APS112: Engineering Strategies & Practice II

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Preface and Acknowledgements

Engineering Strategies & Practice (ESP) is a two-course program within the first-year curriculum at University of Toronto's Faculty of Applied Science & Engineering. These are introductory design courses, meaning that students work in teams on projects brought forward by real-life clients. In the fall semester, all groups work on one of a few projects brought forward by the same client (Hart House in my year, and Sidney Smith Commons the year prior). In the winter semester, however, teams work on projects that come a wide variety of clients at UofT and in industry. The primary text for this course is *Designing Engineers: An Introductory Text*, written mostly by University of Toronto professors.

This notes package is in no way a complete representation of the course. That being said, this notes do a good job of covering the content that will be covered in the midterm assessment, which is all the textbook readings from the winter semester. Know that everything you lean in APS111 (ESP I) also applies to this course.

There is one topic not covered well in the textbook – reading & making Gantt Charts. There will be, without doubt, at least a few questions on Gantt Charts, and this website is a good tool to recheck (or gain) your knowledge of them [click me!].

This study guide was written in LaTeX using Overleaf. The source project can viewed here [click me!]. Additionally, my notes for APS111 (ESP I) can be found here [click me!]. If you find any errors (or just want to provide feedback) feel free to reach out to arnav.patil@mail.utoronto.ca!

1 Skeptical Thinking

Introduction

- Skeptical thinking is a process of questioning information.
- Systematic doubt means you do not accept an idea as valid without testing and retesting it.

What Skepticism is Not

- A cynic is someone who has a negative view of the world and is unwilling to accept new ideas.
- In the absence of good evidence, a skeptic does not judge.

Two Techniques for Skeptical Thinking

- Triangulate - find two or more sources that support the original source.
- Look for a counter-example: it only takes one proven falsehood to disprove a claim, no matter how many tests can prove it to be true.

Three Obstacles to Skeptical Thinking

1. Confusing correlation with causation.
2. Confusing examples for evidence.
3. Creating false dichotomies - a dichotomy is a two-sided idea.
   (a) An example of creating a false dichotomy is: "If A is false, then NOT A (the opposite of A) must be true."

2 Estimating Cost and Time

Creating the Plan: Finding Time/Cost Information

- Project planners must think carefully when using published information and consider issues such as scaling.
- Some typical sources of major error in estimation.
  - Not allowing sufficient time for preparation tasks and disruptions in the workplace.
  - Not sufficiently allowing for the conditions of equipment and systems.
  - Time taken for testing is not allocated or considered.
  - Informing and communication, which take up a large amount of a project planner's time.
  - Using ideal estimation, which means you do not include the 'fudge factor.'
- **Effort driven versus fixed duration** → Effort driven tasks are those whose time can be reduces by increasing the effort on the task (called man-hours or resource-hours). Tasks that cannot be finished faster by throwing resources are known as fixed-duration tasks.

Trading Cost for Time

Project cost will tend to decrease if more time is allowed for finishing the project, only up to a point. Then the cost will increase. This suggests there exists a **target time to completion**.

3 Client Meetings

Preparing for a Meeting

- In order to get the most out of any communication, you should prepare an audience assessment.
- A brief outline of topics that will be discussed will often be communicated in advance of the meeting as an agenda.
- Make a list of open AND closed questions.

4 Introduction to Estimation

Why Not Just Compute the Answer?

- In engineering practice, we won't have the necessary time or information required to make an accurate estimation.
- A **ballpark answer** is one that is very approximately correct.
- An **order of magnitude estimate** is one that is within a factor of ten of the true answer.
- **Back of the envelope** answers provide very quick approximate answers, based on what is known/easily known.

Basic Estimation Process

1. Determine the underlying questions, and work out how much accuracy the answer needs.
2. List the data that is available or easily found.
3. Brainstorm one or more approaches to the calculation and choose the most promising one.
4. Find sufficiently accurate values for the input data required.
5. Determine the key physical relationships that must be used in the calculation.
6. Perform the calculation.
7. Consider the potential error bounds for the calculation given the approximations made.

5 Estimation Techniques

Basic Methods

- Perform unit analysis to make sure you correctly went from the input units to the output units.
- As a rule of thumb, you don't need data to be more accurate than the least accurate piece of data you are going to use.

Finding the Information for an Estimate

- Measuring length, area, or volume.
- Working from known information. Interpolate or extrapolate as needed.
- Sometimes engineers can get estimated using a complexity count, which is a count of the difficult and interrelated parts of the system.

