Develop

Ideate and model concepts based on identified opportunities

MINSET

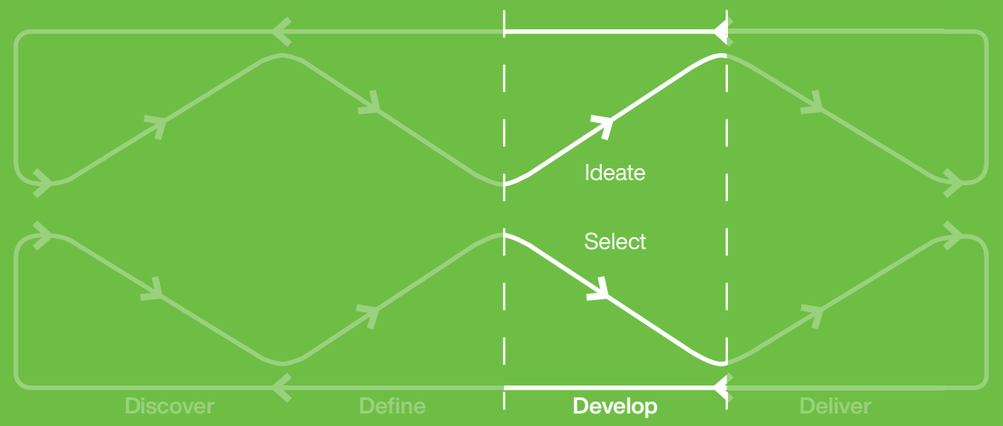
Joyfulness

Ideate

- How do we ideate?
- What are key methods we might use?
- How do we maximise quantity?
- What analogies may be used?
- How do we add depth and fidelity?

Select

- How do we down select ideas that ‘wow’?
- What are the 3 to 6 ideas to emerge from this sprint?
- How do we increase and embrace playfulness?
- How might ideas be combined to create improvements?



Method

Brainstorming

Design Thinking | Intuitive Ideation

Brainstorming is a common method of generating ideas.

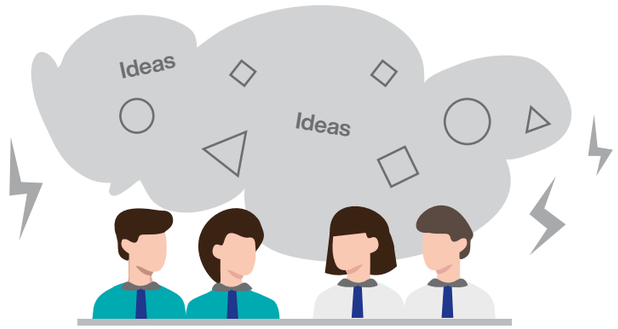
Why: Brainstorming is used when there is an opportunity and the team is ready to dive into ideation to solve a design problem.

Time: 0.5 - 1 hours

Material: Whiteboard

Complementary methods: User Interviews, Affinity Analysis, Activity Diagram, Hierarchy of Purpose, Systems Function Model

Acronym: GPS - Global Positioning System



Procedure

1 **Define**

the design opportunity. Be reminded of the design opportunity throughout the exercise. Use the keywords in the opportunity to brainstorm.

2 **Generate ideas individually**

This allows everyone to not have 'group think', where ideation is led by someone who is dominating the conversation.

3 **Share ideas with team**

Discuss and have conversations about each idea. Have one conversation at a time so that all ideas can be heard and built upon.

4 **Build on one another's ideas**

Think 'yes, and' rather than 'no, but'.

Best Practices

Defer judgment[1]

There is no bad ideas at this point. Ideas can be refined at a later stage of ideation.

Encourage wild ideas[1]

It is the wild ideas that often provide the breakthroughs. It is always easy to generate realistic rather than wild ideas.

Divide and conquer

The team can divide the design opportunity into various spaces. Be focused and disciplined so that the team can get a broad variety of ideas.

Involve everyone

First generate categories and solutions individually, then come together to synthesise your categories and solutions.

Worked Example

How might we locate or detect a lost golf ball?

- Bright coloured ball
- Sound horn in ball
- Exploding ball
- Golf lessons
- GPS system
- Scent-human
- Scent-dog
- Electronic grid with ball emitter
- Pressure sensitive ground
- String attached to ball
- Smoke trail
- Shorter golf course
- Spotters paced every 10m
- Coloured golf course
- Trajectory calculation system
- Robotic arm hits ball
- Mini camera in ball
- Light emitting ball
- Ball shoots flare
- Plexiglasside walls on golf course
- Speaker in ball; use microphone to call yourself

Method

DI Mindmapping

CARD 2 Joyfulness

Design Thinking | Intuitive Ideation

DI Mindmapping is an ideation method that is analogous to human memory. Ideas are organised in a hierarchical structure with individual ideas under categories which in turn map to a topic or design opportunity.

Why: DI Mindmapping serves as an effective visual documentation of brainstorming session and helps in down-selecting the favourite choices by conducting a voting session at the end of discussion.

Time: 0.5 - 1 hour

Materials: Whiteboard

Complementary methods: User Interviews, Affinity Analysis, Activity Diagram, Hierarchy of Purpose, Systems Function Model, Brainstorming

Acronyms:
AM - Additive Manufacturing
AV - Autonomous Vehicle
DI - Design Innovation
FDM - Fused Deposition Modeling
SLA - Stereolithography
SLS - Selective Laser Sintering
UX - User Experience

Procedure

1 State the design opportunity statement/HMW statement

in the centre of a large sheet of paper or whiteboard.

2 Generate ideas individually for 10-15 mins

Write each individual idea on a sticky note for easier categorisation and moving later. Aim for actionable ideas that are implementable, even if they are wild!

3 Consolidate ideas and cluster similar ones

Participants take turns to share their ideas and cluster similar ideas under common categories.

4 Identify the categories your ideas fall under

5 Utilise the categories to generate further ideas

Take the category as a start point to generate further related ideas you previously have not thought of.

Best Practices

Involve everyone

First generate categories and solutions individually, then come together to synthesise your categories and solutions.

Expand your mind map

A standard procedure is to start with categories and then creating solutions under subcategories. However, a new idea can open up a category which leads to more ideas.

Go for quantity

Target to generate at least 50 solutions to capture a diverse range of solutions as a team.

Discuss as a team

Not only does Mind Mapping allow organisation of ideas, it also facilitates ideation and discussion as a team. Discuss as a team with the mind map and build on it!

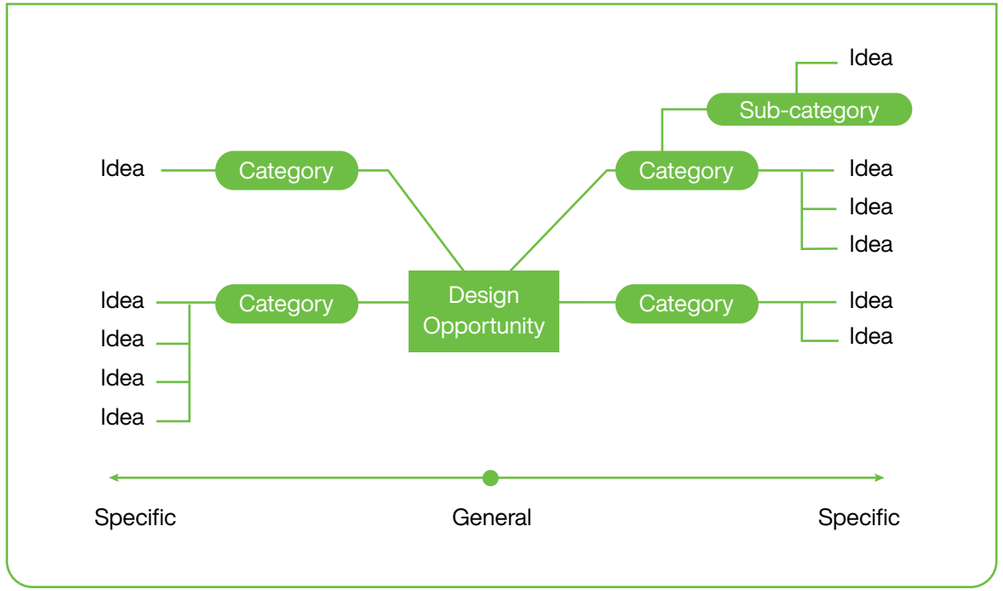
Have implementable ideas

Target to have solutions that are specific enough to be actionable. Solutions usually answer the 'How do we do it?' question.

Useful Tip

Ideas should be actionable.

Structure

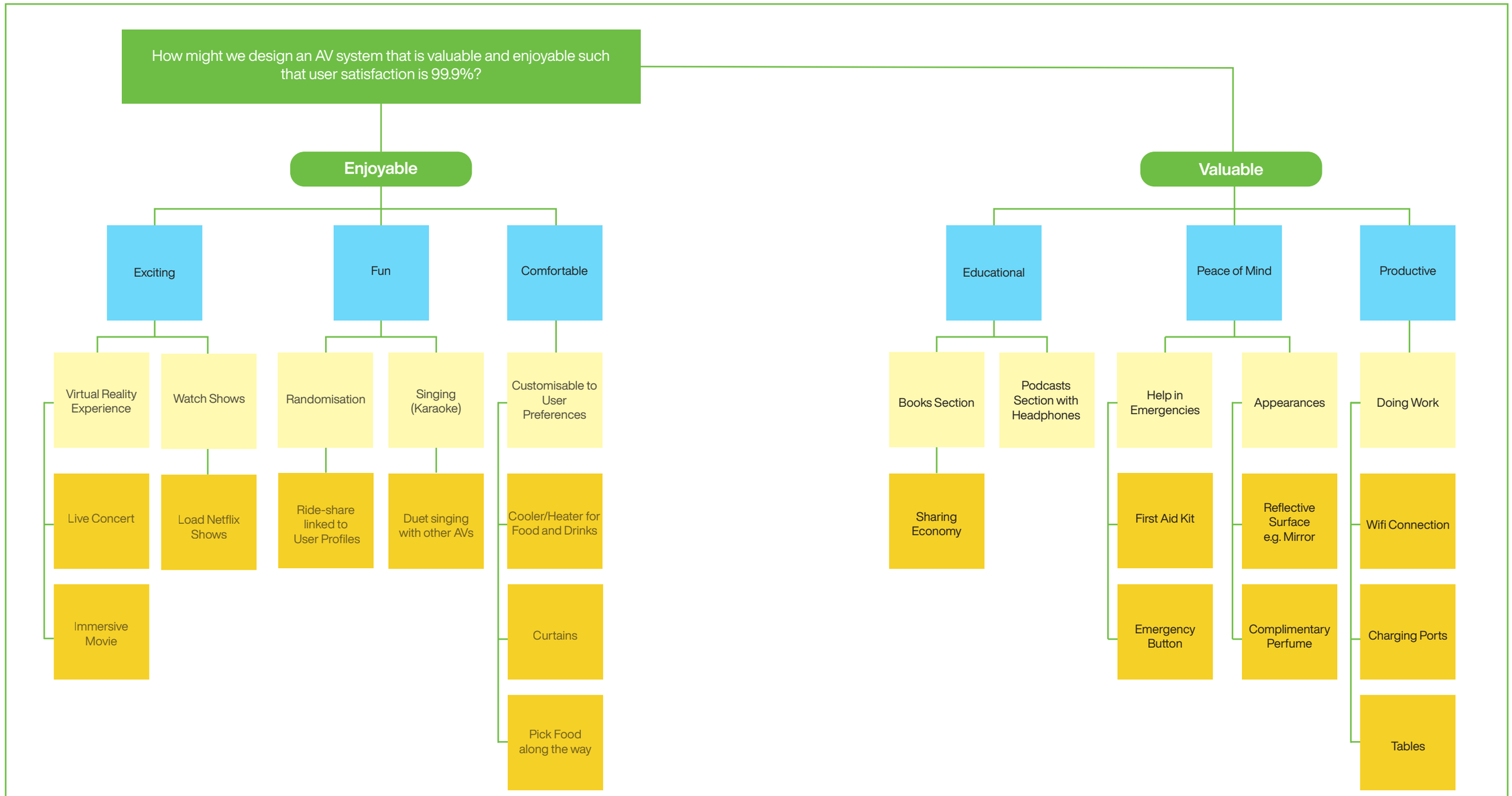


Worked Example 1

This is a portion of a mind map with the opportunity statement 'How might we design an autonomous vehicle (AV) system that is valuable and enjoyable such that user satisfaction is 99.9%?'.

