A Research Informed Generative AI Framework to Provide Context in Project Management Teaching

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NAO slams MoD for £1.35bn cost of poor project management

Poor planning and use of lessons learnt

10 JAN 2020 | BY CAROLINE WADHAM AND LEM BINGLEY

Final bill for electrifying the Great Western Mainline from South Wales to London £2bn over original budget

Business Live

Poor planning

The orig

Abandoned NHS IT system has cost £10bn so far

The Guardian Newspaper

Bill for abortive plan, described as 'the biggest IT failure ever seen', was originally estimated to be £6.4bn

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Poor requirements

Management

Getting to the point

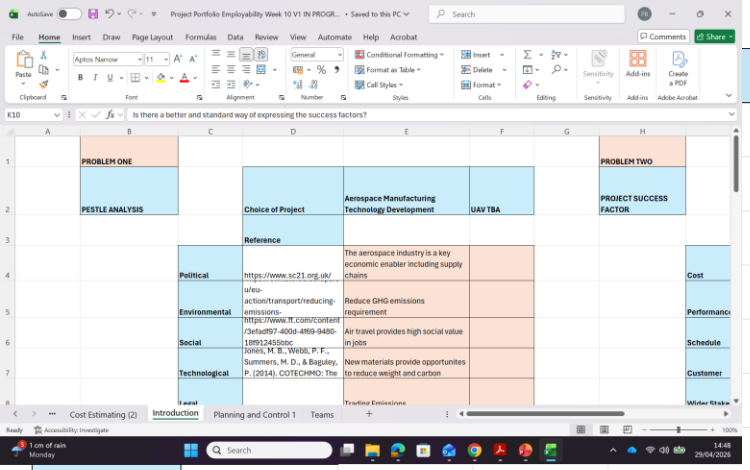
- Generative AI to work on cost estimating tasks as part of a cost estimating process
- Prompt Engineering to obtain information from Gen AI
- Thought chain prompting
- Link to live data and custom GPT
- Technical understanding of large language models and then agentic to assess their quality of output
- Data security problems with company cost data bases
- RAG (Retrieval Augmented Generation) to focus on specific information to mitigate generalisations and improve prompts

Work with industry

- NISTA working on data quality and assurance, available data sets, linking to live information, generating scenarios, making estimating dynamic
- Bentley improving productivity
- Sodexo automating data analysis tasks
- Rolls Royce exploring capability

The Teaching and Learning problem

- Second year undergraduates in mechanical and aerospace with minimal knowledge of project management and cost estimation
- Digital tools provide a motivation by aligning with technical and algorithmic solutions familiar to students
- Links to industry provide employability motivation
- Generative AI tool as a result of internship coded to be used by undergraduate students



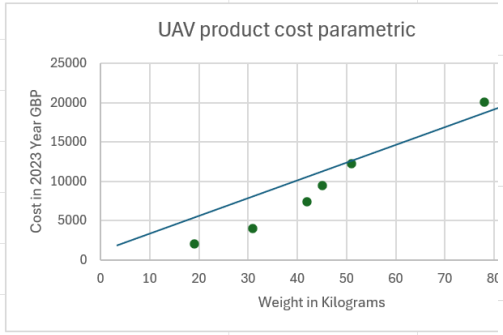
Risk Id	Risk Owner	Risk Event	Probability of Occurrence	Impact	Risk S
AAAAAAA1	Paul	Assembly Documentation Failure	Low	High	Mediu
AAAAAAA2	John	Data corruption	Low	High	Mediu
AAAAAAA3	George	Manufacturing App failure related delays	Low	Low	Low
AAAAAAA4	Luke	CAD system fault	High	Low	Mediu
AAAAAAA5	Phil	Factory Fire	Low	High	Mediu

PROBLEM THREE				
DELIVERABLES ID		Choice of Project	E.g. Design 1 Course	UAV TBA
	om/getmedia/e3848fff-3738-44e6-8b42-0d13009b133e/Appe	Reference	for gas distribution crossings	
	Deliverable 1		Painted pipe	
	Deliverable 2		New anti-vandal device	
	Deliverable 3		Survey results	
	Deliverable 4			

