not necessarily unique in its entirety, but there are parts that require a particular and new planning process.

- A P/S can be unique even if the category to which it belongs is vast (e.g. photovoltaic power plants).
- Some aspects of uniqueness can be found in:
  - user
  - design
  - location
  - client.
- Even the presence of repetitive elements (e.g. components or suppliers) does not substantially change the particularity of the initiative.

Examples

- Two wind farms with the same productivity and technology are built in two different sites.
- Two cargo ships of the same model are built consecutively.
- A new model of micro-turbine is designed and engineered.

- One critical aspect is *quality assurance*.
- The results expected from the project must be obtained the first and only time.
- It is not possible to apply an incremental approach to quality as in standard manufacturing production.
- The tool for guaranteeing the quality of the result is the quality of the process.
- One can only rely on previous experiences of the same type.

There is a multiplicity of activities and skills

- The realisation process is a combination of:
  - *operational processes*, related to the "physical" progress of the project
  - *management processes*, related to the planning and control of operational processes
  - *organisational processes*, related to the definition and coordination of the various roles involved in operational and management processes.
- A key aspect of projects is then the *integration* of different specialist skills.

- The objectives and strategies established at the beginning of the project are gradually elaborated and detailed during its development.
- On the other hand, what was established initially will be the reference point for everything that will be decided and defined later.
- The availability of the information necessary for the project, and developed by the various actors involved, is progressively increasing and more articulated.
- However, it is not possible to effectively process continually evolving information: it is then necessary to “freeze” the technical documentation at a certain stage of development before starting the next stage.

Resources available for the project are limited

- Production and management activities require human and technological resources.
- The unique characteristics of the product and process and their complexity require:
  - a wide range of skills and roles
  - mobilisation of an organisation's limited resources
  - commitment to multiple projects at the same time.
- On the other hand, the results of the project cannot be immediately predetermined.

- The resources committed to the project cannot be used for other initiatives or activities.
- For example, the man-hours dedicated to the project, materials, energy, etc.
- The quality and quantity of the resources committed require the project to be time-limited.
- There is a competition for resources between different projects.

Stages of an industrial project

- solution concept (product/service)
- market analysis
- feasibility study
- cost estimation
- evaluation of technology
- design and development of product/service
- funding

