Week 1

GSOE9820 Engineering Project Management
Term 1 2025
Dr Imrana I. Kabir

Project Scope

C3PE Methodology
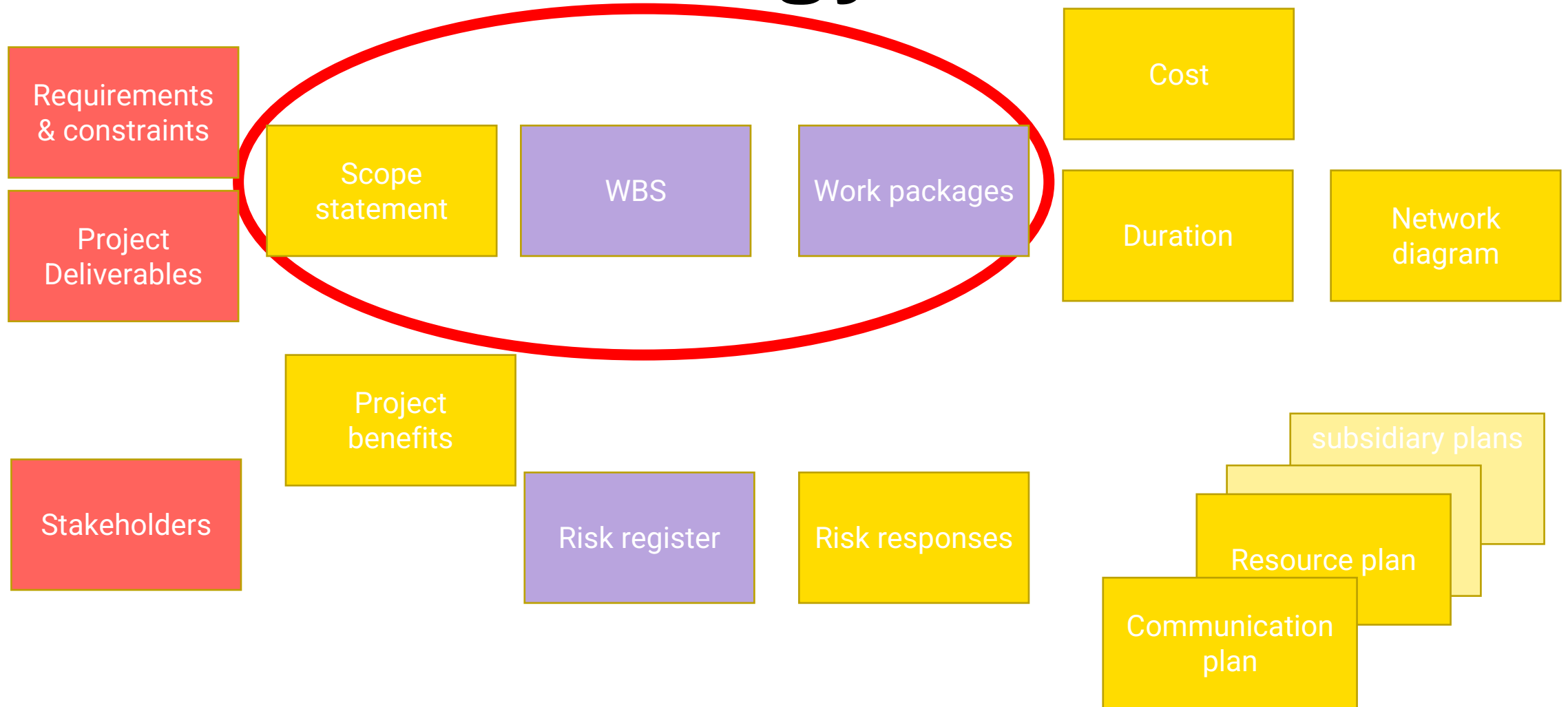
Requirements & constraints

Project Deliverables

Scope statement

WBS

Work packages

Cost

Duration

Network diagram

Project benefits

Stakeholders

Risk register

Risk responses

subsidiary plans

Resource plan

Communication plan

UNSW SYDNEY

Why do projects fail?

- The project was not adequately defined at the beginning.

- A lack of clearly defined project goals and objectives.

- Project planning was done with insufficient data.

- Poor work definition.

Black, K. (1996). Causes of project failure: a survey of professional engineers. *PM Network, 10*(11), 21–24.

Collect requirements

Collecting Requirements (PM Methods)

- Brainstorming
- Interviews
- Focus Groups
- Questionnaires and surveys
- Benchmarking
- Document analysis:
  - Specifications, RFPs
  - Standards
  - Regulations

- Affinity diagramming
- Mind mapping
- Nominal group technique (Delphi methods - wikipedia)
- Observation
- Prototyping/concept designs

Dwivedi, N. "Elicitation Techniques" video in course Software Design: Developing effective requirements, accessed 23/02/2021, LinkedIn Learning accessed through UNSW

Writing requirements

When you are writing a specification:

- Say **"shall"** for mandatory requirements.

- Say **"should"** for optional requirements.

- Be **SMART** (specific, measurable ,attainable, relevant, timely)

How about an agile specification? User stories!

A user story is an informal, general explanation of a feature written from the perspective of the end user.

- "**As...** a student, **I want to...** find out when my lectures are happening, **so that...** I can meet my friends on campus.

- User stories are clever because they connect **stakeholder**, **requirement** and **benefit** together in one trackable item.

Sydney Harbour foreshore authority

Pyrmont bridge

- Timber bridge
- 14 timber truss spans, each 25m long with a total span of ~ 370m.
- Electric swing span (1st of its kind in the world)
- Central pier to provide access into the harbour for larger boats – the swing path opens
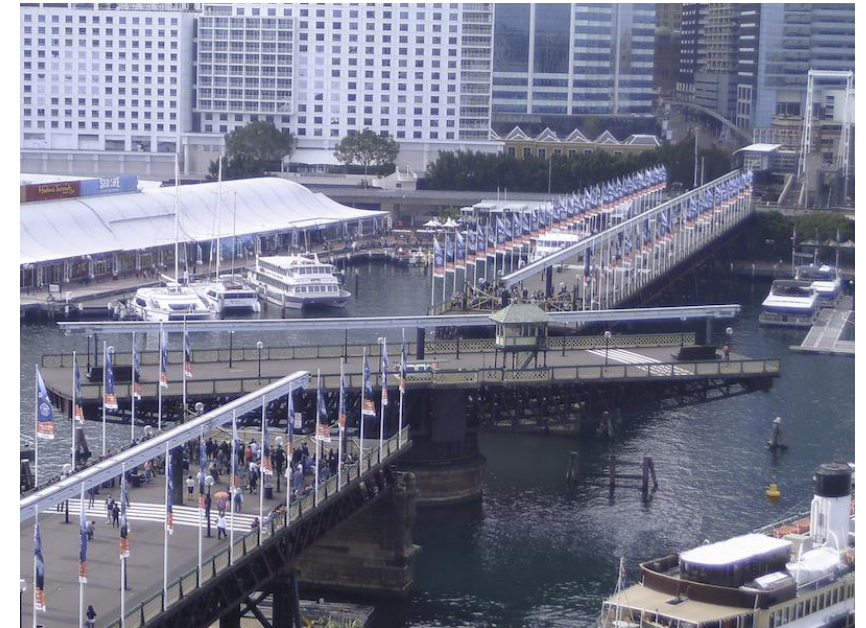
Reference: NSW Government, The Star Group

Pyrmont bridge

Requirements Method: Document analysis
Reviewed Roads and Maritime Services (RMS) report on existing conditions (e.g. traffic and transport use)

Identified:

- timber trusses and piers, required replacement.

- the restoration was determined to be completed in two stages
  - *Stage 1* : replacement of the timber pier sets
  - *Stage 2*: replacement of the timber trusses

- heritage-listed icon and requires ongoing maintenance (public safety)

Reference: Pyrmont Master Plan, Traffic and Transport, December 2005
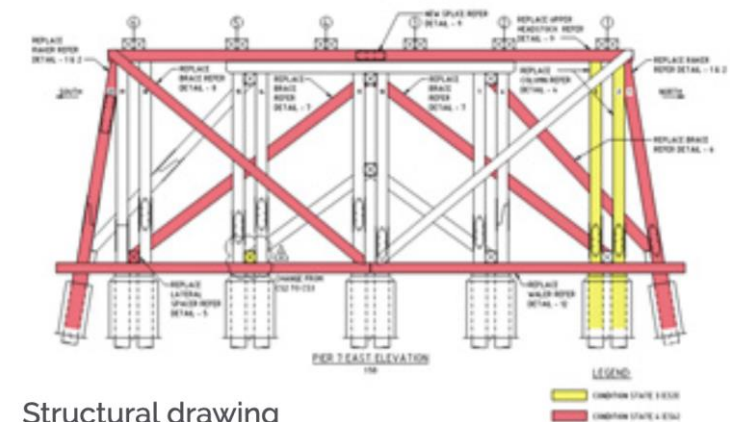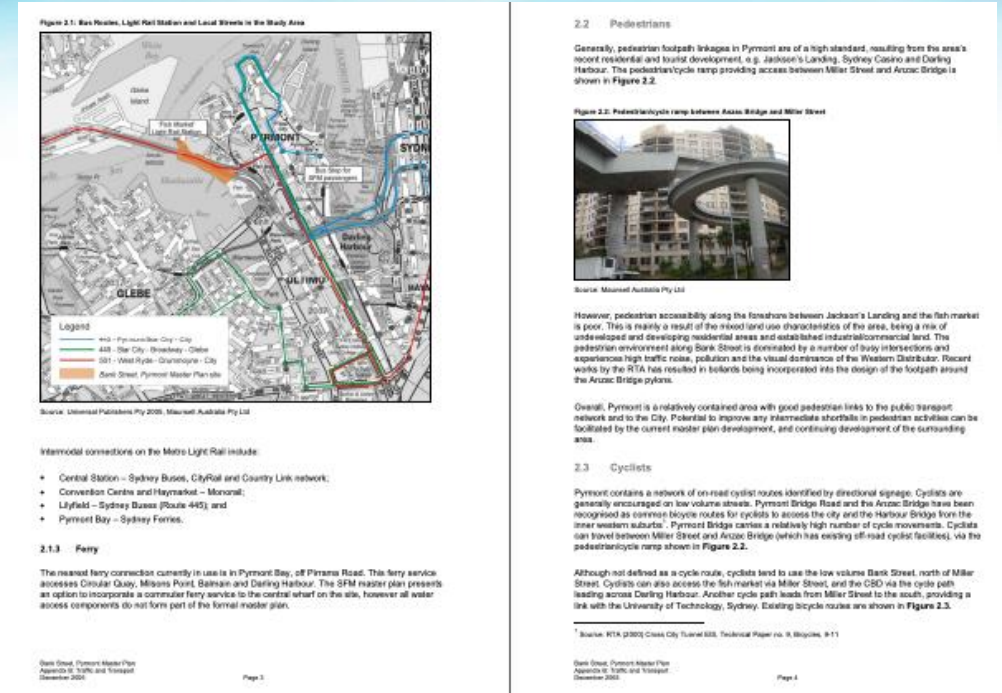
Structural drawing