FORMATIVE ASSESSMENT EMPLOYABILITY SPREADSHEET

Date	Sub-Assembly	Owner	Quality Attribute	Quality Specification (operationalised quality attribute)	Deviance from Specification
Dec-23	Propulsion System	Paul	Reliability	Persistent operation for 100 hours	Zero
Oct-23	Propulsion System	Paul	Performance	NAFEMS convergence criteria reached on each part	Three parts in the assembly
Nov-23	Propulsion System	Paul	Durability	Able to withstand impact and function	Fail
Dec-23	Propulsion System	Paul	Reliability	Bird strike simulation	Pass
Dec-23	Propulsion System	Paul	Aesthetics	Surface Roughness Measures	Pass

Cost
2020
4012
7452
9421
12233
20100



Lessons Learnt Examples for cost estimating an Automated Tape Laying Process
There is minimal available time in the business to engage busy experts in new composite resources because of the demands from the business in this new developmental area
Questionnaires should be used to structure knowledge capture in cost estimates because of lack of knowledge in cost estimating by the composites team. These should be provided before any estimating workshop.
There is a difference between process times for development of prototype parts and process times for full volume production

Concept	Team Building Preliminaries	Example from a Project Team to develop the 5 year capital replacement plan for utilities
	Role of Sponsor	Provide optimal 5 year plan to the board of directors
	Clarify Objectives	Estimate average unit cost of all assets in the strategic plan at feasibility planning level
	Develop good working process	Estimating process from UK Gov specifically tailored to the company environment. Continuous improvement weekly team meetings for what went well and did not go so well
	When is the team formed	One year before the final detailed plan is due
		Combination of experienced personnel from the company because of the requirement for contextual knowledge of

Project Development

- Project Goal and Project Need
- Project Charter
- Outline Business Case
- Statement of Work
- Detailed Business Case

Group	Payload Weight (pounds)	Operational Altitude (Ft or FL)	Speed (Knts)	Endurance (Hours)	Launch Method	Examples
1	0 - 20	< 1200 AGL	< 100	1.5	Hand Launch	Raven, Wasp
2	21 - 55	< 3500 AGL	< 250	24	Catapult	Scan Eagle
3	< 1320	< FL 180	< 250	5 - 18	Runway	Hunter, Shadow
4	> 1320	< FL 180	Various	15 - 26	Runway	Predator, Gray Eagle
5	> 1320	> FL 180	Various	17 - 36	Runway	Global Hawk, Reaper

Malone et al

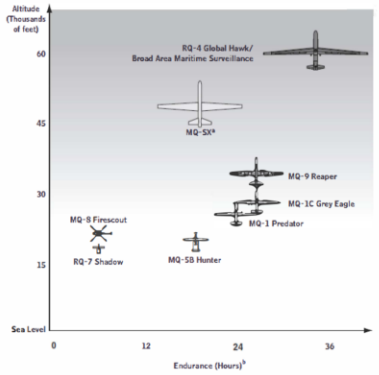


Figure 1 - Select UAVs plotting Endurance (Hours)

Estimating by Analogy

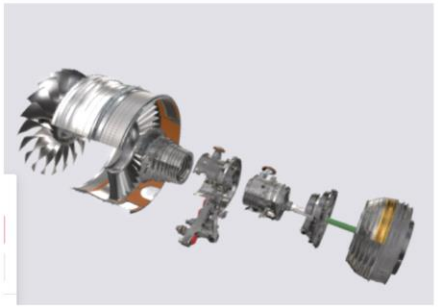
Project	Excavation	Excavation depth	Excavator used	Contractor	Schedule	Location	Reinstatement	Pressure of Valve	Project cost
NW	Complex	30 metres	Vacuum	PMC, high quality	20 weeks	Urban in road	High quality	30 bar	2M GBP
London	Complex	50 metres	Conventional	Low quality	50 weeks	Verge	High quality	25 bar	4M GBP

