ENGG1000 – 2018 – Semester 1

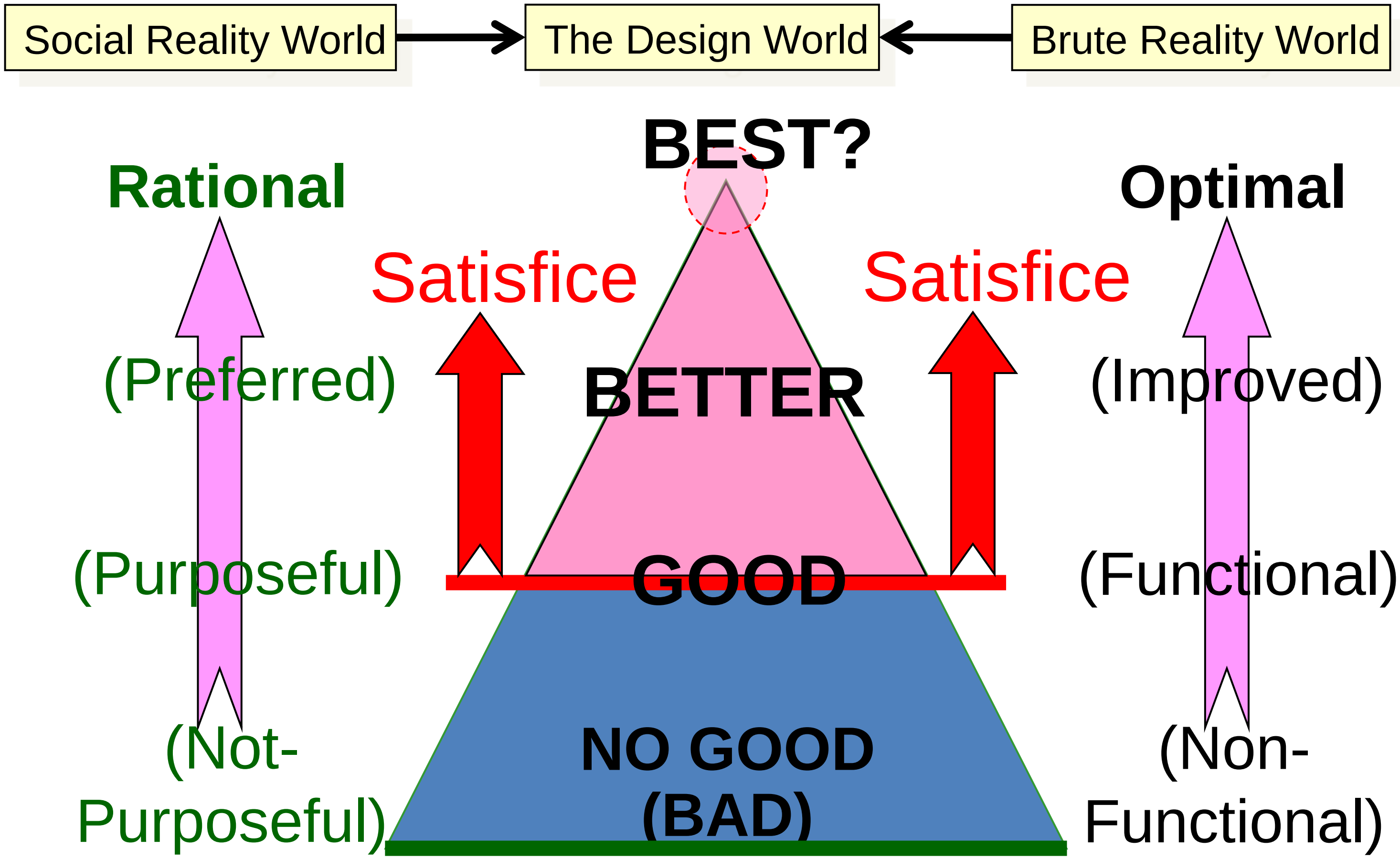
Never Stand Still | Faculty of Engineering | School of Mechanical and Manufacturing Engineering

Dr Binghao Li

Week 05:

Design Phase 3 of 3 - Evaluating the Design

Design strategy of satisficing



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Design strategy of satisficing

When to choose the strategy of satisficing?