Try to write observable requirements that give the client what they actually want and maximum design freedom (and accountability) to your engineers:

An **OK** requirement for bridge design life:

"The bridge shall always be standing."

A **better** one:

"The bridge shall be fully functional for 95% of the time and traffic performance intended at design.

Writing great requirements simplifies testing and configuration management!

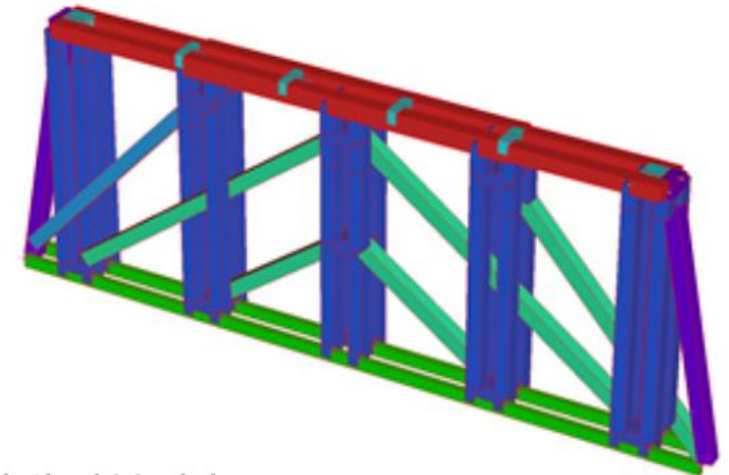*Functional requirement*: describes behaviour of the product by actions, processes…
Non-functional requirement: qualities/conditions for product to be effective (PMBOK 5.3.2)

User Stories – Agile Requirements

As a purchaser, *I want* the receipt to display the date of my purchase in ISO 8601 format Comic Sans 12pt font with 9pt leading, *so that* I can maintain my records. ✗

As a purchaser, *I want* the receipt to indicate when I completed the purchase, *so that* I can maintain my records. ✓

*Requirements are not an explicit contract – they need to enable **design freedom** for the **solution** to address it.*

A user must never have to wait long for a screen to appear ✗

New screens appear within 2 seconds 95% of time ✓

*Requirements need to be **testable** and **verifiable**. Should be clear and precise.*

As a good world citizen, *I want* world peace, *so that* we can all live in harmony. ✗

As a movie goer, *I want* to be able to pay by Paypal, so that I don't have to use my credit card. ✓

*Requirements need to have boundaries to estimate **scheduling/work** and to understand **completion**.*

As *a* movie goer, *I want* to be able to find and purchase movie tickets online, *so that* I have something to do tonight. ✗

As a movie goer, *I want* to be able to find a movie by title, so that I can quickly locate the details of a movie I am interested in. ✓

*Requirements need to be **measurable** and **trackable**. Keep them **short** and **concise** – not too much!*

Define scope

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Defining Scope

Project Scope

- A definition of the end result or mission of the project. This is often in the form of a product or service for a customer.

- The work that needs to be accomplished to deliver a product, service, or result with the specified features and functions.

Purpose of the Scope Statement

- To clearly define the deliverable(s) for the end user.

- To focus the project on successful completion of its goals.

- To be used by the project owner and participants as a planning tool and for measuring project success.

The challenge in scope definition

Scope definition is the creative center of project management

Requirements

Constraints

Project priorities

Develop project scope

Scope statements and WBS

'The problem'

'The solution'

What does this mean for me?

The bad ☹

- Scope definition is only deceptively simple.
- You will need your own (or you will need to access) domain-specific knowledge to be effective.
- You can't assume that scope definition will be procedural or routine or even particularly 'easy'.
- In planning complex projects, it will involve a high degree of negotiation, compromise and hard work.

What does this mean for me?

The good ☺

- Scope definition and the WBS is not a forgone conclusion.
- As PM, scope definition is where you leave your creative mark on the project.

But, what if you only partly know all the requirements and the scope at the beginning?
(surprisingly, common situation)

Triple constraint

Triple Constraint Model
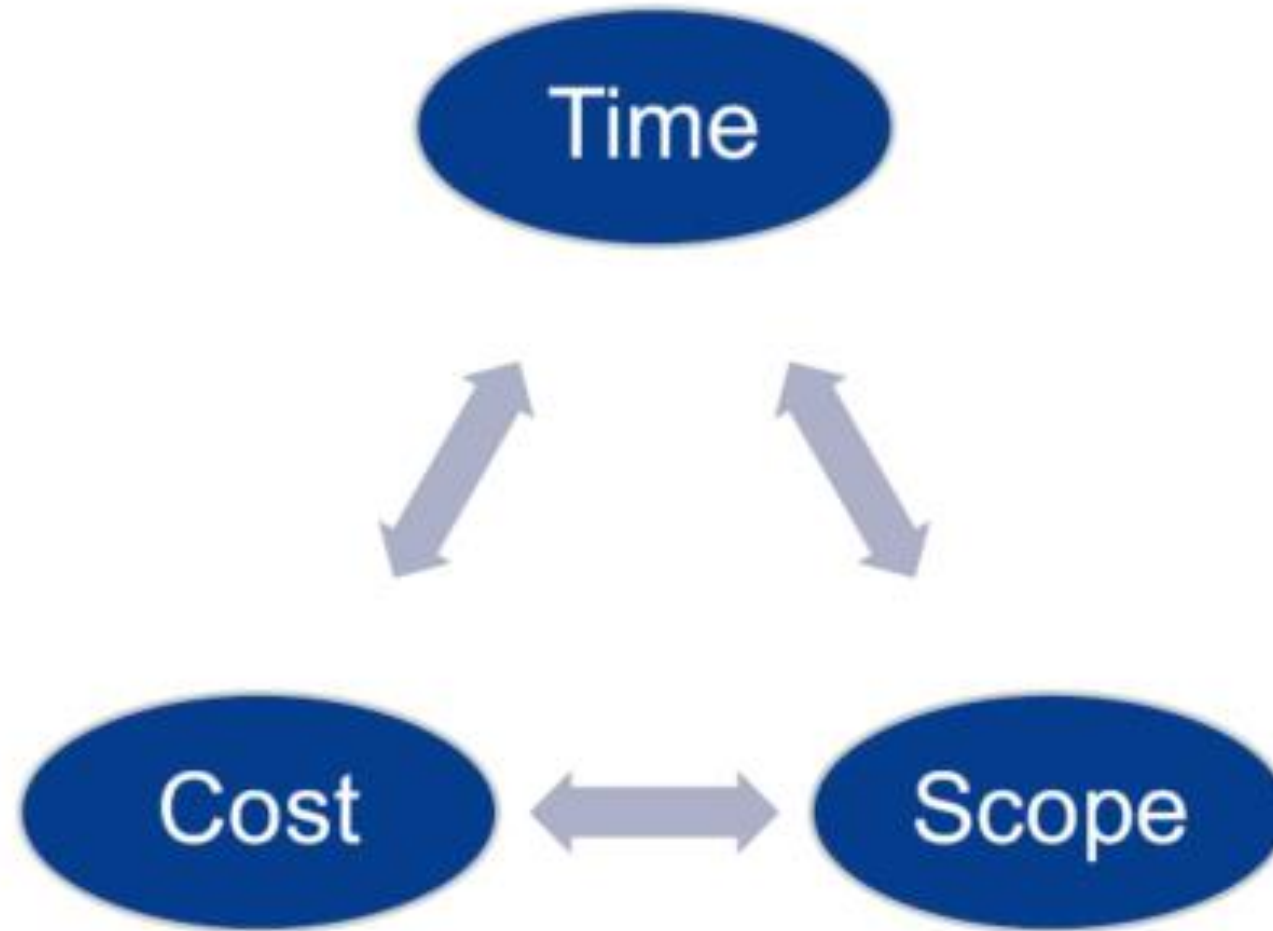
Establishing Project Priorities

Quality and the ultimate success of a project are traditionally defined as meeting and/or exceeding the expectations of the key stakeholders.

E.g. Customers/Upper management.

It is often measured in terms of

- Cost (budget)
- Time (schedule)
- Scope (performance)

NOW ☑

LATER ☐

Trade Offs / Compromises

Causes of Project Trade-offs

- Shifts in the relative importance of criterions related to cost, time and scope

Managing the Priorities of Project Trade-offs

- Constrain
  - a parameter is a fixed requirement.
- Enhance
  - optimizing a criterion over others.
- Accept
  - reducing (or not meeting) a criterion requirement.

Project Priority Matrix

The purpose is to define and agree on what the priorities and constraints of the project are so that the right decisions can be made at the appropriate time.