This hypothetical example only shows some data. There would be a lot more data fields available about each project.
There are only two projects.
Cost estimating by analogy means selecting the most similar cost example and using that value AS IS, i.e. do not adjust it

PBS of the Trent 7000

The University of

- Fan System (1.1)
  - Blades (1.1.1)
- Ip Compressor (1.2)
  - Advanced Core (1.2.1)
  - Heated ESS (1.2.2)
  - IP Power Offtake (1.2.3)
- HP system (1.3)
  - Combuster (1.3.1)
  - Turbine Blades (1.3.2)



Discuss

The University of

- When is a work package complete for **welding a ship section**?
- https://gcaptain.com/spotd-queen-elizabeths-mega/

EXAMPLE ACTIVE LEARNING ON COURSE

Monte Carlo Tool

Monte Carlo Analysis Made Simple

Version 1.1

Welcome to **The Monte Carlo Tool**.

This tool provides an easy way to implement Monte Carlo analysis following the simulation segment of ASTM E1369. The user can enter equations and models where variables within the model are drawn from random sampling. What is Monte Carlo Analysis?

What is the Quality Watch?

Activity: NASA 'Survival on the Moon' Team Exercise

Your spacecraft has crash-landed on the Moon.
Work as a team to prioritise survival items.

Frankenstein Model

AN OVERVIEW ON THE APPLICATION OF CHATGPT IN COST ESTIMATION: RESULTS PRODUCED

Chiara Alpini

Supervised By Dr Paul Baguley

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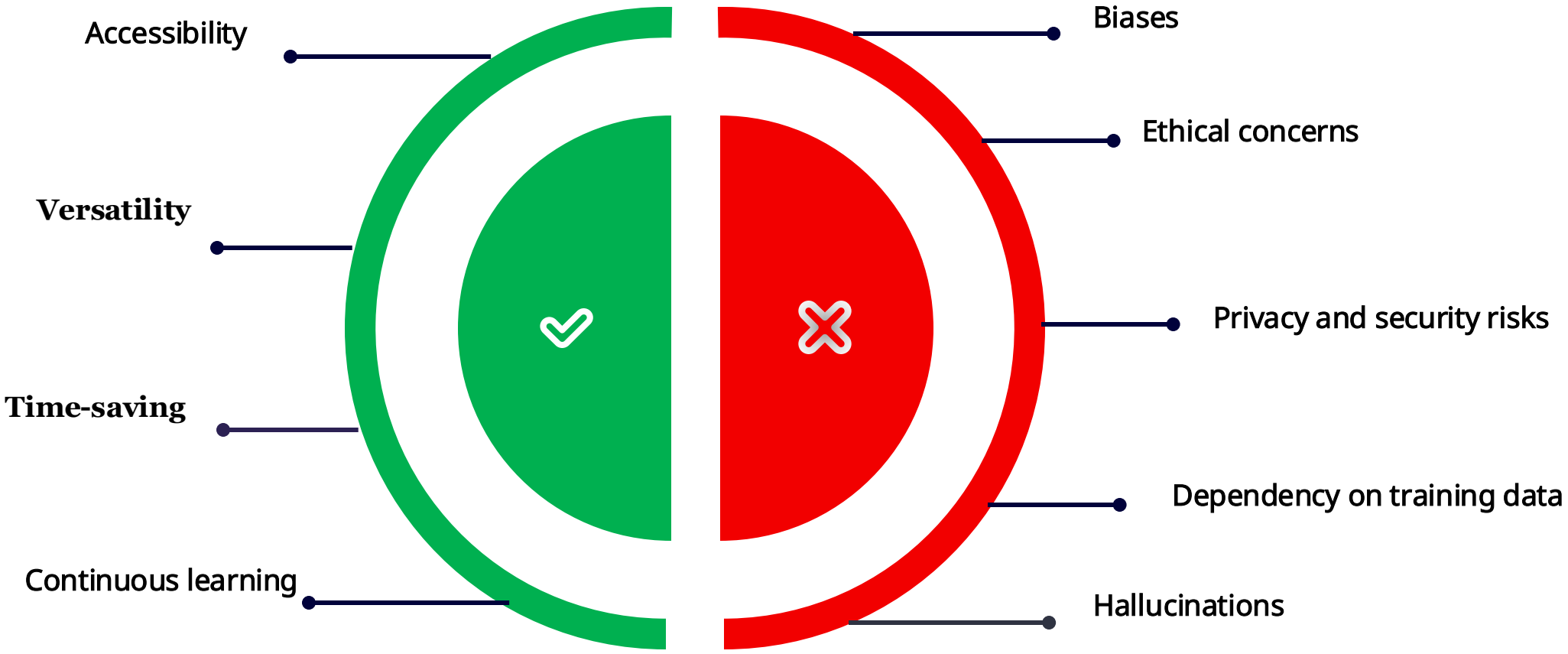
Advantages and Limitations