Useful Tip

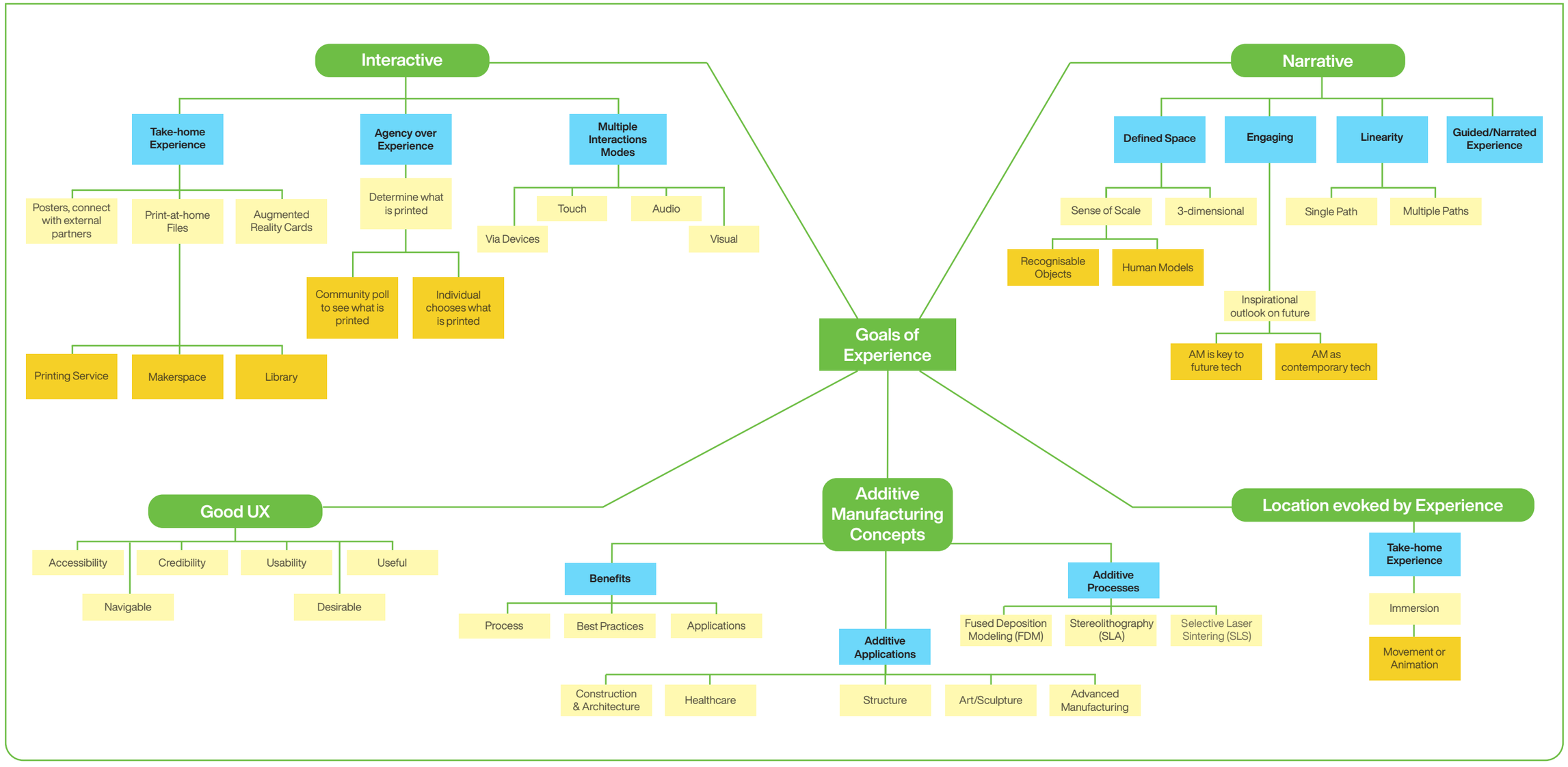
Don't forget about your personas when developing the mind map. Ideating with the users in mind is important for the solutions to be relevant.



Worked Example 2

This mind map was created for a project that focuses on developing a multi-sensory experience for users to learn more about additive manufacturing (AM) and how its application is enabling a better future.

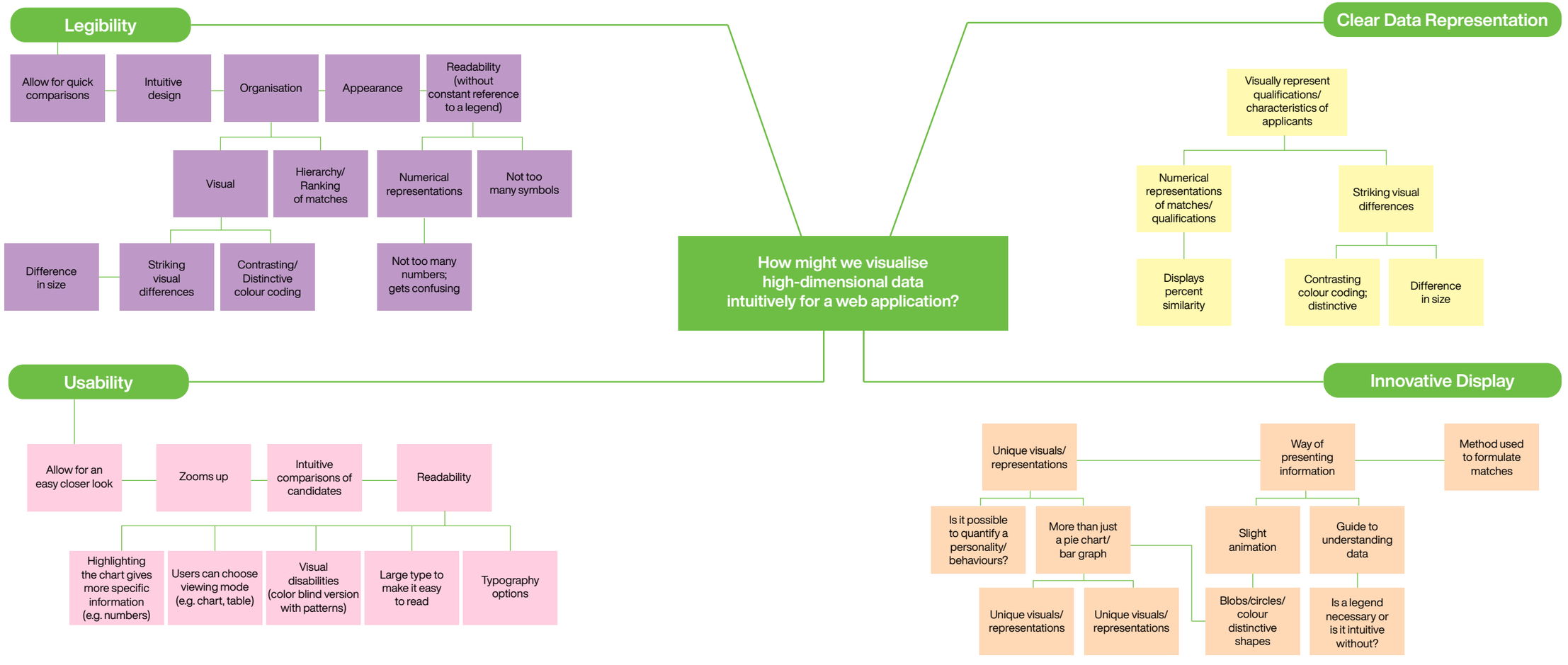
The ideas generated from this mindmap gave rise to the conception of a virtual and physical kiosk[1] that includes a series of display objects that provide a fun and tactile experience, demonstrations of topology optimisation, an augmented reality experience that brings the user to the surface of Mars, and a set of souvenir cards with a space-themed hologram.



Worked Example 3

This is a mind map completed by a team that focuses on the opportunity statement 'How might we visualise high-dimensional data intuitively for a web application?'

This was done in about an hour and the team generated 40+ ideas! They used Sticky Notes to write down ideas; each Post-it represents a single idea they had. The team members initially divided the opportunity space among themselves so that there was less overlapping of ideas, and more breadth and diversity of ideas. After several minutes of initial ideas, the team came together to ideate additional concepts collaboratively, building on each others' work.



Method

Design by Analogy

Design Thinking | Directed Ideation

CARD 3 Joyfulness

Design by Analogy is a method where inspiration for ideation is drawn from comparing a problem or opportunity to existing solutions or situations in other fields.[1]

Why: Design by Analogy helps designers, engineers, and professionals to generate creative ideas that are novel and useful with the help of prompts.

Materials: Design by Analogy Tools (see below)

Complementary methods: User Interviews, Affinity Analysis, Activity Diagram, Hierarchy of Purpose, Systems Function Model, Brainstorming, DI Mindmapping

Acronym: LED - Light Emitting Diode

Procedure

1 Identify characteristics, key words or prompts

that describe or may help to solve the problem or opportunity.

2 Observe similarities elsewhere

Look at other fields, like in nature, or other industries, drawing similarities in existing solutions or situations. Take note of similarities in function, appearance, process, etc.

3 Transfer and apply learnings

from existing solution(s) to the problem or opportunity.

Design by Analogy Tools

Use these tools to help ideate analogies, particularly in retrieving appropriate prompts:

Word Tree | www.wordvis.com

Provides a visual network of related words prompted by a single keyword of your choice, thus expanding the options available for exploration to work on your problem.[11]

AskNature[12] | www.asknature.org

A biomimetic database which inspires innovators with biological phenomena. Explore how nature may provide insight into solving your problem.

