Introduction of Design

- The nature and methodology of the design process
- Its application to the design

Designing

It involves creative problem solving and team work in which basic knowledge in chemical engineering and economics are applied and flavored by the humanities and social science.

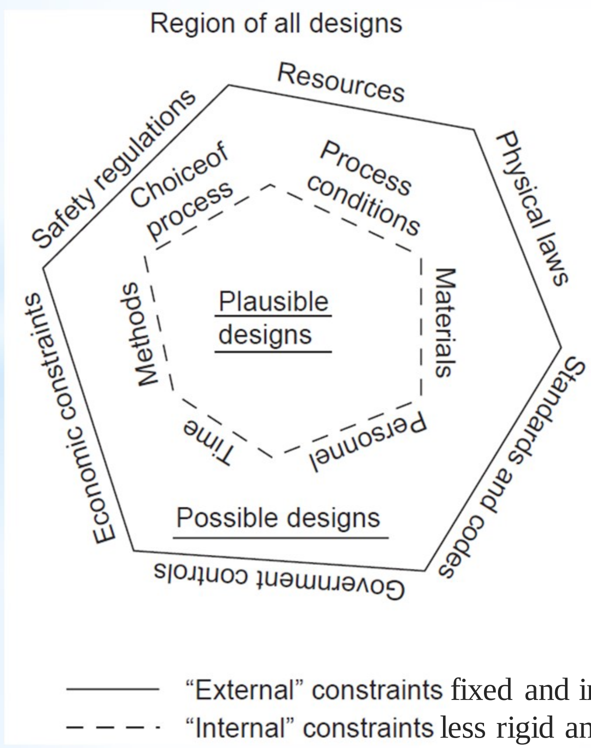
Nature of design

When designer considering all possible ways of achieving the objective, then he has faced constraint by many factors, which narrow down the number of possible designs.

However, it is rare that just one possible solution to the problem, means just one design.

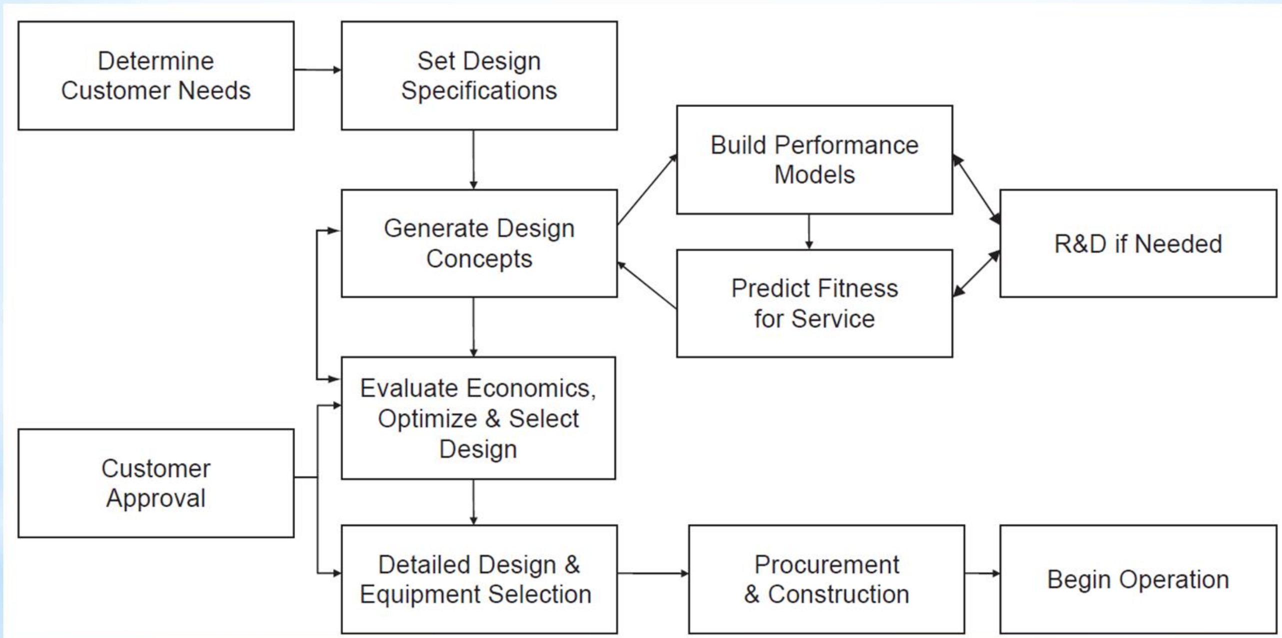
Several alternative ways normally be possible to meet the objective.