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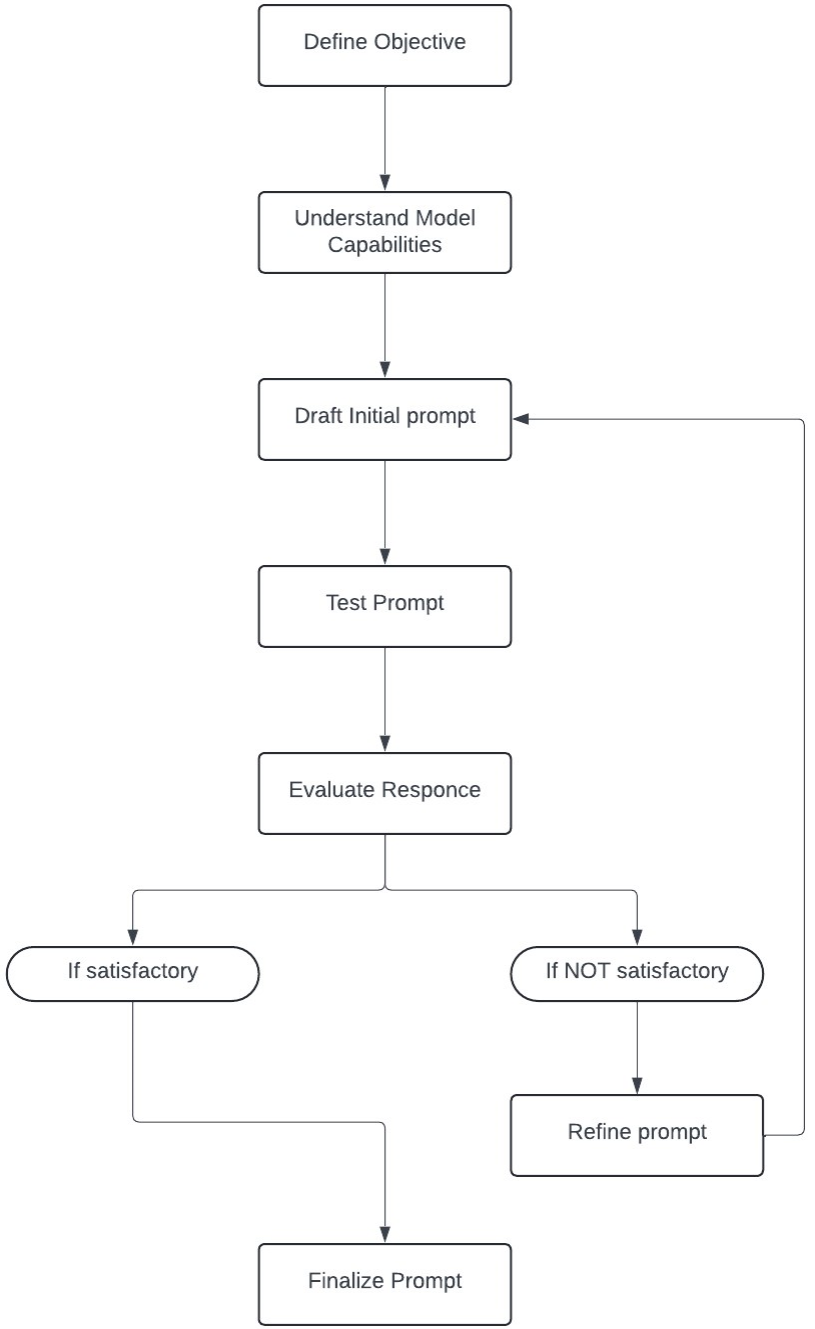