	Time	Performance	Cost
Constrain		●	
Enhance	●		
Accept			●
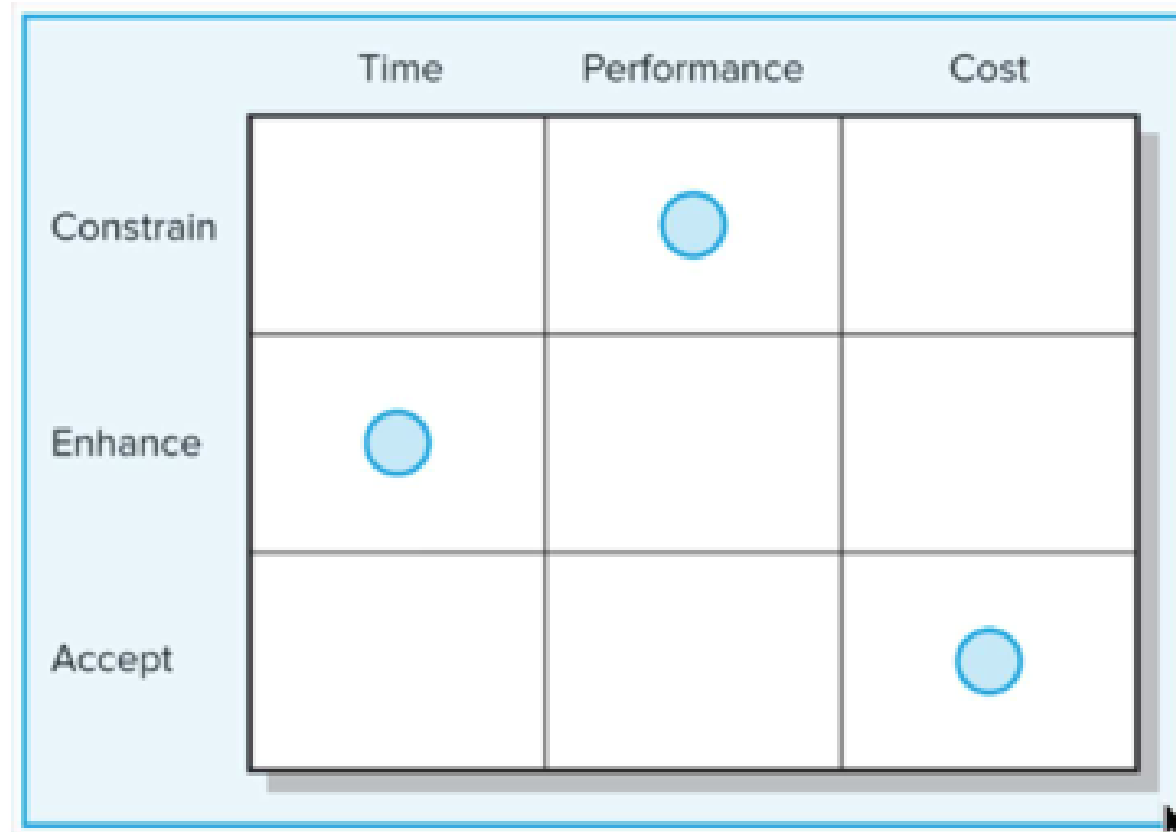
The WBS

WBS summary (definition)

The WBS represents a clear description of the project's deliverables and scope—the "what" of the project. It is *not* a description of a process or schedule that defines how or when the deliverables will be produced, but rather is specifically limited to describing and detailing the project's outcome or scope. As

"The WBS organizes and defines the total scope of the project. The WBS subdivides the project work into smaller, more manageable pieces of work, with each descending level of the WBS representing an increasingly detailed definition of the project work. The planned work contained in the lowest level WBS components, which are called work packages, can be scheduled, cost estimated, monitored, and controlled."

From: Project Management Institute, Practice Standard for Work Breakdown Structures (Project Management Institute, 2nd ed., 2006)

PMBOK Guide (6th Ed) Part 1, Sec. 5.4.1

Generating the WBS

STEP 1 : Defining the Project Scope

STEP 2 : Establishing Project Priorities

STEP 3 : Creating the Project Scope diagram

STEP 4 : Coding the WBS/PBS for the Information System

STEP 5 : Integrating the WBS/PBS with the Organisation

Iterative
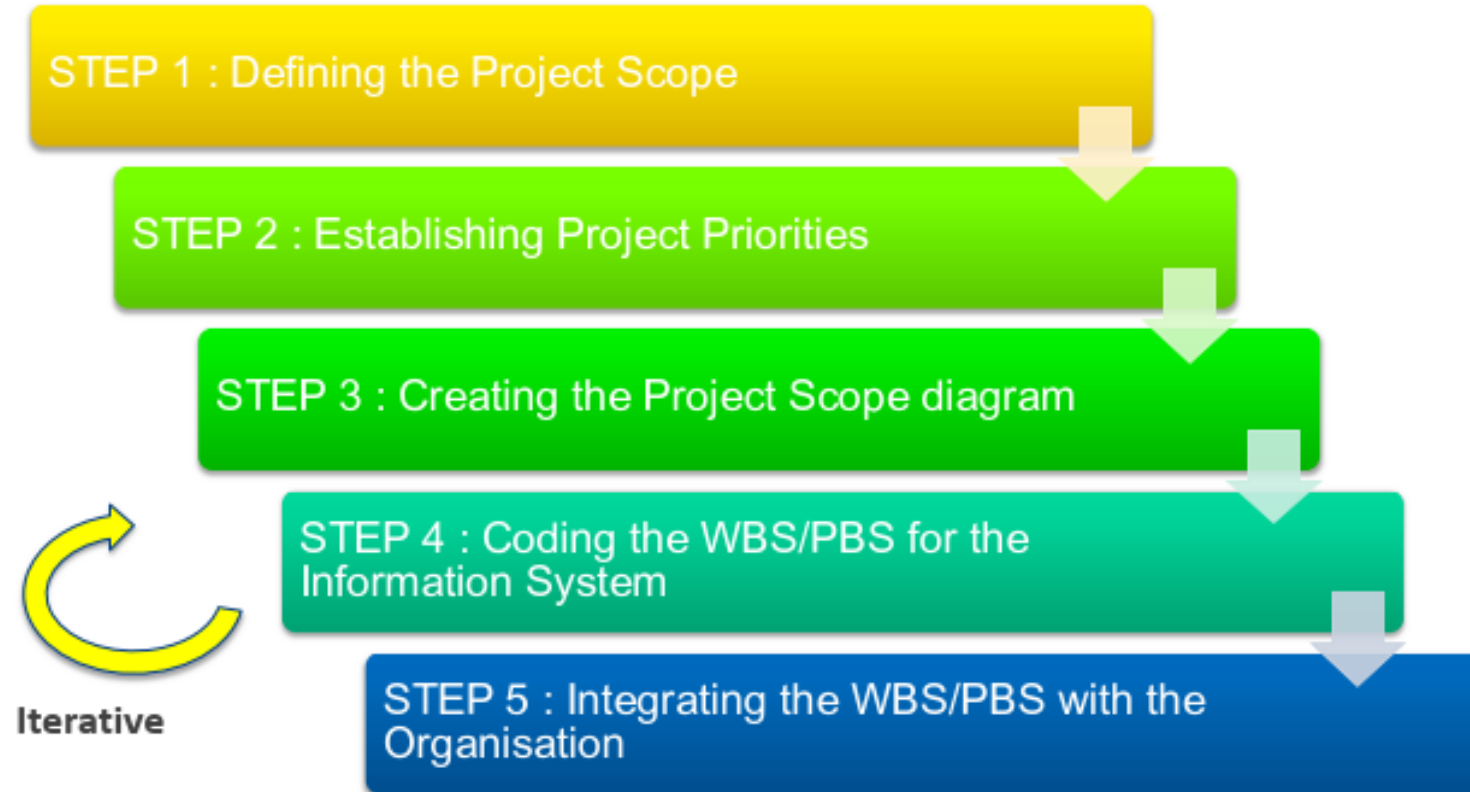
The Project Scope Diagram
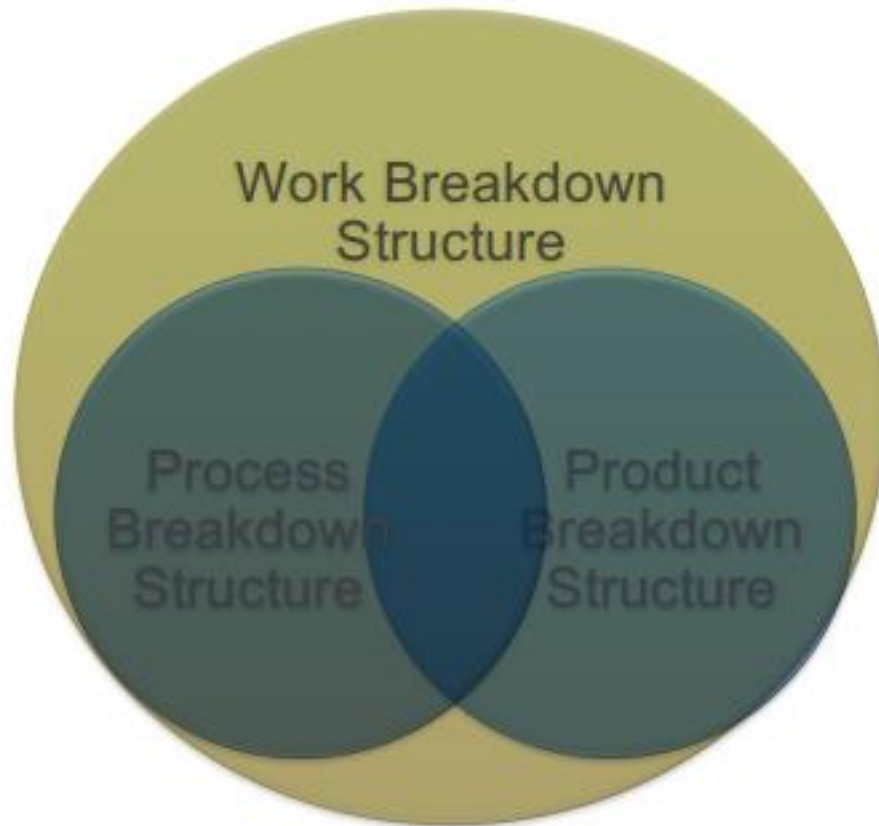
This video gives a nice explanation of how the WBS includes more than just the PBS, and how it is not about scheduling, and the presenter defines the work packages correctly.