Even several designs are best, depending on the nature of the constraints.



Design Constraint

The stages in the development of a design, from the initial identification of the objective to the final design.



Design Process

The Design Objective (The Need)

In the design of a chemical process, the need is the public need for the product, creating a commercial opportunity, as foreseen by the sales and marketing organization.

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From the overall objective, the designer will recognize sub-objectives, the requirements of the various units that make up the overall process.

It is important to distinguish between the needs that are "must haves" and those that are "should haves."

The "should haves" are those parts of the initial specification that may be thought desirable, but that can be relaxed if required.

For example:
A particular product specification may be considered desirable by the sales department, If it is difficult to achieve and costly to obtain, then some relaxation are given in the specification if possible and produce a saleable but cheaper product.

Setting the Design Basis

The most important step in starting a process design is translating the customer need into a design basis.

It will normally include the production rate and purity specifications of the main product, together with information on constraints that will influence the design, such as

1. The system of units to be used.
2. The national, local or company design codes that must be followed.
3. Details of raw materials that are available.
4. Information on potential sites where the plant might be located, including climate data, seismic conditions, and infrastructure availability.
5. Information on the conditions, availability, and price of utility services such as fuel (gas), steam, cooling water, process air, process water, and electricity, that will be needed to run the process.

Generation of Possible Design Concepts

Creative part of the design is the generation of possible solutions to the problem for analysis, evaluation, and selection.

In this activity, most designers largely rely on previous experience—their own and that of others.

For Example:

In the chemical industry, modern distillation processes have developed from the ancient stills used for rectification of spirits.

Experienced engineers usually prefer the tried-and-tested methods, rather than possibly more exciting but untried novel designs.

Commercialization of new technology is difficult and expensive, and few companies are willing to make multimillion

dollar investments in technology that is not well proven.

Development of new processes inevitably requires much more interaction with researchers and collection of data from laboratories and pilot plants.

Chemical engineering projects can be divided into three types, depending on the novelty involved:

A. Modifications, and additions, to existing plant; usually carried out by the plant design group.

B. New production capacity to meet growing sales demand and the sale of established processes by contractors.

C. New processes, developed from laboratory research, through pilot plant, to a commercial process.

Fitness Testing

Design engineer determine how well each design concept meets the identified need.

In the field of chemical engineering, it is usually excessively expensive to build several designs to find out which one works best.

Therefore, the design engineer builds a mathematical model of the process, containing reactors, and other key equipment and solve the model usually in the form of computer simulations.

In some cases, the performance model may include a pilot plant or other facility for predicting plant performance and collecting the necessary design data.

Once the data has been collected and a working model of the process has been established, then the design engineer determine equipment sizes and costs.

At this stage it will become clear that some designs are uneconomical and they can be rejected without further analysis.

At last, make sure that all of the designs that are considered are fit for the service, i.e., meet the customer's "must have" requirements.

Economic Evaluation, Optimization, and Selection

Once the designer has identified few designs that meet the customer objective, then the process of design selection can begin.

The primary criterion for design selection is usually economic performance, while factors such as safety and environmental impact may also play a strong role.

The economic evaluation of design usually entails analyzing the capital and operating costs of the process to determine the return on investment.

When all of the applicant designs have been optimized, the best design can be selected.

Sometimes several designs have very close economic performance, in which case the safest design or that which has the best commercial track record will be chosen.

