Engineering Projects and the Role of Design

The Lifecycle of an Engineering Asset

Engineers get involved at all stages of the life of an engineering asset – a bridge, tunnel, power station, mobile phone, etc. Some of these stages are:

Stage	**Example**
Strategic planning – What will we need in 5, 10 or 20 years time?	How will we meet Melbourne's water needs over this period?
Research & Development – What gaps in our understanding do we need to plug? How do we do this?	We need to research changing patterns of water consumption in Melbourne over the next 20 years.
Conceptual design – What solution do we need?	What is the next water supply option for Melbourne?
Detailed design – How should this solution be specified, ready to build?	If recycled water is the solution, how big does the plant need to be, what equipment is required, what will it cost, how will it be financed? Where should it be built?
Construction – How will we build the preferred design?	What project management and construction management is required? What equipment, people and other resources will be required?
Commissioning and Operation – What plans and training do we need to operate this plant? What regular maintenance is required? How will this fit around production schedules?	How will our new recycled water plant be operated and maintained? How will safety be embodied?
Decommissioning – Closing a plant or other asset. What else is required? Does it need to be demolished or recycled? In what way will the site be returned to its original state?	At some point, the recycled water plant will be inefficient or of limited capacity. It may need to be removed or refurbished, generating another project.

Of all these processes, design is the easiest to teach at university. The processes of conceptual design and detailed design are discussed in more detail below. In your university studies, you may also have opportunity to explore the engineering processes required in each of the other stages of the lifecycle of an engineered asset.

Competency being developed

Engineers Australia's competency statement for design is:

2.3 Application of systematic engineering synthesis and design processes.

a) Proficiently applies technical knowledge and open-ended problem solving skills as well as appropriate tools and resources to design components, elements, systems, plant, facilities and/or processes to satisfy user requirements.

b) Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.

c) Executes and leads a whole systems design cycle approach including tasks such as:
- determining client requirements and identifying the impact of relevant contextual factors, including business planning and costing targets;
- systematically addressing sustainability criteria;
- working within projected development, production and implementation constraints;
- eliciting, scoping and documenting the required outcomes of the design task and defining acceptance criteria;
- identifying assessing and managing technical, health and safety risks integral to the design process;
- writing engineering specifications, that fully satisfy the formal requirements;
- ensuring compliance with essential engineering standards and codes of practice;
- partitioning the design task into appropriate modular, functional elements; that can be separately addressed and subsequently integrated through defined interfaces;
- identifying and analysing possible design approaches and justifying an optimal approach;
- developing and completing the design using appropriate engineering principles, tools, and processes;
- integrating functional elements to form a coherent design solution;
- quantifying the materials, components, systems, equipment, facilities, engineering resources and operating arrangements needed for implementation of the solution;
- checking the design solution for each element and the integrated system against the engineering specifications;
- devising and documenting tests that will verify performance of the elements and the integrated realisation;
- prototyping/implementing the design solution and verifying performance against specification;
- documenting, commissioning and reporting the design outcome.

d) Is aware of the accountabilities of the professional engineer in relation to the 'design authority' role.

The Design Process

Much engineering work requires the design of new artefacts (buildings, chemical processing plants, waste treatment facilities, electric vehicles, etc). Design typically moves through two major stages:

- **Conceptual design (or preliminary design)** is intended to recommend a suitable solution to a complex problem. It often requires broad estimates rather than detailed analysis. The basic question here is: *What solution is required?*
- **Detailed design** brings into play detailed analysis techniques for the specification of pieces of infrastructure and equipment. The basic question here is: *How will the solution be implemented?*

Both stages require the range of phases described below.

Phases

Projects typically pass through a series of phases as they move from client need to project implementation. These phases are shown in the diagram below. Each phase produces **documentation**, the lifeblood of engineering work.