Rogers, J. "Work breakdown structure" video in course Construction Management, Planning and Scheduling, accessed 23/02/2021, LinkedIn Learning accessed through UNSW

The Work Breakdown Structure

- The WBS is a hierarchical outline (map/diagram) that identifies the **total scope of work** to be carried out by the project team to accomplish the project objectives and create the required deliverables.

- Defines the relationship of the final deliverable (the project) to its sub-deliverables, and in turn, their relationships to **work packages**.

Building a WBS hierarchy

Level	Hierarchical breakdown	Description
1	Project	Complete project
2	Deliverable	Major deliverables
3	Subdeliverable	Supporting deliverables
4	Lowest subdeliverable	Lowest management responsibility level
5	Cost account*	Grouping of work packages for monitoring progress and responsibility
	Work package	Identifiable work activities
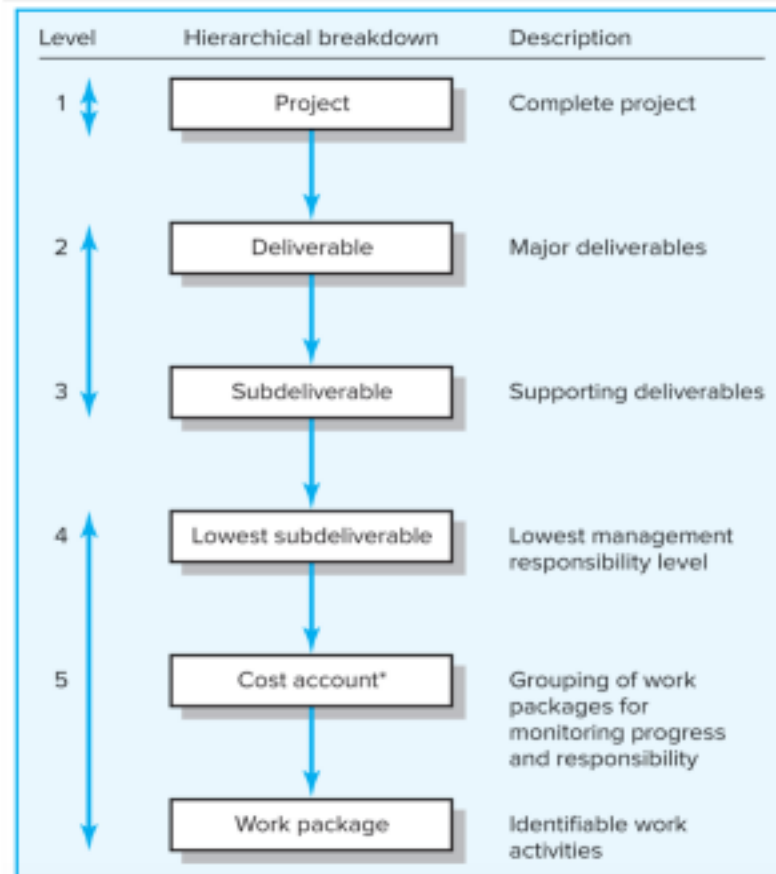
Advantages of using a WBS

- To improve estimating

- To better control the project execution

- To more accurately verify project completion

- To improve the opportunity for use of historical information, which, can aid in both speed and accuracy of future projects.

- Is a repeatable process that can be used as a template for future similar projects.

Example WBS for a software project

The WBS is illustrative only. It is not intended to represent the full project scope of any specific project, nor to imply that this is the only way to organize a WBS on this type of project.

PMBOK Guide (6th Ed) Part 1, Sec. 5.4.2
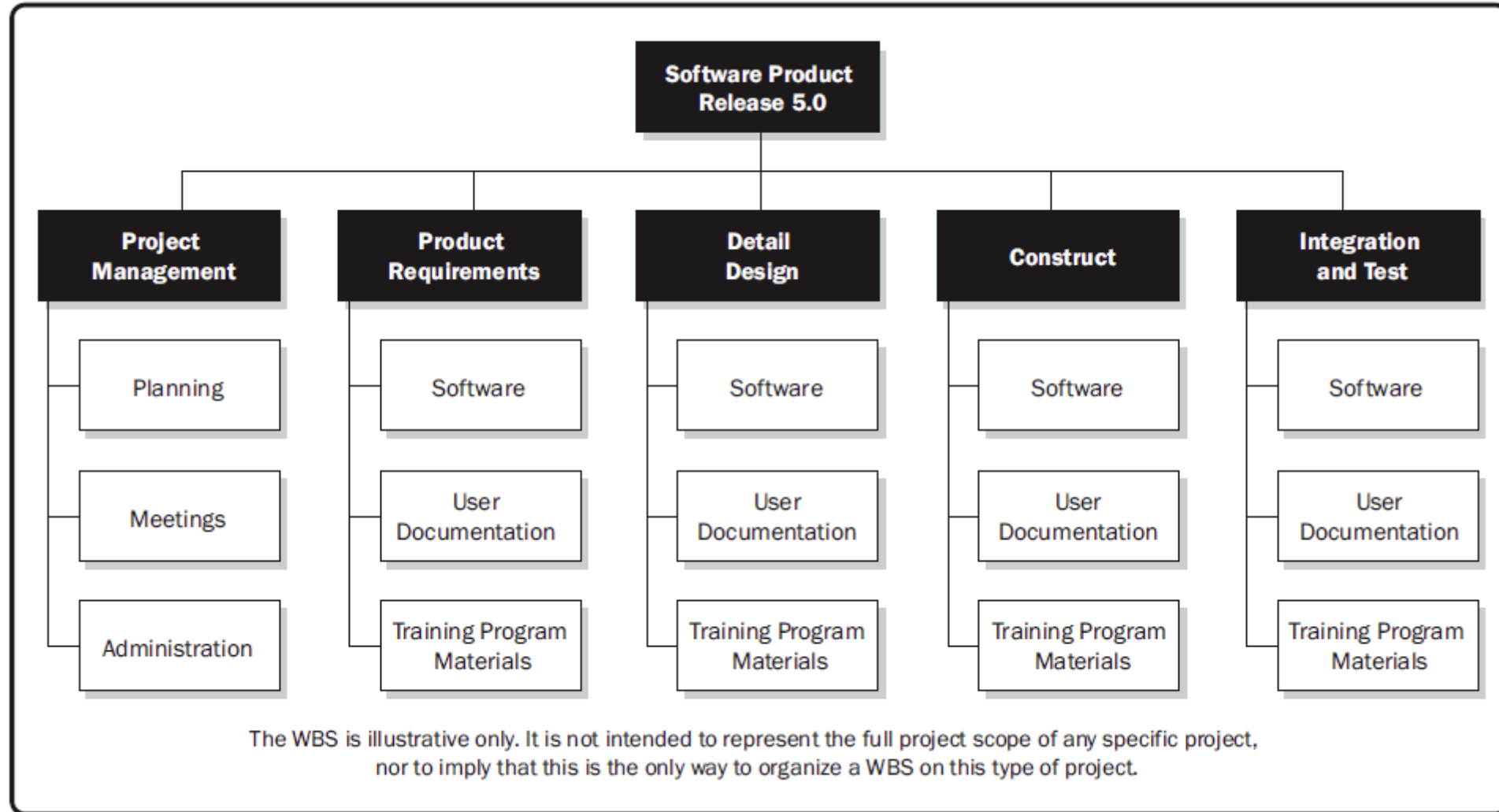
Example WBS for an engineering project

