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Engineering Design Portfolio

Praxis II | April 2025

"Every person who comes into our life comes for a reason; some come to learn and others come to teach."

– Antoine de Saint-Exupéry

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1 Introduction

Claim: My engineering design process reflects my values, biases and experiences. Throughout this year, I have grown from the experiences and projects I have been provided with.

Who am I? I am trying to find an answer to this question: a student? A learner? A futurist engineer? But what does it mean to be an engineer? Am I fit to be an engineer?

From my first semester in engineering, I learnt that being an engineer means being a resilient problem-solver and understanding what makes your practice unique. The diverse perspectives each engineer develops from their experiences and position makes each engineer a trademark to their team.

This portfolio answers these questions and highlights my unique engineering profile. This includes:

- my learning from the tools, models and frameworks I used.
- how my position has changed with my experience
- how I can implement my wisdom towards projects in the future.

As my journey progresses, I will iterate upon this document to show my growth.

2 Student Engineer or Engineering Student?

I am a student engineer. A student engineer is someone who believes themselves as an engineer, although they happen to be a student, whereas an engineering student is a student who happens to be studying engineering.

My goal is to bridge the gap between theory and application. I want to practice my knowledge and contribute to the infinite knowledge that is yet to be discovered around me. This degree is my starting point for 'catching up' with the speck of knowledge we have.

2.1 My Position and Values

From the start of Praxis II, I reflected upon my position as an engineering design student. I created an escape room presentation about my values, found **here**

> "**Engineering Design is a process integrating the creativity of design and the application of engineering concepts, intuition or experience to problem-solve and build innovative systems to advance quality of living. - Aarya's Old and Current Position Statement**

Some of my new-found values are:

- **Purpose:** the quote on page 2 is my favourite quote because I believe everything happens for a good reason. Whether it is meeting new people or discovering new ideas. This allows me to be optimistic and embrace challenges with a smile. I take failures as learning opportunities. This value makes me open-minded to new ideas and alternate ways of using CTMFs. This trait also makes me curious and interested in the projects I am involved with as seen in **my original position.**
- **Productivity:** I never understood how much productivity mattered to me until I entered the busy life of EngSci. I defined productivity as number of tasks on my to-do list I can write and cross-off. This is a quantitative approach, and helps me feel accomplished. However, this value often creates planning fallacy [11](underestimating how much time is required for a certain deliverable) during group projects, and stresses me out.

- **Creativity and Innovation:** I value bringing the best work forward. I like to imagine that every assignment I am completing is important, something not done by a student (as it often feels inexperienced), but rather a professional publishing their findings. However, combined with my value for productivity, this creates (refer to page 5)

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2.2 Why I Chose LaTeX

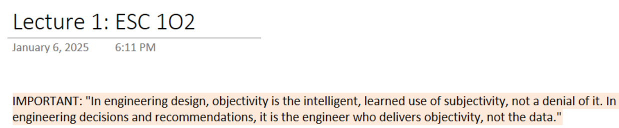

Figure 1: A quote I retained from my first Praxis II lecture [7].

The quote that our professors told us on the first day of Praxis II made me believe that engineers need be objective (to me, this also meant very confident and able to convey that their claim was strong enough to be considered a fact). Not only does this require structure, but it requires professionalism, sophistication and confidence in your ideas. I chose LaTex because I believed it would best convey my deep and meaningful insights.

My value of being open-minded pushed me to use LaTex. I was intimidated of using LaTex because I thought it would be complicated; However, our groupmate suggested we use this for a design report in Praxis I, and contrary to my assumption, LaTex was a skill I was able to pick up quite quickly.

The colourful one-pages showcase my creativity. I value being authentic and optimistic, and my truest self is when I am outdoors (hence the colour theme of these one-pagers).

I recognize that as I read this document in the future, I would want it to be designed for quick access and readability, which is why I am writing incorporating short paragraphs, bullet points and visuals. However, I need it to be explained in detail, so I can clearly understand my justification.

From the first day of Praxis I, I learnt that engineering was all about creating strong arguments to support your claims. Consequently, every CTMF is written as a claim. All CTMFs I found useful will be highlighted in green and others will be highlighted in red. My one-pager summaries are annotated or directly incorporated into my one-pager.

2.3 My Biases and Assumptions

- **Procedural Bias [17]:**This bias states that the type of setting and environment you are in alters your perception and biases. For instance, during Praxis I, our group used the lotus blossom technique while diverging on ideas for a prototype. We realized it was ineffective because it failed to generate new ideas as it tried to focus on shifting our perspective of the opportunity. However, in Praxis II, we used this strategy to assess potential opportunities and communities and found it advantageous in finding different communities and aspects of an opportunity. I acknowledge that my practice is dependent on the group I collaborate with and the developing project.

- **Outcome Bias [6]:** While I want to showcase my best efforts, a bias is that my perception of 'how well' this handbook is depends on the grades (a quantitative metric) I receive from my assessors; my views may differ from the perspectives of my assessors.

- **Conformity Bias [4]:** Due to my value of being efficient and productive, sometimes I become impatient during long design decision meetings and discussions. Due to the large workload of this program, sometimes it is important to just move on with a decision, even though it may not be the optimal one.
- **Affinity and Attribution Bias [4]:** As much as I love working with diverse individuals, I value efficiency and strong communication. Hence, when individuals cannot complete their deliverables in time or show up to meetings, I believe it's because people do not want to work on the task at hand. Therefore, when faced with the situation, I gravitate towards individuals who live up to my expectations.

Praxis I Design Summary: Shoulder Straps

Helping EngScis keep a better back posture

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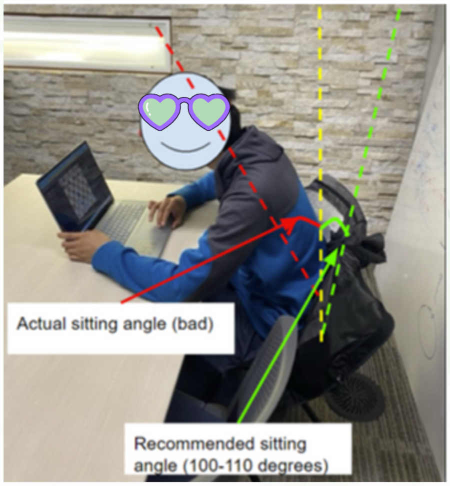
UNIVERSITY OF TORONTO

Opportunity

Correcting back posture of EngSci first year students with a comfortable and minimally visible design



Designing For:

Fixing back posture

Safety

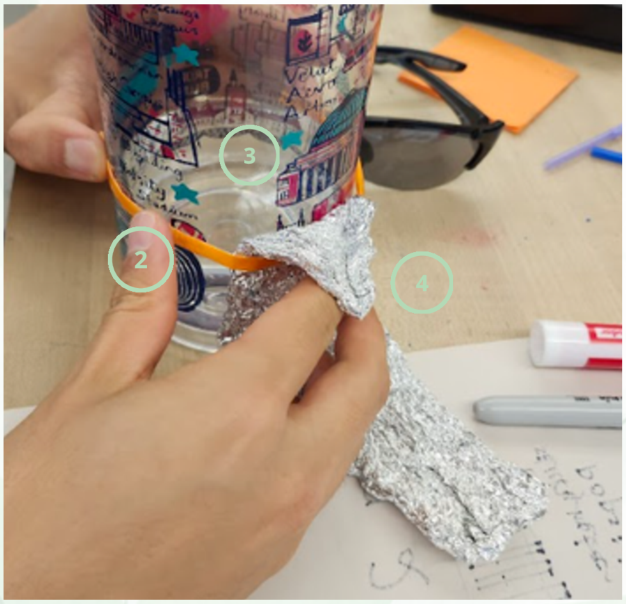
Portability

Durability

Aesthetics

Our Proposed Design

Our final proposed design was influenced by shoulder straps. It solves the problem by forcing the user to sit up in a chair.



1 Clips

2 Straps

3 Backrest

4 User

Design Features

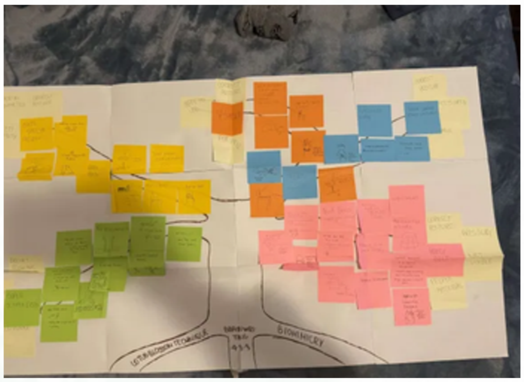
① Clips

The clips can be adjusted throughout the length of the rope and are for quick release.

② Straps

The straps have a larger SA to increase the comfort of the user.

CTMFs



Diverging Tree Using the Biomimicry, Brainwriting 6-3-5, Random Input and Lotus Blossom Technique

- *Pugh Chart:* Ranked designs against each other by comparing key requirements.
- *Brainwriting:* Used to quickly explore the design space.
- *Biomimicry:* Used to explore a broader design space by making connections to animals (i.e. giraffes).
- *Perry Model:* Combined and critiqued individual ideas to become an integrated authority.

Verification and Validation

- *Testing posture correction:* Wore each prototype to determine it's effectiveness in fixing back posture qualitatively (see picture to the right)
- *Testing for safety:* Used safety standards to inform safe design.
- *Testing for durability:* Dropped prototypes from 3 ft to test durability

Next steps

Further testing with higher fidelity prototypes is required to validate our design choices. As well, we would like to test with our stakeholders, and reframe our design and associated requirements from stakeholder feedback.

Skills Learned

Engineering Writing
CAD and Physical Prototyping
Mathematical Modelling
Communication
Decision-Making
Researching

Acknowledgments

We would like to thank the best Praxis I TAs, Ben and Joy. We would also like to thank the Engcis that agreed to be interviewed and in our photos.

3 ESC 101: Improving Back Posture among First Year Engineering Science Students

3.1 Goals and Objectives Shall Follow A DfX Framework

Framework: Design For X [14]

Designing for Excellence (or DfX) is a curated set of standards and practices to ensure a design can achieve a specific goal. Examples include Designing for Safety, Designing for Durability and Sustainability.
Our team used DfX handbooks when establishing goals and ways we can make our products safer to use and more comfortable. The clear-cut procedures of increasing the radii or avoiding bright colors provided a basis for our requirements and the justification to provide them.

Establishing goals and objectives using DfX felt more intuitive (ex. reducing sharp corners help increase safety) because of our lived experience, whereas codes and standards require specific tests we may not have prior knowledge on. Therefore, it is harder to start doing research on codes and standards for an opportunity when you do not have clear objectives and ways you want to accomplish those objectives (which is where DfX comes into play).

However, a limitation to DFX is that they do not provide metrics using tests, making it much harder to make requirements out of them. For instance, when designing our prototype for 'Aesthetics', we wanted it to be concealed (not have a bulge). However, a dFX handbook could not provide a metric of what is considered 'concealed' or 'protruding'. Hence, our requirement and justification were more speculative (seen in Figure 2, which was looked upon by our assessors .

R11	If the prototype is worn underneath clothes, it should not protrude more than 2 inches from any part of the users body.	Based on primary research, EngSci students prefer a concealed device. A 2-inch protrusion is considered small enough to be sufficiently concealed, since first-trimester pregnancies, which have baby bumps of 2-4 inches [13], are considered concealed.

Figure 2: We wanted to design for aesthetics, which meant making sure something did not protrude. Intuitively, one can tell if something protrudes or not, but finding a requirement can be hard for specific contexts. In this scenario, the justification felt very weak and not something that would be written in a mastered requirements framework.

Going forward, I will focus on using DfX to first establish my objectives and the ways I can accomplish them before consulting specific codes and standards to have grounded justifications.

3.2 Independent Collaboration Should Be Used to Optimize Meaningful Discussions

Model: Perry Model [10],Toulmin's Model [2]

The Perry Model states the four stages students undergo during intellectual or ethical maturity. They start with the knowledge they know (dualism). However, knowledge has contradictions; it is intertwined with bias. As you expose yourself to contradicting knowledge, you are left with confusion and curiosity (multiplicity). You consult diverse authorities, developing your own beliefs and biases of what's right, reaching contextual relativism and ultimately a 'commitment in relativism' as you curate your position and claims while recognizing it may iterate as you undercover more knowledge.

Toulmin's Model is the fundamental tool to generate an effective engineering argument; every good claim needs evidence and justification while addressing qualifiers and counterclaims to explore all perspectives and strengthen their decisions.

Combining the Perry Model and Toulmin's Model allows for stronger decisions as the idea undergoes refinements and attacks from various perspectives.

Independent Collaboration is a phrase I developed while writing my process analysis (Figure **??**). It allows individuals to spend more time justifying their thoughts and claims before having to defend their theses to different standards and authorities. In my process analysis (excerpt below), I noted how I created CAD Models for a pillow prototype and how my teammates found holes in my design decisions. Their diverse insight throughout editing and refining the final prototype allowed us to scrap the unbelievable designs we initially had and to pivot towards a more minimalistic and simpler approach to being adjustable for everyone.

This shaped my values of being more open-minded because I would not have created something I was truly proud of and admired if I had not improved it. The information and biases of my groupmates, along with their thoughtful justification and arguments, led to the ultimate design of this pillow, making us a 'singular authority.' At the end of the design process, I felt accomplished and purposeful instead of feeling like the meeting was a waste of time.

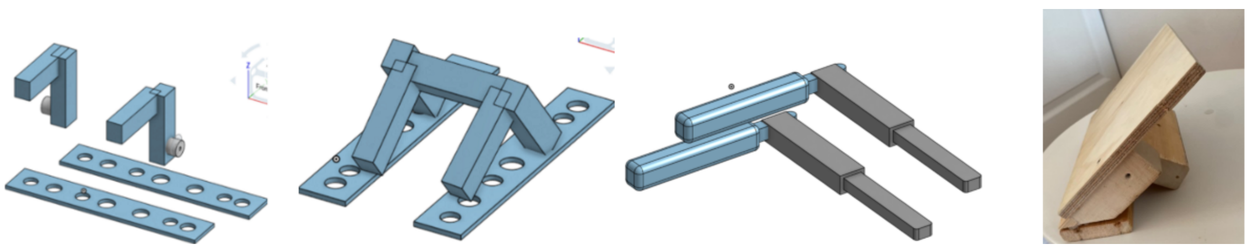


Figure 3: A timeline iteration of the adjustable support for our pillow prototype. This was one of our top prototypes because it was innovative, and careful thought went into building a prototype that validated all our criticism (all iterations were made by me).