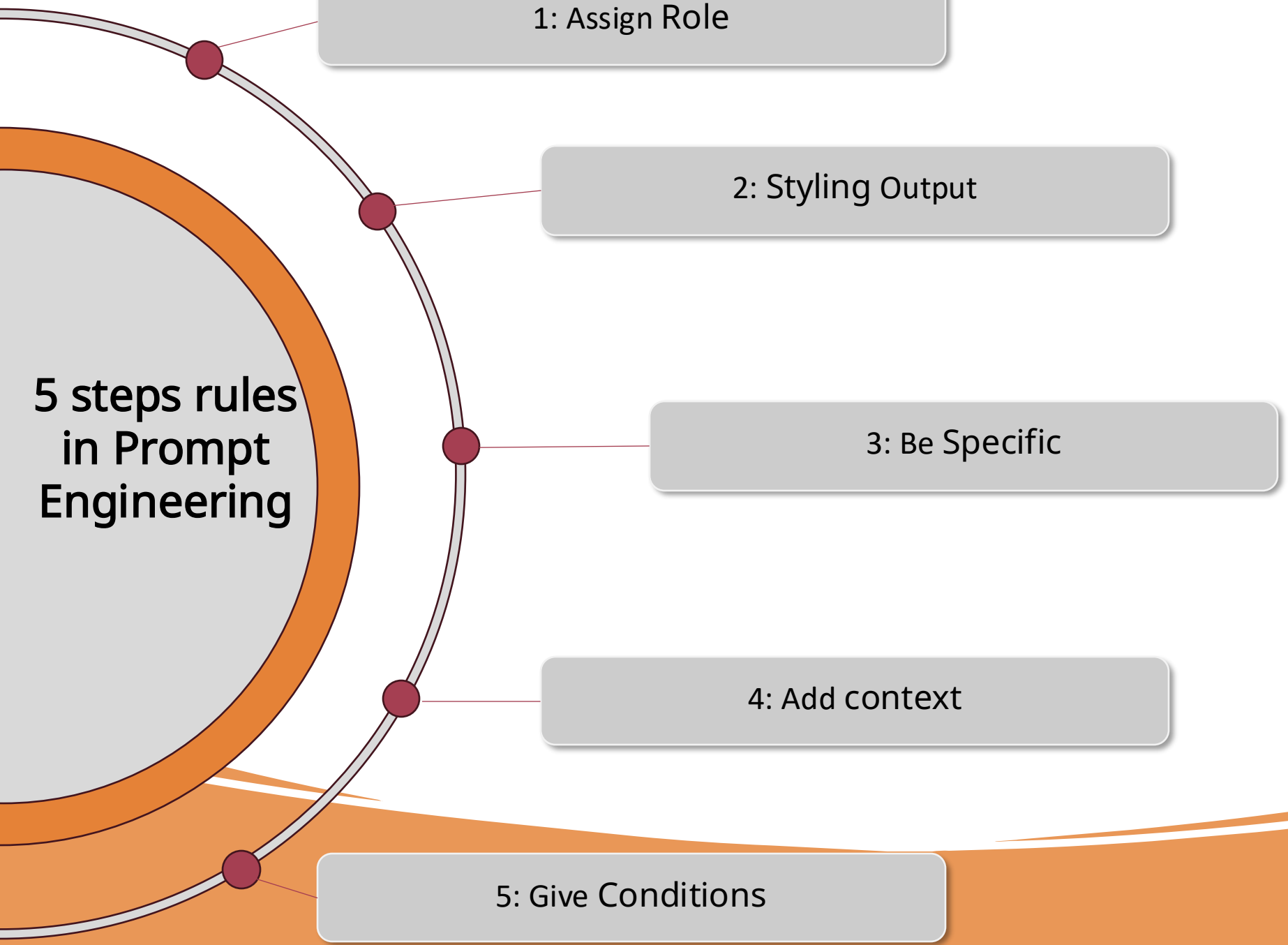
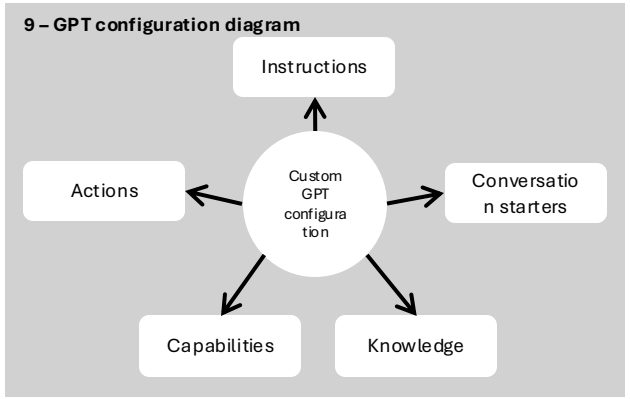
PROMPT ENGINEERING

