Introduction to Creative Thinking in Engineering Design

The Business Imperative for Creativity

In today's global marketplace, characterized by fierce competition for markets, new products, and engineering dominance, traditional business approaches are being challenged. Modern business strategists emphasize that organizational survival and success depend on creating the most innovative and advanced products and processes. This environment creates a strong incentive for engineers to enhance their creative abilities and apply them effectively to engineering challenges.

Understanding Creativity as a Process

An important discovery in creativity research is that the thought processes used to develop creative ideas are fundamentally the same mental operations that everyone uses. This means:

- Creative thinking is not an innate talent limited to a select few
- Creativity can be enhanced through deliberate application of specific techniques and methods
- Even computational tools and software programs can assist in the creative process

Research Strategies in Creativity

Researchers have adopted two primary approaches to studying creativity:

1. Studying Creative Individuals

- Examining the thinking processes of people considered creative
- Identifying steps or procedures that can enhance anyone's creative thinking
- This approach has led to the development of creativity process techniques

2. Studying Creative Artifacts

- Analyzing the development of inventions that demonstrate creativity
- Identifying key decisions or defining moments that contributed to creative outcomes
- This requires adequate documentation of the development process
- Has led to techniques that use previous successful designs as inspiration for new ones

Applications of Creativity Research

These research strategies have produced different methodological approaches:

- **From studying creative individuals**: Process techniques for enhancing creativity

- **From studying creative objects**: Methods like:
    - Analogy-based approaches (e.g., WordTree method)
    - Principle-generalization methods (e.g., TRIZ)

Significance for Engineers

Understanding these aspects of creativity is crucial for engineers because:

- Creativity can be deliberately cultivated and improved
- Specific techniques can help overcome mental blocks
- Understanding the process allows for more consistent creative output
- Computational tools can augment human creative capabilities

This knowledge empowers engineers to systematically enhance their creative abilities, which is essential for developing innovative solutions in a competitive global environment.

💥 Creativity and Problem Solving

🧠 What is Creative Thinking?

- **Creative thinkers** solve problems with **novel and effective solutions**.
- A **creative engineer** generates many **useful and practical ideas**.
- Creativity doesn't always mean brand-new ideas—it often comes from **combining existing ideas** in a **new and useful way**.

🔄 How Do Creative People Think?

- They can **break down problems** and look at them from **new perspectives**.
- They often connect the problem to **unrelated facts or observations**, which leads to **fresh ideas**.

⚡ Myth vs. Reality of Creativity

- ❌ **Myth**: Creative ideas come like a **flash of lightning** or a sudden "aha" moment.
- ✅ **Reality**: Most creative ideas emerge from a **slow, thoughtful process** that can be **learned and improved** through **practice**.

🔍 Stages in the Creative Process

- Creative ideas often start as **vague or unclear**.
- The process moves from:
  - **Vague → Clear**
  - **Chaotic → Organized**
  - **Hidden → Obvious (Explicit)**

🧩 Engineers and Creativity

- Engineers are trained to value **structure, clarity, and precision**.
- But creativity requires comfort with **uncertainty and ambiguity**.
- Engineers need to **train themselves** to be **open to chaos and unclear ideas** in the early stages of creativity.

📌 Tips to Enhance Creative Problem Solving

1. Accept that **creative flow takes time**—you can't force it.
2. Identify the **conditions or environments** that help you think creatively.
3. Be ready to **capture and write down** creative ideas whenever they come—they can be **elusive and short-lived**.

Supports to Creative Thinking

🔹 What is Creative Cognition?

- **Creative Cognition** is using normal thinking abilities in new and imaginative ways.
- It helps solve problems by combining logic with creativity.
- Anyone can be creative by applying proven methods used by others.

✅ Steps to Improve Creative Thinking:

1. Have a Creative Attitude

- Believe in yourself and your ability to find a solution.
- You may not know the full answer at the start, but stay confident.

2. Use Your Imagination

- Think like a child again—ask **"why?"** and **"what if?"**
- Don't be afraid to ask simple or silly questions.
- Practice using thought games to spark imagination.

3. Be Persistent

- Don't give up easily—most problems need effort and time.
- Example: Edison tested 6000 materials before inventing a working lightbulb.
- Remember: "Invention is 95% hard work, 5% inspiration."

4. Keep an Open Mind

- Accept ideas from all sources, even unusual ones.
- Be ready to explore new or different ways of thinking.