- Very complex problems, for which, an optimal solution is extremely difficult if not impossible to obtain
- Time limited problems, for which, the tight schedule prevents a thorough analysis and optimization
- Problems for which “anything beyond satisfactory solution yields diminishing returns”
- Unique problems, for which, customers have no alternative solutions

Engineers of Mercedes realized that there is no need to build an absolutely optimal car, as long as it is better than that of BMW!

Designers at Swatch realized that, increasing accuracy is longer valued by the customers (accuracy within one minute a day is good enough), after all, customers buy Swatch because it’s fashionable

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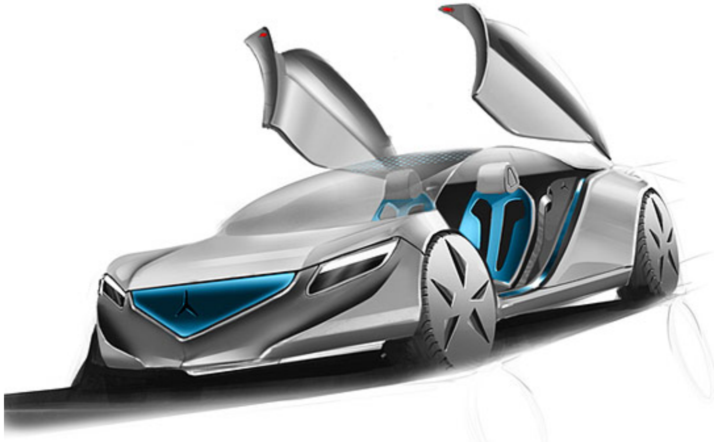
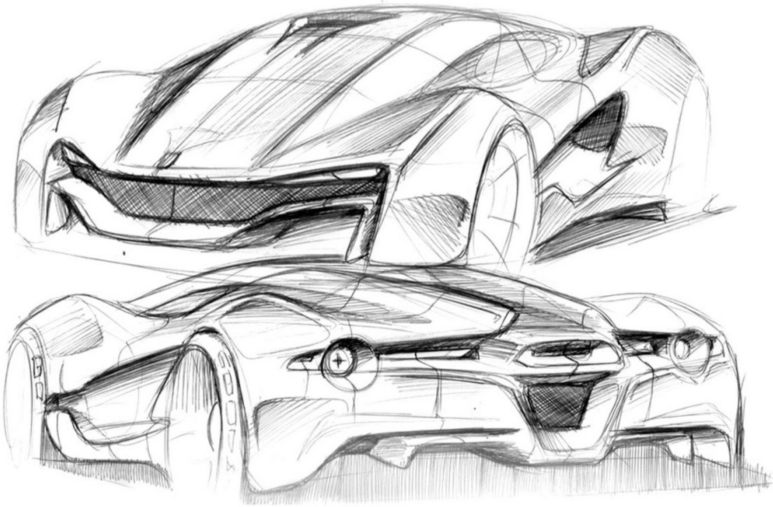
Design Phase 3 of 3 - Evaluating the Design