Going forward, for more in-depth and meaningful conversations about prototypes or decisions, I will give my team at least 24 hours to think of ideas and claims they have so they can formulate proper justification before debating and converging to some decisions. This connects with Toulmin's Model as formulating strong arguments and justification requires time, and to become a powerful Authority, you need the time to collect your thoughts and assess all your sources.

3.3 All Arguments Should Have Justification Using the AID Model

Model: AID Model [5]

The AID Model stands for "Action, Impact and Development"; it answers the questions "What?", "So What?" and "Now What?" This method is primarily in giving constructive feedback to your teammates, as the examples provided are very specific.

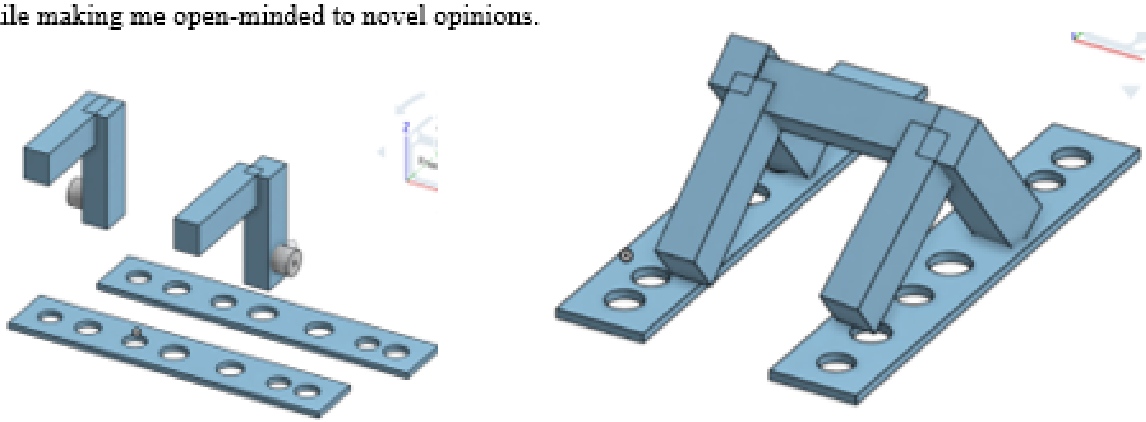
From writing more reflective texts (position statement or process analysis) to writing formalized requirements and justifications, I began to use the AID Model outside of just for providing feedback. I thought it was a more standardized and justified approach regarding why I was going about a certain task. There was constructive and specific evidence. I often value solving the problem, rather than getting fixated on what the problem is, and I found that the AID Model's "Now What" allows for progression rather than solely providing information. An example is seen below in my process analysis, where I implicitly use an AID Model approach, something that helped me and my assessor.

First Action: Integrating Multiple Authorities to Consider Various Perspectives:

While converging on five prototypes, we implemented an inclined pillow idea, which would prompt the user to lean backwards while sitting, preventing hunched backs. The unbelievable aspect of this prototype was that it was "designed for accessibility". This was our most unique and ambitious idea. I took the initiative to build a CAD model and use math to show the execution of this pillow. My initial model had wheels and sliders, so the pillow could change shape and be adjusted to any position. In our group chat, my team seemed to understand the idea. However, in our in-person meeting, when I presented the final draft, they thought the idea was complex and different from what they had interpreted. They encouraged me to justify my design choices. As a longtime authority, this was easy because I had the time to know what meaning the design provided. Nonetheless, justifying forced me to share my claims, and make them vulnerable to attacks. These new perspectives sparked innovation. After hearing me, a teammate suggested using wheels might be unnecessary when the pillow could simply be flipped around. Some concerns became related to safety, prompting us to reframe our requirements. We decided to make the adjustable mechanism out of steel instead of wood so it can be washed, and created requirements that it should exert a maximum pressure of 20-40g/cm^2, My teammates' contributions evolved them into authorities. We effectively communicated through body language and sketches, which were far more effective than words. Ultimately, we discovered future opportunities, and this became our strongest prototype (*Figure 2*). I felt accomplished and grateful for a group that trusted and respected my ideas, while making me open-minded to novel opinions.

Details what I experienced

My feelings answer 'so what' as it shows how essential the experience was.



Figures 1 + 2: The evolution of the unbelievable aspect of the inclined pillow mechanism, as we explored the design space individually and collaboratively.

Part of engineering design process is recognizing the best approach to express ourselves. Body language and hands on learning were our best method of communication *(Figure 3)*, which requires preparation. Our success was becoming experts in specific fields and working together to educate each other and create more connections, allowing us to explore a full design space. These fun activities encouraged us to bond together and become one bigger authority. There was no such thing as 'my prototype', but rather a 'our prototype', and I was merely an initial contributor to it.

I like to learn my mistakes to [then know] what to do

Going forward, we will reinforce more in-person meetings and have internal deadlines before these meetups to boost productivity. We recognize these meetings might be long as we delve deeper into these intriguing concepts and discussions.

Figure 4: An Extract of My Process Analysis Last Semester, with Annotations of How it Correlated with the AID Model

Going forward, I realized that the AID Model can be powerful for any form of justification. It states a fact, provides justification and ends off with speculation or a clear way of how we can use this knowledge for betterment, since engineering focuses on innovation and solving problems.

For this reason, the reflections in my handbook follow this standard AID Model Procedure.

3.4 Pairwise Comparison Shall Be Used Only During Final Converging

Framework: Pairwise Comparison, [13]Requirements Framework,

Pairwise Comparison is a converging tool that compares two designs or features against a list of requirements or features to determine the optimal prototype or design decision.

During Alpha, our group had informally ranked our top 5 prototypes from favourite to least favourite. Our top prototype was a pressure sensor as it provided instant metric feedback, had a software aspect, and could be demoed using a kitchen scale. This placed an anchoring bias [1] on our group, where the first ranking held major influence afterward.

During studio, our team used multi-volting, a group-based decision-making technique, combined with pairwise comparison to debate on which designs were the most effective. More specifically, to make this debate better, we decided that each individual will become an advocate for a design they did not build. My opponent was arguing for shoulder straps, while I was debating the pressure sensor. This was the prototype that he had built. I knew the pressure sensor would win. Surprisingly, my teammate eliminated our biases and convinced us that the shoulder straps were the best idea by tying each argument to a specific requirement or evaluation criteria. We realized this was more effective because it provided an objective guideline on what made a good design, and then the pairwise comparison was easier to implement and debate on, and the conclusions we had were more justified.

A major limitation with using the pairwise comparison was that it was ineffective in initial converging. Since we first had five different prototypes to compare, it was too time-consuming to debate all of our prototypes one by one. So upon pivoting to a requirements framework comparison, we used a Pugh chart (Figure **??**), as it provided a higher-level comparison between the prototypes.

As I advance, I realized the best way to approach converging, especially if we're using a pairwise comparison, is to start by evaluating the importance of your requirements framework. This is the optimal time to rank your requirements because I feel that when I have many constraints from the beginning, it's harder to think of innovative ideas. After all, they may seem crazy at first but can be useful after.

If our group could redo the converging phase, we would have created more than one Pugh chart because they depend on your reference point. Creating more Pugh charts would allow us to better choose which two devices to have an ultimate pairwise comparison with.

7.2.1 A Pugh Chart With Some Bias

Pugh Chart

REQUIREMENTS	POKEY BELT (REFERENCE)	SHOULDER STRAPS	INCLINED PILLOW	PRESSURE SENSOR
[R1] Trunk Inclination: The more constrictive the better.	O	+	O	−
[R2] Carcinogens: The fewer carcinogens (in mg/kg) and flame retardant chemicals (ppm) used the better	O	O	O	O
[R3] Voltage: The less voltage (V) required to operate, the better.	O	X	X	−
[R4] Design For Simplicity: The fewer electromechanical parts required in manufacturing, the better.	X	X	X	−
[R5] Shoulder Pressure: The less pressure load provided on shoulders (measured in Pa and compared to the % of user's body weight) , the better	O	−	+	+
[R7] Dimensions: The smaller the dimensions (in cm) OR more number of features enhancing portability, the better	O	+	−	+
[R9] Mass: The less mass (kg), the better	O	+	−	+
[R10] Breathability: The less thermal evaporative coefficient, the better.	O	O	+	X
[R11] Visibility: The less visibility/protrusion (inches), the better.	O	O	−	+

Shoulder Straps	Pressure Sensor
- No electromechanical parts	- Portable
- Constrictive and provides pressure feedback	- Provides instant feedback and notification based tracking throughout day
- Safer to use (no voltage)	- Positive reinforcement to train back muscles
- No protrusion since it's worn	- Less pressure on shoulder
- Durable	- Less volume

Figure 5: The pugh chart and pairwise comparison we established. Upon ranking our requirements, although the shoulder straps do not have more "pluses", they fulfill more high-level requirements. After a pugh chart, we realized the pressure sensor and shoulder straps would be the best comparison. The pressure sensor had more 'pluses' and was our highest-ranked design, although it did not score well on the most important requirements.

These tools and frameworks strengthen my definition of Engineering design.(refer to 2.1). In Praxis I, my group used our creative thinking to develop unique ideas that aligned with market trends. Some ideas like a 'pokey belt' or an inclined pillow have not been implemented yet. However, they require safety protocols and calculations. Upon performing those calculations, we would run into problems about ensuring proper requirements were met, or the FOS values were sufficient. This enhanced our problem-solving skills because it meant we would have to diverge for better ideas.

CIV 102 Bridge Project

Video of Bridge Testing

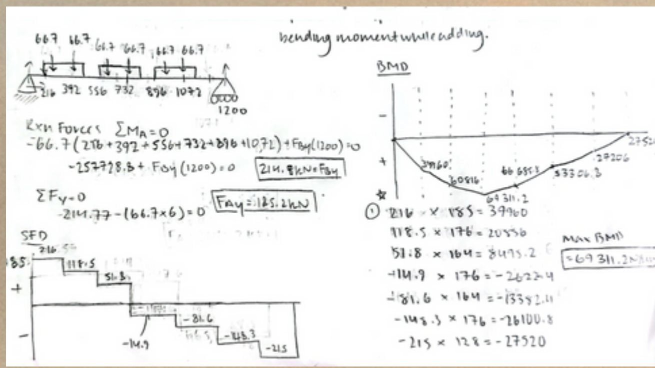
Overview

Bridge Failure Video

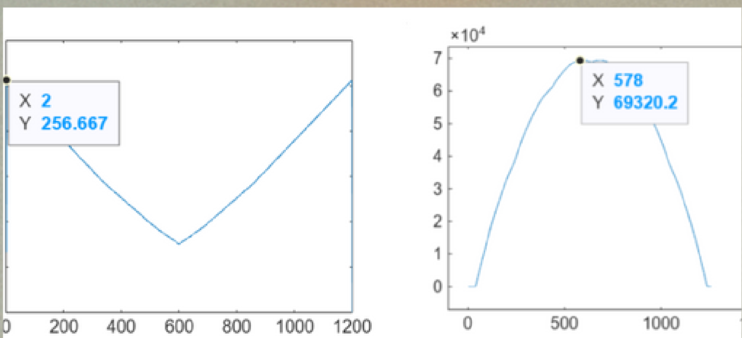
We aimed to apply our structural knowledge to create a 'box-girder beam bridge' that could withstand a dynamic load of 400N. We were constrained to a 813 mm × 1016 mm × 1.27 mm piece of matboard and 60L of contact cement. Our assessment criteria was based on the accuracy of our FOS values (all FOS values shall be greater than 2.0, but the closer together all the FOS values are about each other, the better), and the higher the strength-to-weight ratio, the better.

REQUIREMENT FRAMEWORK:

- The bridge shall be within1250mm-1270mm in length
- The bridge shall not have a track height over 200mm, The distance from the tracks to the supports shall be a multiple of 20mm.
- The bridge deck shall exceed 100mm in width
- The bridge shall have a flat 50mm surface on either edge for the supports.



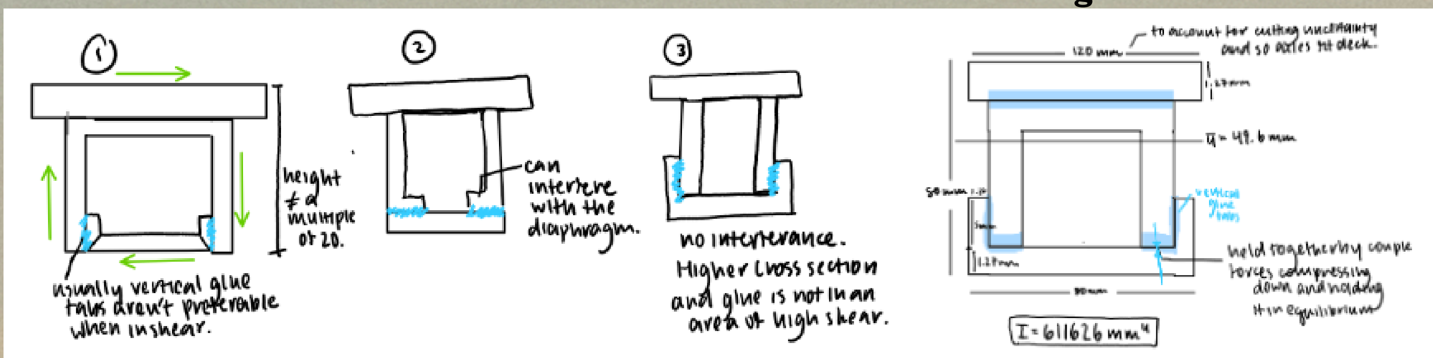
Developing MATLAB code to Simulate Maximum SFD and BMD.



DESIGN DECISIONS:

- Varying distances between diaphragms to account for areas with different shear/bending moments.
- Using shear splice connections, not lapping
- Only using 10mm glue tabs
- Adding a small support between the web of cross-section 3 to lower thin plate buckling
- Changing the dimensions of our bridge to length 1260mm, height 80mm and width 120mm.

Evolution of Our Cross Sections From Design 0

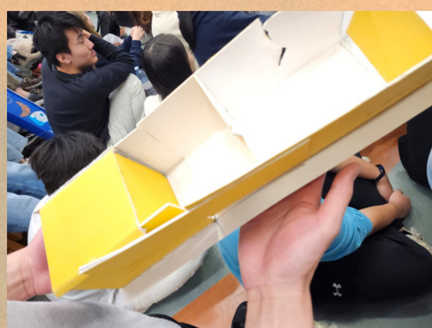


SKILLS LEARNT:

- MATLAB
- Engineering Drawings
- Applying Theory to Real Work Situations
- Constructing
- Design Report Communication
- Predicting Failures in Bridges
- .Google Spreadsheets For Computation

Theoretical Load: 460 N
Failure predicted due to buckling of the compressive flanges between the webs of cross-section 2.