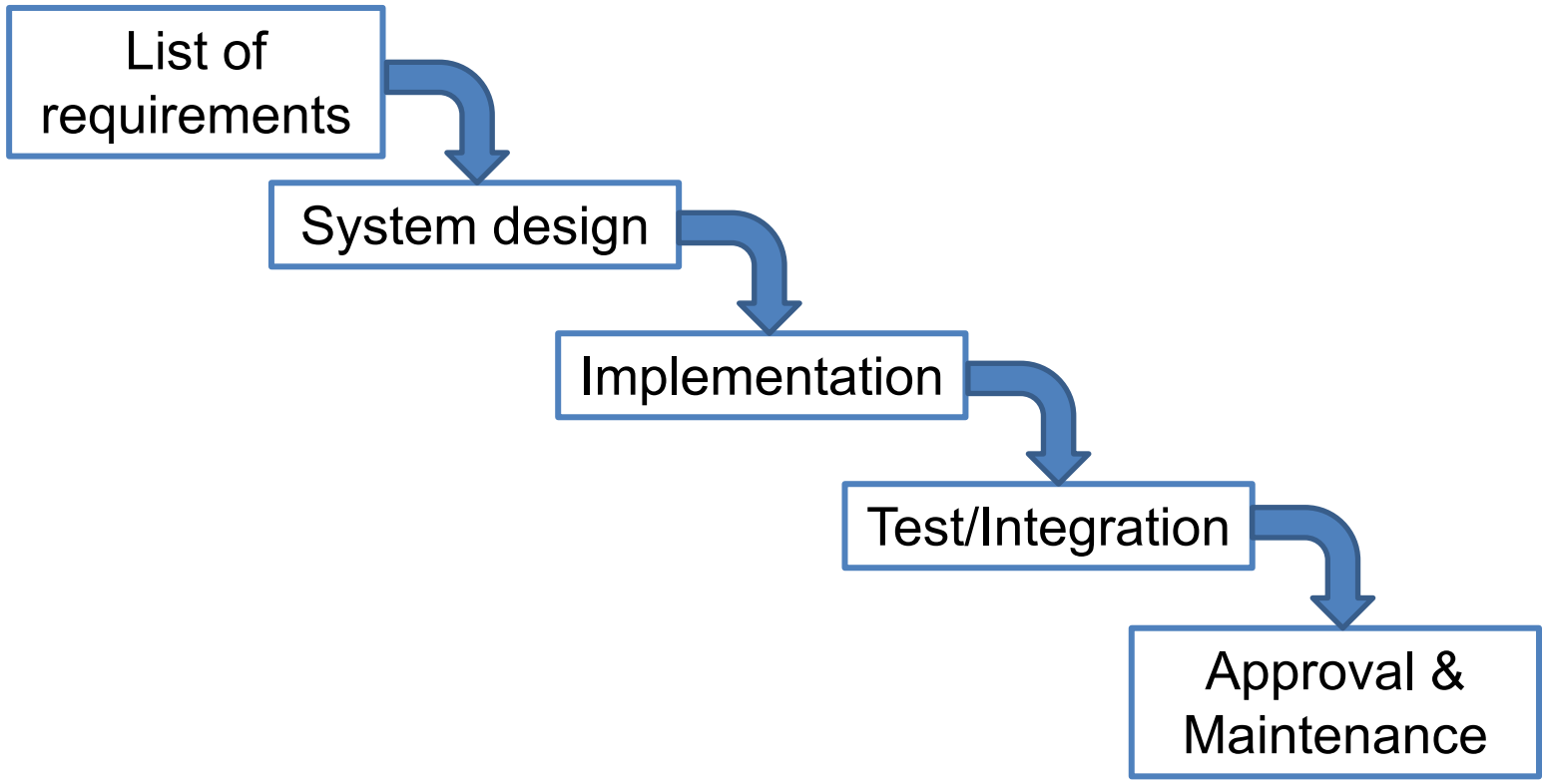
- planning of production process
- quality requirements
- human resource requirements and training
- operations planning
- layout planning
- system integration

- production scheduling
- production execution
- distribution and delivery of product/service
- execution of after-sale service