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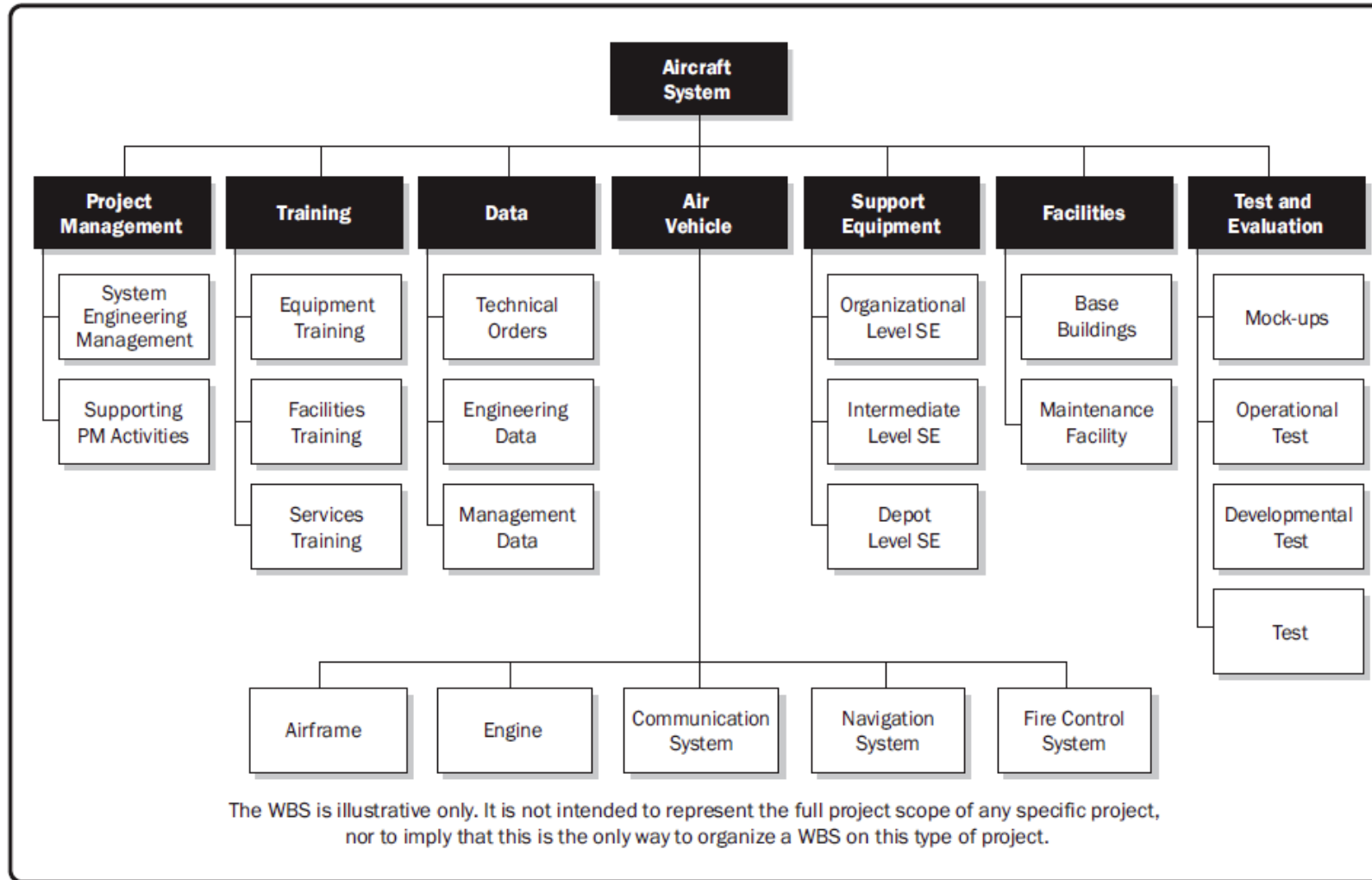
Work Packages

A work package is the lowest level of the WBS.

It is **output-oriented** and contains the project details:

1. Defines work (what)

2. Identifies time to complete a work package (how long)

3. Identifies a time-phased budget to complete a work package (cost)

4. Identifies resources needed to complete a work package (how much)

5. Identifies a person responsible for units of work (who)

6. Identifies monitoring points (milestones) for measuring success.

Product Breakdown Structure (PBS)

- The PBS is a hierarchical outline (map) that identifies **ALL** the **things** that the project will make or outcomes that it will deliver.

- The PBS diagram differentiates between the different types of product
  - e.g. final product, assemblies, internal and external products

Integrating the WBS into the Organisation

The Organizational Breakdown Structure (OBS):

- Depicts how the firm is organized to discharge its work responsibility for a project

- Provides a framework to summarize organization work unit performance

- Identifies organization units responsible for work packages

- Ties the organizational units to cost control accounts

Sample PBS with integrated OBS
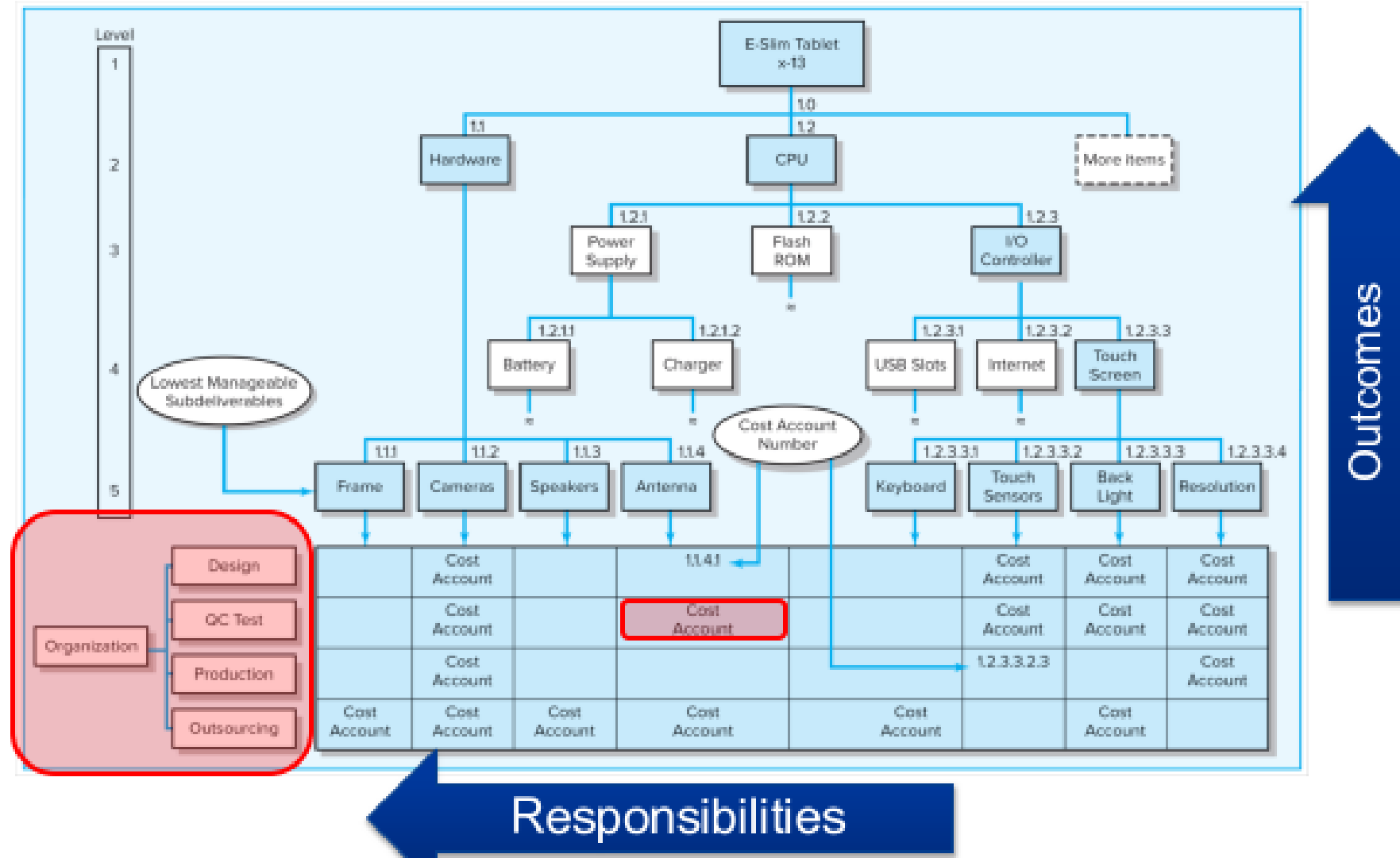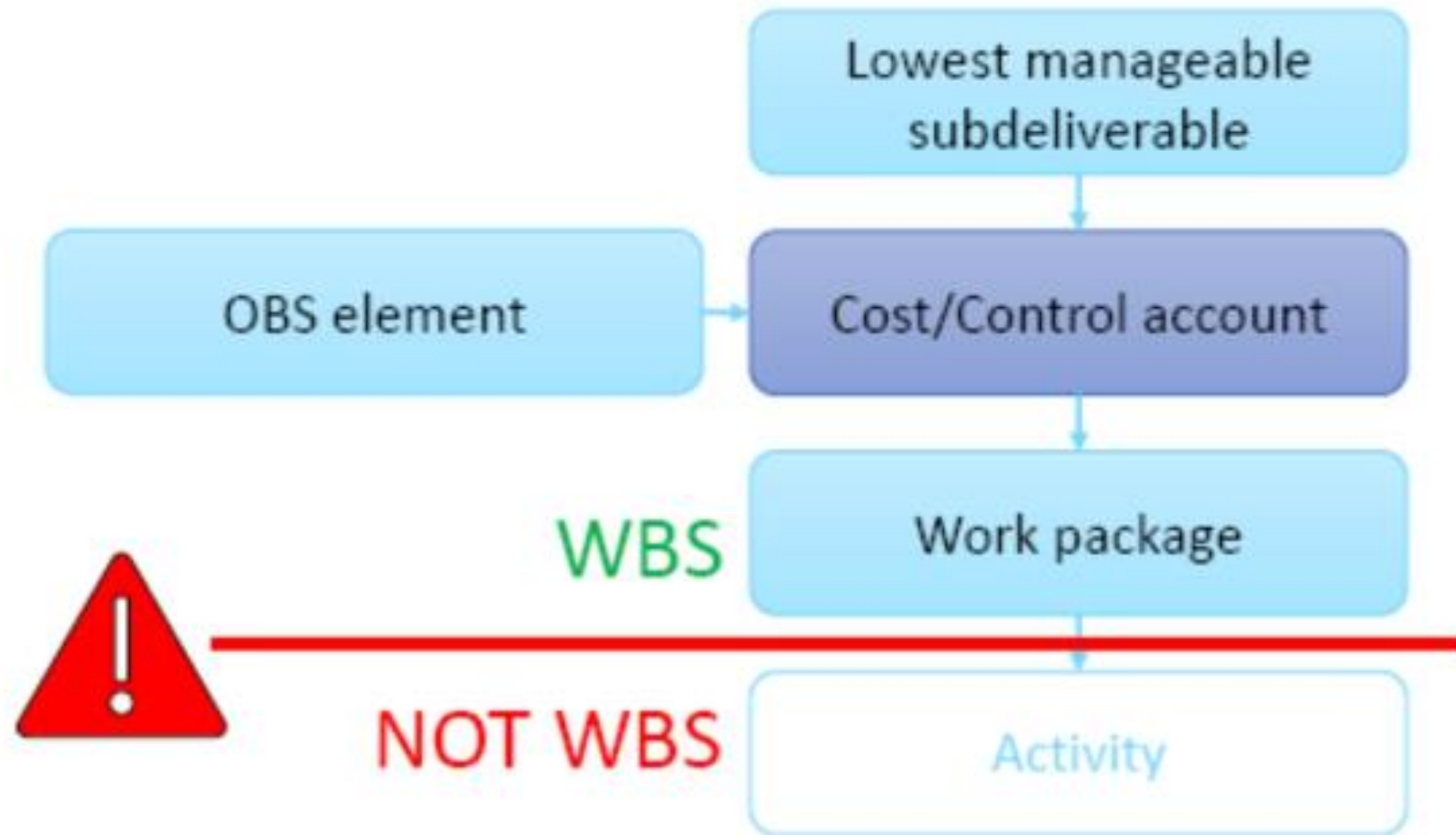
Coding the Work Package