- Prompt engineering is the process where you guide generative artificial intelligence (generative AI) solutions to generate desired outputs.




5 steps rules in Prompt Engineering
1: Assign Role
2: Styling Output
3: Be Specific
4: Add context
5: Give Conditions



Estimate the cost to manufacture an aluminium car wheel

Figure 7: Prompt 1 basic

Using the current price of aluminium, calculate the cost of manufacturing a 19 inch (volume is 3,681.33 cm^3) aluminium car wheel. The wheel I want an estimate for is manufactured using forging and machining and manufactured in the UK with a quantity of 100,000 pieces. Break it down into individual steps and explain each step.

Figure 8: Prompt 1 engineered

How much more would it cost to make a car wheel from aluminium rather than titanium

Figure 9: Prompt 3 basic

Using the cost data set I have provided you with, estimate the material cost of producing a car wheel for three different materials; steel, aluminium and titanium. Don't worry about estimating the cost for any other parts of the manufacturing process. Use the metal price API for live material prices. Take as long as you need and after each cost estimate provide a rationale and identify the key cost drivers.

Figure 10: Prompt 3 engineered

Testing of prompts

Example for a bad prompt:

Give me the cost to make a car wheel

Example for a good prompt:

Using the current price of aluminium, calculate the cost of manufacturing a 19 inch (volume is 3,681.33 cm^3) aluminium car wheel. The wheel I want an estimate for is manufactured using forging and machining and manufactured in the UK with a quantity of 100,000 pieces. Break it down into individual steps and explain each step.

Microsoft Copilot with instruction and context-based prompting, combined with Chain-of-Thought reasoning

Step 1: Upload the Dataset in Microsoft Copilot

Step 2:

You are an Analytical + Decision-Support Agent.

Dataset: Use the sheet "in" which contains:

- Core Service
- Building Type
- Indoor Space Group
- Average with Seed (numeric)

Task: Apply Chain-of-Thought reasoning.

Phase A (Plan):

- Step 1: Profile dataset (rows, columns, missing data, numeric vs non-numeric).
- Step 2: Define possible KPIs (total cost, cost per Building Type, cost per Indoor Space Group).
- Step 3: Identify possible visualizations (distributions, boxplots).
- Step 4: Plan correlation/trend analysis (note if not feasible).
- Step 5: Plan risk scoring (0–100).
- Step 6: Plan decision outputs (recommendations.csv + decision_matrix.csv)

Step 3:

Good. Now execute Phase B (Act) and Phase C (Decision) step by step as planned.