TRIZ[10] | www.triz40.com

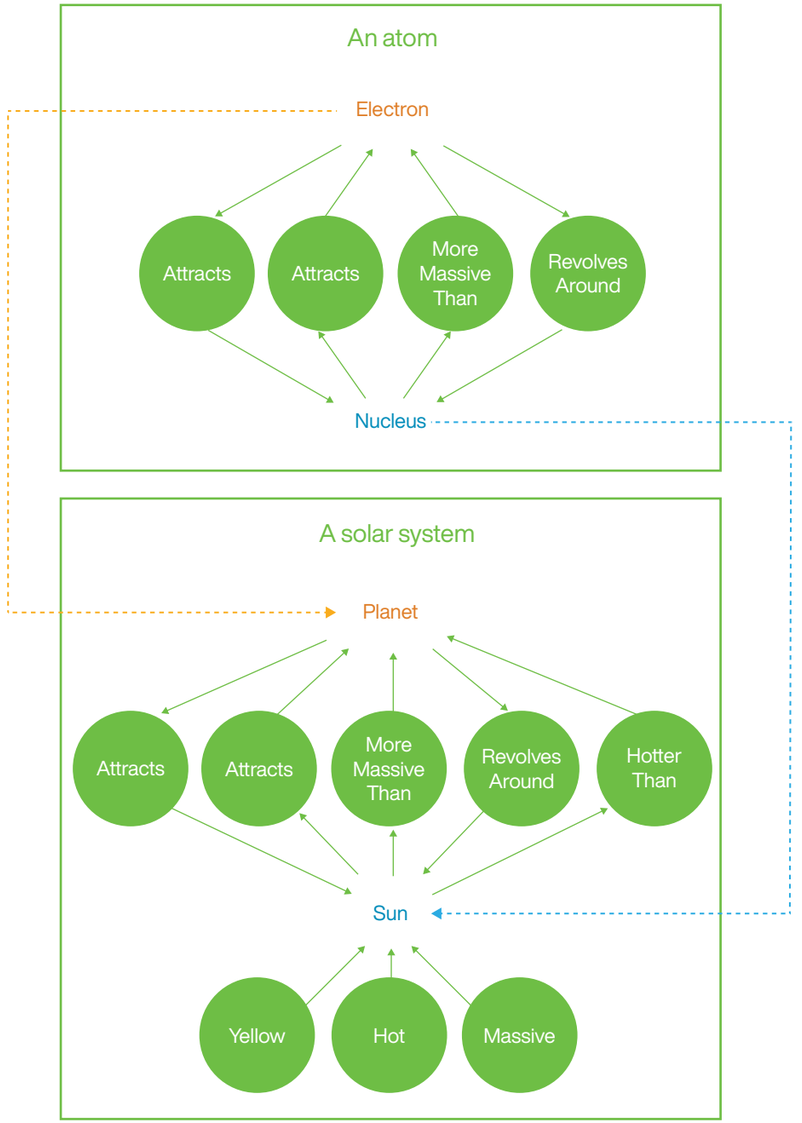
A systematic approach for understanding and solving problems based on principles of engineering and physics.

Analogous Inspiration [7,8]

Draws inspiration from tapping on memories of one's own experiences or from immersing oneself in other settings.

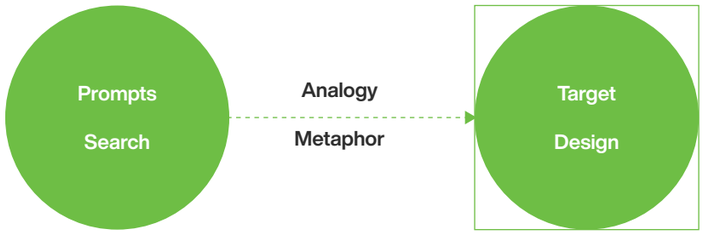
Illustrated Explanation[2]

An atom is analogous to a solar system because they have similar relationships.

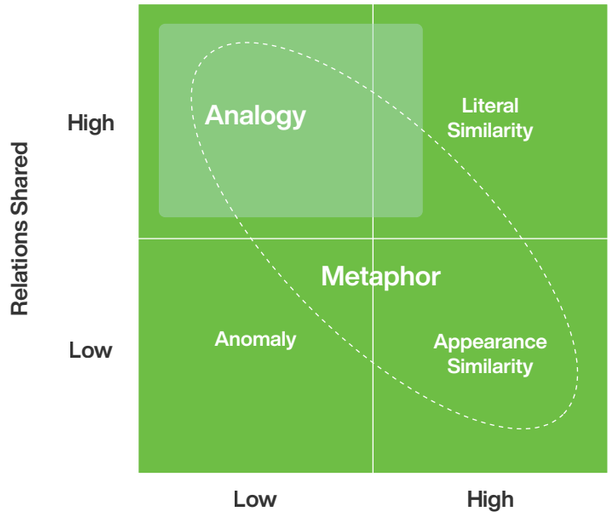


Concept of Design by Analogy[4,6]

The 3 diagrams aim to compare analogy and metaphor, understanding their similarity and differences.

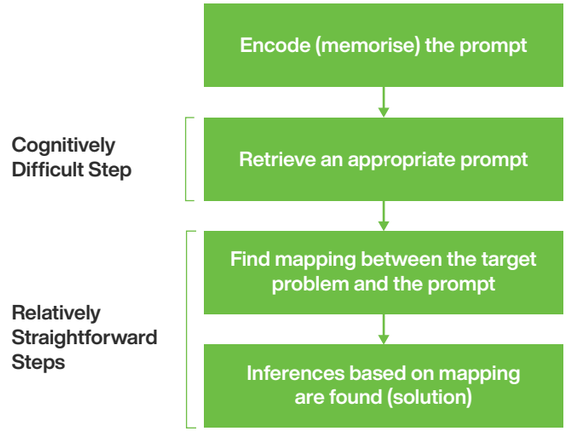


This diagram describes how the process of analogy and metaphor occurs. The designer usually searches for inspiration from a different domain (prompt) and applies it to the domain of interest (target). The prompt domain may not exactly map to the target domain (as seen in their incompatible shape), but proves to have some form of overlap.



The overlap, of relations and attributes, is shown in a graphical representation (on the right). The x-axis denotes the extent of the attributes shared by the prompt and target domain while the y-axis denotes the extent of relations shared by them.

Analogy, which takes the form of the rounded rectangle on the top left, is pictured as having high relational resemblance but low attribute resemblances between the prompt and target domain. Metaphor, which is represented by the area covered by the oval, shares some similarity to analogy but could also be inspirations that has high appearance similarity.



Understanding the difficulty of applying design by analogy

The diagram shows the general processes involved in applying Design by Analogy. It also highlights the retrieval of an appropriate prompt as the cognitively difficult step.

Worked Example

A Multi-functional shelves that are inspired by waffles can be unlocked and rotated to reveal the inner parts of the shelves. The inner parts can be used to store more secured documents.

B An information board inspired by tree rings can be used to chronologically record additions to the document and grow bigger progressively.

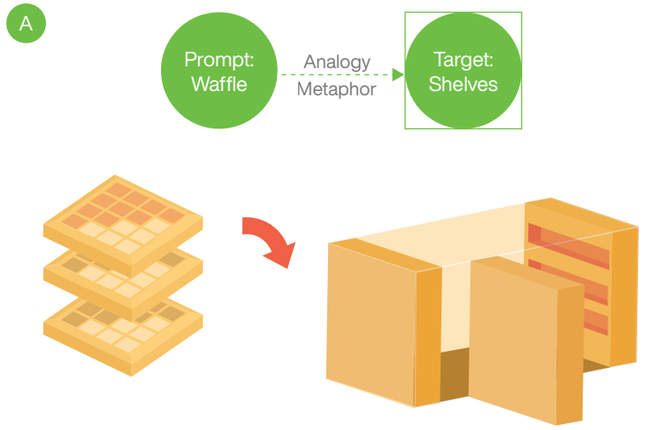
C Train platform inspired by Venus flytrap can be designed to lure people to less crowded area at the ends of the platform.

D LEDs inspired by lanterns can be used to lead people out of train tunnels during disruption. The LEDs gradually light up and provide assurance to the passenger in times of panic and chaos.

E A train nose could be reshaped, drawing inspiration from how Kingfishers dive at high speed into water without a splash, mimicking the streamline geometry of the kingfisher bill to drastically reduce sonic boom effect.15

How might we design a station that increases the productivity and efficiency of its processes while enhancing user satisfaction?

A



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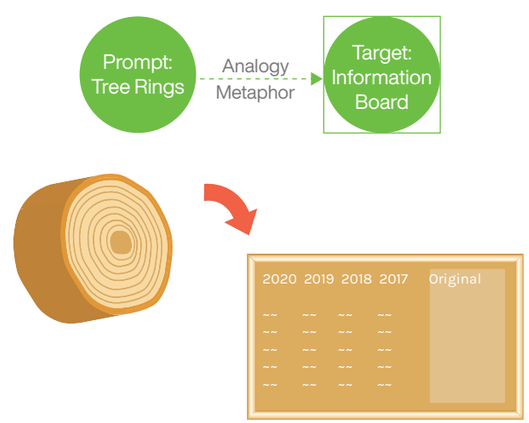
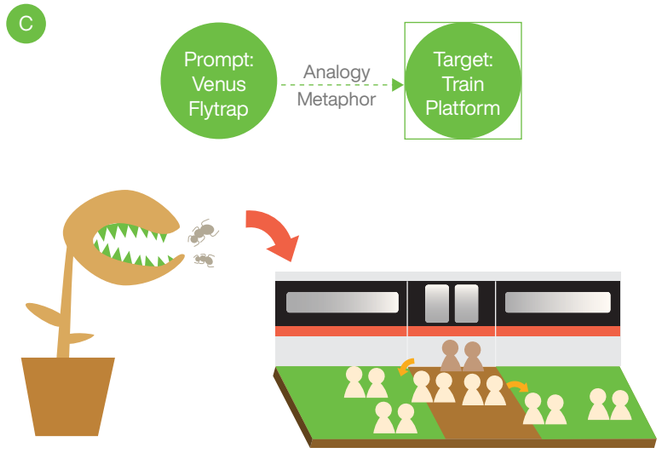
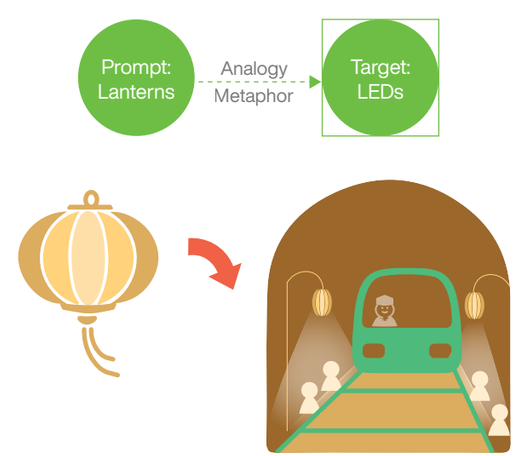


C

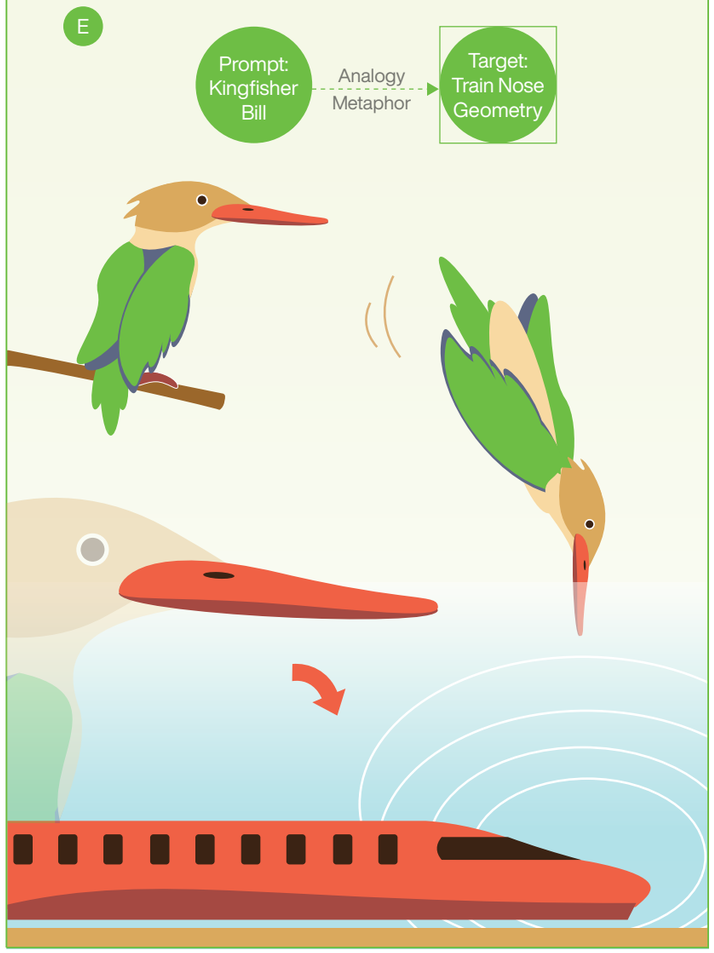


D



How might we rectify the problem of a loud sonic boom generated when trains travel through tunnels at high speeds?