Actual Load: 490 N
Failure due to second splice connection



Design Teammates: Owen Poyner, Brian Ye

4 CIV 1O2: Creating a Bridge Using Mat board

4.1 All Group Projects shall Begin With an Establishment of position

Tools: Stakeholder analysis [16], Checklists and Gantt Charts on Asana

Stakeholders are members of the society that have an impact or influence on the project results (from Praxis II I realized that even fish can be stakeholders!). Stakeholder analysis incorporates a set of tools to help cultivate our needs, goals, and objectives. Teammates are also stakeholders. We have our expectations as we embark on a project, and for a successful project, it is important to analyze your stakeholders' norms.

Our group did this by establishing our team norms(seen in Figure 6).

Must Have	Good to Have	Do not Want
- Mutual Trust/Honesty - No ChatGPT - No procrastination, do tasks on time - Group Calendar - Checking the group chat - Helping out and equal division based on skillset - Instagram Messages within 4 hours	- Not late nights on Friday - Not late nights in general - 9:00am to 7:00pm?	- Early mornings - People not communicating about their part.

Figure 6: Team Norms Our Group Established During our First Meeting

Additionally, our team indicated that we would put in effort but did not want to go 'over the top' with this assignment because exams were approaching and our teammates had other commitments. I was relieved our group was not going to pressure each other with high expectations.

However, our team struggled with project and deadline management. We would text in the group chat when we were available to work, only to be left 'on read' (violated team norm 1) because it was difficult to find a time. Only one person in our group was comfortable coding through MATLAB, and we assumed they could independently complete the task within a week. This was important to advance to the next stage of this project, but also an unrealistic expectation. This caused our progress to be backtracked as we scrambled to use an Excel spreadsheet I made for myself. We also did not use a team calendar to track our deadlines (violated team norm 2)

Additionally, one group member wanted to finish construction by the start of the weekend. Contrastingly, the rest of the group was unavailable for those days and convinced us to move it by a day and complete it throughout the weekend. Our teammates never communicated why they wanted to complete the project before the weekend (violated team norm 3). On Saturday night, our teammate confessed why he was determined to get the project done by the weekend and stated that he would not be able to contribute time after Sunday night (partially violated team norm 4). This was frustrating as it meant the rest of the group would have a heavier workload, and our deadlines would change, and the teammate mentioned they '[needed to] get above an 85%. (violating our discussion about how much effort we wanted to put into this project).

Reflecting, I realize that analyzing stakeholders' values needs purpose. I felt that there was no meaning in understanding your stakeholders only to not take the feedback seriously. It felt meaningless, and the primary stakeholders' needs were unmet. Additionally, I noted that our deadlines need to be specific and realistic.

Upon researching and discussing, I realized that going forward, I would create some incentive or small punishment if individuals violated internal stakeholder expectations (whether it's a compliment or reward when someone meets the team norms, or openly communicating your disappointment when they have neglected a core value.

4.2 Technological Simulations and Calculations Should Be Used for Visualization and To Double-Check Hand Calculations

Concept: Verification Procedures, Prototyping, CRAAP Testing Your Own Work [**12**] Technology is an integral part of engineering design. It makes sources readily available and computation much quicker. CRAAP test is a concept to evaluate the creditability of secondary sources; it helps eliminate bias and ensure precision. The full definition of CRAAP is seen below **??**.

CRAAP Criteria	**Application in Primary Calculations**
Currency	Does the method I am using in the previous question still apply?
Relevant	Are the equations I am using still relevant and up-to-date?
Authority	How much can I trust myself vs the spreadsheet I have made (have I hardcoded any sections that I forget to verify?)
Accuracy	Are the numbers reasonable? Are the units reasonable?
Purpose	What makes these calculations different from the previous set or goal?

Table 1: CRAAP test can be implemented for verification purposes and for primary research/data you collect

However, I believe this definition of the CRAAP test can be applied to primary research as well, especially when using technology to perform verification procedures or prototyping decisions.

While designing our bridge, we were tasked to code the maximum bending moment (BMD) and shear force (SFD) of a bridge subjected to a moving load. I was in charge of the calculations on hand. To organize my calculations, I created an Excel spreadsheet with my calculations. We thought this was a helpful approach, and so instead of finishing our MATLAB code to verify our code calculations, we stuck to the Excel spreadsheet.

As we moved through iterations, we duplicated the Excel spreadsheet so the equations would stay the same. However, as my groupmates did not know much about this spreadsheet, they would often plug in numbers to get the wrong FOS output because they hadn't changed a specific variable throughout the whole sheet. Some of these errors went unnoticed until the sheet started outputting errors due to our numbers. Correcting these mistakes was very time-consuming, and we had to redo hand-calculations to ensure all the numbers were updated. I learnt later in Praxis II, when talking to my professors, that technology should not be used to simulate a calculation if you do not know what every number means, as that can be imprecise and can lead to devastating losses in a professional setting and can be time-consuming to troubleshoot. Instead, it's better to use technology to verify that your work. This made me reflect on the moments we spent hours trying to solve our codes and figure out if our numbers were correct or not.

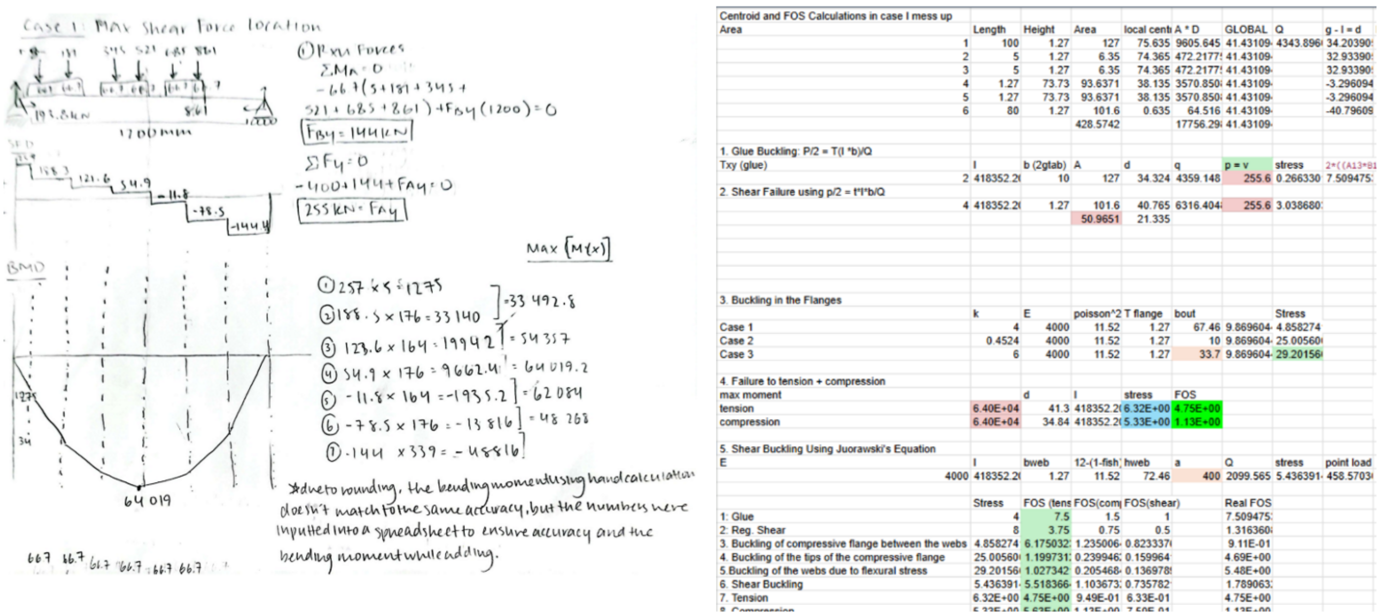


Figure 7: Using Hand Calculations, Followed by an Excel Spreadsheet for Verification. As different alterations were made, the Excel Spreadsheet Would Be Incorrect, and Needed to be Rechecked.

4.3 All Calculations Should State the Limitations They Made

Framework: Hoover Dam Model [8]

The Hoover Dam Model states the gap between the world we perceive and dream of and the world we live in. We often try to recreate the theoretical world using our mathematical equations, but many of these equations model an ideal condition that is usually not possible.

While testing our CIV Bridge Project, our professor wrote the theoretical loads the bridges were predicted to withstand, and compared it to their actual failure load. Many individuals designed a bridge that surpassed 1000N. I was intimidated because our group had also made conservative estimates of our splice connections, and our theoretical laod was only 460N.

However, from the board seen in Figure 8, only 7 teams were able to surpass the base case (our bridge being one of them with an actual failure just over 490N).

The reason many bridges failed was due to the splice connection and the scarce glue or mat board that was provided. This taught us that while individuals can have the best theoretical/ book design, it is more important to implement a design that accurately resembles your theory and perception, as engineering is about implementation and application. We were very proud by our progress.

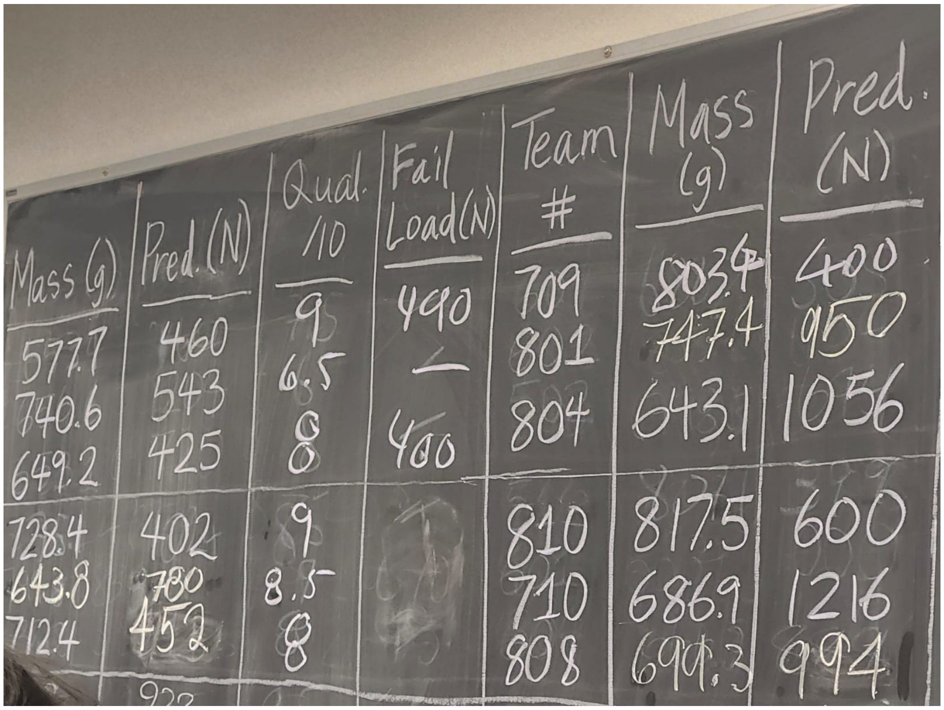
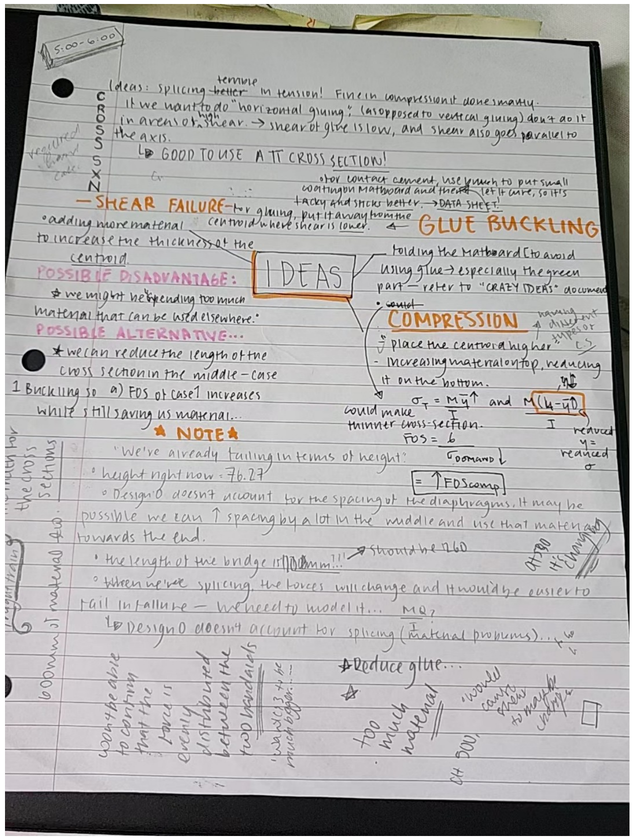


Figure 8: Results of Our Cohort's Theoretical VS. Actual Failure Loads. You can see that theoretical calculations are not a good approximations of how implementation will look like.

Additionally, to improve design 0 calculations, we diverged using mathematical models and challenge assumptions diverging technique (informally). We incorporated mathematical equations to increase the mass or the thickness of a flange, and noted how it can change our FOS values. We realized many mathematical conclusions stated that we would not need a lot of reinforcement or diaphragms. We filtered through the ideas based on what seemed realistic in our case. However, "To find the answer, you must know the answer"; we used challenge assumptions to note the limitations in the models. Since our bridges were made of mat board, they could be subject to inaccurate folding or cutting, we would need more reinforcement and diaphragms to support our structure.

Figure 9: These are some of the ideas we generated after performing Design 0 calculations. We used mathematical equations to understand the changes we would experience if we changes thickness or height of our bridge. We then used challenge assumptions because in reality, many ideas are harder to implement and are not an ideal representation of reality.



I realized the importance of remembering the Hoover Dam Model during all theoretical calculations, to find limitations in the models and how I can challenge the assumptions they provide, and this is a technique I will remember.