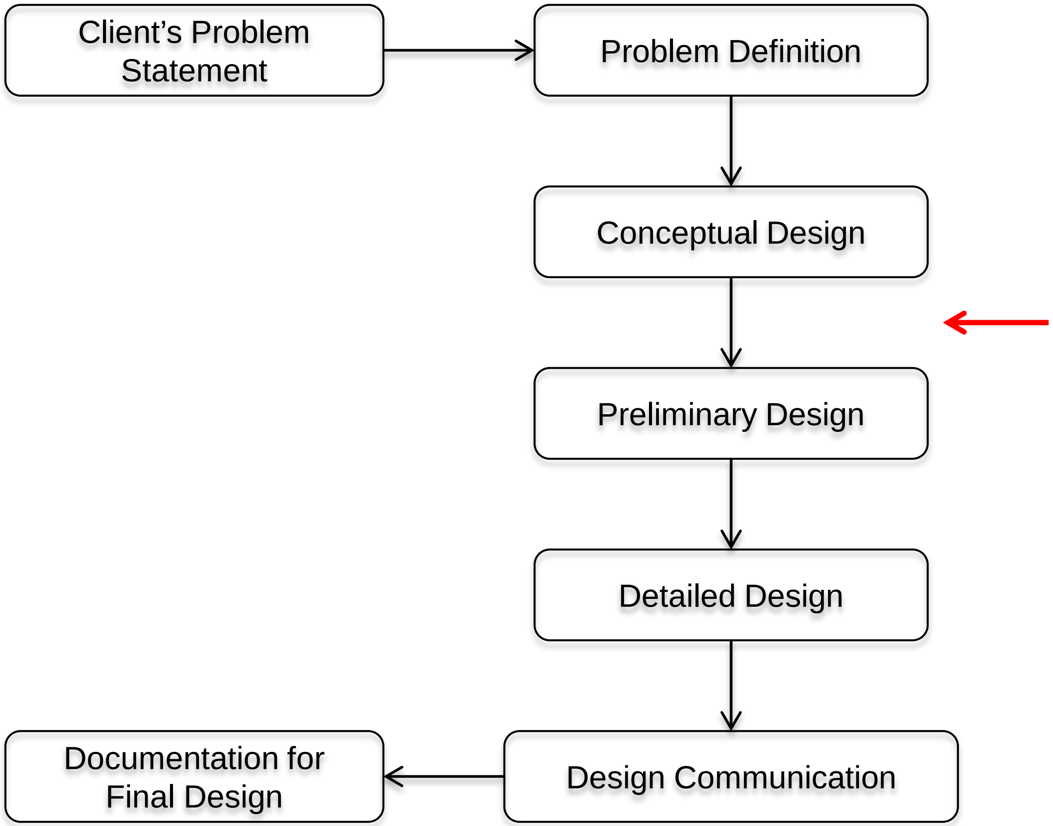
Which design is best, how do we choose based on metrics?





http://zeocars.com, http://www.carbodydesign.com,, accessed 310814

Dym's Model



We have practised translating a Client's problem statement into **our engineering problem statement**.

We have generated potential **design solutions**.

Now to pick one to concentrate on – and for which to build a prototype!

Phase 3: Evaluating the Design

Previous Milestones

…

1.4 Revise the Client's Problem Statement.

…

2.3 Establish the Means for achieving the Functions.

2.4 Generate design alternatives.

Now

3.1 Refine and Apply Metrics to the design alternatives.

3.2 Choose a design!

Important for your design proposal, presentation and further group assessments.

Notes regarding Phase 3:

We need to choose which design concept (or two) is best because we don't have the resources to build prototypes of them all.

How do we pick the best one or two solutions?

- We *should* use a **structured** method.

  → For generating designs we used *divergent* thinking.

  Now to evaluate the designs we must use *convergent* thinking.

- We need a method that allows us to consider the relative strengths and weaknesses of our concepts in an as much of an **objective way** as possible.

Just be aware….

We said we wanted to be *objective* **but** of course sometimes *subjectivity* can't be avoided.