E



Method

C-Sketch (6-3-5)

CARD 4 Joyfulness

Design Thinking | Intuitive Ideation

C-Sketch (6-3-5), or Collaborative Sketch, is a rapid way to generate and build upon the ideas that you and your team members have.

Why: C-Sketch is effective because it helps to provide different perspectives or insights into the solutions that are hidden from the sketcher. The design team can produce over 100 ideas with the help of this method!

Time: 1.5 hours

Materials: Coloured Markers, Timer

Complementary methods: User Interviews, Affinity Analysis, Activity Diagram, Hierarchy of Purpose, Systems Function Model, Brainstorming, DI Mindmapping, SCAMPER

It is called 6-3-5 because of 6 people, 3 ideas, 5 iterations

Procedure

1 Divide paper

into 3 sections.

2 Ideate individually, each using different coloured pens

where each design team member uses 15 minutes to sketch a total of 3 diverse ideas, 1 in each section. Label if necessary.

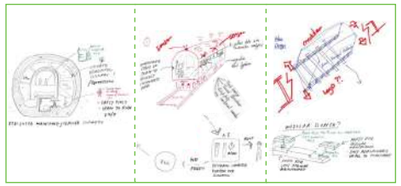
Members should stay silent till step 4.

3 Pass & improve on the ideas

or sketch by inserting an entirely new idea for 10 minutes. Repeat until the papers return to their owners.

4 Discuss & refine the ideas

with the feedback received. Additional guidelines include: no judgment or criticisms and to build on the variety of ideas generated by other teammates.



C-Sketch sheet
(digitalised on the facing page)

Best Practices

Be silent

Lack of communication between the team members may sprout very differing solutions due to their own perspective. Questions should be kept until the end of the entire sessions and be asked later.

Be free

If there is no more ideas that can be added to the paper, be daring to use the ideas as inspirations to create an entirely novel idea.

Be positive

Negative comments and malicious remarks make people discouraged and restrict them from voicing out their ideas in the future. The assessment of the idea's feasibility should also not be made during C-sketch.

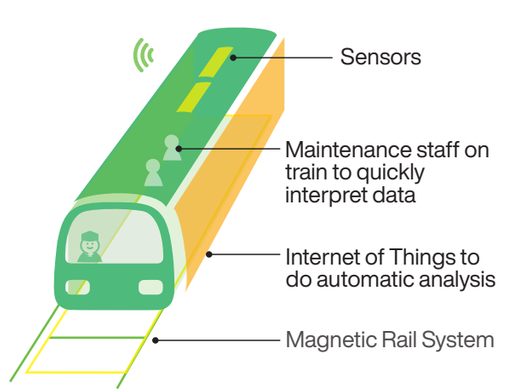
Co-create

Get users involved as participants in the 6-3-5 (C-sketch) method.

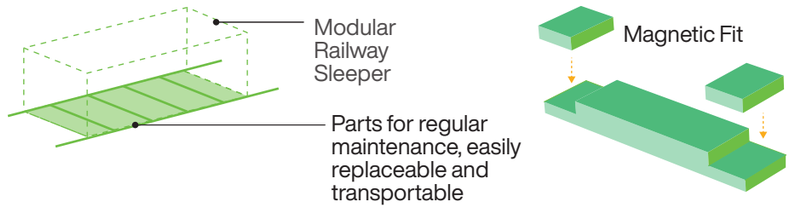
Worked Example

Changing the Tunnel Design

Maintenance-free Train



New Track Design to Ease Track Replacement



Method

Real-Win-Worth

CARD 12 Joyfulness

Design Thinking | Concept Selection

Real-Win-Worth is a strategy to manage risk and reward. It provides a way to rapidly assess the marketability of the Products, Services and Systems (PSS) by asking a series of questions.

Why: Real-Win-Worth is a systematic process to reveal faulty assumptions and possible risks which helps to prevent and/or fix problems of idea execution.

Time: 0.5 - 1 hour

Materials: 3 different Coloured Stickers

Complementary methods: Brainstorming, DI Mindmapping, C-Sketch (6-3-5), Design by Analogy, SCAMPER

Acronym: PSS - Product, Service, or System

Procedure

1 **Prepare**

a list of ideas or concepts that the design team has come up with, and work with assessors with relevant backgrounds to assess and progressively downselect them by asking the following questions.

2 **First, test for 'WIN'.**

Evaluate if ideas have a 'wow' factor that makes them desirable. Items that pass move on.

3 **Then, test for 'WORTH'.**

Question if ideas that have passed 'WIN', are potentially viable as a business, or simply make sense financially for the organisation to pursue.

4 **Lastly, test for 'REAL'**

For ideas that have passed 'WIN' and 'WORTH', question if they are feasible to produce. Does the technology for it exist? Items that pass all 3 criteria are top ideas that should be brought forward for prototyping.

5 **Discuss**

if any ideas can be improved to meet all three criteria.

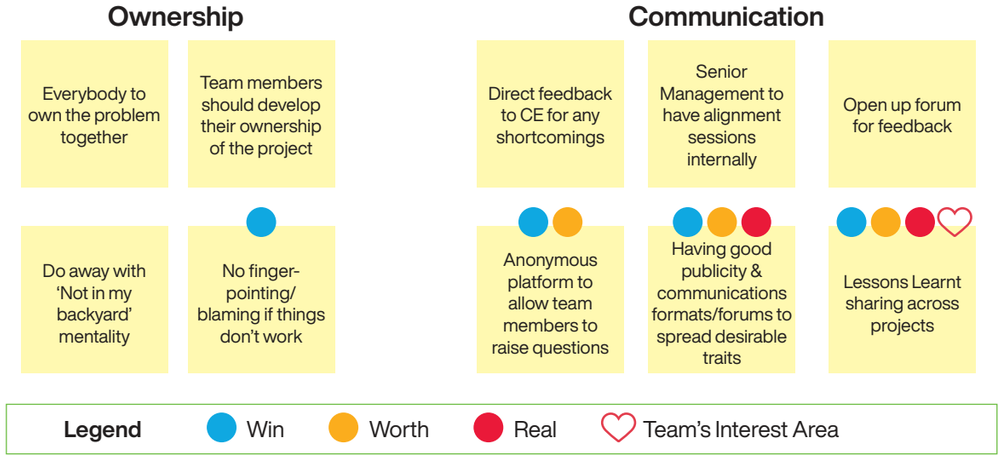
Guiding Sub-questions[1]

Real Is it real?	1. Is the market real?	▪ Is there a need or desire for the PSS? ▪ Is there buy-in from the stakeholders? ▪ Is the size of the potential market adequate? ▪ Will the customer buy/use the PSS?
	2. Is the PSS real?	▪ Is there a clear concept? ▪ Can the PSS be made? ▪ Is it technically feasible? ▪ Will the final PSS satisfy the market?
Win Can we win?	1. Can the PSS be competitive?	▪ Does it have a competitive advantage? ▪ Can the advantage be sustained? ▪ How will competitors respond?
	2. Can our company be competitive?	▪ Do we have superior resources? ▪ Do we have appropriate management? ▪ Can we understand and respond to the market?
Worth Is it worth doing?	1. Will the PSS be profitable at an acceptable risk?	▪ Are forecasted returns greater than costs? ▪ Are the risks acceptable?
	2. Does launching the PSS make strategic sense?	▪ Does the PSS fit our overall growth strategy? ▪ Will top management support it?

Worked Example 1

The team discussed their ideas as a team using Real-Win-Worth Questions. Stickers were placed on ideas that fulfilled the respective criteria, progressively downselecting the ideas. The team added one more criterion, 'Team's Interest Area', as part of the downselection.

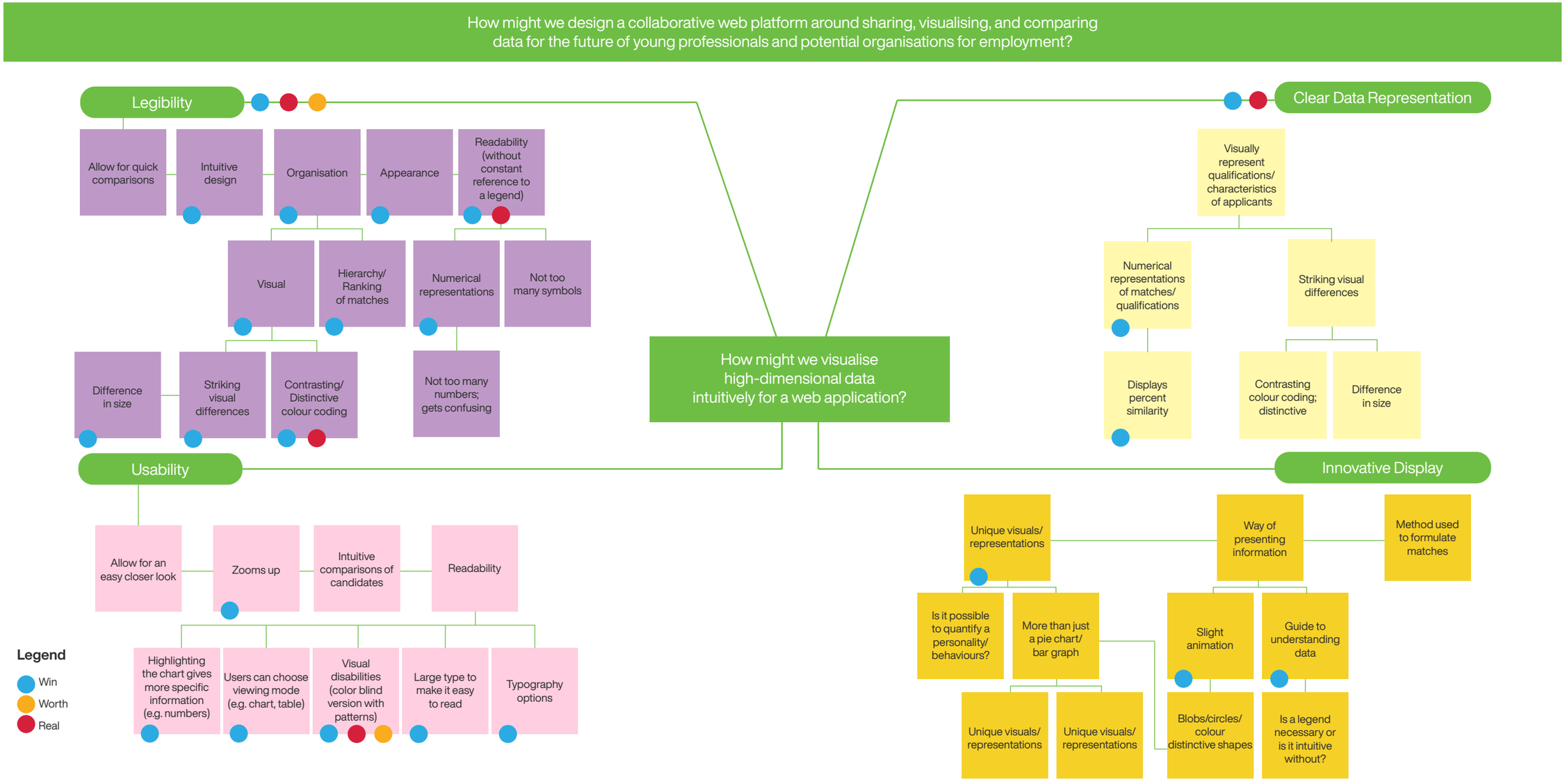
How might we align towards a clear vision for a project and break silos within disciplines?