Detailed Design and Equipment Selection

The detailed specifications of equipment such as vessels, exchangers, pumps, and instruments are determined.

The design engineer may work with other engineering disciplines, such as civil engineers for site preparation, mechanical engineers for design of vessels and structures, and electrical engineers for instrumentation and control.

Many companies engage specialist Engineering, Procurement, and Construction (EPC) companies, commonly known as contractors, at the detailed design stage.

The EPC companies maintain large design staffs that can quickly and competently execute projects at relatively low cost.

During the detailed design stage there may still be some changes to the design, and there will certainly be ongoing optimization

Procurement, Construction, and Operation

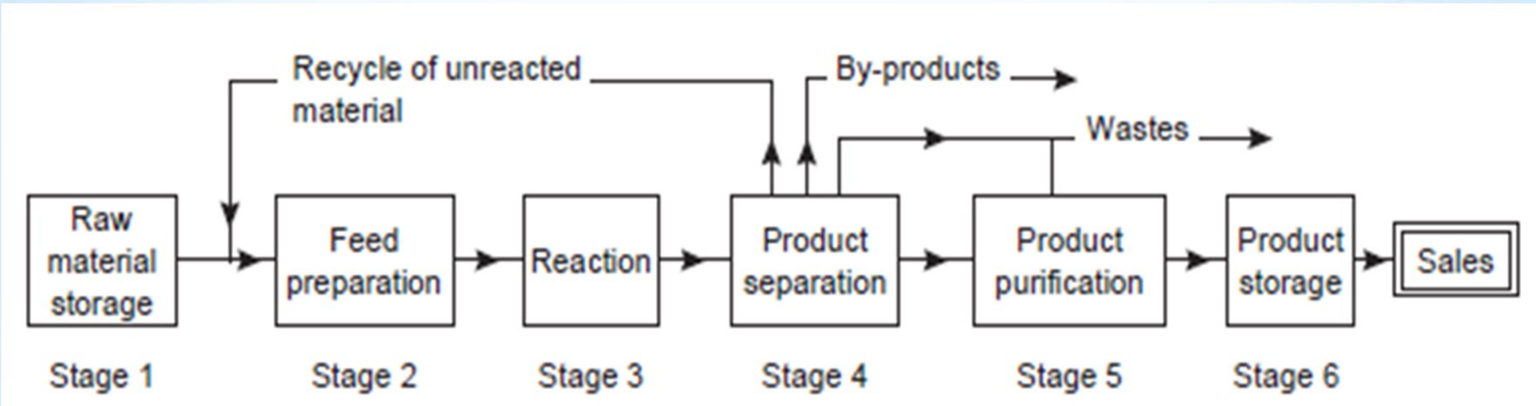
When the details of the design have been finalized, the equipment can be purchased and the plant can be built.

Procurement and construction are usually carried out by an EPC firm unless the project is very small. Because they work on many different projects each year.

EPC firms are able to place bulk orders for items such as piping, wire, valves, etc., and can use their purchasing power to get discounts on most equipment.

The EPC companies also have a great deal of experience in field construction, inspection, testing, and equipment installation.

The Anatomy of a Chemical Manufacturing Process



Each block represents a stage in the overall process for producing a product from the raw materials.

The complexity of each stage will depend on the nature of the process.

Stage 1. Raw material storage: some provision will have to be made to store raw material for several days' or weeks' to tolerate any fluctuations and interruptions in supply.

Stage 2. Feed preparation: Some purification and preparation of the raw materials will usually be necessary before they fed to the reaction stage.

Stage 3. Reaction: The reaction stage is the heart of a chemical manufacturing process.

Stage 4. Product separation: After the reactor(s) the products and byproducts are separated from any unreacted material. If in sufficient quantity, the unreacted material will be recycled to the reaction stage or to the feed purification and preparation stage.

Stage 5. Purification: Before sale, the main product will often need purification to meet the product specifications.

Stage 6. Product storage: Some inventory of finished product must be held to match production with sales.