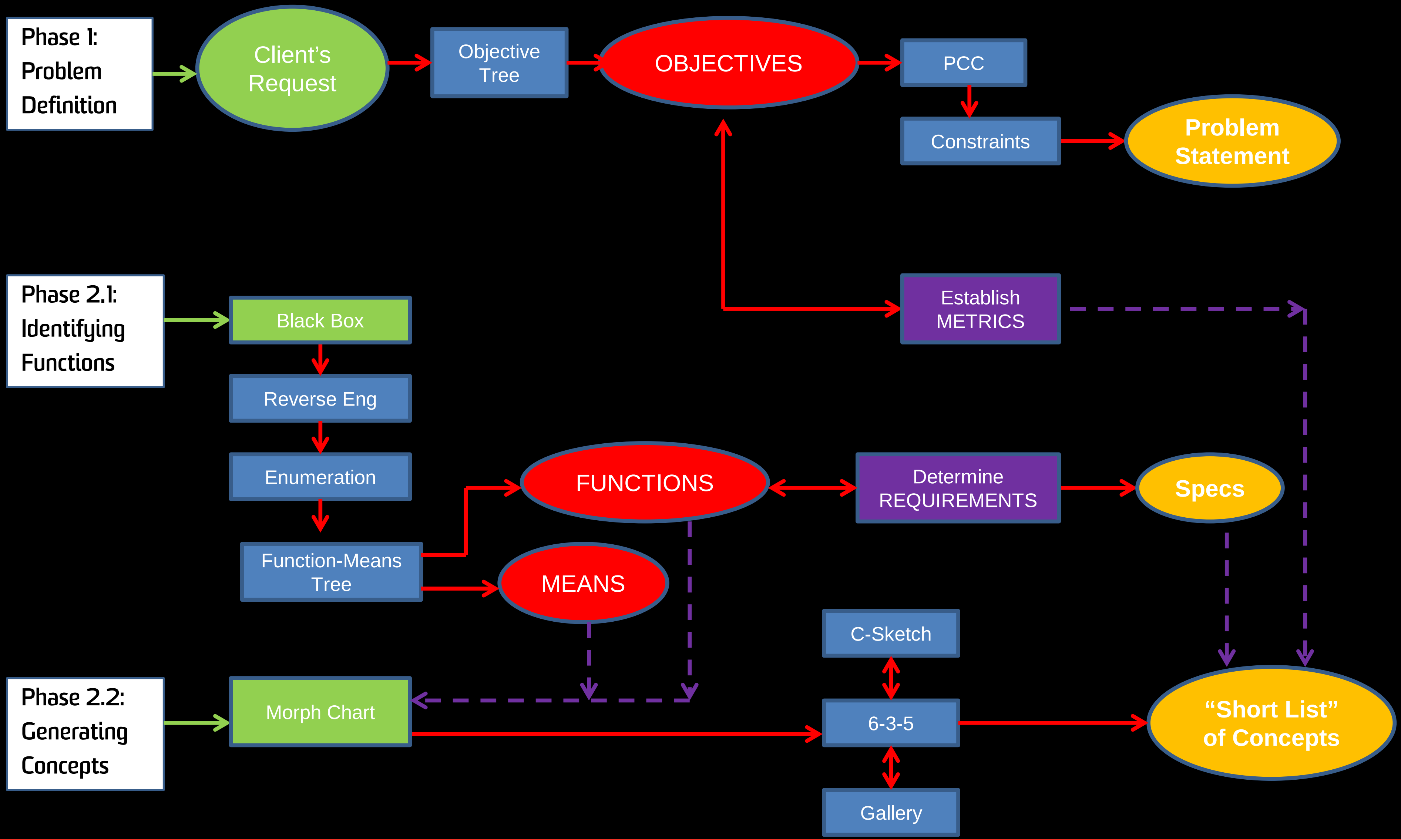
Sometimes – for reasons unspecified – the Client will make a pretty random decision as to which way they want to go.

A good engineer will, though take as rigorous an approach as possible.

In this case:

Pros?	Good for hay fever; keeps your pockets free; inexpensive
Cons?	You look like a geek; no good if it rains; messes up your $50 hairstyle