Phase	Description	Documentation
Client Need	The **client need** begins the process, usually by providing a *client brief* to the consultant/engineer. The client brief may or may not provide a clear statement of the problem.	Client brief
Planning	At this stage, there needs to be some **planning** to decide how we will address this client need. This could be as simple as estimating the immediate workload impact and who might do the work. This planning results in a preliminary workplan or project plan.	Project plan
Problem definition	When the work begins, the immediate need is to properly **define the problem**. (Clients often report symptoms rather than problem definitions). From this phase comes a problem specification, which would often be discussed with the client so there is mutual understanding of the scope of work required.	Problem specification
Research	Around the problem definition, there is often the need for **research**, including data gathering. In fact, much of this may need to be done before the problem specification can be written. The research will produce a range of briefing papers on particular topics. The research phase will also identify potential solutions or actions for this problem.	Briefing papers
Selection criteria	An essential part of the problem definition is to decide on some **selection criteria**. All problems have multiple ways of being resolved. The selection criteria will be the measures against which we will evaluate all the possible solutions. Some of these will be quantitative (eg, cost, weight, height, loudness, salinity, etc) while others will be qualitative (eg, desirability, aesthetics, etc). They are usually developed in conjunction with stakeholders. The selection criteria will typically take a sustainability approach – social, environmental, economic and social criteria. Risk minimization and quality management will be other criteria.	Selection criteria (agreed with clients and stakeholders)
Alternative actions	A range of **alternative actions** needs to be identified. This will involve research as well as creative thinking, which is best done with your whole group. These alternatives would likely be discussed with the client.	Alternative solutions
Analysis	Once a set of alternatives has been generated, an **analysis** phase begins. This is the stage where your technical engineering skills come to the fore. Typically, there are many calculations to perform, calculating stress, energy needs, water quality, etc.	Computer analyses; summaries; design reports

Phase	Description	Documentation
	Evaluation may also require other forms of data gathering, eg, community surveys. This phase produces one or more design reports.	
Decision (choosing)	When all the data have been gathered, a **decision** must be made. Each alternative is evaluated against the original selection criteria and a recommendation made to the client. Much discussion (and disagreement) may ensue around this decision making process!	Recommendation report
Evaluation	An agreeable solution for the client does not end the process. Quality assurance processes within companies will require that the project process is **evaluated** for improvement possibilities. This is a reflective process that is aimed at improving company performance in a very competitive environment. This process may require talking with the client to make sure that they have received satisfactory service. This stage will result in some form of final project report.	Evaluation report

In the following diagram (Figure 1), these phases are presented as a Gantt chart, which is a common representation for engineering projects. It gives a quick visual representation of how the tasks (phases) are arranged within the project timeframe. It shows that you often have to revisit previous phases (eg, collect new information) before you can move forwards again.

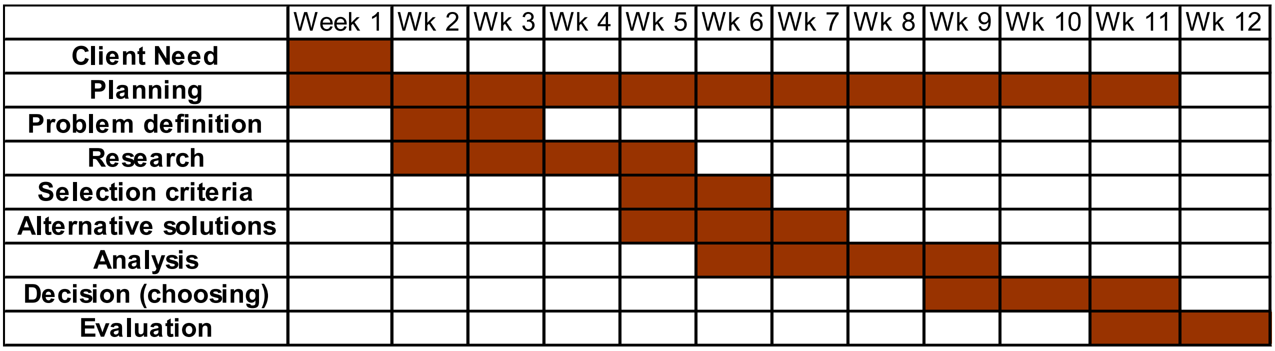


Figure 1 -Gantt chart of the process

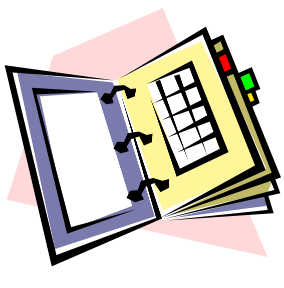
Once the project is complete, we are ready to begin a new project. Sometimes this means doing the detailed design once we're finished the conceptual design.

Detailed design

It is likely that at the end of the first problem solving round that the client wishes to move towards implementation. For example, if the recommendation is to build something, there will need to be a second round of design that produces a set of detailed drawings and specifications in readiness for tendering and construction.

Within this process, all of the phases mentioned above come into play at many different levels within the detailed design.