Worked Example 2

The team discussed their ideas together and evaluated them using Real? Win? Worth It? questions. Stickers were placed on ideas that fulfilled the respective criteria, starting with "Win", followed by "Real", then "Worth", progressively downselecting the ideas.

After evaluating the ideas, the team felt that the categories "Legibility" and "Clear Data Representation" were highly important and rated them with "Win", "Real" and "Worth" stickers as well.



**You can't use up creativity.
The more you use,
the more you have.**

Maya Angelou

*Author, actress, screenwriter,
dancer, poet and civil rights activist*

Method

Co-Creation

CARD 12 Joyfulness

Design Thinking | Ideation Approaches

In co-creation or co-design, the person(s) who will eventually benefit from the design process is included as a member of the design team. They play an active role in the project development.

Why: In co-creation, the users' opinions are valued and their considerations and suggestions are being heard throughout the design process, which shorten the feedback and testing process.

Acronym: AFM - Atomic Force Microscope

Procedure

1 **Establish**

the most important challenges and pain points.

2 **Ideate**

Use ideation methods to solve these challenges.

3 **Iterate Collectively**

on the solution concepts generated.

KEY COMPONENTS

Quick Improvement Cycles

- Quick improvements of concepts
- Inclusion of multiple stakeholders
- Breaks traditional roles and fixation
- Extract user needs upfront

Problem-Solution Linkage

- Connect need finding to solutions directly
- Higher accuracy in need finding
- Keep the design team 'grounded'

Worked Example

Schedule from a co-creation event

Till 9.00 AM	Check-in & Breakfast
9.00 AM	Day 2 Kickoff
9.50 AM	Break into tracks
10.00 AM	Team Pitches
11.00 AM	Find Team Formation
12.00 PM	Lunch
1.00 PM - 6.00 PM	Hacking
6.00 PM	Dinner
7.30 PM	Pulse Checks
7.30 PM	End of Day 2

Schedule a hackathon to understand how each stakeholder is affected by a problem

Co-creating Prototypes

The design team working along stakeholders for the next generation atomic force microscope (AFM), a collaboration between LEGO and Tsinghua University

Method

Rip & Rap

Design Thinking | Permutational Ideation

CARD 6 Joyfulness

Rip & Rap allows research and design teams to 'cut' a variety of images sourced across different media (e.g. magazines, internet, photographs) and 'paste' them into a collage.

Why: This method is great for expressing creativity in other than words and helps the design team describe their ideas quickly using existing images.

Complementary methods: Morph Matrix, Mashup

Acronym: AV - Autonomous Vehicle

Procedure

1 State design opportunity statement/HMW statement

and break into teams of 3 to work. Have ready a blank physical or digital canvas to build a collage of images.

2 Start collecting images

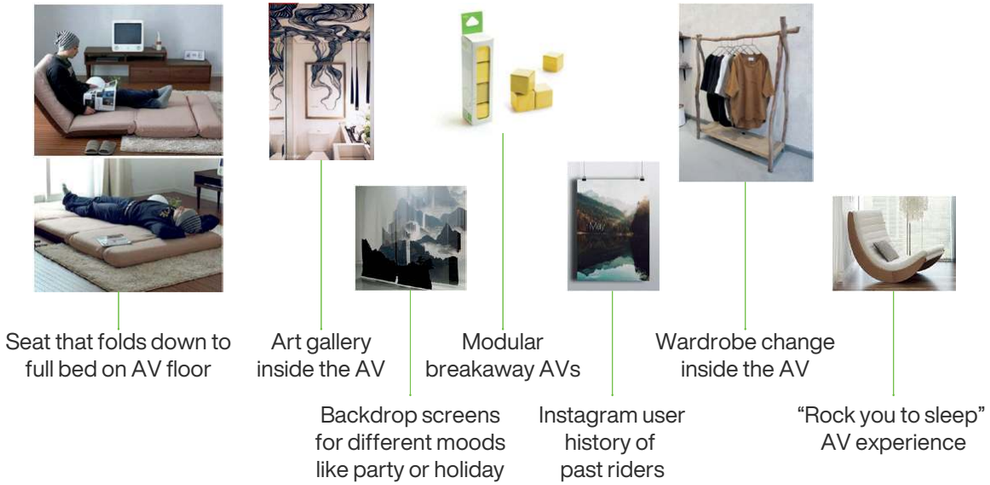
They may come from completely unrelated domains that can be linked to the design problem/ HMW statement.

3 Consolidate and present collage

Explain your collage to others and gather responses.

Worked Example

Ideas for additions to an autonomous vehicle



Example of a Rip & Rap moodboard with the interpretations of each picture in the context of improving an AV.

Method

Mashup

Design Thinking | Permutational Ideation

CARD 5 Joyfulness

Mash-Up is a collaborative method that combines one or more unrelated fields or domain of design.

Why: It generates odd or unexpected ideas by introducing elements from other unrelated domain into the opportunity statement to generate fresh ideas.

Materials: Whiteboard

Complementary methods: Rip & Rap, Morph Matrix

Procedure

1 **Pick one or more unrelated categories**
One of these should be loosely related to the design opportunity statement.

2 **Generate and list ideas**
Come up with as many ideas as possible related to each category.

3 **Combine ideas and consider how the mashup could be implemented**
Consider elements from both categories and combine them to produce new mashed-up ideas.

Best Practices

Be thorough in the combination of ideas and do not bring any prejudice beforehand.

Template Structure

Category 1	Category 2
1.	A.
2.	B.
3.	C.
4.	D.
5.	E.
6.	F.
7.	G.
8.	H.
9.	I.
10.	J.

Final list of mashup

Worked Example

An indoor entertainment/taxi service mashup

Indoor Entertainment (Unrelated to the Opportunity Statement)	Taxi Service (Related to the Opportunity Statement)
1. Massage Seats	A. Booking App
2. Minibar	B. Payment Options
3. Karaoke TV	C. Pick-Up Point
4. Cinema	D. Loyalty Program
5. Online Courses	E. Shared Ride
6. E-Library	F. Multiple Destinations
7. Cafeteria	G. Transporting Additional Pay
8. Climate Control	H. Charge Per Kilometre
9. Bed for Rest	I. Charge for Waiting Time
10. Washroom	J. Vehicle Identification

Final list of mashup

1A. Book a vehicle with massage seats
2D. Minibar inside a vehicle for loyal customers
4B. Pay for in-car cinema experience

Method

SCAMPER

CARD 7 Joyfulness

Systems Thinking | Permutational Ideation

SCAMPER is a tool to help to come up with creative ideas for improving existing solution. It is a mnemonic that stands for: Substitute, Combine, Adapt, Modify, Put to Other Use, Eliminate, Reverse.

Why: SCAMPER asks questions, challenges assumptions that exist and prompts designers to come up with creative ideas to difficult problems easily.

Materials: Whiteboard, Sticky Notes

Complementary methods: User Interviews, Affinity Analysis, Activity Diagram, Hierarchy of Purpose, Systems Function Model

Acronym: PSS - Product, Service, or System

SCAMPER questions

S — Substitute
What can be substituted?
Can the rules be changed?

C — Combine
What purpose can be combined?
Can resources/talents be combined to create new solution?

A — Adapt
What else is similar to this?
Who could we emulate?

M — Modify
What can be magnified, expand, or extended?
What changes can be made in the plans or process or marketing?

P — Put to Other Use
Can this be used elsewhere?
Who else can use it?

E — Eliminate
How can you simplify the Products, Services and Complex Systems (PSS)?
What features can be eliminated?

R — Reverse
What other arrangement is better?
What are the opposites or negatives of this?

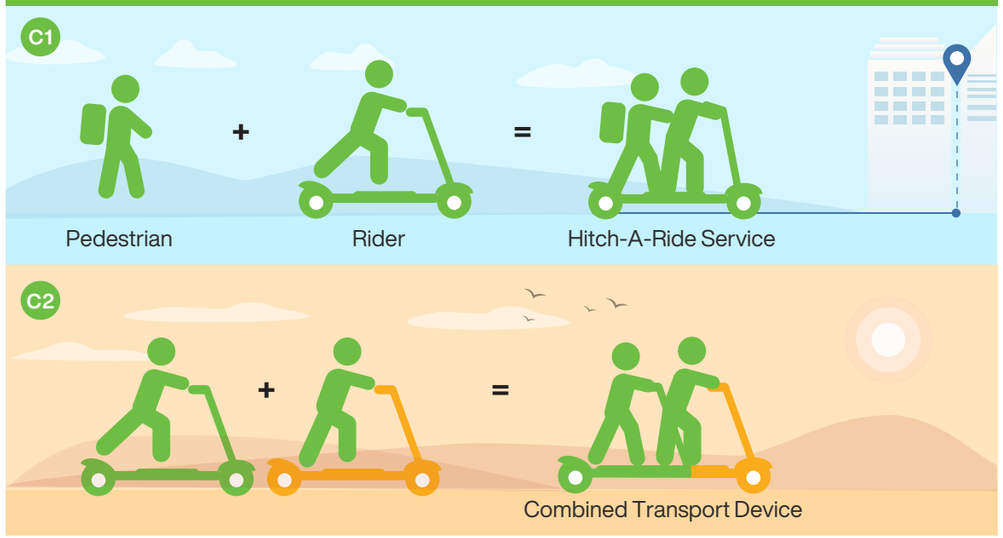
Procedure

1. **State the design opportunity statement/ HMW statement**
2. **Read and Apply**
   each SCAMPER question to the design problem/ HMW statement.
3. **Generate and Record**
   on the solution concepts generated.

Useful Tip
It's natural for some ideas generated with SCAMPER to be impractical. Don't worry about it - just generate as many ideas as you can!

Worked Example

How might we drastically reduce or protect people against accidents related to using last mile transportation devices while inspiring travellers?



Combine

C1 By combining the commuting experience of riders and pedestrians, we can start a hitch-a-ride service for both groups to reach their destination together.

C2 We can combine two or more last mile transportation devices together, either by from the back or attaching them side-by-side, which will create new commuter experience for families and friends.

Worked Example (cont'd)

Adapt

A1 Speed humps, which are used on the roads, can also be placed in pedestrian walkways to reduce the speed of last mile transportation devices.

A2 Obstacle avoidance algorithms used in manoeuvring autonomous vehicle/robots can be installed in last mile transportation devices to stop and avoid collision with pedestrians.

Put to Other Use

Equipment used in sports event can be used for protecting oneself when riding on last mile transportation devices.

P1 For example, a soccer ball used in a soccer match can be transformed into a helmet by deflating and connecting with a chin strap.

P2 Another example would be to use a shin guard as an elbow guard to protect against falling injuries when riding on a last mile transportation device.

Reverse

R1 To prevent riders from falling off their last mile transportation device and suffer injuries, an airbag could be positioned at the base near the ground which will activate and cushion the fall of the riders.

R2 Detection devices can be placed on pedestrians to alert them of incoming vehicles instead of relying on the riders to spot nearby pedestrians. This could also be a communication device to alert riders of incoming pedestrians.

Method

Morph Matrix

CARD 10 Joyfulness

Design Thinking | Permutational Ideation

Morph Matrix or Morphological Matrix breaks down a concept into different functional aspects or design parameters and creates permutation using different ideas for each aspect. It is very similar to mashup, but contains more atomic parts.

Why: It is a systematic way of going through different possibilities and finding new combinations of different aspects for a novel and impactful concept.

Materials: Whiteboard

Complementary methods: Systems Function Model

Procedure

1 **Identify key functions**
of what the ideal product, service, or system (PSS) must do or have.

2 **List functions**
or components in the first column of a matrix.

3 **List ideas**
in the subsequent columns for the respective function or component. Ideas can come from concept generation methods.