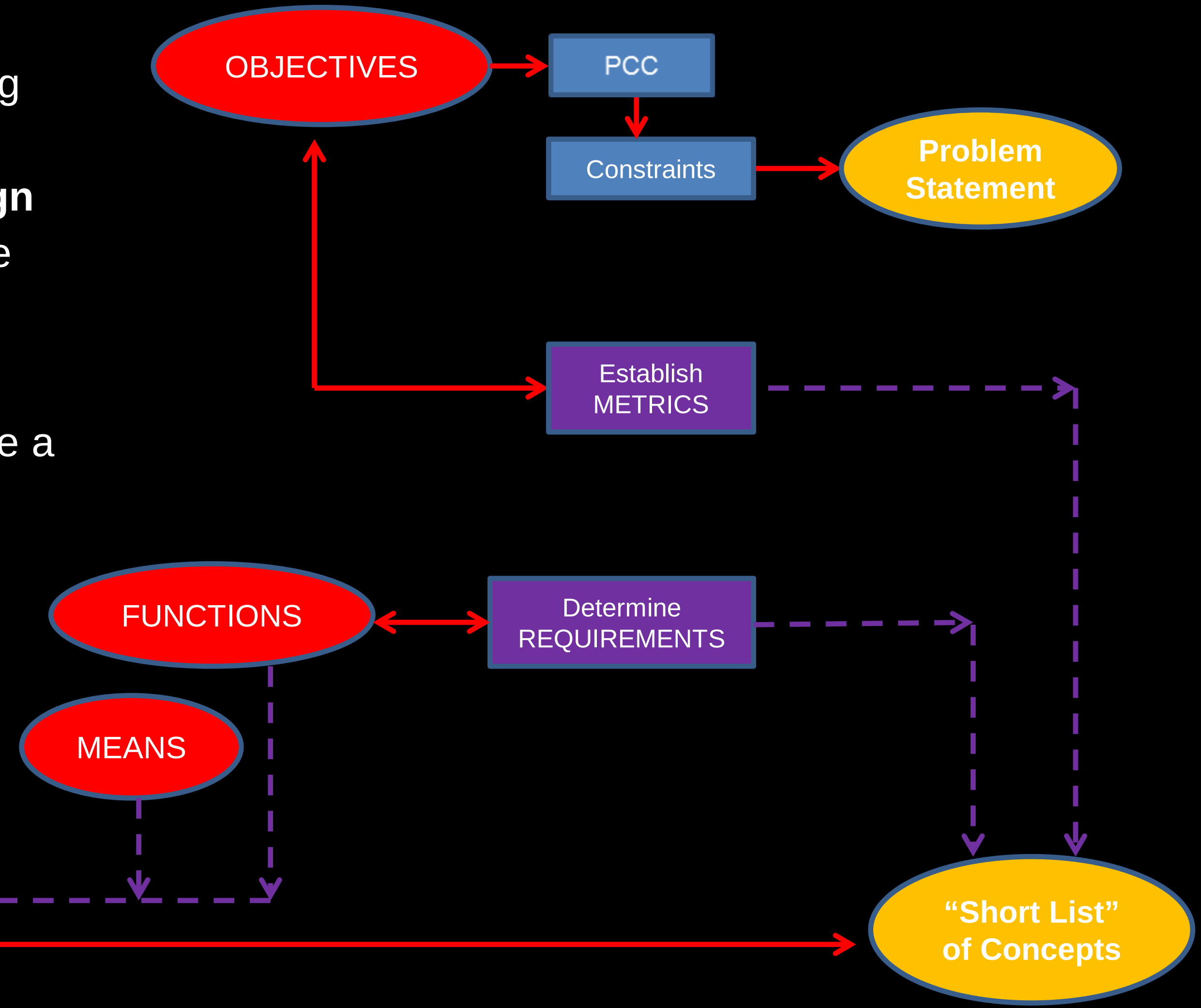
We've done this hard work ….



…. To now have Inputs for how to Evaluate which of our Conceptual Designs is worth Pursuing

Remember how, when introducing Phase 1 with the **flowchart from Dym** and the **Engineering Design Project Plan**, we noted that there was no provision for feedback?

Well, now we're going to re-iterate a bit….