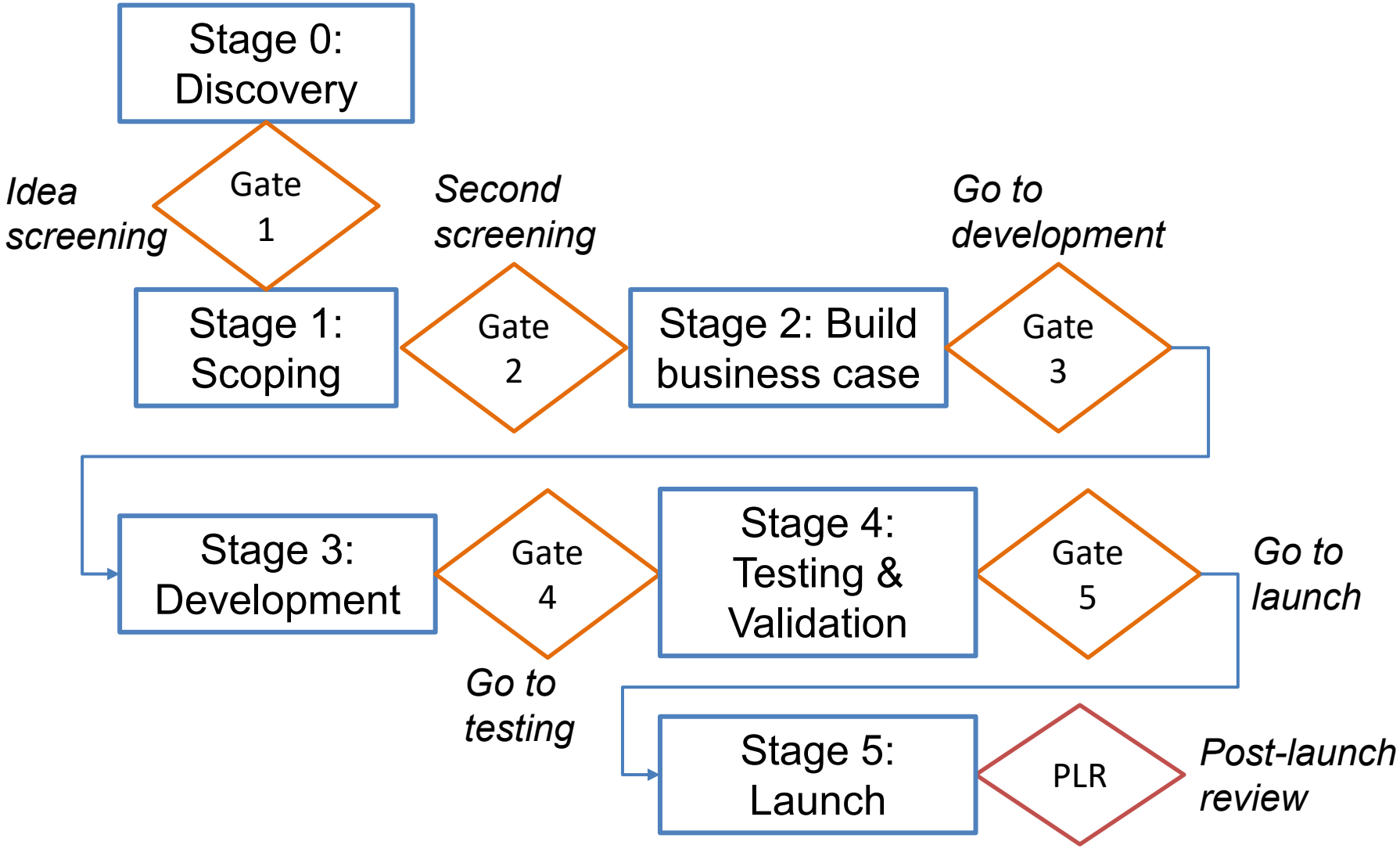
- management of product end-of-life

- These are the typical stages of a project for a new product.
- Other industrial projects do not have all these stages.