The WBS Coding System defines:
- Levels and elements of the WBS
- Organization elements
- Work packages
- Budget and cost information

The most commonly used scheme is numeric indention

Allows reports to be consolidated at any level in the organization structure

On larger projects the WBS is often further supported with a WBS dictionary

An Activity

Activity

- A distinct, scheduled **portion of work** performed during the course of a project

- A series of actions results in a work package

- It cannot be handed over to the project stakeholders

- It is generally defined using a **verb** (polishing, testing)

Sample WBS Coding

Numbering element	Description	Level
1.0	Project/Contract name	1
1.1	Major project Subsystem	2
1.1.1	Task	3
1.1.1.1	Subtask	4
1.1.1.1.1	Work Package	5
1.1.1.1.1.1	Components	6

Example of alternative coding scheme : **3R-237A-P2-33.6**

Activities combine to form part of a Work Package
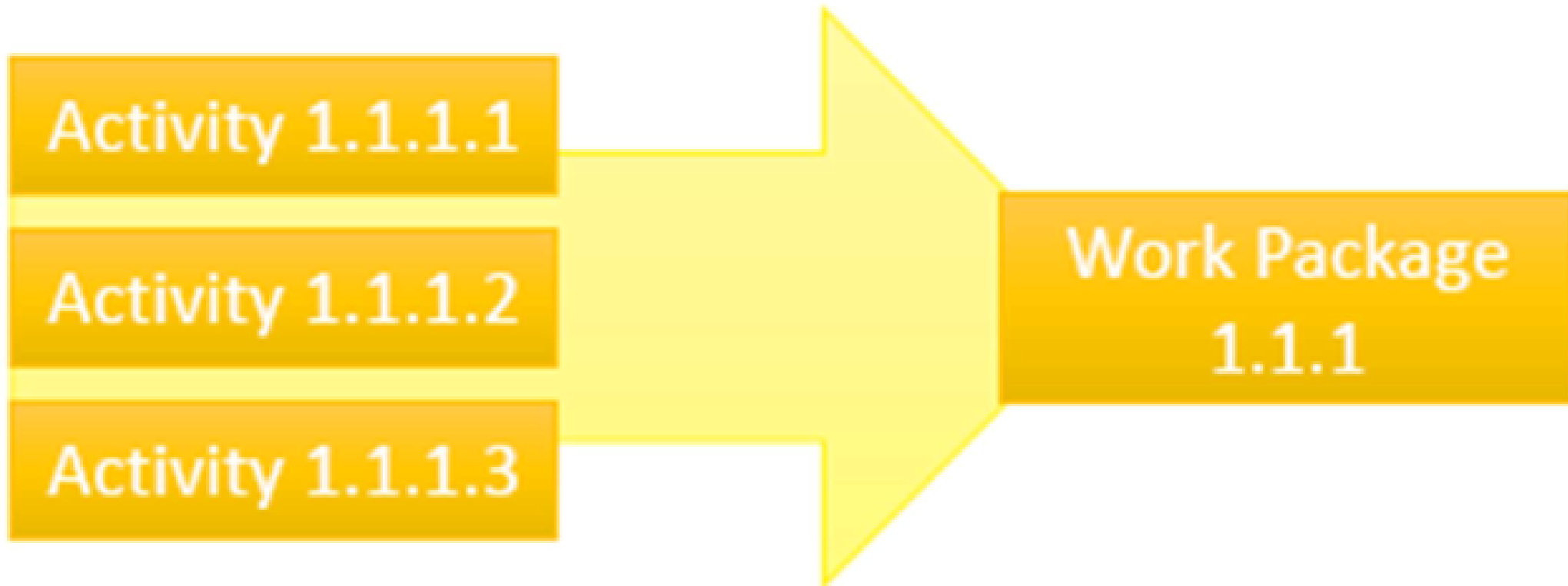
Common WBS Misconceptions

A WBS is not an exhaustive list of work. It is instead a comprehensive classification of project scope.

A WBS is neither a project plan, a schedule, nor a chronological listing. It specifies **what** will be done, not how or when.

A WBS is not an organizational hierarchy, although it may be used when assigning responsibilities.

WBS Tips

Plan outcomes, not just actions

100% Rule
- The WBS must capture all deliverables of the project

Have mutually exclusive work packages
- No work package should be described in more than one sub-deliverable

Level of Detail
- Sub-deliverables should be small enough for 1 person to be responsible
- No activity should be longer than 10 days or a single reporting period

Example Project – Zero Emission Buses

Plan a project for Transport for NSW (TfNSW) to shift towards net zero emissions with the goal to **transition all 8000 buses** in NSW to a zero-emissions fleet.

Duration: 3 year
Budget: $6,000,000
Scope: optimize

Rapid transition to ZEB and EV will help NSW to reach net zero emissions by 2050

> NSW's bus fleet will transition to zero emission buses (ZEBs)
> Industry will be encouraged to adapt and supply EVs
> Our EV charging network will expand across NSW
> We will explore use of hydrogen technology to support zero emissions target

Key infrastructure requirements of ZEBs

- One off capex payment
- Recurring capex payment

Grid upgrades
Potential requirement to upgrade grid capacity (substations, lines) to cope with increased demand from depot charging

Charging points
Choices regarding charging solutions could impact fleet numbers

Depot generation / storage capacity
Optional installation of solar generation and storage capacity at depots to reduce peak grid energy requirements

Electric

Hydrogen

Diesel decommission
Once depots have been fully converted, cost of decommissioning legacy diesel infrastructure on site

Depots and workshops
Different requirements for the size, location and configuration (incl. charge points) of new depots and workshops

Hydrogen infrastructure
Hydrogen storage tanks and refuelling stations will have to be constructed as needed

Depot infrastructure

Infrastructure for different fuel types

Analyse project information from TfNSW (Project Sponsor)

Key infrastructure requirements of ZEBs

- 🟢 One off capex payment
- 🔵 Recurring capex payment

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Infrastructure for different fuel types

"The NSW Government is working towards achieving a target of net-zero emissions by 2050. Transport for NSW has responded accordingly and will attempt to transition the NSW bus fleet to net zero by 2030."

OUR CUSTOMERS

- Residents and communities
- Public transport users
- Service providers
- Road users (private, public, freight)
- Pedestrians and bike riders
- Visitors and tourists
- Infrastructure managers
- Local and global businesses
- Freight rail customers

Activity Stream

1. Engage key partners and support industry readiness activities
   - Release strategy
   - Engage key partners: Energy providers, Operators, Manufacturers
   - Build momentum by starting the replacement of diesel buses with ZEBs
   - Build industry readiness for rapid acceleration from 2023

2. Pursue 'no regrets' enabling activities to provide foundation for full transition
   - Business cases
   - Re-contracting
   - Grid upgrades to TfNSW depots
   - Minor depot works
   - New technology trials i.e. hydrogen and regional buses

3. Deliver a first phase, followed by strategic review
   - Business case funding
   - Depot upgrades
   - Deliver first phase of transition
   - Strategic review 2024: assess emerging technology and optimise transition approach

4. Deliver at scale to target (from 2024) and move to business as usual
   - Respond to strategic review
   - Greater focus in regions
   - Deliver full transition at scale
   - Monitor for opportunities and emerging technologies

Example - Purpose Statement

The main purpose of this project is to **help the NSW Government achieve its 2050 net zero-emission target**, by reducing emissions from the NSW bus fleet and associated infrastructure to support zero-emission buses (ZEBs). This will **enhance economical activity** for the energy/transport sector and environmental **benefits for the NSW general public**.

Why is the project being done? ✔

What broader organizational strategy does this target? For whom? ✔

Disclaimer: these statements are not perfect and are not guaranteed 100%!

Example - Scope Statement

This three-year project **involves** **renovating** the existing NSW bus diesel depots and **constructing** new depots for zero-emission operation. This needs to be achieved under AUD **$2,000,000** per calendar year starting **January 1st 2021 – December 31st 2023.**

This project will incorporate appropriate data **analysis** to consider the most appropriate power method such as **hydrogen and electric infrastructure.** Guided **evaluations** will be performed to consider charging techniques and technologies, depot **specifications**/equipment/facilities, digital **uplifts** and smart sensors, system safety/verification/performance <u>testing</u>, and training/transition workshops to smooth the transition for 8000 future ZEBs.

What is being delivered (in a reasonable amount of detail)? ✔

What are the constraints of the project? ✔

Does this represent 100% of the work to indicate project completion? ✔

Disclaimer: these statements are not perfect and are not guaranteed 100%!