4 **Combine ideas**
that seek to satisfy the specifications of the product, service or system to create diverse concepts.

Framework

Apply Extreme-User Experience Framework

read more about the framework on page 39

Include the system-functions identified from applying extreme-user perspectives.

Systems Fuction + How Might We statements

used as inputs for

Morph Matrix

Outcome

Problem

- Clear problem decomposition
- Broad exploration of design space
- Compose new design module combinations

Useful Tip

Doing market research and trending technologies might help to inspire unconventional ways of providing the functions.

TEMPLATE STRUCTURE

Function	Idea 1	Idea 2
Function 1		
Function 2		
Function 3		

Worked EXAMPLE

Autonomous vehicle (taxi)

Function	Idea 1	Idea 2	Idea 3
Store and supply energy	Diesel	Gas	Electricity
Convert energy into motion	Wheels	Magnetic levitation	Track
Allow access	Conventional	Canopy	Sliding
Support customer comfortably	Sun shades	Automated doors	Reclined seats
Entertain customer	Music	Livestream video	Games
Passenger door opens automatically	Voice activation	Motion Sensor	Bluetooth signals from app to taxi
Non-visual feedback when door is opened	Music	Announcement	Phone vibration

New Concept 1

Extreme-User Experience Framework

Method

TRIZ

Design Thinking | Directed Ideation

CARD 8 Joyfulness

TRIZ, a Russian acronym for the Theory of Inventive Problem Solving (TIPS), is a collection of universal principles and physical effects for creativity and physical systems.

Why: TRIZ can assist in developing innovative, creative and novel solutions through design-by-analogy, the application of design principles, and the solving of complex problems with inherent contradictions and conflicts.

Materials: TRIZ reference table

Complementary methods: SCAMPER

Acronyms: CPR - Cardio-pulmonary Respiration
PSS - Product, Service, or System
USSR - Union of Soviet Socialist Republics

Scan or click here for a digital copy of the template

Procedure

1 Identify

design conflicts of the product, service, or system.

2 Select TRIZ feature

Decide which TRIZ feature (also known as Generalized Parameter) to preserve and which to improve (list at the next page).

3 Identify conflicts

Identify the TRIZ principles for breaking your conflict with the TRIZ matrix (from the list of design principles).

4 Ideate Solutions

using the suggested TRIZ principles.

Useful Tip

Conflicts and contradictions are avenues for innovation and creative tensions and we encourage you not to look for compromise between the two features. Look for solutions in which the influence of the main problem factor/feature is either totally eliminated or even reversed.

While the original method is meant for physical product design, it is possible to create a set of generalised design principles for digital or virtual products as well.

Fun Fact:

TRIZ was developed in the U.S.S.R. between 1946 and 1985, by engineer and scientist Genrich S. Altshuller and his colleagues.

Worked Example

Designing a cardoor

Before

The force required to close doors was found to be too high for users in order to create a complete seal around the door.

Conflicts:

Shape & force of intensity

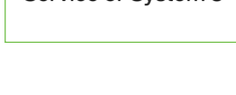
Rubber Door Seal before using TRIZ

After

The parameter change principle was used to make the door seal robust by changing its flexibility using a hollow cross section that still makes the door easy to open.

Parameters:

- Parameter Change
- Preliminary Action
- Thermal Expansion
- Composite Materials



Template Structure (Contradictions Matrix)

* The full matrix can be found online at www.triz40.com

Improving Features \ Worsening Features	Parameters of Product, Service, or System 1	Parameters of Product, Service, or System 2	Parameters of Product, Service, or System 3
Parameters of Product, Service or System 1	+	-	8,15
Parameters of Product, Service or System 2	-	+	-
Parameters of Product, Service or System 3	8,15	-	+

Triz 40 Inventive Principles

Segmentation	Partial/Excessive Actions	Flexible Shells and Thin Films
Taking Out	Another Dimension	Porous Materials
Local Quality	Mechanical Vibration	Colour Changes
Asymmetry	Periodic Action	Homogeneity
Merging	Continuity of Useful Action	Discarding and Recovering
Universality	Skipping	Parameter Changes
Russian Dolls, 'Nesting'	Blessing in Disguise	Phase Transitions
Anti-Weight	Feedback	Thermal Expansion
Preliminary Anti-Action	Intermediary	Strong Oxidants
Preliminary Action	Self-Service	Inert Atmosphere
Beforehand Cushioning	Copying	Composite Materials
Equipotentiality	Cheap Short-Lived Objects	
'The Other Way Round'	Mechanics Substitution	
Spheroidality – Curvature	Pneumatics and Hydraulics	

Worked Example 1

Examples of the Inventive Principle: Periodic Action

Instead of continuous action, use periodic or pulsating actions.

- Hitting something repeatedly with a hammer
- Replace a continuous siren with a pulsed sound.

If an action is already periodic, change the periodic magnitude or frequency.

- Use Frequency Modulation to convey information, instead of Morse code.
- Replace a continuous siren with sound that changes amplitude and frequency.

Use pauses between impulses to perform a different action.

- In cardio-pulmonary respiration (CPR) breathe after every 5 chest compressions.

Worked Example 2

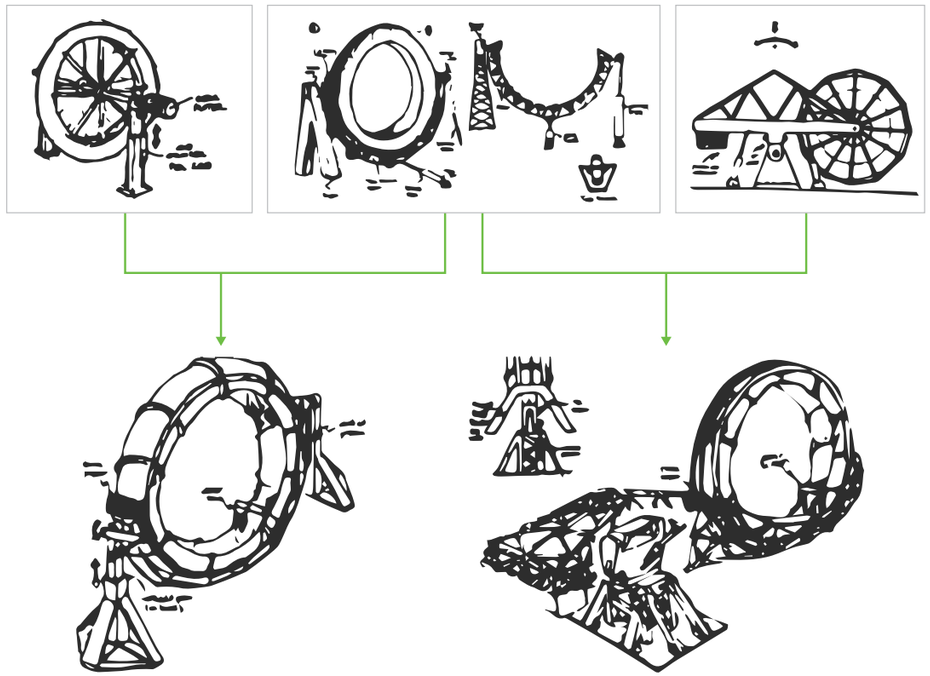
The Other Way Round (Inversion) Inventive Principle - Water slide ride as a perpetual motion machine

To overcome space and water supply limitations / conflicts, an idea for a new water slide amusement park ride is developed with the TRIZ inventive principle of The Other Way Round (Inversion). A rotary slide is created, with water held at the bottom of a rotating wheel. A person rides the rotating and oscillating wheel (donut) on an inner-tube, applying the inventive principles by inverting the motion of a typical water slide ride. In this case, the wheel rotates and oscillates, emulating the motions, velocities and effects of a cutting-edge water slide ride, and the rider stays at the bottom of the wheel, as opposed to the slide staying fixed and the rider moving downward.

Water slide are often thrilling and contains element of surprises. That can be done by adding sideway motions swinging the users to the left or right, and increasing or decreasing the velocity of the slide.

The sketches represent the mechanical and system consideration when integration all the elements into a single novel structure.

How might we develop a water slide with limited space and with virtually no water?



Method

Core-periphery Word Cloud

CARD 9 Joyfulness

Design Thinking | Directed Ideation

This method is used to generate a word cloud comprising of key words and idea functions derived from previously generated ideas and descriptions for further directed ideation.

Why: Core-periphery Word Cloud is a systematic ideation method to generate diverse ideas and can be easily automated to generate a list of ideas from the inputs. It also prioritise the functions that appeared in higher frequency.

Procedure

1 **Extract keywords**

from the descriptions of previously generated ideas. Keyword extraction tools can be applied if the data set is large.

2 **Rank words by their applicability to the design problem**

which can be estimated as the frequency of words in ideas, the connectivity of the words in their co-occurrence network, or other indicators.

3 **Generate a core-periphery word cloud**

where words with higher applicability are positioned more central in the cloud. Words in the core provide relevance, while words in the periphery provide more novelty.

4 **Browse and recombine words**

in the core and periphery.

5 **Elaborate and generate ideas**

based on the recombination of words to generate new design ideas that are both novel and relevant.

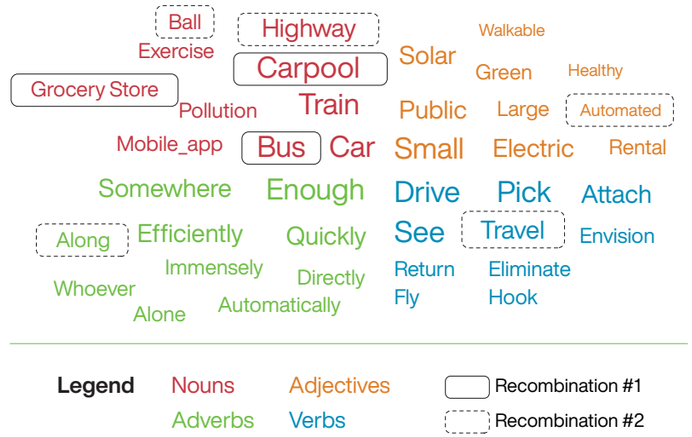
Template Structure

Prep work: Previously generated ideas

1. Keywords
2. Applicability ranking of words
3. Core-Periphery Word Cloud
4. Key-Word Recombination
5. New Ideas

Worked Example

Core-periphery word clouds generated from previous ideas on public transport



Generating new ideas from recombinations

No.	Key-word recombination	New Ideas
1	Bus, Carpool, Grocery store	Buses can be carpooled to a grocery store on weekends.
2	Small, Bag,Travel, Along, Highway	Small automated balls with occupants travel along highways.
...	...	...

Method

Parallel Sketching

CARD 11 Joyfulness

Design Thinking | Intuitive Ideation

Parallel sketching is used to combine and modify features from different sketches of the ideas. A table template would help to organise the combining process.

Why: Parallel sketching is a design ideation tool to accelerate the development of many variations on a design.

Complementary methods: Morph Matrix

Procedure

1 **Define**

the basic optical framework of your product, service, or system.

2 **Create Templates**

Create a number of empty templates using the framework from step 1.

3 **Sketch 5 variants**

Try to sketch at least 5 or more different ideas on the templates.

4 **Review Sketches**

and try to create new 'very different' ideas, sketch it on the template.