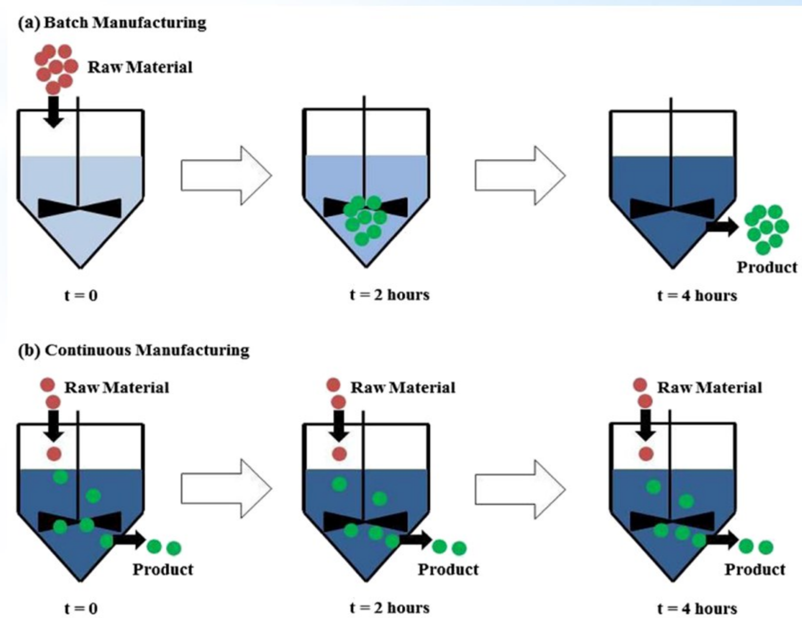
Ancillary Processes

In addition to the main process stages provision must be made for the supply of the services (utilities) needed, such as process water, cooling water, compressed air, and steam.

Facilities are also needed for maintenance, firefighting, offices and other accommodation, and laboratories.

Continuous and Batch Processes

Continuous processes are designed to operate 24 hours a day, 7 days a week, throughout the year.



Some downtime will be allowed for maintenance and, for some processes, catalyst regeneration.

The plant attainment or operating rate is the percentage of the available hours in a year that the plant operates, and is usually between 90 and 95%.

$$\textbf{\textit{Attainment}}\ \% = \frac{\textbf{\textit{hours operated}}}{\mathbf{8760}} \times \mathbf{100}$$

Batch processes are designed to operate intermittently and the process units being frequently shut down and started up.

It is quite common for batch plants to use a combination of batch and continuous operations.
For example:
A batch reactor may be used to feed a continuous distillation column.

Continuous processes	Batch processes
Usually be more economical for large-scale production.	When some flexibility is wanted in production rate or product specifications.

Advantages of batch process

- Batch processing allows production of multiple different products or different product grades in the same equipment.
- Integrity of a batch process is preserved as it moves from operation to operation. This can be very useful for quality control purposes.
- The production rate of batch plants is very flexible, as there are no turn-down issues when operating at low output.
- Batch plants are easier to clean and maintain sterile operation.
- Batch processes are easier to scale up from chemist's recipes.
- Batch plants have low capital for small production volumes. The same piece of equipment can often be used for several unit operations.