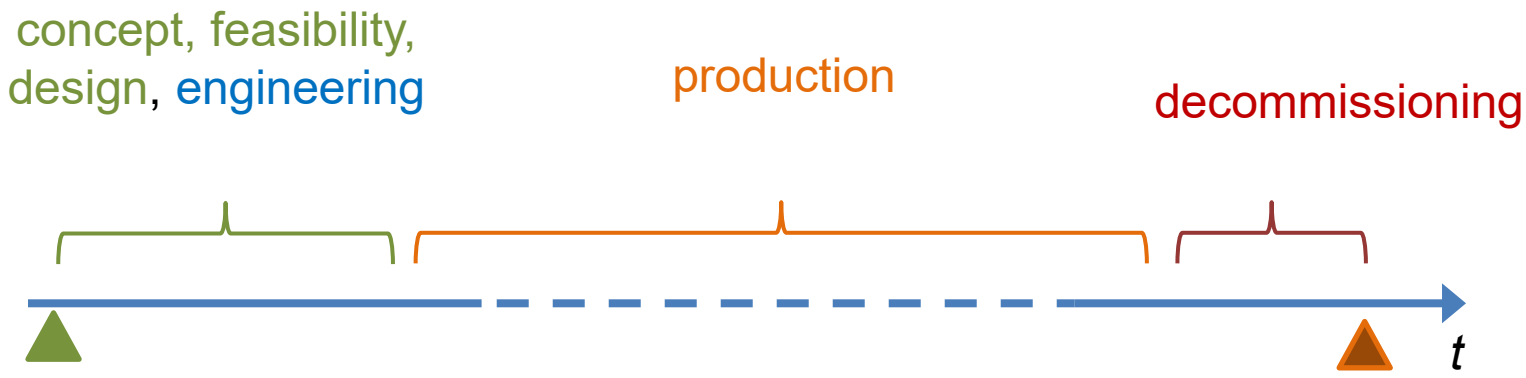
Waterfall model



Stage-gate model



- Example: a company will produce a high-efficiency plate heat exchanger for process industries
  - feasibility and development
  - engineering
  - production
  - decommissioning



- A product is always linked to at least one project.
- However, a product may include several designs (referring to components, stages or variants).
- If production and utilisation of the product are separated from the project, the life cycle of that project may be shorter than that of the product.
- If the main output of a project is a service, the end of the project corresponds to service termination.

- *Example*: Consider a production facility where a family (KV) of roller bearings is manufactured.

  The KV bearing heat treatment plant, is undergoing *upgrades* to reduce industrial water consumption and the energy absorbed by the pumping plant.

  The grinding line will be refurbished to enable more effective containment of diffuse dust emissions and separation of collected material.

- An enterprise must decide how to deploy resources in different projects and within the individual project.

Decisions and Evaluation

- What does the term *decision* mean?
- *Examples*:
  - choosing a technology
  - selecting a supplier
  - allocating financial resources to a production facility.

- R.A. Howard (1966) put forward a clear definition of *decision*:

  "*A decision is an irrevocable allocation of resources, irrevocable in the sense that it is impossible or extremely costly to change back to the situation that existed before making the decision.*

  (...) *a decision is not a mental commitment to follow a course of action but rather the actual pursuit of that course of action*."

- Decisions are made by individuals who are vested, by an organization or business, with the authority and responsibility to implement them.
- Often, such individuals (*decision makers*) also represent the interests of others.

(*Howard, R. 1966. Decision Analysis: Applied Decision Theory. In Proceedings Fourth International Conference Operational Research. pp. 55–71. Wiley-Interscience.)

- In *decision making*, two aspects can always be identified:
  - the *result* of the decision
  - the *process* leading to the decision.
- The decision maker (DM) performs a series of actions.
- In this he is *supported* by a *decision aiding process*.
- *Decision aiding*
  - is an activity
  - uses explicit models (not always formalized)
  - aims to provide answers to one or more actors in the decision-making process.

- The purpose of decision aiding is to make the final decision consistent with the goals and value system of the subjects for whom the activity is carried out (Roy, 1985*).
- The result of decision aiding process is a *recommendation* (*prescription*) that may or may not be followed by the actors.

(*Roy, Bernard. 1985. Méthodologie Multicritère d'Aide à la Décision. Paris: Economica.)

- A decision support method is effective when it enables the following
  - integrate “objectively” measurable aspects with value judgments
  - make explicit and manage aspects related to the inevitable subjectivity present in decision-making processes.

- According to Keeney and Raiffa (1972*), formal analysis is meant to serve as an aid to the DMs and not as a substitute for them.
  As a process, it is intended to force hard thinking about the problem area.

(* Keeney, Ralph L., and Howard Raiffa. 1972. "A Critique of Formal Analysis in Public Decision Making." In Analysis of Public Systems, edited by Alvin W. Drake, Ralph L. Keeney, and Philip M. Morse, 64-74. Cambridge, MA: MIT press).

- We will cover different methods that are united by the basic principle of *rationality* of the decision maker.
- In a nutshell, this principle states that the DM performs actions that are expected to produce desirable outcomes.
- We will better define the meaning of this principle for our context.

- Let us then introduce the principle of rationality in an industrial context

Decisions in production

- The production of a good or service requires the use of resources *that are diverted from other uses*.
- Examples:
  - hours-operator
  - energy
  - materials.
- Such use must therefore be justified: the transformation activity must *create value* for one or more beneficiaries.