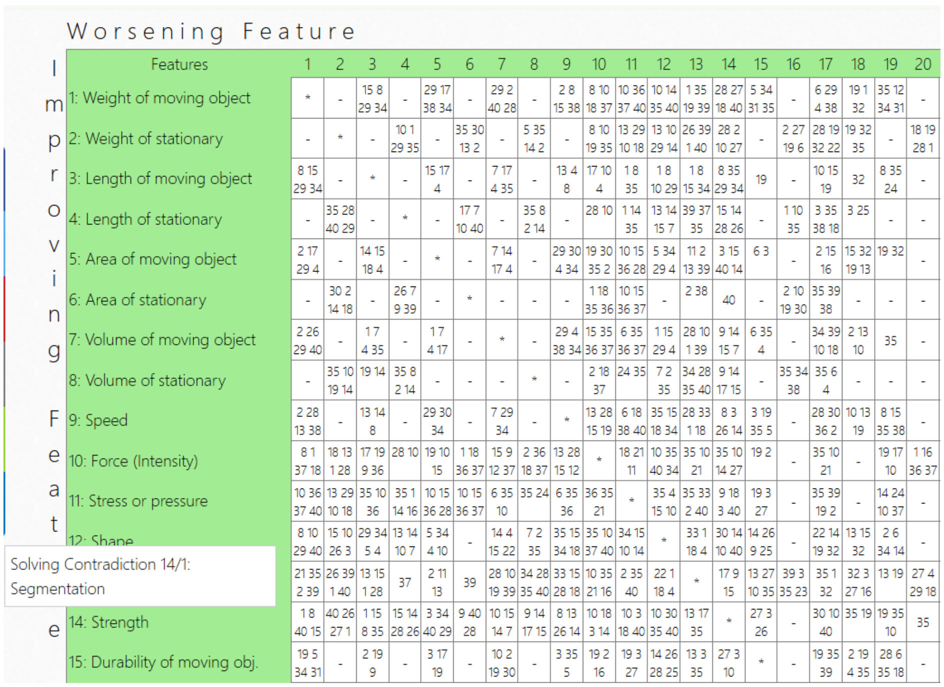
4.4 All Design Processes Shall Incorporate One Round of TRIZ

Tool: The TRIZ matrix [9]

TRIZ, which stands for Teoriya Resheniya Izobretatelskikh Zadatch (The Theory of Inventive Problem Solving), provides guidelines for solving the most pertinent problems without compromise.

In engineering design, many objectives conflict with each other, causing compromises and a suboptimal design. During our project, we were provided 1060 x 813 mm mat board to build a 1270 mm bridge. Our objectives were to design for strength and weightlessness (which require materials), but our main constraint was the scarcity of resources.

We hadn't formally looked at a TRIZ database; we researched to find that splice connections would be the optimal way to elongate the bridge instead of using lapping techniques. Lapping would require more contact cement and mat board while still providing similar benefits. We iterated to create two symmetrical splice connections, and with the excess material we had because from not using lapping, we used to strengthen the cross sections by implementing different types of cross sections, and by having more diaphragms. Since we didn't use a formal TRIZ process, it was harder to think creatively, and we needed to CRAAP test our sources to ensure these techniques would be effective. After learning about the TRIZ matrix, we realized many of the solutions we proposed or used were quite clearly noted in the database. They also looked at many more compromise categories like ensuring 'limited resources' and length of stationary, which we had overlooked. This TRIZ Matrix encompassed many of our proposed solutions, which could have saved us time.



Worsening Feature

Improving Feature

Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1: Weight of moving object	*	-	15 8 29 34	-	29 17 38 34	-	29 2 40 28	-	2 8 15 38	8 10 18 37	10 36 37 40	10 14 35 40	1 35 19 39	28 27 18 40	5 34 31 35	-	6 29 4 38	19 1 32	35 12 34 31	-
2: Weight of stationary	-	*	-	10 1 29 35	-	35 30 13 2	-	5 35 14 2	-	8 10 19 35	13 29 10 18	13 10 29 14	26 39 1 40	28 2 10 27	-	2 27 19 6	28 19 32 22	19 32 35	-	18 19 28 1
3: Length of moving object	8 15 29 34	-	*	-	15 17 4	-	7 17 4 35	-	13 4 8	17 10 4	1 8 35	1 8 10 29	1 8 15 34	8 35 29 34	19	-	10 15 19	32	8 35 24	-
4: Length of stationary	-	35 28 40 29	-	*	-	17 7 10 40	-	35 8 2 14	-	28 10	1 14 35	13 14 15 7	39 37 35	15 14 28 26	-	1 10 35	3 35 38 18	3 25	-	-
5: Area of moving object	2 17 29 4	-	14 15 18 4	-	*	-	7 14 17 4	-	29 30 4 34	19 30 35 2	10 15 36 28	5 34 29 4	11 2 13 39	3 15 40 14	6 3	-	2 15 16	15 32 19 13	19 32	-
6: Area of stationary	-	30 2 14 18	-	26 7 9 39	-	*	-	-	-	1 18 35 36	10 15 36 37	-	2 38	40	-	2 10 19 30	35 39 38	-	-	-
7: Volume of moving object	2 26 29 40	-	1 7 4 35	-	1 7 4 17	-	*	-	29 4 38 34	15 35 36 37	6 35 36 37	1 15 29 4	28 10 1 39	9 14 15 7	6 35 4	-	34 39 10 18	2 13 10	35	-
8: Volume of stationary	-	35 10 19 14	19 14	35 8 2 14	-	-	-	*	-	2 18 37	24 35	7 2 35	34 28 35 40	9 14 17 15	-	35 34 38	35 6 4	-	-	-
9: Speed	2 28 13 38	-	13 14 8	-	29 30 34	-	7 29 34	-	*	13 28 15 19	6 18 38 40	35 15 18 34	28 33 1 18	8 3 26 14	3 19 35 5	-	28 30 36 2	10 13 19	8 15 35 38	-
10: Force (Intensity)	8 1 37 18	18 13 1 28	17 19 9 36	28 10	19 10 15	1 18 36 37	15 9 12 37	2 36 18 37	13 28 15 12	*	18 21 11	10 35 40 34	35 10 21	35 10 14 27	19 2	-	35 10 21	-	19 17 10	1 16 36 37
11: Stress or pressure	10 36 37 40	13 29 10 18	35 10 36	35 1 14 16	10 15 36 28	10 15 36 37	6 35 10	35 24	6 35 36	36 35 21	*	35 4 15 10	35 33 2 40	9 18 3 40	19 3 27	-	35 39 19 2	-	14 24 10 37	-
12: Shape	8 10 29 40	15 10 26 3	29 34 5 4	13 14 10 7	5 34 4 10	-	14 4 15 22	7 2 35	35 15 34 18	35 10 37 40	34 15 10 14	*	33 1 18 4	30 14 10 40	14 26 9 25	-	22 14 19 32	13 15 32	2 6 34 14	-
Solving Contradiction 14/1: Segmentation	21 35 2 39	26 39 1 40	13 15 1 28	37	2 11 13	39	28 10 19 39	34 28 35 40	33 15 28 18	10 35 21 16	2 35 40	22 1 18 4	*	17 9 15	13 27 10 35	39 3 35 23	35 1 32	32 3 27 16	13 19	27 4 29 18
14: Strength	1 8 40 15	40 26 27 1	1 15 8 35	15 14 28 26	3 34 40 29	9 40 28	10 15 14 7	9 14 17 15	8 13 26 14	10 18 3 14	10 3 18 40	10 30 35 40	13 17 35	*	27 3 26	-	30 10 40	35 19	19 35 10	35
15: Durability of moving obj.	19 5 34 31	-	2 19 9	-	3 17 19	-	10 2 19 30	-	3 35 5	19 2 16	19 3 27	14 26 28 25	13 3 35	27 3 10	*	-	19 35 39	2 19 4 35	28 6 35 18	-

Figure 10: A TRIZ matrix I found in Praxis II. It indicates that the best way to have a higher strength to weight ratio (improved strength while lightening the weight) is to use segmentations or dynamic simulations. [3].

In CIV 102, our group used designs to think of potential ideas on how to correct FOS values based on intuition, experience, and assumptions. We were allowed to think of crazy ideas and alternatives. However, the reality of engineering and applied science hindered many of our ideas; options like implementing a circular cross section (we researched to be the best types of cross sections) would be hard to manufacture, and harder to calculate an FOS value for. The engineering requirements allowed us to converge, as they were our most important requirements. The better we could incorporate design and engineering concepts, the better the bridge would be.

Sustainability Safety Usability Durability Detectability Precision + Accuracy

EAAA

Enhanced Autonomous Anchor Arm

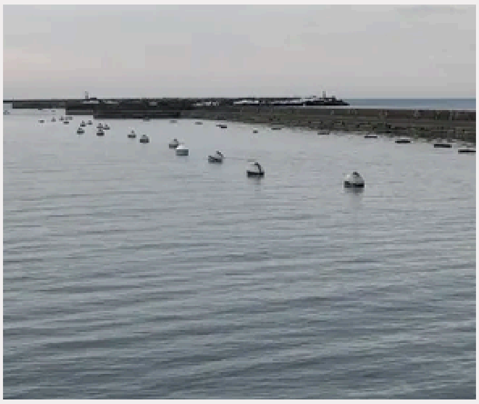
We chose this RFP because we valued risk taking and mooring was something our team had no experience in. This allowed us to foster a sense of curiosity, aligning with our values.

Opportunity:

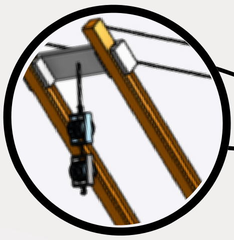
The Toronto Mooring and Sailing Club uses a barge to lift moors during the inspection process. After inspecting the anchors and chains, they return the moors to the lakebed. However, the imprecision in placing these moors shifts the anchors, causing different ranges of motion for buoys. This makes it difficult for boats to moor.

Our goal is to reduce the number of moors misaligned during the inspection process to ensure precise alignment and fewer shifted buoys.

Main Concept: Create a robotic arm extension on a barge that uses polar coordinates to place moors in predetermined positions.



We started with one design: a robotic arm. We expanded it to multiple features because our calculations sometimes stated that there would be failure.



1 Linear Rail

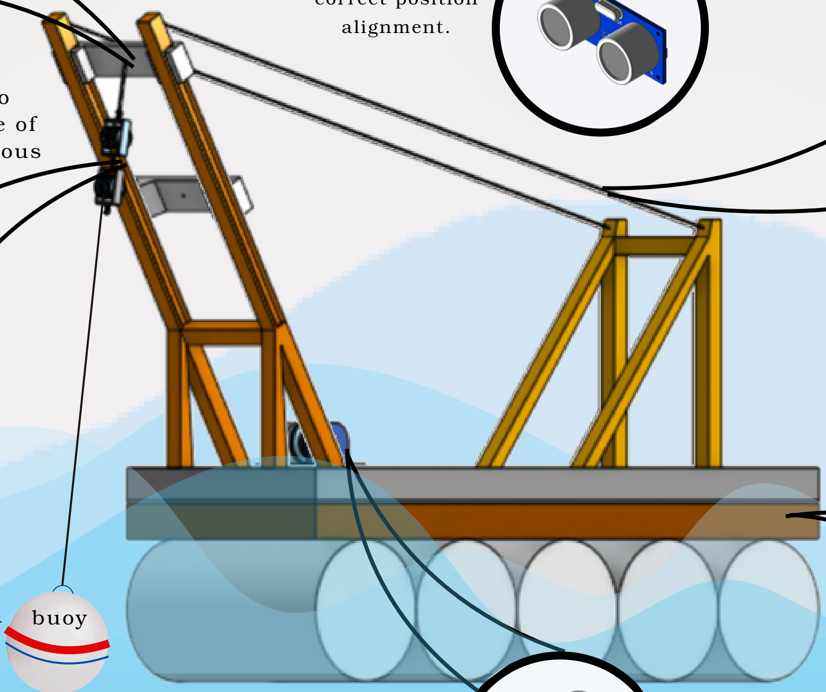
Slides the bearing block to extend and retract the range of the arm, so it can reach various distances

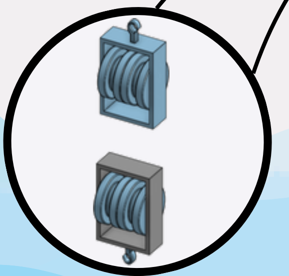
2 Sonar Sensor

The sonar sensors provide metric feedback to ensure correct position alignment.

3 Fixed Support and Cables

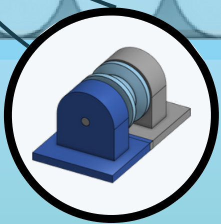
Provides equal distribution of weight throughout the barge. Helps avoid tipping and reduces flexural stresses experienced by the arm





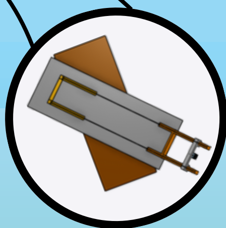
4 Four-Pulley System

Alleviates 25% of the load the winch can carry, to allow greater strength.



5 Electric Winch

A sustainable way for the cable to be reined in, to provide constant tension when placing and picking up the moors.

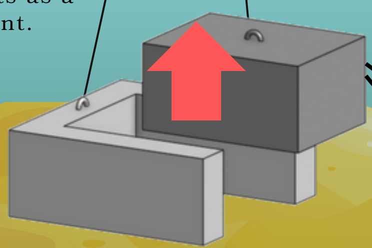


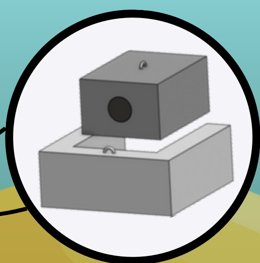
6 Rotating Base

Allowing the barge to rotate ±180° to place moors without physically moving. (uses θ from polar coordinates)

7 Jigsaw Anchors

'Jigsaw' anchors that connect when placed together. At all times, there is a 'sister anchor' that acts as a reference point.





8 Embedded Magnetic and Sonar Sensors

The magnets allow for tolerance if the anchors are accidentally separated

Key Design Decisions

Sustainability: preventing damage environment

Unlike traditional winches, which use gas and diesel, we implemented an electric winch.
Reusing the existing concrete anchors.

Sustainability was our key design decision because it was a shared value of our team. We wanted to create something representing ourselves

Durability: maximizing the load the barge can carry (in N) without hindering functionality

We included a pulley system, which would alleviate the force applied on the winch by 25%, bringing the load on the winch to 1790 N. The fixed supports lower the flexural stress, supporting the arm.

Precision and Accuracy: ensuring the arm standardizes placement during inspection.

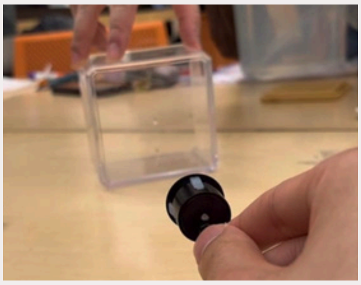
We use a linear rail and a rotating base that utilize polar coordinates to navigate the arm relative to the barge. The sonar sensor provides metric feedback when anchors are aligned, and the magnets correct the anchor's positions during an error.