Example - WBS

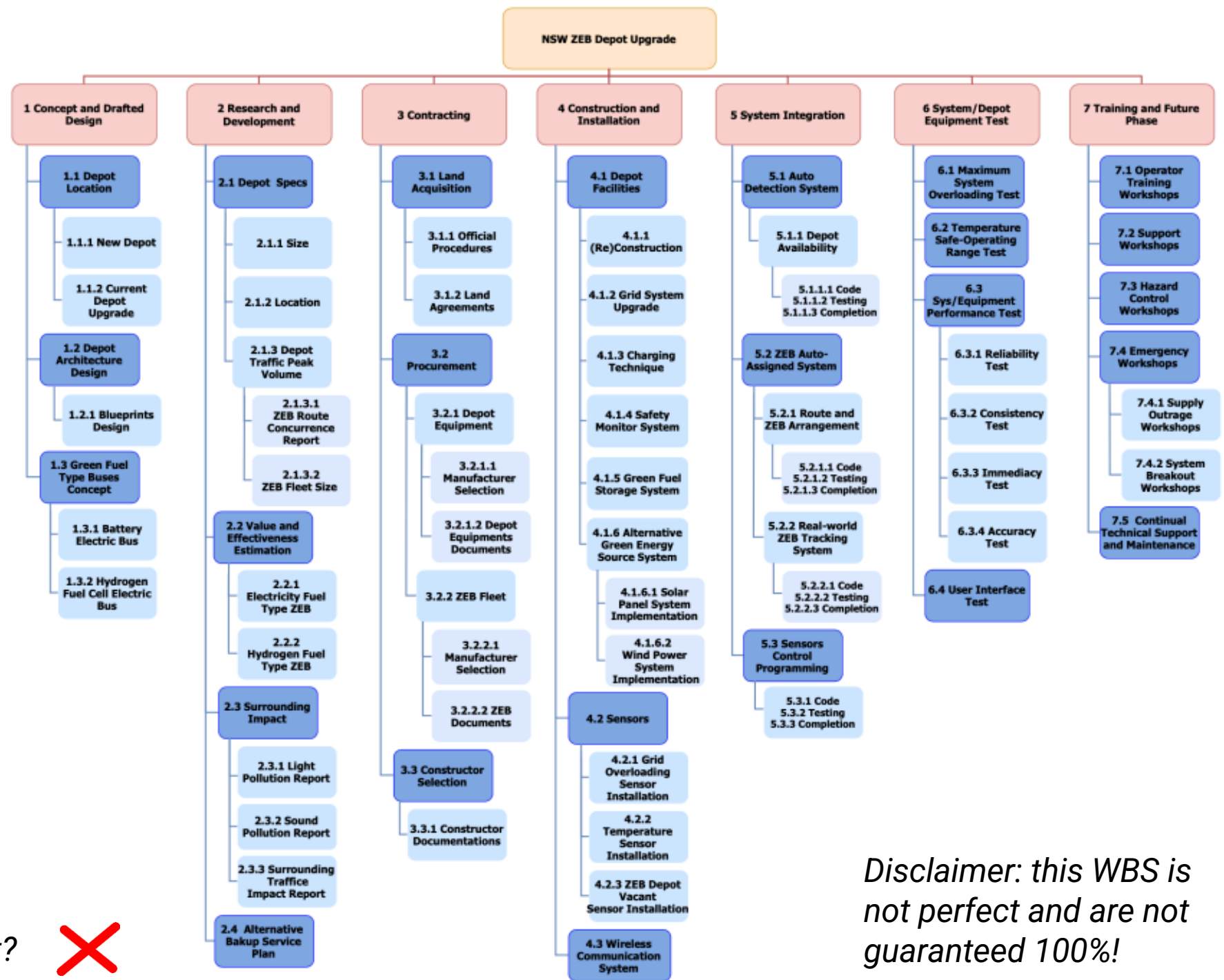*Is each sub-deliverable small enough for 1 person to be responsible?* ⚠️

Is each work package indicative of a noun, and NOT an activity/verb? Does it focus on objectives and deliverables, rather than actions? ⚠️

Does this represent 100% of the scope to indicate project completion? ⚠️
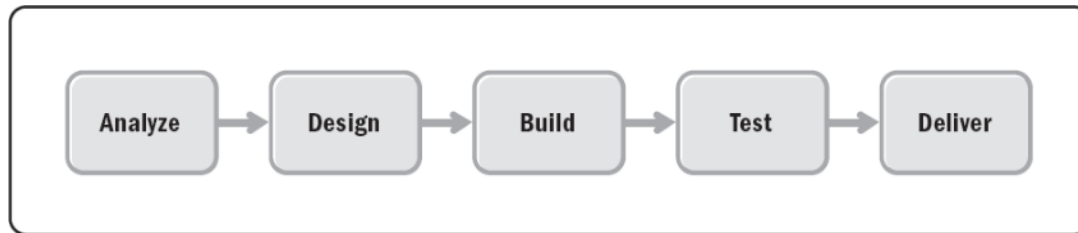
Is the WBS Coding correct? ❌

NSW ZEB Depot Upgrade

1 Concept and Drafted Design
- **1.1 Depot Location**
  - 1.1.1 New Depot
  - 1.1.2 Current Depot Upgrade
- **1.2 Depot Architecture Design**
  - 1.2.1 Blueprints Design
- **1.3 Green Fuel Type Buses Concept**
  - 1.3.1 Battery Electric Bus
  - 1.3.2 Hydrogen Fuel Cell Electric Bus

2 Research and Development
- **2.1 Depot Specs**
  - 2.1.1 Size
  - 2.1.2 Location
  - 2.1.3 Depot Traffic Peak Volume
    - 2.1.3.1 ZEB Route Concurrence Report
    - 2.1.3.2 ZEB Fleet Size
- **2.2 Value and Effectiveness Estimation**
  - 2.2.1 Electricity Fuel Type ZEB
  - 2.2.2 Hydrogen Fuel Type ZEB
- **2.3 Surrounding Impact**
  - 2.3.1 Light Pollution Report
  - 2.3.2 Sound Pollution Report
  - 2.3.3 Surrounding Traffic Impact Report
- **2.4 Alternative Bakup Service Plan**

3 Contracting
- **3.1 Land Acquisition**
  - 3.1.1 Official Procedures
  - 3.1.2 Land Agreements
- **3.2 Procurement**
  - 3.2.1 Depot Equipment
    - 3.2.1.1 Manufacturer Selection
    - 3.2.1.2 Depot Equipments Documents
  - 3.2.2 ZEB Fleet
    - 3.2.2.1 Manufacturer Selection
    - 3.2.2.2 ZEB Documents
- **3.3 Constructor Selection**
  - 3.3.1 Constructor Documentations

4 Construction and Installation
- **4.1 Depot Facilities**
  - 4.1.1 (Re)Construction
  - 4.1.2 Grid System Upgrade
  - 4.1.3 Charging Technique
  - 4.1.4 Safety Monitor System
  - 4.1.5 Green Fuel Storage System
  - 4.1.6 Alternative Green Energy Source System
    - 4.1.6.1 Solar Panel System Implementation
    - 4.1.6.2 Wind Power System Implementation
- **4.2 Sensors**
  - 4.2.1 Grid Overloading Sensor Installation
  - 4.2.2 Temperature Sensor Installation
  - 4.2.3 ZEB Depot Vacant Sensor Installation
- **4.3 Wireless Communication System**

5 System Integration
- **5.1 Auto Detection System**
  - 5.1.1 Depot Availability
    - 5.1.1.1 Code
    - 5.1.1.2 Testing
    - 5.1.1.3 Completion
- **5.2 ZEB Auto-Assigned System**
  - 5.2.1 Route and ZEB Arrangement
    - 5.2.1.1 Code
    - 5.2.1.2 Testing
    - 5.2.1.3 Completion
  - 5.2.2 Real-world ZEB Tracking System
    - 5.2.2.1 Code
    - 5.2.2.2 Testing
    - 5.2.2.3 Completion
- **5.3 Sensors Control Programming**
  - 5.3.1 Code
  - 5.3.2 Testing
  - 5.3.3 Completion

6 System/Depot Equipment Test
- **6.1 Maximum System Overloading Test**
- **6.2 Temperature Safe-Operating Range Test**
- **6.3 Sys/Equipment Performance Test**
  - 6.3.1 Reliability Test
  - 6.3.2 Consistency Test
  - 6.3.3 Immediacy Test
  - 6.3.4 Accuracy Test
- **6.4 User Interface Test**

7 Training and Future Phase
- **7.1 Operator Training Workshops**
- **7.2 Support Workshops**
- **7.3 Hazard Control Workshops**
- **7.4 Emergency Workshops**
  - 7.4.1 Supply Outrage Workshops
  - 7.4.2 System Breakout Workshops
- **7.5 Continual Technical Support and Maintenance**

Disclaimer: this WBS is not perfect and are not guaranteed 100%!

Formulating WBS in different PM lifecycles

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Predictive lifecycle

Concept

Characteristics

- Take advantage of **prior knowledge** and **experience**

- Useful for project with **extensive design**, e.g. safety requirements, regulatory constraints

- **Reduced uncertainty** in deliverables

- Should **reduce complexity** in projects and **minimise cost** (but change needs to be carefully controlled, if not can become overwhelming)

Iterative lifecycle

Concept
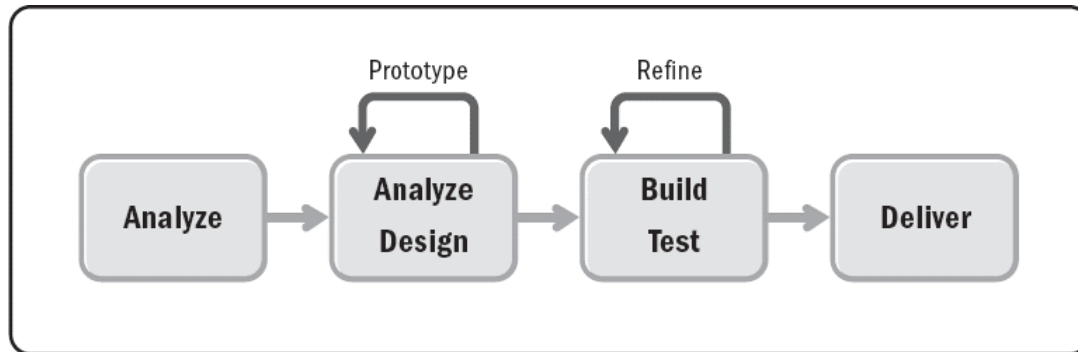
Characteristics

- Implicit in **prototyping**: improve the product or result through successive prototypes or proofs of concept.