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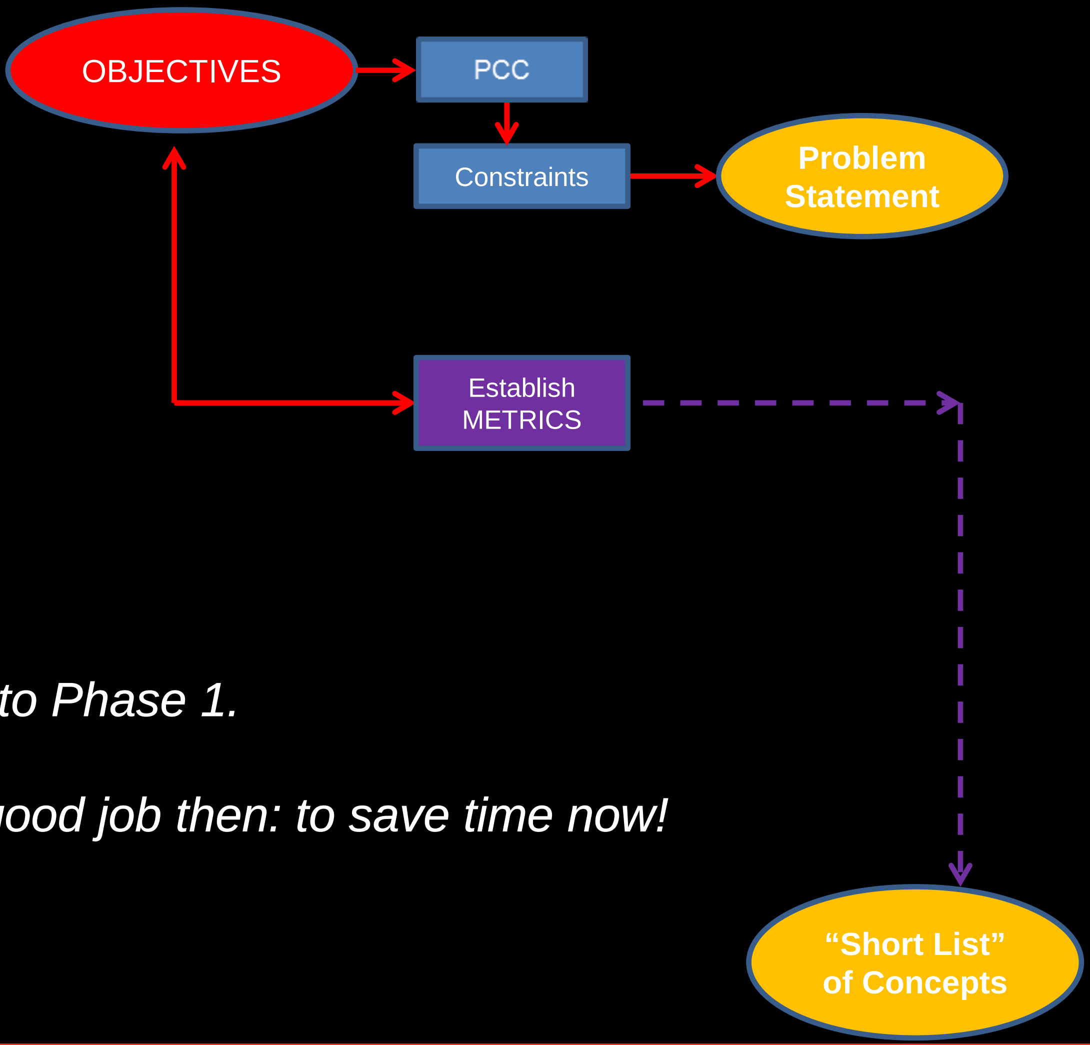

In fact, we're going all the way back to Phase 1.

That's why it was important to do a good job then: to save time now!

3.1 Applying the Metrics

Basic approach:

1. Establish the rank order of the Objectives

   (In theory, you should already have done this!)

2. Prioritise (weight) your design Objectives.

*This helps improve the **objectivity** of the process to then help **reduce errors from bias**.*

3.1.1 Ranking the Objectives

Remember from Phase 1 we made sure that each of our Objectives were measurable?

We then ranked our Objectives in the order of their importance using a **Pairwise Comparison Chart** (PCC).