Documenting the process

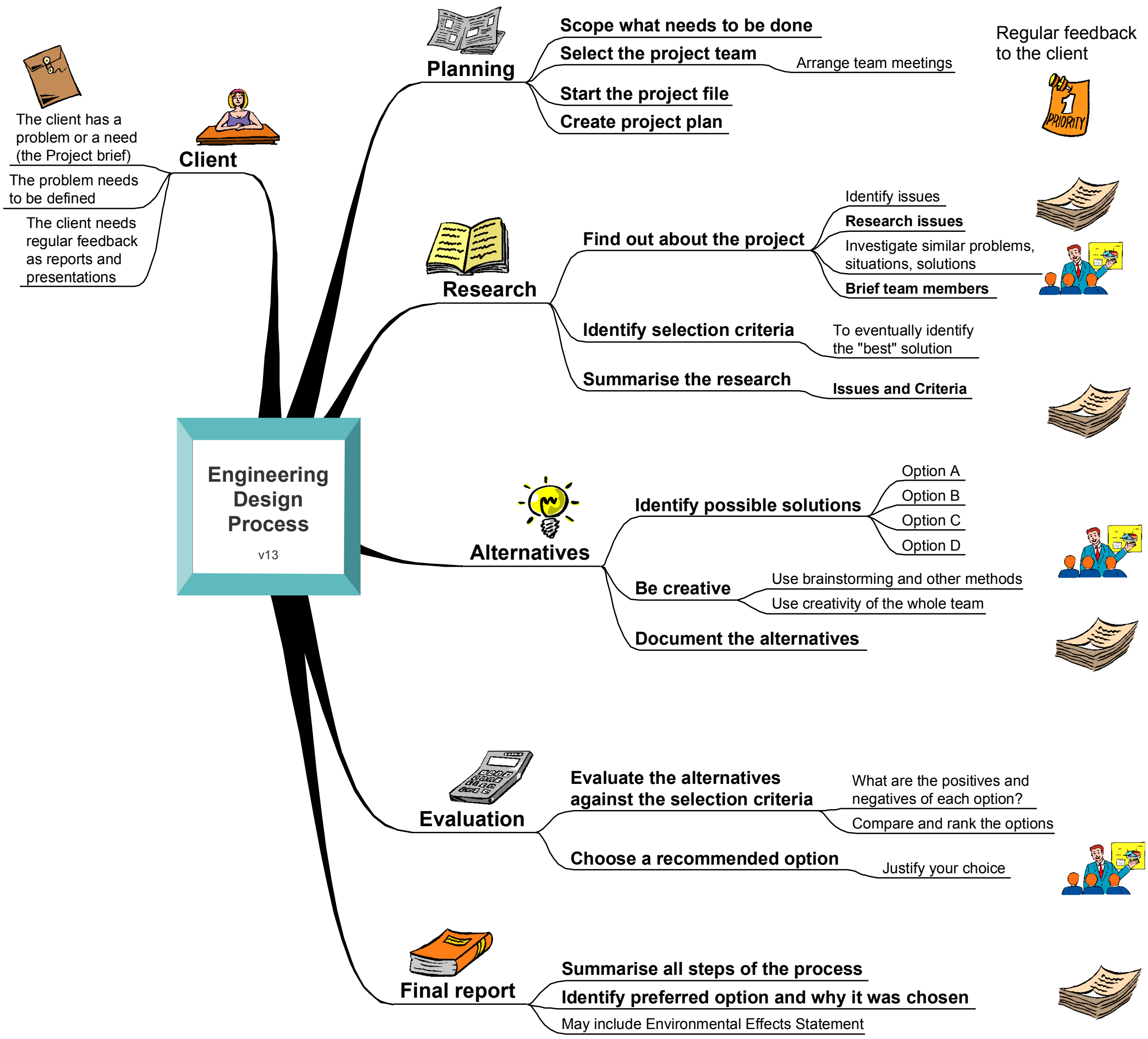


The discussion above clearly shows the range of documentation that must be produced within an engineering project. Any project team needs a way of keeping all of that documentation together, both on paper and electronically. There is more information in another chapter (p11) on keeping track of all this information using a **Design File**. We have also discussed the advantage of a group website or wiki for tracking all the documents you produce (p5). Email is also helpful, as are mobile phones and SMS.

In your design projects, we will ask you to submit some or all of these documents for assessment. The regular production of documentation helps us to project manage your design team (and all the other teams in the class). It is also an essential engineering skill, as described on p11.

Summary

Here is a summary of the design process as a mindmap:



More information

See Dowling, Carew and Hadgraft (2010) and Dym and Little (2008) as well as many other introductory books on Engineering design.