- In particular:
  - the value generated must be greater than the value “consumed” in the transformation
  - the value generated must be greater than the value given up (alternative uses)
  - the balance between value obtained and value “spent” must be favourable to the former.

- We can say that a transformation generates value, in the first place, if the result of the process contributes to the achievement of the *customer*'s goals.
- Different activities will enable these goals to be met to varying degrees (*effectiveness*).
- For the same result, different activities may use more or fewer resources (*efficiency*).

- Business activity can be viewed as a succession of projects.
- Resources are needed
  - for the *acquisition* of *assets* necessary for production
  - for operating and managing assets in production.
- The success of the enterprise depends on its ability to select projects and allocate resources to them efficiently.

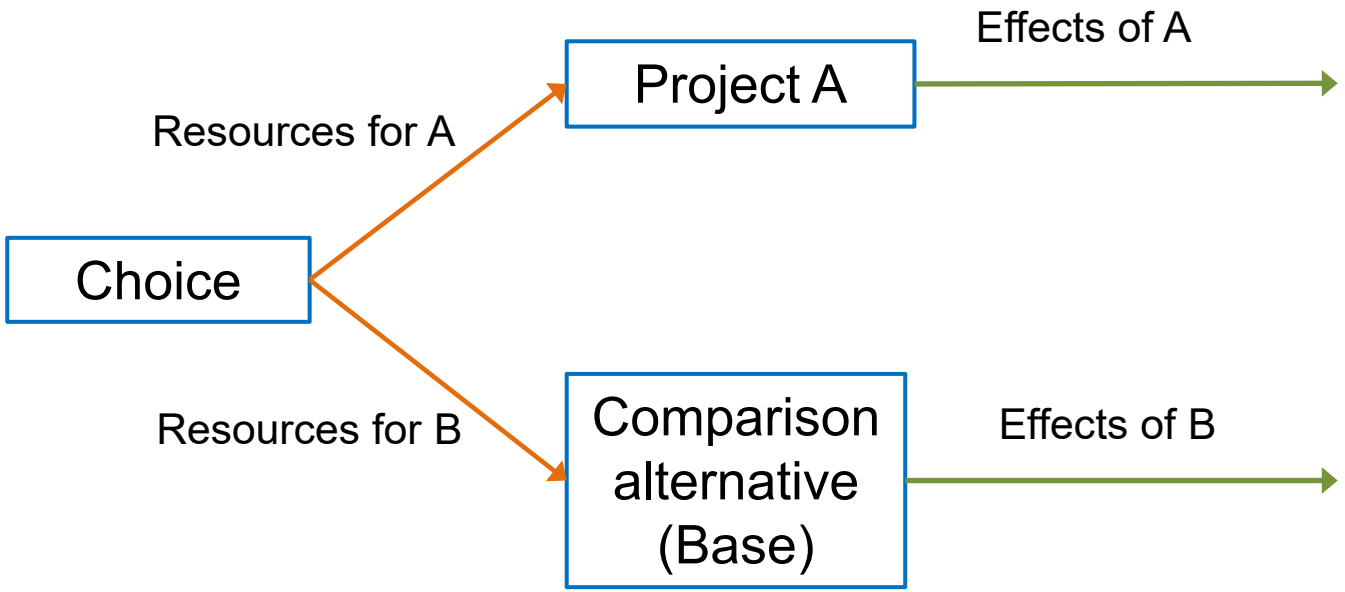
- The purpose of *economic evaluation* is to weigh the costs and benefits of a project referable to all project stakeholders.
- Aspects to be evaluated in a project:
  - alignment between a project and the enterprise's strategy
  - market opportunity of the product or service realised by the project
  - economic feasibility
  - technical feasibility.

- In engineering, a project must ensure the technical feasibility of proposed solutions.
- In case there are more than one *technically feasible* solution, the choice of the solution to be implemented cannot disregard the comparison between solution performances.
- Specifically, the solution that provides the most favourable result, comparing the *benefits produced* and the *costs incurred*, will be chosen.