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For our Formula SAE example, we previously discussed the objectives

Our PCC will look something like this:

Objectives	Fast	Reliable	Frugal	Safe	*Score*
Fast	-	1	1	0	2
Reliable	0	-	1	0	1
Frugal	0	0	-	0	0
Safe	1	1	1	-	3

So our **Objectives** and associated **Metrics** for this example in order of importance are:

- Safe (deceleration force in the event of an accident, g)
- Fast (lap time, s)
- Reliable (distance between re-builds, km)
- Frugal (fuel consumption, L/100km)

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3.1.2 Weighting the Objectives

Start by just giving them HIGH, MEDIUM or LOW priority.

Why?

- Need to limit our analysis to the client's most important objectives.
- Establish our metrics with common sense of scale.
- Keep in mind that our information reflects a fair amount of subjectivity.

- Our metrics should be thought more of indicating a sense of direction rather than a numerical solution.

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This is best illustrated with an example. Let's do another PCC.

Client's Request:

"We think there's a niche in everyday, student drink bottle market. Please investigate."

Approach from Phase 1:

→ Determine the Objectives and their Metrics.

→ Rank the Objectives (using a PCC chart).

Lets think about the objectives for the everyday student drink bottle.

What are some of the objectives?

Needs to carry a suitable amount of liquid

What size bottle

Should not leak

Strong

Looks cool.

PCC Chart for the drink bottle for our example.

	Capacity	Mass	Sealing	Durability	Aesthetics	SCORE	RANK
Capacity	-	1	0	0	1	2	3
Mass	0	-	0	0	0	0	5
Sealing	1	1	-	1	1	4	1
Durability	1	1	0	-	1	3	2
Aesthetics	0	1	0	0	-	1	4

Ranking order

1. Sealing
2. Durability
3. Capacity
4. Aesthetics
5. Mass

3.2 Choosing the Best Design Concepts

Having prioritised and weighted our Objectives, we now use this info as an input to a **decision matrix**.

This tool forces us to view the various design alternatives in a careful and thoughtful manner.

Dym details three variations of the **Pugh selection chart** (p. 106):

1. Numerical Evaluation Matrices
2. The "Priority-Checkmark" Method
3. The "Best-of-Class" Chart

The three above are listed in order of decreasing "mathematical rigour".

Prof Stuart Pugh

3.2.1 *The Numerical Evaluation Matrix*

Client's Request:

"We think there's a niche in everyday, student drink bottle market. Please investigate."

Problem Statement

"Produce a vessel, for use by university students, which is suitable for transporting a rehydrating fluid without spillage and then for dispensing it to the mouth."

Then

→ Determine the Objectives and their Metrics.

→ Rank the Objectives (using a PCC chart).

→ (generate design concepts)….

→ Then determine **weightings**.

→ Create the decision matrix and choose the design to proceed with development.

TABLE 8.1 **A *numerical evaluation matrix* for the juice container design problem. Note that only three of the six objectives originally identified for this design are utilized here, in part because we think these three objectives are more important than the other three, and in part because we have metrics (and presumably data) for these three objectives**

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	×	×		
C: Chemically inert				
O: Environmentally benign			80	40
O: Easy to distribute			40	60
O: Long shelf life			90	100

Example, from Dym, of a “Numerical Evaluation Matrix”, p108.

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3.2.1 *The Numerical Evaluation Matrix*

- The matrix shows both constraints (upper rows) and objectives (lower rows) in the left hand column.
- Simplicity sake, limited objectives to ones the client indicated important.
- **We can immediately rule out glass bottles and aluminium cans because they have a potential for sharp edges.**
- Only need to evaluate two designs Mylar bag and Polyethylene bottle against metrics for relevant objectives.
- How good do we consider a product for a particular objective on a Scale of 0-100.

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3.2.2 The *Priority-Checkmark* Method

Good for cutting-through large numbers of concepts.

Client's Request:

"We think there's a niche in the everyday, student drink bottle market. Please investigate."

Problem Statement

"Produce a vessel, for use by university students, which is suitable for transporting a rehydrating fluid without spillage and then for dispensing it to the mouth."