Verification Results

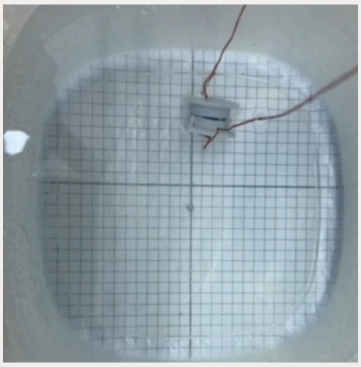
Calculations of the FOS for Our Crane Structure

The 100 Gauss magnets attracted in water at 4.30 cm.
The arm can rotate to 67° with the provided load.

The sonar sensors rely more on reference designs and secondary research more than physical prototyping due to the limited materials we have.



Testing Magnetic Attraction (in cm) in water



Testing Sonar Detection

Personal Skills Learnt

- CAD Designing
- Ansys Aqwa Simulations
- Rigorous Diverging (answering why our design decisions were optimal)
- Community Stakeholder Analysis
- TRIZ Matrix
- Physical and Software Prototyping
- Verification and Validation Procedures
- Uncovering Team Values

II learnt the importance of a strong Group B dynamic, and good teams are not always about being productive, but about being caring and diligent with their work.

Why An Arm?

During community visit, the TSCC expressed future goals of having an improved barge, so this is design aligns with their future plans.

The arm can also be used to retrieve orphan anchors or sunken buoys.

Next Steps

- Implementing testing of the anchors, sensors and arm on a larger-scale, that replicates the conditions of the lake.
- Validating our design with our community
- Optimizing materials for their intended purposes (ex. having a heavy base to lower the center of gravity, while allowing the barge to float).

Ethan Fong, Aarya Shah, Adi Singh, Ablah Gadallah

5 Praxis II: Improving Mooring Inspection at the Toronto Canoe and Sailing Club

5.1 When Communicating with Communities, Framing Should be Done Using the PIAA Model

Source: PIAA Model

The PIAA model stands for "Perceive, Interpret, Assess and Act"; it refers to how individuals should frame their claims or opportunities so that it is engaging and best understood by respective stakeholders. This is essential because you want to reach out to accomplish a purpose.

When we were venturing out to meet our mooring community online and through a site visit, our team wanted to understand the lived experience of the community; lived experience referred to the daily challenges and routines the workers of the TSCC undertake.

We had three ways to tackle our opportunity of misaligned moors during inspection and were already diverging. Our three ways were:

- by automating the inspection process using sensors.
- by focusing on the precise repositioning of the moors and anchors when they are lifted during inspection
- having a mechanism that would by reducing the number of anchors in the lakebed; this was because the number of misaligned moors caused shifting in the buoys, making it difficult for boats to moor.

Our community expressed that they were saving up money to build an improved barge while finding mechanisms to retrieve orphan anchors. We perceived hope and desire in their voice, as they were excited about talking about their future aspirations. We interpreted that they liked using a barge for inspections and did not need to pivot to a unique solution. However, we observed that conducting inspections on the barge was difficult because it was constantly shifting. From this information, we reassessed our divergence, pivoting to designs that could be implemented onto a barge to ensure precision. While we were unable to get validation from our community, some tests we conducted simulated the currents of Lake Ontario and saw how much the barge or anchors would shift under water conditions, as that is a challenge the community would face.

When framing our opportunity, we decided to talk about repositioning of the anchors properly. I felt using the PIAA model was more effective in creating design decisions and understanding the lived experience of the community because you need to change your perspective to successfully appeal to different communities and show them you care.

A slight limitation with this model is that when using the PIAA model, you use observations to create claims. Oftentimes, these claims can become speculative or 'far-fetched' if you have not conducted adequate research or assessed your assumptions beforehand.

From now on, I will explicitly mention my biases and assumptions to my team to seek some clarification from someone with more knowledge than I do. Using this knowledge, we can stand on common ground with our communities, making it easier to empathize with them and formulate a better PIAA model for framing.

5.2 Work Sessions Depend on the Group You are Working With

Time Management Tools
Effective Use of Time Management Tools

UTAT taught me the value of having work sessions over meetings. They enhanced collaboration and productivity. There was a committed time dedicated solely to building rockets.

After reflecting on our experiences in CIV 1O2 and other courses, our team established a norm to have 2-hour weekly 'work sessions'. During these two hours, we would spend 30 minutes creating Gantt charts and checklists detailing our deadlines (seen in Figure 11. Many teammates would arrive late as we all commuted. Additionally, we would spend time on diverging and editing or converging. However, our group had lengthy discussions and we would run out of time, so we would have more work sessions and delegate tasks between them.

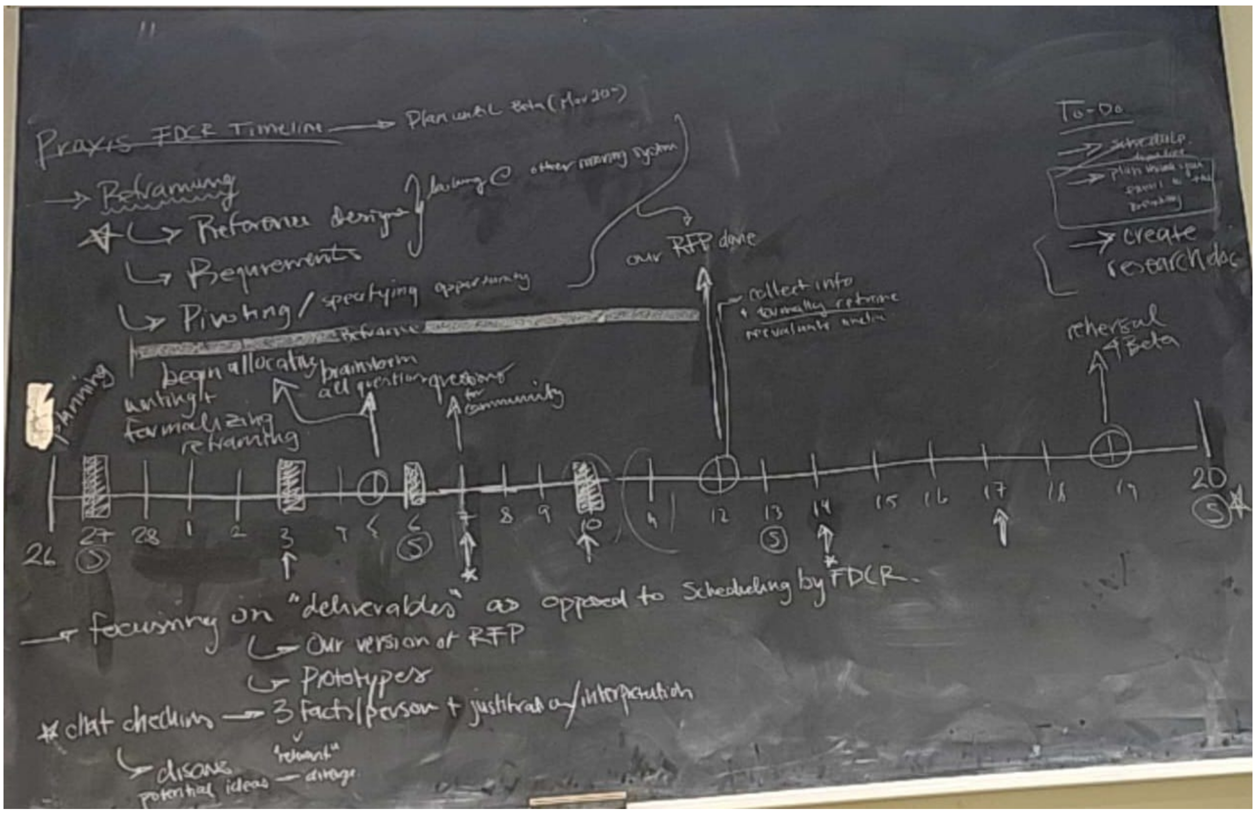


Figure 11: A combination of a Gantt Chart and Checklist Approach We Made During Each Meeting.

However, it was challenging constantly spending time for one course, as I and many of my teammates valued productivity. Consequently, our brains would be tricked to thinking they were productive and could not spend more time working on Praxis II because I could check-off the meeting from my to-do list. We began arriving to our work sessions without fully completing all our deliverables and re-evaluating our progress instead of working. Additionally, because of the extensive communication, my group members would neglect updating the group chat because they "had enough of Praxis for a day". This led to unproductive work sessions, which would make me frustrated.

I realized UTAT was successful with work sessions because they would prepare ahead, and it was only once a day, and they would not be mandated to work after hours. Additionally, they separated their meetings (which were short) and work sessions. In contrast, our work sessions felt more like long meetings where we were gaining nothing out of them.

Going forward, I realized group work sessions should be only used for pertinent tasks, and should allow for individuals to work with a flexible schedule and communicate more regularly in the small intervals of time they have during lectures or in group chats.

Figure 12: A diverging tree of all our design ideas. We generated over 50 ideas, many iterations of each other, and this shows some of them

5.3 SCAMPER and Morph Charts Should Be Used For Initial Converging and Diverging

Source: SCAMPER and Morph Charts

We generated over 50 design ideas during our diverging process, mapping them all into a diverging tree **??**, using Brainwriting 6-3-5, Random Input, and Challenge Assumptions techniques. It became difficult to converge because many prototypes addressed different purposes (see 5.1 We were transitioning from diverging to converging, and it would be hard to compare. We found this was very time-consuming.

We grouped designs based on their purposes. We used SCAMPER to create designs from each category. We wrote our SCAMPER ideas into a Morph Chart. We wrote out the functions we wanted to accomplish. From the different designs we used in SCAMPER, we created our three final designs. (see Figure 13. For example, we used a lily-pad approach and a floating dock because we needed our design to help boats stay still and reduce fouling. The lily pad would allow light to guide any boats docking. The circular dock allows multiple boats to be moored in one spot, ensuring they stay together. Merging ideas allowed us to open our design space one more time for diverging before converging.

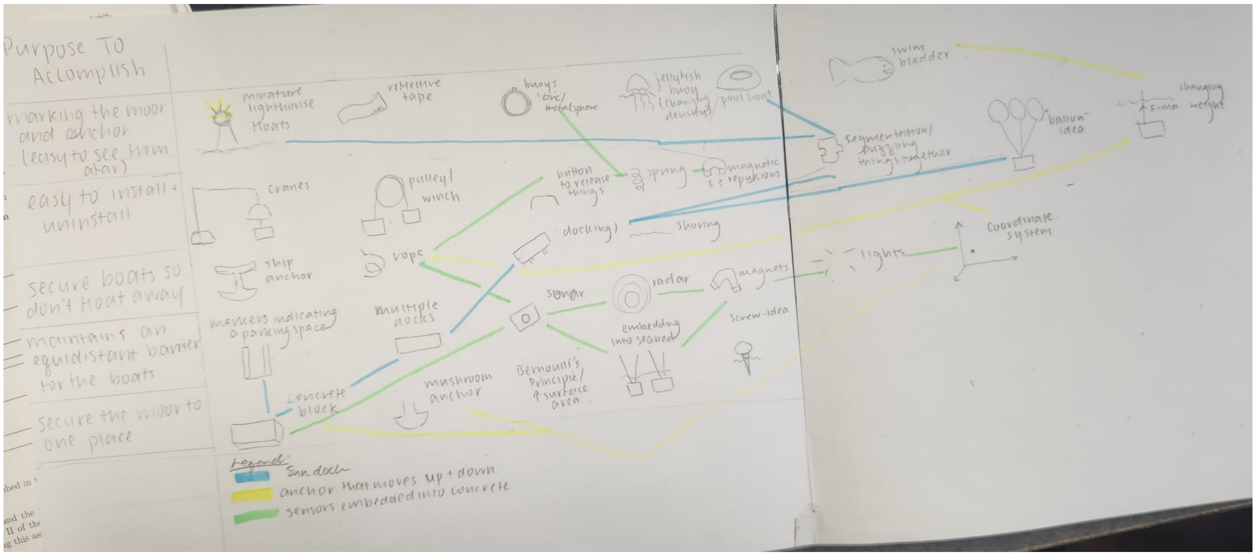


Figure 13: Our initial morph chart. The different colours link different functions to create better and more innovative prototypes. We were converging to diverge, and this would make converging much easier as there were fewer, yet more refined ideas.

I pointed out that the FDCR cycle abruptly transitioned from diverging to converging. We explore vast "unfleshed ideas" and then converge with them using Pugh Charts, Pairwise Comparison or Measurement Matrices. This approach diverges to converge, smoothing the transition between the two and narrowing our selection by improving our designs. This aligned with my values as the ideas I was going to use to converge were more 'fleshed out'. Going forward, I will use a SCAMPER/Morph Chart before formally converging.

5.4 Every Major Decision Must Undergo Independent FDCR Cycles

Tools: The FDCR Cycle [15]

The Framing (F), Divering (D), Converging (C), and Representing (R) cycle is the most fundamental cycle in engineering design. Every design must clearly frame the opportunity using requirements and standards. These requirements are foundational for diverging towards newer ideas and then converging to choose your ultimate design decisions. As engineering focuses on your arguments, to successfully complete engineering design, you must obey each strand in the cycle.

Our group would grow worried that we would often converge only to diverge or revisit our framing phase, which would hinder the amount of tasks we could get done. I felt like a real engineer; I imagined having to sit through multiple meetings a day to ensure our idea would be implemented 'perfectly.'
Below is a visual summarizing our FDCR cycle:

While the FDCR cycle was great at guiding individuals through an engineering design process, it inaccurately represented reality. In the beginning, our group would get stuck during each design decision because our previous decisions were made in haste, and did not undergo rigorous consideration.

Upon learning from our mistakes, we tried to become more patient with each step, ensuring all our decisions were properly justified. This helped us save more time in the long run because our decisions were strong and grounded. Ultimately, I was pleased with our design and appreciated our learnings.

I started to use the tool as a spring coil rather than a cycle; each coil is a decision you have to make. Each decision must undergo FDCR, framing the requirements and reference designs, divering on alternate ways to solve a specific problem, before converging on what the best method to address a specific problem. The decision is then represented with the other components of the large-scaled design. If a decision fails to undergo the full FDCR cycle, all subsequent decisions will be weakly justified; claims will be more vulnerable to attack.

In Praxis II, we attempted to improve the quality of inspections at the Toronto Sailing and Canoe Club (TSCC). We started by designing a singular robotic arm design. However, as we built prototypes and conducted proxy testing, we realized flaws in the designs. They needed to be more feasible and mature. To do this, we would have to problem solve ways we can solve our engineering problems. We started to alter the design of the anchors so increasing precision in placing the anchors; we designed secondary features like a rotational base and a linear rail to automate the inspection process and make it more accurate. We then reassessed our prototypes to determine other limitations in the process.

Near the end of the term, we had made so many decisions, that we created a flowchart of how we approached Engineering Design. This was effective in being organized, and showed me the clear loop between engineering and design.