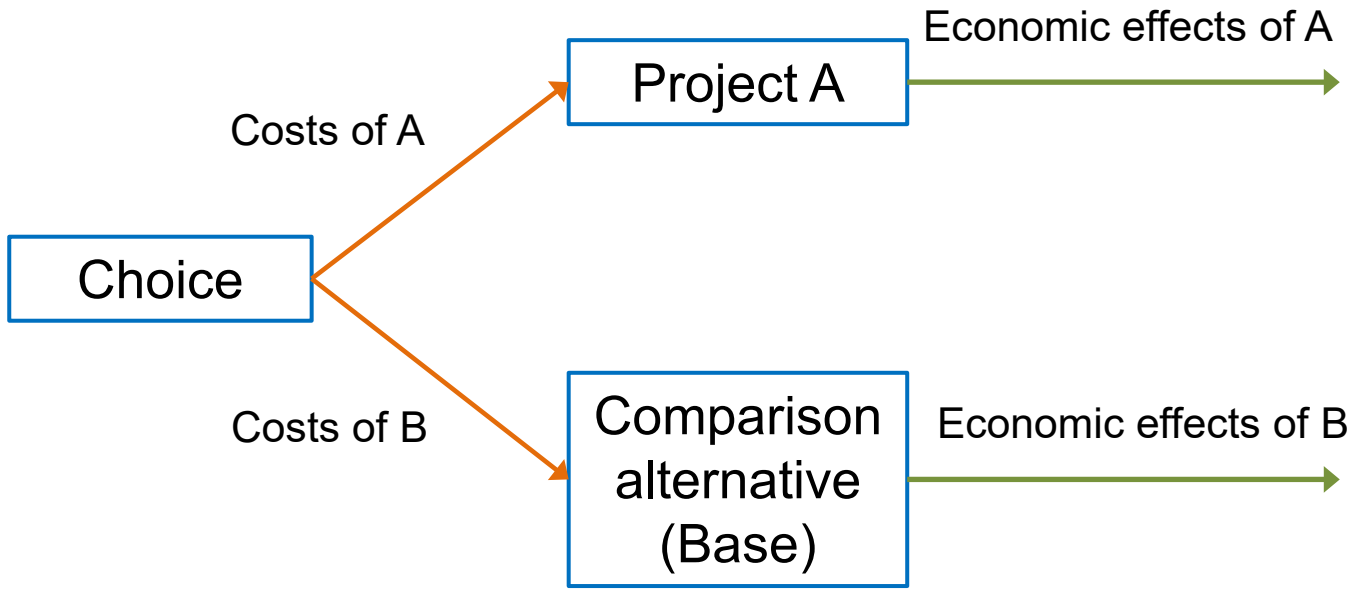
- In industry, production activity is performed through *facilities* and *infrastructure*.
- A production facility (e.g., a welding station) absorbs resources
  - in the *design* phase
  - under *construction*
  - during *operation*.

- The use of resources is justified if the facility generates value that is adequate to achieve the goals of the enterprise.
- Evaluation/decision-making problems ensue:
  - Comparing one project or program with others that are feasible based on available or achievable resources, is it worth undertaking?
  - Comparing a project to the status quo, is there convenience in implementing it?
  - If different solutions can be deployed to solve a problem or seize an opportunity, how do we select the most effective one?

Solutions and projects



- From an economic perspective:

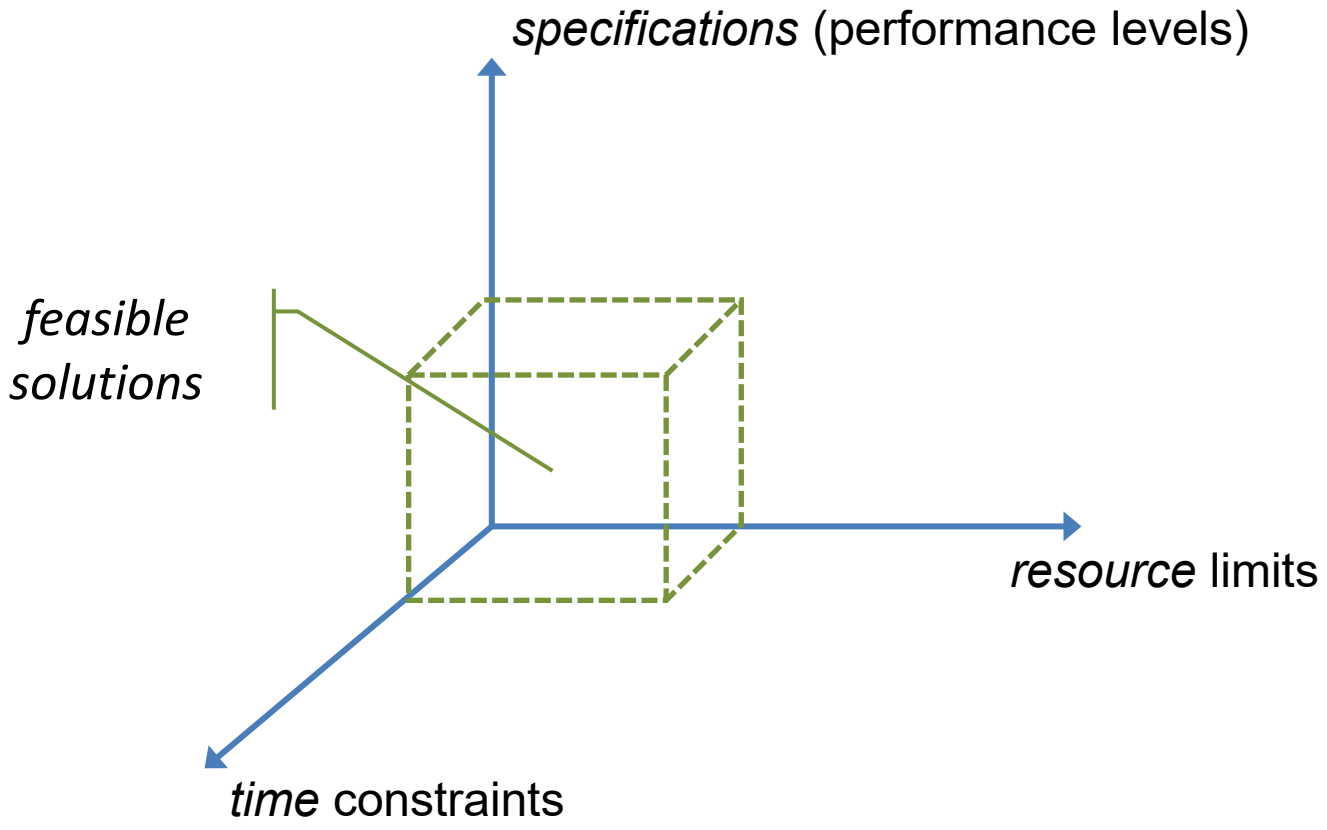


- Evaluation activities involve the acquisition of information of different kinds (technical, economic, organizational, etc.).
- In complex cases, the decision maker does not have all the information or expertise needed to develop a useful assessment.

The role of the industrial engineer

- The role of the engineer can be summarized as finding solutions (technical, but not only) to a problem posed by a “client”.
- The technical aspect cannot be isolated from others.
- For instance, economic motivations influencing technical choices should be included.
- Consumers often base their decisions on cost factors: it is essential that the engineer understands these motivations.
- Therefore, the industrial engineer must develop not only specialized but interdisciplinary skills.

- The development of a solution is subject to constraints that define its feasibility.



- Production systems, infrastructure and service facilities are both *technological assets* and *financial assets*.
- They are therefore subject to technical and economic-financial evaluations.
- Such assets have a *life-cycle* (life-cycle), within the production structure, which includes several stages:
  - design or selection
  - acquisition (of the system or components)
  - installation
  - management and operation
  - decommissioning and divestment.