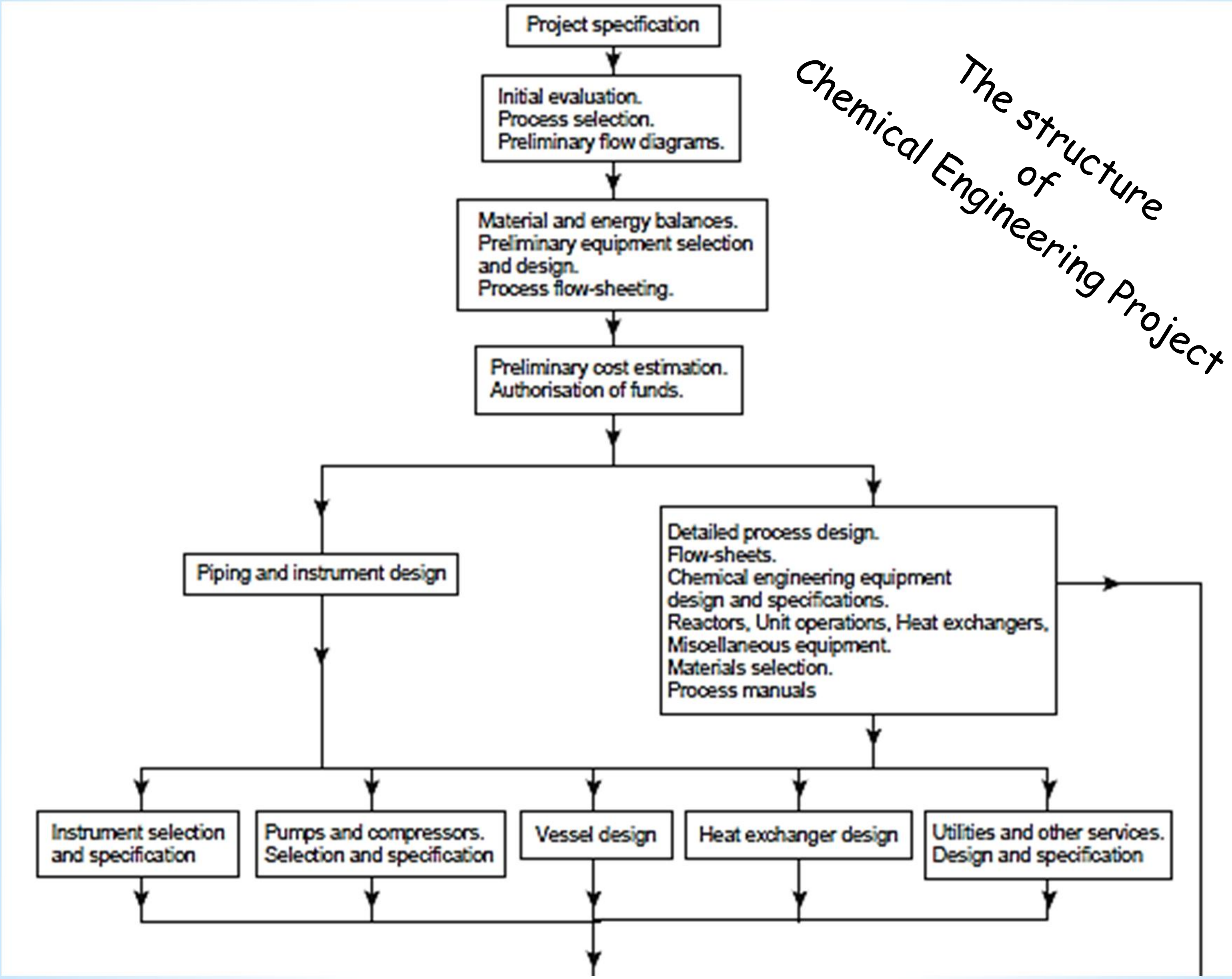
Drawbacks of batch process

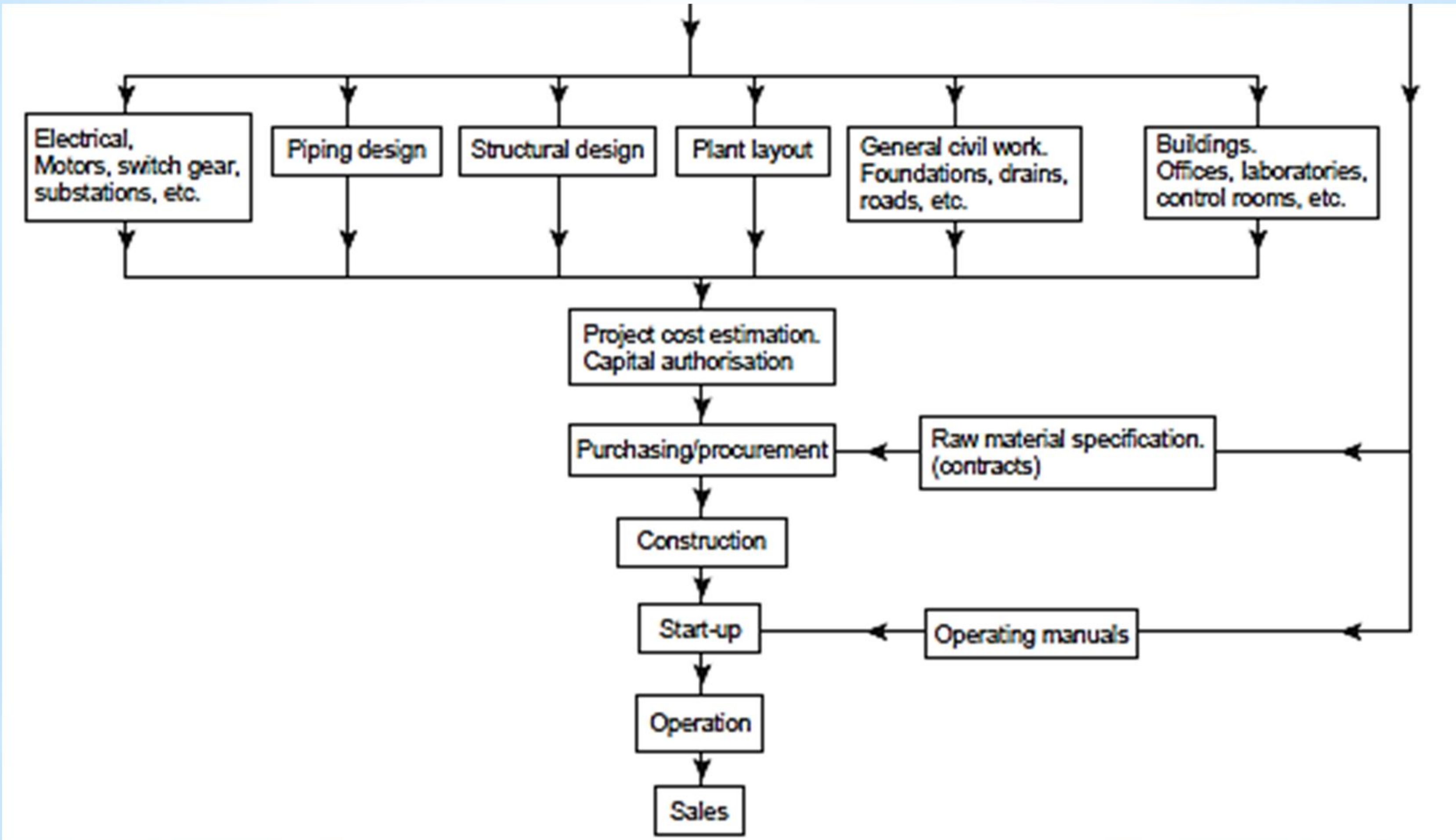
- The scale of production is limited.
- It is difficult to achieve economies of scale by going to high production rates.
- Batch-to-batch quality can vary, leading to high production of waste products or off-spec product.
- Recycle and heat recovery are harder, making batch plants less energy efficient and more likely to produce waste byproducts.
- Asset utilization is lower for batch plants, as the plant almost inevitably is idle part of the time.
- The fixed costs of production are much higher for batch plants on a $/unit mass of product basis.

Batch plants are commonly used for

- Food products
- Specialty chemicals
- Personal care products
- Pharmaceutical products such as drugs, vaccines, and hormones

The structure of Chemical Engineering Project




Electrical,
Motors, switch gear,
substations, etc.
Piping design
Structural design
Plant layout
General civil work.
Foundations, drains,
roads, etc.
Buildings.
Offices, laboratories,
control rooms, etc.
Project cost estimation.
Capital authorisation
Purchasing/procurement
Raw material specification.
(contracts)
Construction
Start-up
Operating manuals
Operation
Sales

Project organization