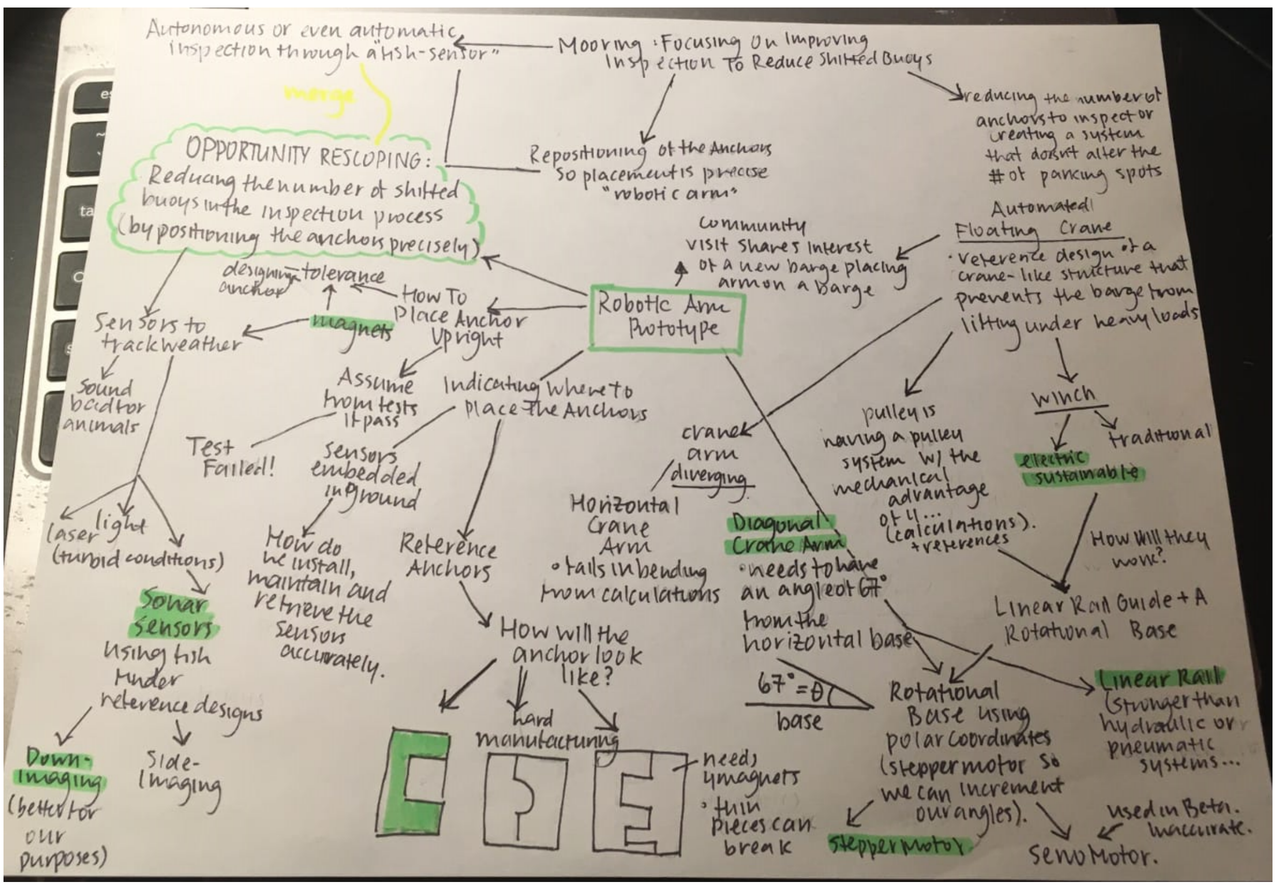


Figure 14: A final flowchart organizing our key decisions and timeline. Our group was always pivoting between diverging and designing to converging and assessing the viability of our ideas. This defines engineering design because it is a combination of creating a dream world and a realistic world.

6 Moving Forward

From my experience in Praxis I, Praxis II and building my CIV Bridge, I used tools including:

- The PIAA model (F + D + R)
- The Toulmin's Model (F)
- The Aid Model (F + C + R)
- Perry Model (F + C + R)
- The Hoover Dam Model (F + D + C)
- The dFX Framework (F)
- Stakeholder Analysis (F)
- CRAAP test (F + C + R)
- TRIZ Matrix (D + C)
- Pairwise Comparison Matrix (C)
- Pugh Charts (C)
- Challenge Assumptions (D)
- Time Management Tools (F + R)
- The FDCR Cycle (F + D + C + R)
- SCAMPER Tool (D)
- Morph Charts (C + D)

These tools have allowed me to foster my main values of being purposeful, diligent, creative and open-minded to different techniques while being easy to implement. They leave me feeling productive, accomplished and innovative. While there might be limitations in this procedure. I will revise this document in the future, as I develop more sophisticated habits and discover newer CTMFs.

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What is the Anchoring bias?

The anchoring bias is a cognitive bias that causes us to rely heavily on the first piece of information we are given about a topic. When we are setting plans or making estimates about something, we interpret newer information from the reference point of our anchor instead of seeing it objectively. This can skew our judgment and prevent us from updating our plans or predictions as much as we should.

Figure 1: Anchoring Bias(1). Source: https://thedecisionlab.com/biases/anchoring-bias

The Toulmin Model is a format for preparing an argument. For more information on argumentation contact the Debate Team.

The Toulmin Model

Claim: The conclusion of the argument or the statement the speaker wishes the audience to believe.

Grounds: The foundation or basis for the claim, the support.

Warrant: The reasoning that authorizes the inferential leap from the grounds to the claim.

Backing: The support for the warrant.

Modality: The degree of certainty with which the advocate makes the claim.

Rebuttal: Exceptions that might be offered to the claim.

Figure 2: Toulmin's Model Argument(2). Source: https://academics.umw.edu/speaking/resources/handouts/toulmin-argument-model/

Worsening Feature

Improving Feature

Features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1: Weight of moving object	*	-	15 8 29 34	-	29 17 38 34	-	29 2 40 28	-	2 8 15 38	8 10 18 37	10 36 37 40	10 14 35 40	1 35 19 39	28 27 18 40	5 34 31 35	-	6 29 4 38	19 1 32	35 12 34 31	-
2: Weight of stationary	-	*	-	10 1 29 35	-	35 30 13 2	-	5 35 14 2	-	8 10 19 35	13 29 10 18	13 10 29 14	26 39 1 40	28 2 10 27	-	2 27 19 6	28 19 32 22	19 32 35	-	18 19 28 1
3: Length of moving object	8 15 29 34	-	*	-	15 17 4	-	7 17 4 35	-	13 4 8	17 10 4	1 8 35	1 8 10 29	1 8 15 34	8 35 29 34	19	-	10 15 19	32	8 35 24	-
4: Length of stationary	-	35 28 40 29	-	*	-	17 7 10 40	-	35 8 2 14	-	28 10	1 14 35	13 14 15 7	39 37 35	15 14 28 26	-	1 10 35	3 35 38 18	3 25	-	-
5: Area of moving object	2 17 29 4	-	14 15 18 4	-	*	-	7 14 17 4	-	29 30 4 34	19 30 35 2	10 15 36 28	5 34 29 4	11 2 13 39	3 15 40 14	6 3	-	2 15 16	15 32 19 13	19 32	-
6: Area of stationary	-	30 2 14 18	-	26 7 9 39	-	*	-	-	-	1 18 35 36	10 15 36 37	-	2 38	40	-	2 10 19 30	35 39 38	-	-	-
7: Volume of moving object	2 26 29 40	-	1 7 4 35	-	1 7 4 17	-	*	-	29 4 38 34	15 35 36 37	6 35 36 37	1 15 29 4	28 10 1 39	9 14 15 7	6 35 4	-	34 39 10 18	2 13 10	35	-
8: Volume of stationary	-	35 10 19 14	19 14	35 8 2 14	-	-	-	*	-	2 18 37	24 35	7 2 35	34 28 35 40	9 14 17 15	-	35 34 38	35 6 4	-	-	-
9: Speed	2 28 13 38	-	13 14 8	-	29 30 34	-	7 29 34	-	*	13 28 15 19	6 18 38 40	35 15 18 34	28 33 1 18	8 3 26 14	3 19 35 5	-	28 30 36 2	10 13 19	8 15 35 38	-
10: Force (Intensity)	8 1 37 18	18 13 1 28	17 19 9 36	28 10	19 10 15	1 18 36 37	15 9 12 37	2 36 18 37	13 28 15 12	*	18 21 11	10 35 40 34	35 10 21	35 10 14 27	19 2	-	35 10 21	-	19 17 10	1 16 36 37
11: Stress or pressure	10 36 37 40	13 29 10 18	35 10 36	35 1 14 16	10 15 36 28	10 15 36 37	6 35 10	35 24	6 35 36	36 35 21	*	35 4 15 10	35 33 2 40	9 18 3 40	19 3 27	-	35 39 19 2	-	14 24 10 37	-
12: Shape	8 10 29 40	15 10 26 3	29 34 5 4	13 14 10 7	5 34 4 10	-	14 4 15 22	7 2 35	35 15 34 18	35 10 37 40	34 15 10 14	*	33 1 18 4	30 14 10 40	14 26 9 25	-	22 14 19 32	13 15 32	2 6 34 14	-
13: Stability of the object	21 35 2 39	26 39 1 40	13 15 1 28	37	2 11 13	39	28 10 19 39	34 28 35 40	33 15 28 18	10 35 21 16	2 35 40	22 1 18 4	*	17 9 15	13 27 10 35	39 3 35 23	35 1 32	32 3 27 16	13 19	27 4 29 18
14: Strength	1 8 40 15	40 26 27 1	1 15 8 35	15 14 28 26	3 34 40 29	9 40 28	10 15 14 7	9 14 17 15	8 13 26 14	10 18 3 14	10 3 18 40	10 30 35 40	13 17 35	*	27 3 26	-	30 10 40	35 19	19 35 10	35
15: Durability of moving obj.	19 5 34 31	-	2 19 9	-	3 17 19	-	10 2 19 30	-	3 35 5	19 2 16	19 3 27	14 26 28 25	13 3 35	27 3 10	*	-	19 35 39	2 19 4 35	28 6 35 18	-
16: Durability of non moving obj.	-	6 27 19 16	-	1 40 35	-	-	-	35 34 38	-	-	-	-	39 3 35 23	-	-	*	19 18 36 40	-	-	-
17: Temperature	36 22 6 38	22 35 32	15 19 9	15 19 9	3 35 39 18	35 38	34 39 40 18	35 6 4	2 28 36 30	35 10 3 21	35 39 19 2	14 22 19 32	1 35 32	10 30 22 40	19 13 39	19 18 36 40	*	32 30 21 16	19 15 3 17	-
18: Illumination intensity	19 1 32	2 35 32	19 32 16	-	19 32 26	-	2 13 10	-	10 13 19	26 19 6	-	32 30	32 3 27	35 19	2 19 6	-	32 35 19	*	32 1 19	32 35 1 15
19: Use of energy by moving	12 18 28 31	-	12 28	-	15 19 25	-	35 13 18	-	8 35	16 26 21 2	23 14 25	12 2 29	19 13 17 24	5 19 9 35	28 35 6 18	-	19 24 3 14	2 15 19	*	-
20: Use of energy by stationary	-	19 9 6 27	-	-	-	-	-	-	-	36 37	-	-	27 4 29 18	35	-	-	-	19 2 35 32	-	*
21: Power	8 36 38 31	19 26 17 27	1 10 35 37	-	19 38	17 32 13 38	35 6 38	30 6 25	15 35 2	26 2 36 35	22 10 35	29 14 2 40	35 32 15 31	26 10 28	19 35 10 38	16	2 14 17 25	16 6 19	16 6 19 37	-