- Useful for **high complexity**, **frequent changes**

- Sometimes prototypes are the only way to obtain comprehensive requirements

- Projects **take longer** because they prioritise learning rather than speed of delivery

Incremental lifecycle

Characteristics

- Delivering value to sponsors or customers **more often than a single, final product.**

- The delivery team may deviate from the original plan, but can manage this change because they keep on delivering value to customer **very soon after**
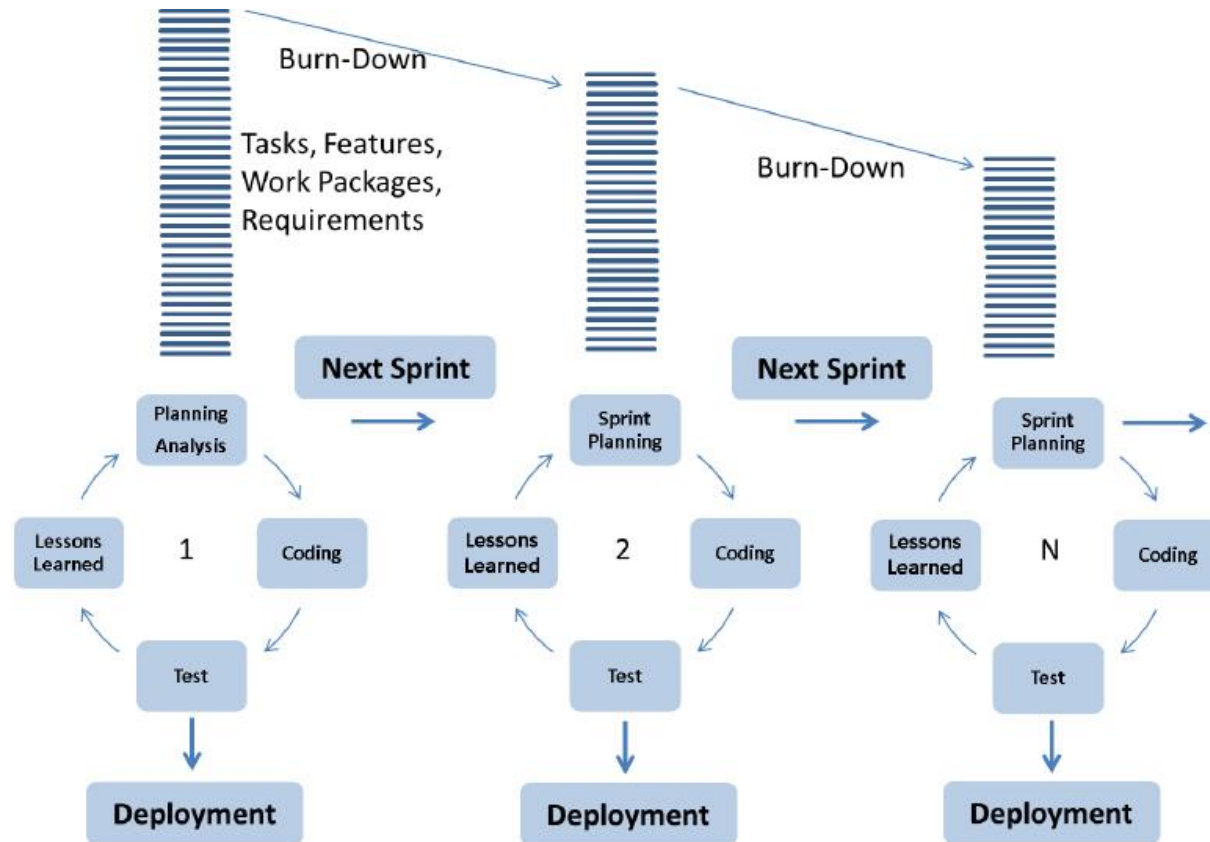
Example:

- Software - provide a customer with a single, fully working function in a new software design;

- Builder: build and completely decorate a single room in a new house and show it to the customer

Concept
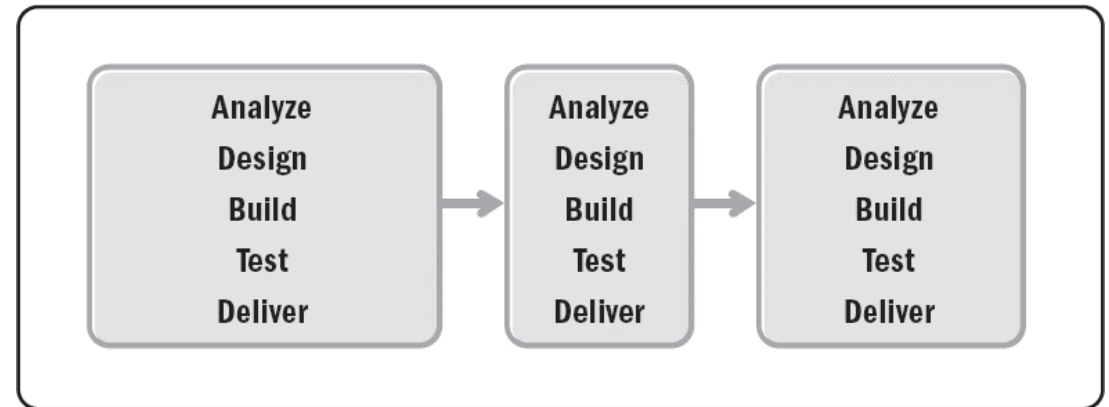
Agile lifecycle

The 100% 'Agile' PM model works best with few interdependencies between most of the work packages

Focused on continuous releases that incorporate customer feedback, which can be more suitable for modern businesses with rapid responses/change

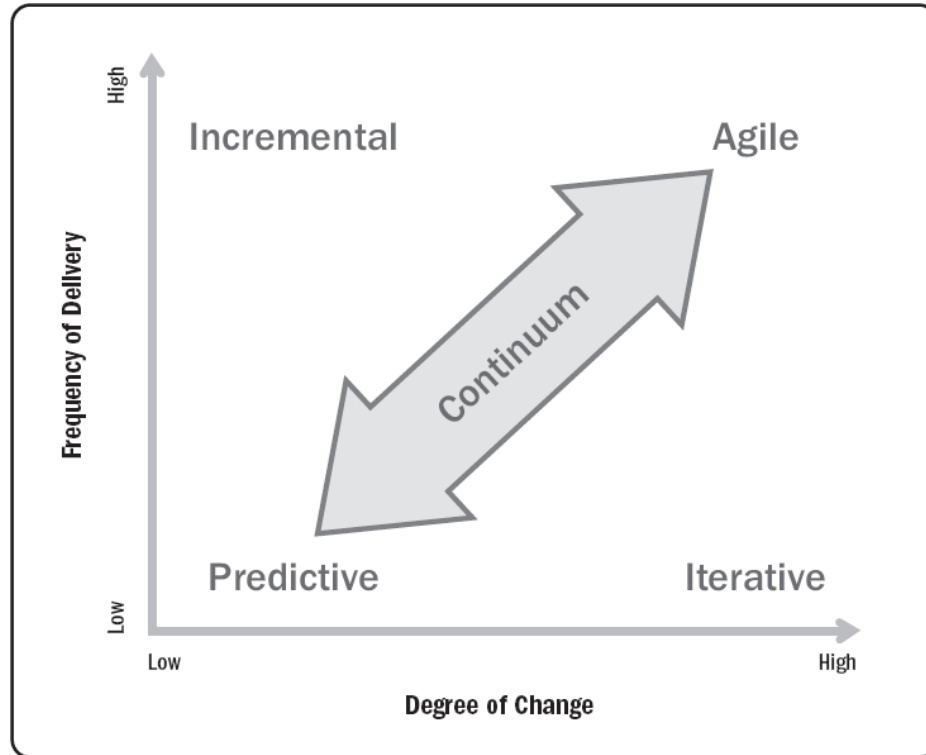Straçusser, G. (2015). Agile project management concepts applied to construction and other non-IT fields. Paper presented at PMI® Global Congress 2015—North America, Orlando, FL. Newtown Square, PA: Project Management Institute.

Lifecycle summary

Figure 3-1. The Continuum of Life Cycles

Table 3-1. Characteristics of Four Categories of Life Cycles

	Characteristics			
Approach	**Requirements**	**Activities**	**Delivery**	**Goal**
Predictive	Fixed	Performed once for the entire project	Single delivery	Manage cost
Iterative	Dynamic	Repeated until correct	Single delivery	Correctness of solution
Incremental	Dynamic	Performed once for a given increment	Frequent smaller deliveries	Speed
Agile	Dynamic	Repeated until correct	Frequent small deliveries	Customer value via frequent deliveries and feedback

Tips:

Initial goals ⟶ **Mid-term goals** ⟶ **Long term goals**

C3PA and PMBOK Knowledge Areas

Requirements & constraints

Project Deliverables

Scope statement

WBS

Work packages

Cost (Part 1, Sec. 7)

Cost

Duration

Network diagram

Scope (Part 1, Sec. 5)

Schedule (Part 1, Sec. 6)

Stakeholders (Part 1, Sec. 13)

Stakeholders

Project benefits

Risk register

Risk responses

subsidiary plans

Resource plan

Communication plan

Resources (Part 1, Sec.9)

Communications (Part 1, Sec. 10)

Risk (Part 1, Sec 11)

PMBOK Guide (6th Ed) Part 2, Sec. 1.9 Table 1-1