Then

→ Determine the Objectives and their Metrics.
→ Rank the Objectives (using a PCC chart).
→ (generate design concepts)….
→ Attribute **priority** check-marks.
→ Create the decision matrix (and so choose the best design with which to proceed).

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3.2.2 The *Priority-Checkmark* Method

- Simpler qualitative version of the numerical evaluation matrix we have just considered.
- We simply rank objective as high, medium or low in priority.
- High priority given 3 checks
- Medium priority given 2 checks
- Low priority given 1 check.
- Metric results assigned 1 if awarded an arbitrary high number such as 60 or 70 (0-100 scale) and 0 if less than value set.
- Losses some information that may be useful in determining between close alternatives.

TABLE 8.2 A *priority benchmark chart* for the juice container design problem. This chart qualitatively reflects a client's values in terms of the priority assigned to each objective, so it uses the ordering in the PCC of Figure 4.4

Design Constraints and Objectives	Priority (✓)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges		×	×		
C: Chemically inert					
O: Environmentally benign	✓✓✓			1 × ✓✓✓ ✓✓✓	0 × ✓✓✓ ●●●●
O: Easy to distribute	✓			0 × ✓ ●●●●	1 × ✓ ✓
O: Long Shelf Life	✓✓			1 × ✓✓ ✓✓	1 × ✓✓ ✓✓

Example, from Dym, of a "Priority-Checkmark" matrix, p109.

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O: Easy to distribute	✓			0 × ✓ ●●●●	1 × ✓ ✓
O: Long Shelf Life	✓✓			1 × ✓✓ ✓✓	1 × ✓✓ ✓✓

Example, from Dym, of a "Priority-Checkmark" matrix, p109.

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3.2.3 The *Best-of-Class Chart*

Encourages evaluation based on opinion rather than testing or actual metrics.

Client's Request:

"We think there's a niche in the everyday, student drink bottle market. Please investigate."

Problem Statement

"Produce a vessel, for use by university students, which is suitable for transporting a rehydrating fluid without spillage and then for dispensing it to the mouth."

Then

→ Determine the Objectives and their Metrics.

→ Rank the Objectives (using a PCC chart).

→ (generate design concepts)….

→ Ranking on which meets objective best (1 for best)

→ Create the decision matrix (and so choose the best design with which to proceed).

TABLE 8.3 A ***best-of-class chart*** **for the juice container design problem. This chart presents the rank ordering of the metrics results for each acceptable design. Notice that in this case, the client and the designer will need to select between the winner for the highest objective, or a design that wins on both of the other ones**

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	*	*		
C: Chemically inert				
O: Environmentally benign			1	2
O: Easy to distribute			2	1
O: Long shelf life			2	1

Example, from Dym, of a "Best-of-Class Chart" matrix, p110.

Note:

- We've made an effort to objectively weigh-up the options

  but

- Decision matrices still rely on a fair bit of subjective decision making….

So be aware of the potential pitfalls involved….

…. also note the differences in the "winning margin" between methods.

Home Work

Read Dym Chapter 8 (very short – 8 pages!)

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Week 6 Lecture

- Next week is the mid-session break

- Next Common Lecture
  - Clancy Auditorium, 2-4pm, no repeat
  - Monday 9th April
  - Report Writing (Pam Mort)

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Week 6 Mentor Session

- **Peer Assessment Activity for the Conceptual Design Phase**
  - Group Presentation
  - See Guidelines on Moodle – Engineering Design Process section
- **Preparation**
  - Review Team Problem Statement
  - Create a Morphological Chart – Functions and Attributes of the solution
  - Conduct a brain-storming session
    - Facilitation Guide on Moodle

Week 6 Mentor Session

- Group Presentation – Mentor meeting Week 6
  - 10 minutes plus 2 minutes question time
  - Concept Generation, Morph Chart, Methods, one aspect of design
  - Assessed by Mentor (50%) and other students (50%)
- Individual Assessment
  - Submitted on Moodle by 9pm Friday, Week 6
  - One page description of a concept or sub-system you individually designed
  - Assessed by mentor