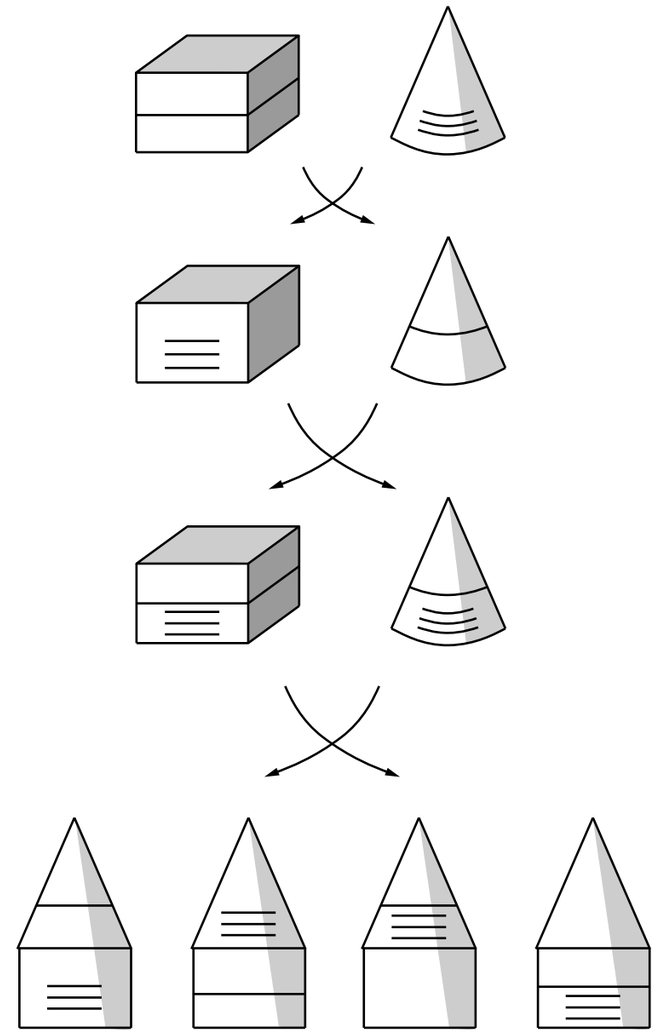
5 **Repeat**

Repeat all the steps until you have populated the matrix, repeat as needed.

From left to right: The bottom, top and front views of a ring (the product)

A printed out template from step 1 as a Matrix

Worked Example



Method

Product-Service-System Design (PSS)

Design Thinking | Ideation Approaches

CARD 13 Joyfulness

Product-service-system design emphasises the relationship between products and services in developing a sustainable competitive advantage.

Why: A holistic understanding of the solution as a system of product and the services developed for the users, ensures that the product and services developed are complementary and support each other.

Acronym: PSS - Product, Service, or System

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Procedure

1 **Customer Needs**
Identify customer needs.

2 **Material Needs**
Identify customers' material (product) needs.

3 **Service Needs**
Identify customer service needs.

4 **Production**
Identify means of producing products.

5 **Providing Service**
Identify means of producing products.

6 **Business Model**
Develop a business model.

7 **Customer Validation**
Validate with customers.

Objectives

- Structure interactions among stakeholders.
- Understand the deeper value that is being provided.
- Develop a sustainable 'ecosystem'.

Template Structure

Customer view	**Needs** What are the customers' needs? **Value** What does the customer perceive as valuable?
Design layers	**Deliverables** What is delivered to the customer? **Life-cycle activities** What are the overall life-cycle activities connecting resources? **Actors** Who are the actors, stakeholders, and business units involved in life-cycle activities? **Core products** What are the core products, services or systems? **Periphery** What is the backstage equipment, which is not directly visible to the customer, and what are the peripheral systems? **Contract** What are the conditions that have to be mentioned, fixed, or expressed by the contract? **Finance** What is the underlying cost structure and cash flow model? **Optional layers** What are the optional layers to emphasize specific characteristics and effect zone in a PSS?

Method

Paired Comparison Chart

CARD 15 Joyfulness

Systems Thinking | Concept Selection

Paired Comparison Chart compares ideas in pairs, relative to one another, without the need for identifying criteria.

Why: Paired Comparison Chart ranks ideas to quickly identify the top ideas to move forward with. This method is particularly useful when evaluation criteria is unclear, or subjective.

Materials: Excel Sheet and Paired Comparison Chart Template

Complementary methods: Prioritisation Matrix, Pugh Chart

Scan or click here for a digital copy of the template

Procedure

1 Draw a table

listing the ideas along the first row and the first column (refer to the template at the back).

2 Compare the ideas in pairs

Going column by column, run down the cells in each column, recording '1' if the idea of the column is evaluated as relatively better than the idea of that row, and '0' if it is relatively worse.

3 Sum up the score in each column

and record the score of the idea represented by each column in the appropriate cells below (refer to the example at the back).

4 Rank the ideas

according to their scores.

Useful Tip

Write down and document the reason why the '1's and '0's are given. This will be helpful to remember the thought process of the team and to also provide justifications.

Template Structure

In Comparison with variant	Variant A	B	C	D	E
A	-				
B		-			
C			-		
D				-	
E					-
Sum					
Rank					

Worked Example

The worked example above explains how prioritisation matrix works. In each box, you can ask: Is [top header variant] better than [leftmost column]? 'Better' is a subjective word and the team can discuss among themselves if there is any clarification needed and explanation. This can be done individually first then as a group, to prevent group thinking.

In Comparison with variant	Variant A	B	C	D	E
A	-	1	0	1	0
B	0	-	0	1	0
C	1	1	-	1	0
D	0	0	0	-	0
E	1	1	1	1	-
Sum	2	3	1	4	0
Rank	3	2	4	1	5

'-' because a concept variant is not compared to itself

'0' indicates that concept variant 1 is not better than 2.

'1' indicates that concept variant 1 is better than 3.

We can’t solve problems by using the same kind of thinking we used when we created them.

Albert Einstein

Theoretical physicist and one of the most influential physicists of all times.

Method

Prioritisation Matrix

Systems Thinking | Concept Selection

CARD 16 Joyfulness

Prioritisation Matrix arranges and visualises ideas or desired features in a 2x2 matrix based on two important criteria.

Why: Prioritisation Matrix allows designers and users to prioritise ideas for testing or implementation, based on their relative positions within the matrix.

Materials: Prioritisation Matrix Template

Complementary methods: User Interviews, Affinity Analysis, Brainstorming, DI Mindmapping, C-Sketch (6-3-5), Design by Analogy, SCAMPER, (Systems Requirements from System Architecture)

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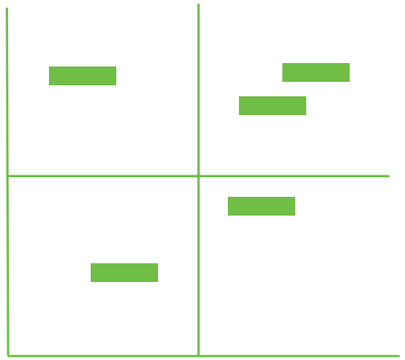


Procedure

1 **Pick two criteria**
central to the design problem.

2 **Draw horizontal and vertical axes (forming a 2x2 matrix)**
and assign the two chosen criteria to the two axes.

3 **Plot ideas on the matrix**
discussing and positioning them as a team, rating them based on the two chosen criteria and the scale.

4 **Discuss the plot**
selecting which ideas to pursue and synthesise.

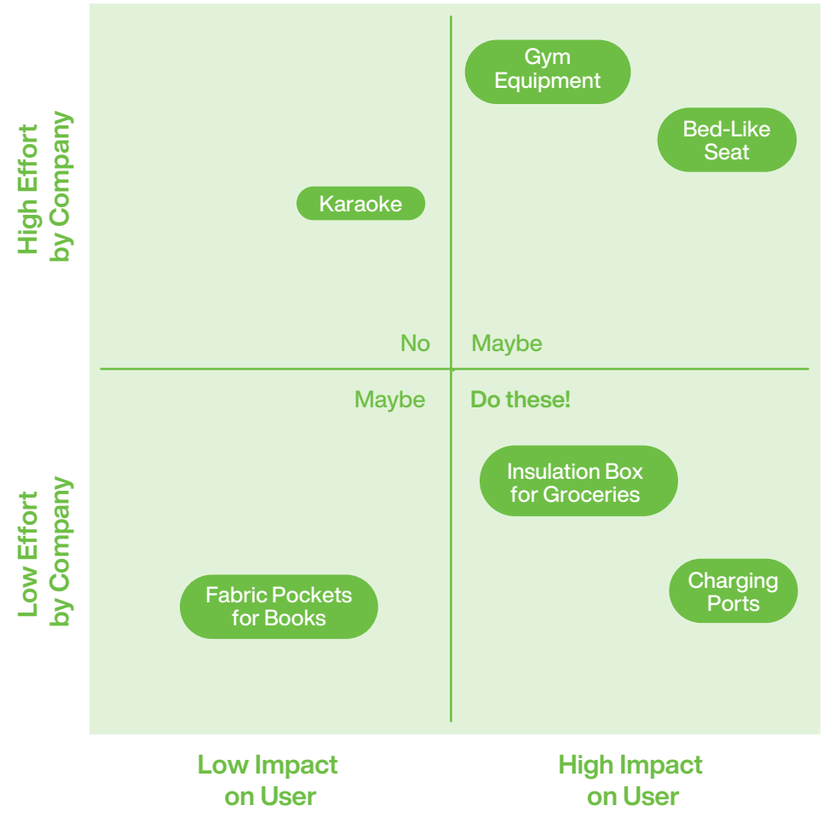
Typical Evaluation Criteria

- Effort
- Cost
- Urgency
- Feasibility
- Risk
- Impact
- Value
- Importance
- Potential
- Reward

Worked Example

Added convenience in vehicles

In this example, 'Impact' and 'Effort' were chosen as evaluation criteria. The ideas were evaluated based on those criteria.



Method

Pugh Chart

Design Engineering | Concept Selection

CARD 17 Joyfulness

Pugh Chart is a method to evaluate the overall value of ideas/ concept variants through a series of pairwise comparisons against a set of selection criteria. It also permits a degree of qualitative optimisation of the alternative concepts through the generation of hybrid concepts.

Why: Pugh Chart presents a clear and neat documentation of the selection process of the solution and identifies weakness in design that can be improved on. Pugh Chart's advantage over other decision-making tools is its ability to handle a large number of decision criteria.

Materials: Excel Sheet

Complementary methods: User Interviews, Affinity Analysis, Brainstorming, DI Mindmapping, C-Sketch (6-3-5), Design by Analogy, SCAMPER, (Systems Requirements from System Architecture)

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Procedure

1 Generate

selection criteria for the concepts and assign weight to each criterion so that the sum of the weights add up to 100%.

2 Draw

a table with concept variants listed in the header row, and selection criteria listed in the leftmost column.

3 Set

a reference concept variant. All other concepts will be compared against this reference concept variant and its rating is 3 by default. Rating for other variants ranges from 0-5.

4 Compare

each variant to the reference variant, oneat a time and for each selection criterion. Record '4' or '5' if it fares better than the reference, '3' if it fares the same, and '1' or '2' if it fares worse.

5 Sum

the total evaluation for each design. The score for each selection criterion is the product of the weight and rating.

Useful Tip

Assign equal weights for each selection criterion for a simpler Pugh matrix. The weights can be ignored, and the ratings can be summed up to give the evaluation directly. Another possible modification to improve the matrix is to add qualitative evaluation to each rating, which may be more objective and encourage discussion and awareness of design decisions.

Template Structure 1

Selection Criteria	Weight (100%)	Concept Variants A	B	C	D	Ref.
						3
						3
						3
						3
						3
						3
						3
Total Score						
Rank						
Continue?						

Template Structure 2

Design Criteria	DATUM	Alternative Design Concepts: Design Concept 1	Design Concept 2	Design Concept 3
Design Criterion 1				
Design Criterion 2				
Design Criterion 3				
Design Criterion 4				
Design Criterion 5				
Total +				
Total –				
Total				

Worked Example

This Pugh Chart example shows several concept variants of an opportunity, 'How might we drastically reduce or protect people against accidents related to using last mile transportation devices while inspiring travellers?'