Features	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
1: Weight of moving object	12 36 18 31	6 2 34 19	5 35 3 31	10 24 35	10 35 20 28	3 26 18 31	1 3 11 27	28 27 35 26	28 35 26 18	22 21 18 27	22 35 31 39	27 28 1 36	35 3 2 24	2 27 28 11	29 5 15 8	26 30 36 34	28 29 26 32	26 35 18 19	35 3 24 37
2: Weight of stationary	15 19 18 22	18 19 28 15	5 8 13 30	10 15 35	10 20 35 26	19 6 18 26	10 28 8 3	18 26 28	10 1 35 17	2 19 22 37	35 22 1 39	28 1 9	6 13 1 32	2 27 28 11	19 15 29	1 10 26 39	25 28 17 15	2 26 35	1 28 15 35
3: Length of moving object	1 35	7 2 35 39	4 29 23 10	1 24	15 2 29	29 35	10 14 29 40	28 32 4	10 28 29 37	1 15 17 24	17 15	1 29 17	15 29 35 4	1 28 10	14 15 1 16	1 19 26 24	35 1 26 24	17 24 26 16	14 4 28 29
4: Length of stationary	12 8	6 28	10 28 24 35	24 26	30 29 14	-	15 29 28	32 28 3	2 32 10	1 18	-	15 17 27	2 25	3	1 35	1 26	26	-	30 14 7 26
5: Area of moving object	19 10 32 18	15 17 30 26	10 35 2 39	30 26	26 4	29 30 6 13	29 9	26 28 32 3	2 32	22 33 28 1	17 2 18 39	13 1 26 24	15 17 13 16	15 13 10 1	15 30	14 1 13	2 36 26 18	14 30 28 23	10 26 34 2
6: Area of stationary	17 32	17 7 30	10 14 18 39	30 16	10 35 4 18	2 18 40 4	32 35 40 4	26 28 32 3	2 29 18 36	27 2 39 35	22 1 40	40 16	16 4	16	15 16	1 18 36	2 35 30 18	23	10 15 17 7
7: Volume of moving object	35 6 13 18	7 15 13 16	36 39 34 10	2 22	2 6 34 10	29 30 7	14 1 40 11	25 26 28	25 28 2 16	22 21 27 35	17 2 40 1	29 1 40	15 13 30 12	10	15 29	26 1	29 26 4	35 34 16 24	10 6 2 34
8: Volume of stationary	30 6	-	10 39 35 34	-	35 16 32 18	35 3	2 35 16	-	35 10 25	34 39 19 27	30 18 35 4	35	-	1	-	1 31	2 17 26	-	35 37 10 2
9: Speed	19 35 38 2	14 20 19 35	10 13 28 38	13 26	-	10 19 29 38	11 35 27 28	28 32 1 24	10 28 32 25	1 28 35 23	2 24 35 21	35 13 8 1	32 28 13 12	34 2 28 27	15 10 26	10 28 4 34	3 34 27 16	10 18	-
10: Force (Intensity)	19 35 18 37	14 15	8 35 40 5	-	10 37 36	14 29 18 36	3 35 13 21	35 10 23 24	28 29 37 36	1 35 40 18	13 3 36 24	15 37 18 1	1 28 3 25	15 1 11	15 17 18 20	26 35 10 18	36 37 10 19	2 35	3 28 35 37
11: Stress or pressure	10 35 14	2 36 25	10 36 3 37	-	37 36 4	10 14 36	10 13 19 35	6 28 25	3 35	22 2 37	2 33 27 18	1 35 16	11	2	35	19 1 35	2 36 37	35 24	10 14 35 37
12: Shape	4 6 2	14	35 29 3 5	-	14 10 34 17	36 22	10 40 16	28 32 1	32 30 40	22 1 2 35	35 1	1 32 17 28	32 15 26	2 13 1	1 15 29	16 29 1 28	15 13 39	15 1 32	17 26 34 10
13: Stability of the object	32 35 27 31	14 2 39 6	2 14 30 40	-	35 27	15 32 35	-	13	18	35 24 30 18	35 40 27 39	35 19	32 35 30	2 35 10 16	35 30 34 2	2 35 22 26	35 22 39 23	1 8 35	23 35 40 3
14: Strength	10 26 35 28	35	35 28 31 40	-	29 3 28 10	29 10 27	11 3	3 27 16	3 27	18 35 37 1	15 35 22 2	11 3 10 32	32 40 25 2	27 11 3	15 3 32	2 13 25 28	27 3 15 40	15	29 35 10 14
15: Durability of moving obj.	19 10 35 38	-	28 27 3 18	10	20 10 28 18	3 35 10 40	11 2 13	3	3 27 16 40	22 15 33 28	21 39 16 22	27 1 4	12 27	29 10 27	1 35 13	10 4 29 15	19 29 39 35	6 10	35 17 14 19
16: Durability of non moving obj.	16	-	27 16 18 38	10	28 20 10 16	3 35 31	34 27 6 40	10 26 24	-	17 1 40 33	22	35 10	1	1	2	-	25 34 6 35	1	20 10 16 38
17: Temperature	2 14 17 25	21 17 35 38	21 36 29 31	-	35 28 21 18	3 17 30 39	19 35 3 10	32 19 24	24	22 33 35 2	22 35 2 24	26 27	26 27	4 10 16	2 18 27	2 17 16	3 27 35 31	26 2 19 16	15 28 35
18: Illumination intensity	32	13 16 1 6	13 1	1 6	19 1 26 17	1 19	-	11 15 32	3 32	15 19	35 19 32 39	19 35 28 26	28 26 19	15 17 13 16	15 1 19	6 32 13	32 15	2 26 10	2 25 16
19: Use of energy by moving	6 19 37 18	12 22 15 24	35 24 18 5	-	35 38 19 18	34 23 16 18	19 21 11 27	3 1 32	-	1 35 6 27	2 35 6	28 26 30	19 35	1 15 17 28	15 17 13 16	2 29 27 28	35 38	32 2	12 28 35
20: Use of energy by stationary	-	-	28 27 18 31	-	-	3 35 31	10 36 23	-	-	10 2 22 37	19 22 18	1 4	-	-	-	-	19 35 16 25	-	1 6
21: Power	*	10 35 38	28 27 18 38	10 19	35 20 10 6	4 34 19	19 24 26 31	32 15 2	32 2	19 22 31 2	2 35 18	26 10 34	26 35 10	35 2 10 34	19 17 34	20 19 30 34	19 35 16	28 2 17	28 35 34

Figure 3: The Triz Matrix Visual(3). Source: https://www.triz40.com/aff_Matrix_TRIZ.php

Attribution bias

Attribution bias can sometimes be involved in the way that we understand and make sense of our own and other's actions. People constantly make attributions – judgements and assumptions about why other people behave in certain ways. However, some attributions do not always accurately reflect reality and these attributions can introduce bias into decision-making.

Attribution bias in the workplace

During recruitment, attribution bias can be involved if recruiters make decisions about candidates where they attribute something unusual or potentially problematic about their application or behaviour as being an inherent feature of their personality or indeed of their gender, ethnicity or other 'protected characteristic'. We might find attribution bias at play when an employee is treated differently because they do not approach a task in the same way as other people in the department and when this difference is negatively attributed to some 'quality' possessed by the employee.

Conformity bias

Conformity bias can take place in situations where, in order to be accepted by a social group, people will tend to agree with the views of the majority within the group regardless of what they might think on an individual basis.

Conformity bias in the workplace

When your recruitment panel get together to review a candidate's application and conduct an interview, conformity bias can cause individuals to sway their opinion of a candidate to match the opinion of the majority. The problem with conformity bias is that the majority is not always right, which may result in your team missing out on an excellent candidate because individual opinions become weakened in a group setting. Conformity bias can also take place where people agree with those individuals who have more power in a group. For example, in team meetings where one individual may hold the power and influence and others in the team feel some pressure to agree with the opinion of this powerful individual.

Confirmation bias can happen when we look for, or give greater weight to, evidence that confirms our views and experiences. This can lead to selective observation and us not seeing or valuing evidence that contradicts our beliefs.

Confirmation bias in the workplace

Confirmation bias can play a role at the very beginning of the recruitment process when you first review an application form and you form an initial opinion of the candidate based on attributes like where they're from, where they went to school or university, or if they have a similar interest to you etc. This opinion you have of the candidate can follow you into the interview process and consequently steer questions to confirm the initial opinion you had of the candidate. This kind of effect can follow the candidate all the way through their career within an organisation, with them being treated more favourably, thus making it easier for them to be successful. Confirmation bias is an example of a bias that is based on 'culture fit'. According to the Harvard Project Implicit study, black people are more likely to face scrutiny over performance and 'culture fit'.

Figure 4: Conformity and Confirmation Bias. Source: https://nshcs.hee.nhs.uk/about/equality-diversity-and-inclusion/conscious-inclusion/understanding-different-types-of-bias/

Using The AID Model to Give Feedback

A simple model for giving clear feedback, the AID model is brilliantly easy to remember and is popular with our clients for giving feedback.

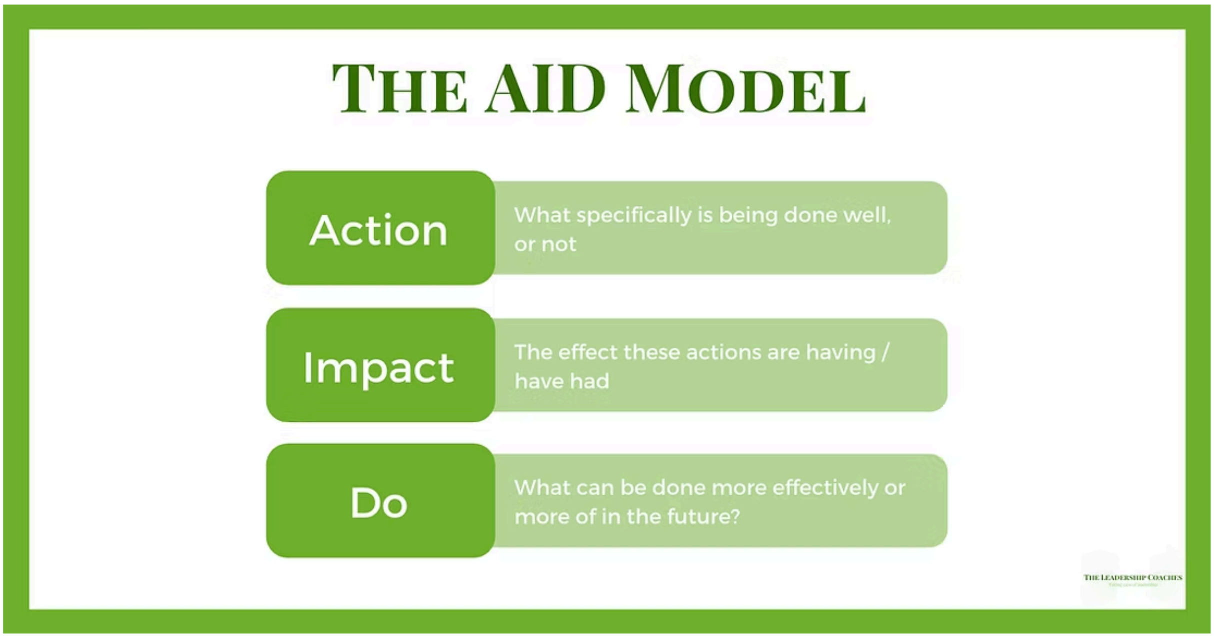

Figure 5(5): AID Model. Source: https://www.the-leadership-coaches.com/post/the-aid-model

Outcome bias is a cognitive bias that refers to the tendency to judge a decision based on its outcome rather than basing it on an assessment of the quality of the decision at the time it was made. Outcome bias can arise when a decision is based on the outcome of previous events without taking into account how the past events developed.

Outcome bias could have a negative impact on safety reporting because the outcome of an event or incident may influence whether a report is made.

Figure 6: What is Outcome Bias

Outcome Bias in Decision Evaluation

Jonathan Baron
University of Pennsylvania

John C. Hershey
Department of Decision Sciences
University of Pennsylvania

In 5 studies, undergraduate subjects were given descriptions and outcomes of decisions made by others under conditions of uncertainty. Decisions concerned either medical matters or monetary gambles. Subjects rated the quality of thinking of the decisions, the competence of the decision maker, or their willingness to let the decision maker decide on their behalf. Subjects understood that they had all relevant information available to the decision maker. Subjects rated the thinking as better, rated the decision maker as more competent, or indicated greater willingness to yield the decision when the outcome was favorable than when it was unfavorable. In monetary gambles, subjects rated the thinking as better when the outcome of the option not chosen turned out poorly than when it turned out well. Although subjects who were asked felt that they should not consider outcomes in making these evaluations, they did so. This effect of outcome knowledge on evaluation may be explained partly in terms of its effect on the salience of arguments for each side of the choice. Implications for the theory of rationality and for practical situations are discussed.

Figure 7(6): More About Outcome Bias. Source: https://www.sas.upenn.edu/~baron/papers/outcomebias.pdf

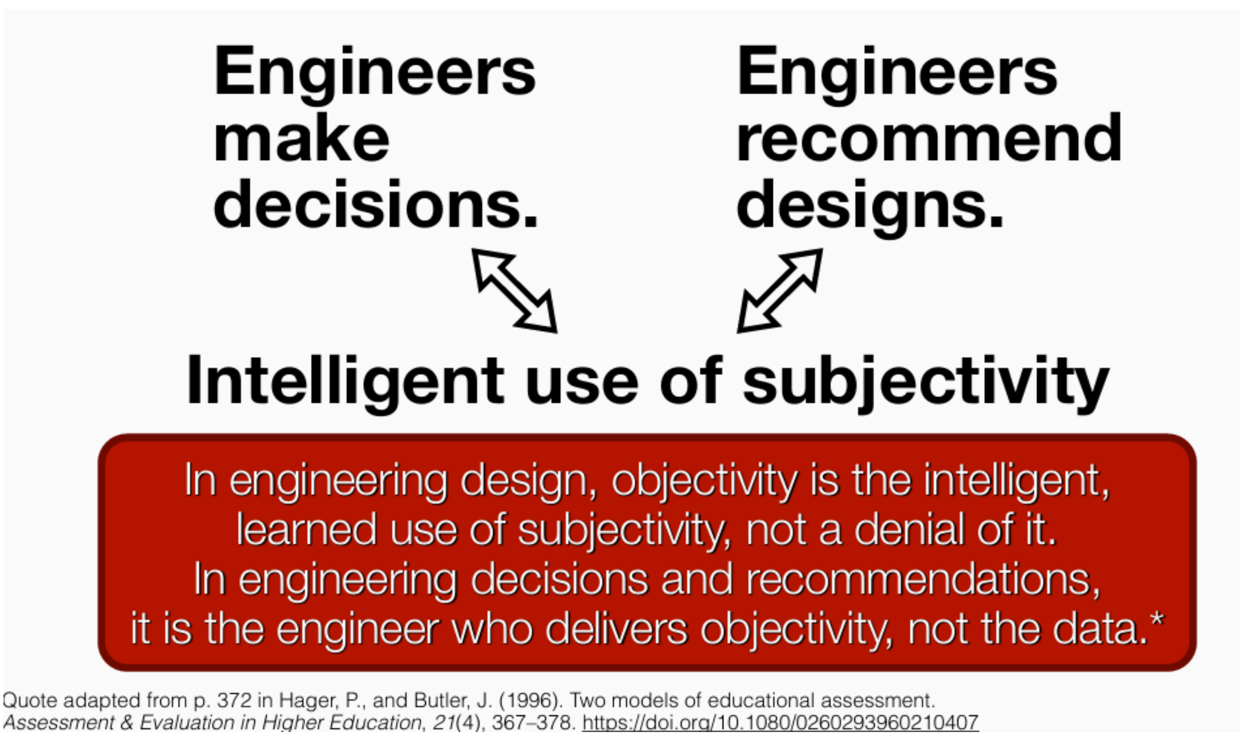

Figure 8(7): Welcome to Praxis II. What is Intelligence in Engineering Design. Source: Praxis II Lecture Slides

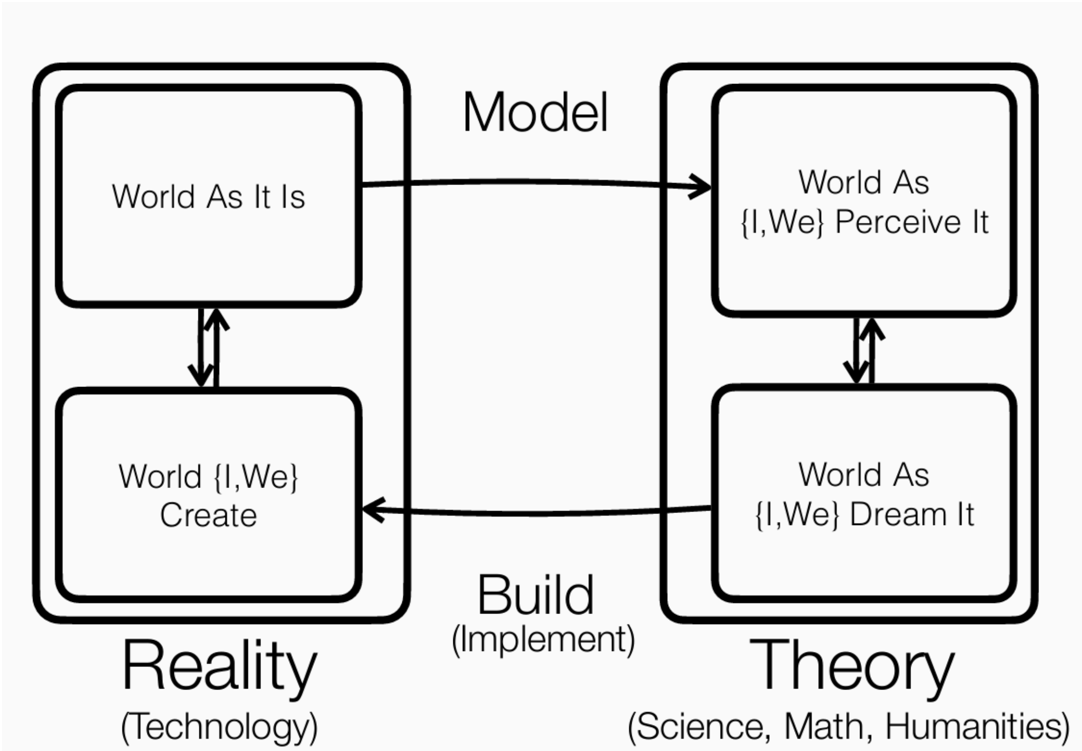

Figure 9(8): The Hoover Dam Model. Source: ESC 101 Lecture 2 Slide

The Origins of TRIZ

Beginning in 1946 and still evolving, TRIZ was developed by the Soviet inventor Genrich Altshuller and his colleagues. TRIZ in Russian = Teoriya Resheniya Izobretatelskikh Zadatch or in English, The Theory of Inventive Problem Solving. Years of Russian research into patents uncovered that there are only 100 known solutions to fundamental problems and made them universally available in three TRIZ solution lists and the Effects Database.