For each step:
- Explain what was done
- Show intermediate outputs (profiling, KPIs, scores, etc.)
- Highlight missing/unknown fields

Finish with:
Final Answer: <Top 3 recommendations>

Simulating the work of a Cost Engineer

- Finding out cost driver information by targeted questioning of company documents which otherwise would have to be studied in detail

OVERCOMING KEY CHALLENGES IN COST ENGINEERING

Addressing inefficiencies and security risks in handling complex financial data

1

MANUAL SEARCHES SLOW DECISION-MAKING

Manual analysis of vast, complex documents like proposals and standards leads to slow, error-prone processes that delay critical cost engineering decisions.

2

PUBLIC AI TOOLS RISK DATA LEAKS

Using public AI tools such as ChatGPT risks exposing confidential financial data and intellectual property, creating significant security vulnerabilities.

GROUNDING AI IN FACTS: RETRIEVAL-AUGMENTED GENERATION (RAG):

Combining language models with external memory for accurate, relevant AI responses

RAG + MEMORY

Integrates **LLMs** with **documents**.

QUERY VECTOR

Converts queries to **semantic vectors**.

APPEND CONTEXT

Adds info to **LLM prompts**.

ACCURATE ANSWERS

Produces **up-to-date**, **relevant** info.

SEMANTIC SEARCH

Retrieves **relevant** doc chunks.

REDUCE HALLUC.

Bases answers on **verified data**.

CORE COMPONENTS OF THE RAG PIPELINE

Key elements ensuring accurate, context-aware, and auditable chatbot responses

1 DOCUMENT PARSING AND STRUCTURING

Advanced parsing preserves logical document structure enabling semantic chunking for improved retrieval accuracy.

2 VECTOR EMBEDDINGS AND SEMANTIC SEARCH

Text chunks converted into vector embeddings; vector database supports similarity search matching user queries.

3 PROMPT ENGINEERING

Designed prompts control LLM behavior to adopt expert persona, provide structured answers, indicate missing data, and generate PBS from context.

KEY CHALLENGE 1: DOCUMENT PARSING

Overcome document structure loss with intelligent layout analysis and strategic trade-offs

1 SIMPLE TEXT EXTRACTION LOSES DOCUMENT STRUCTURE

Extracting text naively flattens content, causing loss of critical elements like tables and headings, which complicates downstream processing and analysis.

2 USED THE UNSTRUCTURED LIBRARY FOR LAYOUT ANALYSIS

Implemented the unstructured library to intelligently parse PDFs, preserving tables, headings, and other structural components for accurate document understanding.

3 CHOSE 'FAST' STRATEGY TO AVOID COMPLEX DEPENDENCIES

Selected the "fast" partition_pdf strategy to eliminate reliance on Poppler and Tesseract, sacrificing scanned image reading to ensure a stable and maintainable environment.

KEY CHALLENGES 2: ENHANCING MODEL OUTPUT

Addressing brief outputs by refining templates, upgrading models, and enabling multimodal learning

INITIAL OUTPUT LIMITS

The model's early outputs were often too short and lacked **detail**, which reduced their effectiveness for **cost engineering** tasks and decision-making.

IN-DEPTH TEMPLATE DESIGN

A more detailed and structured **template** was developed to guide the model, enabling it to generate richer and more **comprehensive responses**.

LLM INTEGRATION

Switching to the **LLaMA 3** model enhanced language understanding and generation quality, significantly improving overall output **performance**.

IMAGE INPUT ENABLED

Incorporating images introduced **multimodal inputs**, boosting the model's ability to process complex **data formats** and visual information.

NEW TRAINING METHOD

A novel training technique was introduced to teach the model advanced skills like generating **Product Breakdown Structures (PBS)** for detailed project analysis.

Demonstrations of RAG and custom GPT

- Demonstration by Auzair Khan of searching document

Quotes from Industry

BENTLEY

- “Cost Engineers can make important productivity improvements by using generative AI to search information during cost estimating”

"in global facilities management then skills and understanding in the use of prompt engineering techniques during the data analysis phase is now a critical skill to join cost engineering."

"insight into how generative AI works can inform the basis of estimate when using such techniques"

"today's cost engineer is innovating with generative AI constantly such that conclusions today are different tomorrow about the use of such techniques"

"productivity improvements are critical using generative AI in data collection and searching information for cost estimates"

Getting to the point

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