6 Design for Safety

Introduction

- A consideration of safety is normally considered to be one of the most design for X principles.
- Good engineers design protective and warning systems, and create training and operational protocols to make losses unlikely.
- A hazard is a situation where there is a possibility of damage.
- The result of exposure to said hazard is called a consequence.
- Unintentional exposure to the hazard is called an accident.
- The destruction resulting from an accident is characterized by its severity.
- The combination of severity of an accident and its probability is called risk, which is quantified as:

$$\textbf{risk} = \textbf{(severity \& cost of consequence)} \times \textbf{(probability of occurrence)}$$

- To reduce the risk threshold below the acceptable risk, we can:
  - Eliminate specific hazard or risk,
  - Reduce or mitigate the risk,
  - Guard against the risk, and
  - Warn against the risk.

7 Design for Human Factors

Introduction

- Designing so that technology can work effectively with all people on all levels is known as ergonomics.
- Information on human physical characteristics is known as anthropomorphic data.

Used-Centred Design

- Engineers put a lot of effort into creating a system that is in tune with people. This is called user-centred or human-centred design.
- More recently, user-centred design has evolved to address more broadly the psychological needs and feelings of people.
  - One step is experience design (UX), which takes into account the quality of the experience the user has when interacting with the technology.
- Tools such as use cases and snapshots are used to help the designer envision the users' experience.
- Storyboards and scenarios can be worked up to assist the designer in imagining the technology from the user's perspective.

Participatory and Universal Design

- Participatory design brings people from the target group into the design process as members of the design team.
- A universal design approach uses a set of principles to design for a broad range of users.
- From the North Carolina State University Centre for Universal Design:
    1. Equitable use,
    2. Flexibility in use,
    3. Simple and intuitive to use,
    4. Perceptible information,
    5. Tolerance for error,
    6. Low physical effort, and
    7. Size and space for approach and use.

8 Sustainability

Basic Principles of Industrial Ecology

- Industrial ecology is a variation of the life cycle assessment method that looks at the life cycle of a product or technology as an ecological system.
- Industrial ecology does not acknowledge that all production comes at a cost; a cost of energy and an opportunity cost, meaning the opportunity to leave the raw materials in their natural state for future use.
- A different approach is preventative engineering which makes this distinction and emphasizes reduce as the first key principle.

9 Introduction to Project Management

Overview of Project Management

- A Gantt Chart is a typical representation of a plan for project management.
- Each task requires a duration of time to be finished, and resources that are put towards finishing it.
- Predecessors of a task are other tasks that must be completed prior to the task in question.
- To be the most useful, the task - or the smallest managed activity - should need the following criteria:
    1. The work done for a task is closely interrelated.
    2. The task has a testable outcome.
    3. A task requires one set of interconnected resources.
    4. The duration of the task is known and is typically completed in one monitoring cycle at most.
    5. The people and equipment involved in the task are usually required for the entire duration of the task.
    6. The task will typically utilize the special competence of the person or group executing the task.
- Some points in the workflow are of particular note because they indicate a well-defined checkpoint in the execution of the project $\rightarrow$ MILESTONES.
- A project plan has three main components:

1. A **work schedule**: Set of tasks frequently described in an ordered graph.
2. A **cost schedule**: Costs are associated with each task and thus the financial needs of the project at any time can be determined from the cost schedule.
3. A **resource schedule**: Equipment, materials, and workers need to be at the right place and the right time.

10 Project Management Concepts

Concepts in Project Management

- Milestones where decisions regarding the future of the project are made, are called gateways.
- Projects have gateways as ways to bringing accountability, are are referred to as gated projects.

Trade-offs in a Plan

When project timing is being considered as a trade-off, one aspect becomes apparent: there is at least one path from the start to the end of the project that will take the most time compared to all other paths. This is known as the **critical path**.

11 Creating a Project Plan

Decomposition of a Project

- A work breakdown structure is an organized list of tasks that is used to plan out a project.
- To deconstruct the work into manageable pieces, a project is organized into sub-projects and tasks in a tree structure.

Other Forms of Plan Representation

- PERT stands for program evaluation and review technique. It is used for small projects and small sub-projects.
- The second representation, activity on the arrow, has numbered nodes with arrow connecting dependencies. Sometimes, dummy tasks are required to display dependencies that might otherwise be visible.
- Slack time (also called float time) is also typically shown; this indicated how late a task can start start before it will affect the end date for the whole project.

Planning: Other Task Timing and Relationships

- A task that begins 'as early as possible' means that a task will begin as soon as its predecessors have been completed. This is known as a **'finish-to-start'** relationship.
- **'Start-to-start'** is used where a second task must wait on the start of the first, but work can begin as soon as the predecessor task begins.
- **'Finish-to-finish'** is used where engineers want two tasks to finish at the same time.
- Lastly, there is **'start-to-finish'** which says the second task will start before the first finishes.
- A **lag** is a delay at the start of a task after its predecessor has been completed.