Through enabling clear thinking and the generation of innovative ideas, TRIZ helps you to find an ideal solution without the need for compromise. However it is not a Theory - it is a big toolkit consisting of many simple tools - most are easy to learn and immediately apply to problems. This amazing capability helps us tackle any problem or challenge even when we face difficult, intractable or apparently impossible situations.

TRIZ helps us keep detail in its place, to see the big picture and avoid getting tripped up with irrelevance, waylaid by trivial issues or seduced by premature solutions. It works alongside and supports other toolkits, and is particularly powerful for getting teams to work together to understand problems effectively, collectively generate ideas and innovate.

Read more

Developed by Oxford Creativity, **Oxford TRIZ™** is simpler than standard or classic TRIZ. Its tools and processes

Figure 10: What is Triz(9). Source: https://www.triz.co.uk/what-is-triz#:~:text=Beginning%20in%201946%20and%20still,Theory%20of%20Inventive%20Problem%20Solving.

Perry's Stages of Cognitive Development: A Journey of the Mind

Alright, let's get to the meat of Perry's theory. He identified four main stages of cognitive development in college students. But don't think of these as rigid boxes. They're more like waypoints on a journey, with each student moving through them at their own pace.

1. Dualism: The Black and White Thinking Stage

Picture a freshman student walking into their first college class. They're likely in the dualism stage. Here, everything is black and white, right or wrong. There are absolute truths, and the job of the student is to learn these truths from the all-knowing authorities (aka professors).

It's like viewing the world through a pair of old-school 3D glasses. Everything is either re or blue, with no room for shades in between. Students in this stage often struggle with ambiguity and can get frustrated when professors don't give them clear-cut answers.

2. Multiplicity: Recognizing Diverse Perspectives

As students progress, they enter the multiplicity stage. This is where things start to get interesting. Suddenly, they realize that not everything has a clear right or wrong answer. Different people can have different opinions, and that's okay!

It's like someone suddenly handed them a whole box of colored pencils instead of just the red and blue ones. They start to see that the world is full of different hues and shades. However, at this stage, students often think that all opinions are equally valid, which can lead to its own set of challenges.

3. Relativism: Understanding Context-Dependent Knowledge

Now we're cooking with gas! In the relativism stage, students start to understand that knowledge is context-dependent. They begin to evaluate the strength of arguments and evidence, rather than just accepting or rejecting ideas outright.

This stage is like upgrading from a box of colored pencils to a full artist's palette. Students can now mix and blend ideas, creating nuanced understandings of complex issues. They start to appreciate that what's "right" in one context might not be in another.

Relativism Stage of Cognitive Development: Navigating Multiple Perspectives is a crucial phase in a student's intellectual journey. It's where they really start to flex their critical thinking muscles.

4. Commitment: Developing Personal Values and Beliefs

The final stage in Perry's theory is commitment. Here, students start to make choices and commitments based on their relativistic understanding of the world. They develop their own values and beliefs, while still recognizing the validity of other perspectives.

Think of this stage as the student becoming the artist, not just using the palette but creating their own unique masterpiece. They're no longer just consumers of knowledge, but active participants in creating and evaluating it.

Figure 11(10): Perry's Theory of Cognitive Development: Stages and Impact on Education
Source: https://neurolaunch.com/perrys-theory-of-cognitive-development/#google_vignette

The planning fallacy is a term used by psychologists to describe our tendency to underestimate the amount of time it will take to complete a task. The term was first coined in 1977 by psychologists Daniel Kahneman and Amos Tversky.

Kahneman and Tversky explained that people have a tendency to disregard historical data when making predictions. Instead of forming estimates based on historical evidence (*it always takes a month to paint a room*), we focus solely on the upcoming task (*this room is small, so it won't take long to paint*).

Kahneman later expanded on the original idea in his 2011 book *Thinking Fast and Slow*. In it, he argues that estimation mistakes can usually be attributed to two key

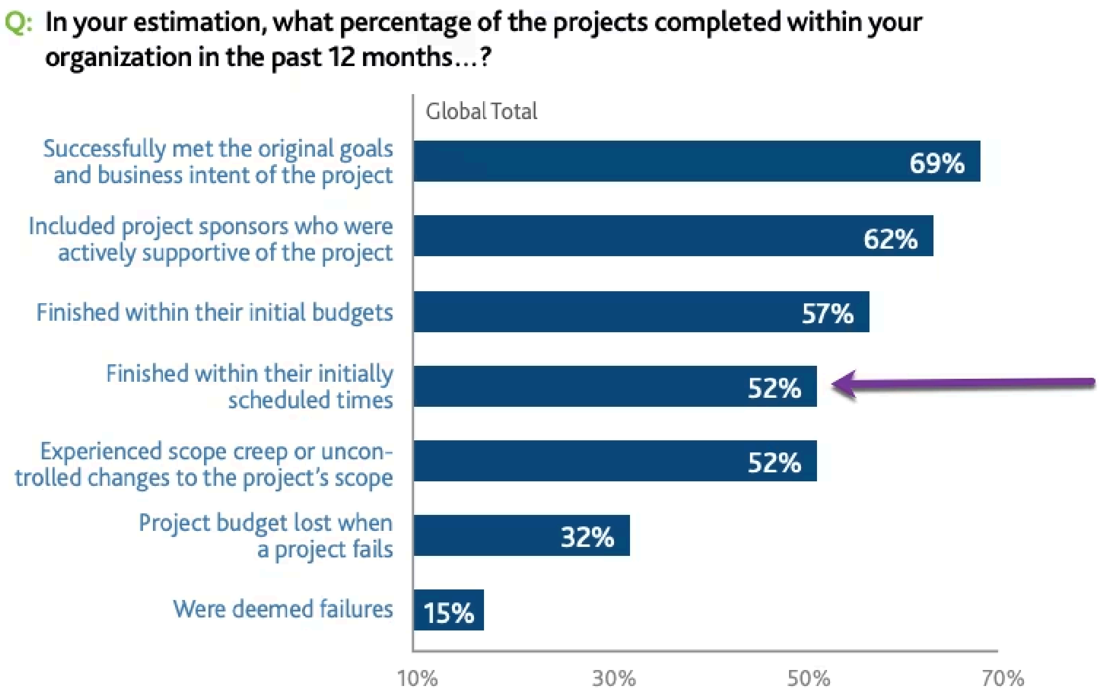

Figure 12a and Figure 12b(11): Why We Are Bad At Estimating Time (and what to do about it). In relation to Planning Fallacy. Source: https://zapier.com/blog/how-to-estimate-time/

What is Pairwise Comparison?

Pairwise comparison is the process of comparing a set of options using head-to-head pairs to judge which one is the most preferred overall. Also known as "pairwise ranking", it is a popular research method used for ranking people's preferences, informing strategic decisions, and conducting voting at scale.

Figure 13(12): What is Pairwise Comparison. Source: https://www.opinionx.co/blog/pairwise-comparison

This book has grown from my experience as a manufacturing engineer, manufacturing executive, and consultant. The design for manufacturability (DFM) approach has provided tremendous benefits to industry in furnishing product designs that are simple and economical to produce. The technique has produced strong competitive advantages to the companies that have used it. However, low cost in manufacturing is only one objective of a sound product design. There are many other desirable objectives—quality of product being one of them. It has become obvious to many DFM practitioners that the same kind of approach used in DFM could be used in a broader way so that not only ease of manufacture but also many other desirable goals of a sound product design could be achieved.

The goal of this book, then, is to explain how the DFM technique is evolving and how it must evolve into an approach that more strongly and more specifically addresses the broad series of important objectives of sound product design. These objectives include: quality and reliability, safety, serviceability, user-friendliness, environmental-friendliness, and short time-to-market.

They can be served through the same knowledge-based technique that works so effectively in improving manufacturability. A suitable name for this expanded approach is *DFX*, where X indicates all important attributes and, thereby, product excellence.

This book reflects my viewpoint of what DFM and DFX are. It may not conform, in some cases, to the viewpoints of others. Where I take the view that DFM refers primarily to that knowledge-based approach that utilizes the knowledge of experienced manufacturing engineers (as expressed in design guidelines or rules of thumb) as a means of

Figure 14(13): The Design for eXcellence Handbook

4. OUR MODEL OF ENGINEERING DESIGN - FDCR

Having critiqued the "commonly taught" in Engineering design models, it seems only fair that we provide our own model and evaluate its strengths and weaknesses as a learning metaphor. Unlike Dieter and Schmidt who turn to science as a foundation, we have turned to theoretical work in engineering design and design education.

Howard et. al. [7] compared existing engineering design and creativity process models, with the goal of developing a new integrated process grounded in cognitive psychology. Their comparison resulted in an abstracted six-phase engineering design process involving: establishing a need; analysis of task; conceptual design;

concepts of design.

4.1. Triangle Representation

In keeping with the “Design Swamp” representation of Hyman; the cycling between convergence and divergence of Pugh; and the findings of Atman et. al. on the importance of non-judgmental movement between stages (i.e. there is no “going backwards”), we represented our process as a bidirectionally connected triangle (Fig. 1). This triangular representation also allows us to visually represent—through a Sierpiński fractal—how this model can be applied at different ‘scales’ within a design activity.

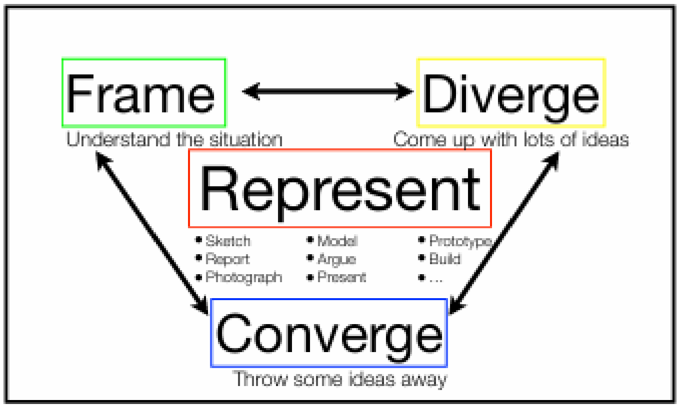

Fig. 1: Triangle Representation of FDCR

4.2. Braid Representation

The braid representation (Fig. 2) grew out of the triangle representation and is grounded in the same FDCR model of design. Instead of focusing design around representation, it instead positions these components with respect to production and learning. The engineering design classroom is one that is both a production environment (responding to deliverables and creating products) and a learning environment (developing an understanding of process components and ways of demonstrating rigour). While the triangle clearly represented the interconnectedness of the components, it did not demonstrate need for their simultaneous execution (or influence) to create viable engineering product.

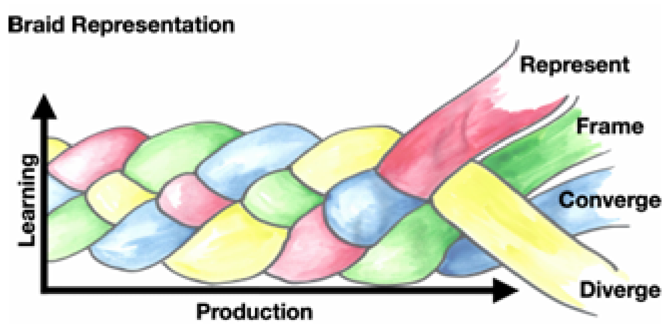

Fig. 2: Braid Representation of FDCR

Figure 15a, 15b, 15c (14). Detailing the FDCR cycle. Source: https://www.researchgate.net/publication/365313393_Metaphors_To_Design_By_Developing_Representations_of_Engineering_Design

Conclusion

Stakeholder analysis is a technique that can assist the project team members understand the variety of stakeholders that have an interest in the project and the individual nuances that can affect project risk. In an environment where office politics often appear to cloud a project's progression, stakeholder analysis provides the team with views and measures and that can help uncover and remove barriers.

The technique described here compels project leaders to identify and support the interests of the key groups. When interests that cannot be supported arise, the knowledge that they exist and what level of influence the stakeholder may impose can be a great asset to the project team. The difference between success and failure can be simply in knowing project advocates and opponents, understanding their respective needs and levels of influence, and aligning the project accordingly.

Figure 16(15): Stakeholder Analysis. Source: https://www.pmi.org/learning/library/stakeholder-analysis-pivotal-practice-projects-8905#:~:text=Stakeholder%20analysis%20is%20a%20technique,that%20can%20affect%20project%20risk.

Another type of methodological bias is procedural bias, which is sometimes referred to as administration bias. This type of bias is related to the study conditions including the setting and how the instruments are administered across cultures (He, 2010). The interaction between the research participant and interviewer is another type of procedural bias that can interfere with cultural comparisons.

Setting

Where the study is conducted can have a major influence on how the data is collected, analyzed and later interpreted. Settings can be small (e.g., home or community center) or settings can be large (e.g., countries or regions) and can influence how a survey is administered or how participants might re-spond. In a large cross-cultural health study Steels and colleagues (2014) found that the postal system in Vietnam was unreliable and demanded a major, and unexpected, change in survey methodology. The researchers

Figure 17(16). Procedural Bias. Source: https://open.maricopa.edu/culturepsychology/chapter/procedural-bias/