Details of each variant can be found in the SCAMPER Method. Variants rated low compared to others may not be pursued depending on the amount of resources available to the design team.

How might we drastically reduce or protect people against accidents related to using last mile transportation devices while inspiring travellers?

Selection Criteria	Weight (100%)	Concept Variants				
		Hitch-a-Ride	2-in-1	Speed Humps	Soccer Ball Helmet	Airbag (Ref.)
Protection against injuries	25	1	1	4	2	3
Mass of transportation devices	20	2	1	5	2	3
Convenience	10	5	2	1	4	3
Affordability	10	2	2	1	4	3
Eco-Friendly	10	5	3	2	2	3
Inclusiveness	10	5	5	3	4	3
Simplicity	15	1	2	5	2	3
Total Score		2.5	1.95	3.45	2.6	3
Rank		4	5	1	3	2
Continue?		No	No	Yes	Yes	Yes

Worked Example

Coffee grinder

Design Criteria	Alternative Design Concepts			
				
Cost	0	+	+	--
Store Grinder	0	++	+	0
Put in Beans	0	0	-	0
Cleanable	0	0	-	0
Total +	0	3	2	0
Total –	0	0	2	2
Total	0	3	0	-2

Method

SWOT Analysis

Business Model Innovation | Concept Selection

SWOT Analysis is a strategic planning and management tool consisting of four components: 'Strengths', 'Weaknesses', 'Opportunities' and 'Threats'. It could be used for strategic planning, in carving out a sustainable niche in the market.

Why: SWOT Analysis could help with strategic planning and carving out a niche in the market, leveraging on strengths and opportunities and being mindful of weaknesses and threats.[1,2]

Materials: SWOT Analysis Template

Complementary methods: Design by Analogy, SCAMPER (Refined Concept Sketches or Models)

Acronyms: SWOT - Strength, Weakness, Opportunity, Threat

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S	W	O	T
Strengths	Weaknesses	Opportunities	Threats

Procedure

1 **Evaluate the internal factors**

with the 2 components, 'Strengths' and 'Weaknesses'.

2 **Evaluate the external factors**

with the 2 components, 'Opportunities' and 'Threats'.

3 **Create**

strategy plan, considering potential connections between the 4 components, and prioritising them.

Useful Tip

SWOT analysis can be used for the design of the business, for the design team as well as design ideas. Use it flexibly to evaluate the current status of the project.

Worked Example[5]

A special meat and fruit pie café sells hot pies and frozen take-home options, as well as an array of fresh salads and drinks. They are planning to open an outlet in Yubetchatown and want to develop a business model that will facilitate scalability and franchising. This is an example of how their SWOT analysis might look like.

	Strengths	Weaknesses
Internal	**Location** Our first location downtown will attract visitors and downtown shoppers. **Uniqueness** We stand out as a unique alternative to fast food and we offer high-quality food in a distinctive atmosphere. **Strong Management** We have assembled a team that embraces different disciplines with expertise in all areas of the business.	**Lack of Capital** All startup funds will come from loans and investors. **Lack of Reputation** We have not established ourselves as reputable meat pie provider yet.
	Opportunities	**Threats**
External	**Area Growth** Yubtchatown is growing by 8.5% annually. **Working Families with Children** This is a growing population, both in numbers and in their choice of convenient foods. Two income families have less time to prepare a meal.	**Competition** One competitor sells similar pies, and has loyal customers and relationship with businesses that regularly buy from them. **Being Unprepared for Opening Numbers** Initial poor service or product quality could discourage customers from returning.

Method

Adjacency Diagram

Systems Thinking | Directed Ideation

Adjacency Diagram is a table that shows what spaces should and should not be near to each other on plan.

Why: Adjacency Diagram helps translate a list of physical spaces and its requirements into a schematic design. It provides a broad overview of spatial relationships and builds upon word or verbal descriptions. It is often used together with bubble diagram which lay out spaces in a certain arrangement using the relationship.

Materials: Wall/Board

Complementary methods: Site Analysis, Benchmarking, Affinity Analysis, Systems Function Model

Procedure

1 Generate

a list of spaces that are to be included in the design.

2 Determine

adjacency of each space in relation to another (refer to Diagram A). Leave blanks for spaces that are not related to each other.

Shade the box green if the 2 spaces must be next to each other, it means that they have an important relationship.

Shade the box grey if the 2 spaces are good to be next to each other, it means that they have a desirable relationship.

3 Draw out

the spaces and represent each space as a bubble. Note that size of each bubble should be proportional to the size of the space allocated.

4 Draw out

the relationship between the spaces, using solid bar (green) to represent an important relationship and hollow bar (grey) to represent a desirable relationship (refer to Diagram B).

Useful Tip

Add more columns to the adjacency diagram to record other useful details, such as floor area and function of spaces.

Worked Example

Diagram A: Adjacency Diagram[12]

Diagram A is the worked example of the adjacency diagram (A) (B). The entity listed as rows is the name of each spaces (A - K are used instead as representation in this example), and the respective coloured box represents different relationships between spaces. Blank boxes might also provide information since it shows a lack of relationship.

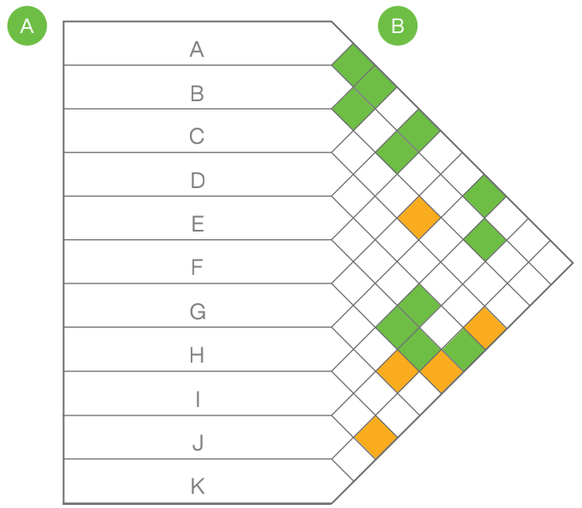
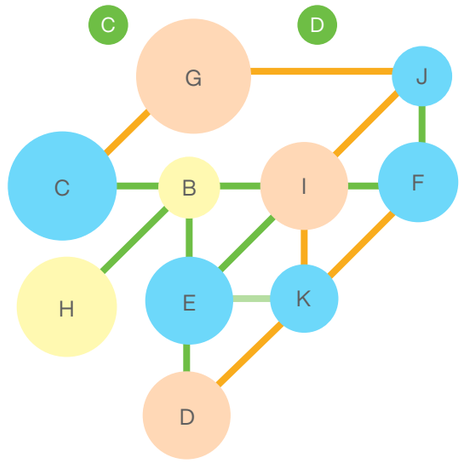


Diagram B: Bubble Diagram[3]

Diagram B is a worked example of the bubble diagram, which is an extension of the adjacency diagram. It translates a set of matrix into a visual representation of the spaces (C) (D). The bubble diagram is meant to be quick and iterative. Because it is usually hand-drawn, the diagram can be rearranged. While drawing the bubble diagram, take into consideration the function of each space and functions are carried out over multiple spaces.



Method

Design Optimisation

Design Engineering | Directed Ideation

Design Optimisation uses a mathematical objective function, encapsulating what gives your design value to users, as a guide to find the design concepts that deliver the most value.

Why: Optimisation algorithms are efficient ways to search a large design space, allowing for iterative testing computationally before prototyping a select number of promising alternatives found from optimisation. Optimisation can also reveal areas of the design space that are not intuitively obvious to explore.

Materials: Software for solving optimisation problems (e.g., Excel, MATLAB)

Complementary methods: Hierarchy of Purpose, Kansei Engineering, Real-Win-Worth, Paired Comparison Chart, Prioritisation Matrix, Pugh Chart, SWOT Analysis and all methods under core and advanced prototyping methods

Procedure

1 **Represent**

your design concept with a set of variables that describe the concept. Examples of design variables are lengths or dimensions, material properties, or quantities of components.

2 **Define**

an objective function that connects the mathematical representation of your design to desired outcomes, such as weight, cost, desirability, usability, or performance.

3 **Bound**

your design space using constraints, for example to ensure lengths are non-negative, or that material properties are realistic. Constraints should be a function of design variables.

4 **Select**

an optimisation algorithm to search the design space defined by your design variables and constraints, and guided by your objective function.

5 **Repeat**

your optimisation using different initial designs as starting points.

6 **Explore**

optimal solutions that are on a constraint. Would your solution improve if you could exceed the constraint? What does that mean practically?

Best Practices & Tips

Well-posed and well-bounded

Sanity check: your objective function and constraints should bound a set of solutions that make physical sense

Visualize your design space

if you can. How many variables do you have? How do you expect your objective function to vary across those variables?

Some optimisation algorithms are computationally expensive

To shorten the time to complete, explore alternative algorithms or use a surrogate model.

Multiple objectives

Designs will often have tradeoffs between multiple objectives, and a best design is one that you decide meets all objectives satisfactorily.

Optimisation Algorithms

Algorithms are computational routines used to efficiently search a design space for optimal solutions. Algorithms search over the design space of potential variable values, evaluating your objective function at selected points to determine where to search next for a maximum or minimum objective value.

Algorithms you can find in common software like Microsoft Excel include:

- **Simplex method** is a type of linear programming, and efficiently solves systems of linear equations such as a linear objective function with linear constraints.
- **Gradient based algorithms** such as gradient descent, Newton's method, or Generalized Reduced Gradient (GRG) are used for continuous, nonlinear objective functions.
- **Evolutionary algorithms** such as genetic algorithms, particle swarm, or simulated annealing evolve designs based on their performance according to the objective function. May be less computationally expensive than gradient based algorithms.

Worked Example

An example design goal, written as an optimisation problem: Maximize the amount of liquid a cylindrical can is able to hold (volume) while minimizing its weight, with a thickness not less than 0.01 centimeters.

The corresponding functions are:

Volume= $\pi(r - t)^2 h$ cm^3

Weight= $(2\pi rh + 2\pi r^2)t\rho$ grams

Legend
r = radius
h = height
t = thickness
ρ = material density

Written mathematically, the optimisation goal can be written as follows, with a and b as parameters that vary the relative importance of each part of the design goal (volume and weight) in the overall design:

Maximize: f(r,h,t) = a*V(r,h,t) – b*W(r,h,t) subject to constraints:

$2 \text{ cm} \leq r \leq 3 \text{ cm}$

$2 \text{ cm} \leq h \leq 15 \text{ cm}$

$0.01 \text{ cm} \leq t \leq 1 \text{ cm}$

$\rho = 2.7 \text{ grams/cm}^3$

By varying the relative importance of weight and volume goals, different solutions are obtained:

Design 1
a = 1
b = 0
Radius = 3 cm
Height = 15 cm
Thickness = 0.01 cm
Volume = 843 cm^3
Weight = 9.2 g

Design 2
a = 0.5
b = 0.5
Radius = 3 cm
Height = 15 cm
Thickness = 0.01 cm
Volume = 843 cm^3
Weight = 9.2 g

Design 3
a = 0
b = 1
Radius = 2 cm
Height = 2 cm
Thickness = 0.01 cm
Volume = 49.8 cm^3
Weight = 1.4 g

Results

Varying parameter values allows exploring the design space defined by the constraints, and there are two dominant solutions in this space. The results indicate that the volume is much more heavily weighted in the mathematical objective formulation, and additional concepts may emerge as alternatives if different relative weights are chosen.

Both extreme concepts are at the edge of what is defined as the possible range of variable values in the optimisation problem formulation, meaning that concepts with a larger volume and lower weight are likely possible if the constraints are changed.