5. Avoid Judging Early

- Don't criticize ideas too soon, especially in the beginning.
- Let ideas grow before evaluating them.
- Engineers often analyze too early—this can block creativity.

6. Set Clear Problem Boundaries

- Define the problem clearly but not too strictly.
- If the problem is too open or too narrow, it limits creative solutions.

🔄 **The 4 Stages of Creative Problem Solving:**

1. Preparation

- Understand and study the problem.
- Gather and discuss information with others.

2. Incubation

- Take a break from the problem (e.g., sleep on it).
- The subconscious mind continues working while you rest.

3. Inspiration

- A new idea or solution suddenly appears.

- Often happens when you're not focusing directly on the problem.

4. Verification

- Test and evaluate the new idea.
- Check if it really solves the problem.

💡 **Key Ideas to Remember:**

- Creative thinking takes **confidence**, **imagination**, and **effort**.
- Give your brain time to rest (incubation) so better ideas can come.
- Stay open, curious, and avoid judging ideas too early.

🚫 Barriers to Creative Thinking

Creative thinking can be blocked by various **mental, emotional, and intellectual obstacles**. These are known as **mental blocks**, and they prevent people from moving forward in the problem-solving process.

🧠 1. Perceptual Blocks

These blocks occur when we **fail to understand or define the problem correctly** or ignore useful information.

- **Stereotyping**: Thinking in traditional or expected ways, which stops fresh, creative ideas.
- **Information Overload**: Trying to consider too many details at once can make it hard to focus on what truly matters.
- **Limiting the Problem Unnecessarily**: Narrow problem definitions restrict creativity; broader views encourage new ideas.
- **Fixation**: Being stuck on past experiences or biases, which blocks us from seeing alternative solutions.
- **Conformity with Cues**: Relying too much on initial examples, leading to limited thinking within those ideas.

❤️ 2. Emotional Blocks

These blocks relate to **fears and insecurities** that prevent free and open exploration of ideas.

- **Fear of Risk Taking**: Avoiding new ideas due to fear of failure or judgment.
- **Unease with Chaos**: Discomfort with unstructured situations, common among those who prefer order (like many engineers).
- **Unwillingness to Incubate Ideas**: Not giving ideas enough time to develop before judging them can kill creativity.

🧩 3. Intellectual Blocks

These blocks happen due to **lack of skills, knowledge, or poor strategies** for solving problems.

- **Wrong Problem-Solving Approach**: Using the wrong "language" (math, visual, or verbal) to solve a problem can hinder creativity. Switching approaches may help.
- **Memory Block**: Sticking to familiar memory patterns, thinking they will solve the problem, even when they don't.
- **Insufficient Knowledge**: Limited knowledge restricts the range of ideas one can generate. That's why **interdisciplinary teams** are helpful.
- **Incorrect Information**: Using wrong or outdated information leads to poor results. Creativity relies on combining accurate ideas.
- **Physical Environment**: Creative thinking is influenced by surroundings. Some people need silence; others can think in noisy places. Know what works best for you.

💡 Brainstorming – A Tool for Creative Idea Generation

🔹 What is Brainstorming?

- A **popular method used by design teams** to generate new and creative ideas.
- First developed by **Alex Osborn** for improving magazine advertising.
- Now widely used in many fields, especially in **design and innovation**.
- Represents **rapid, enthusiastic, free-flowing idea generation**.

🔹 Key Features of Brainstorming:

- Encourages **spontaneous and unfiltered thinking**.
- Works best in a **team setting**, where ideas build on each other.
- Ideal for the **early stages of problem solving**.

🧠 SCAMPER Technique – A Creative Boost Tool

To stimulate more ideas, especially when the flow slows down, use **SCAMPER**, a checklist technique modified by **Eberle**.

Each letter in **SCAMPER** stands for a way to change or approach the problem:

Letter	Question Type
S	**Substitute** – What can be replaced?
C	**Combine** – Can we merge things or ideas?
A	**Adapt** – Can it be adjusted to fit another use?
M	**Modify/Magnify** – Can it be changed or made bigger?
P	**Put to another use** – Can it serve a different function?
E	**Eliminate** – What can be removed or simplified?
R	**Reverse/Rearrange** – Can we flip or change the order?

✔ How to Use SCAMPER:

1. Read one SCAMPER question aloud.
2. Write or sketch any idea that comes to mind.
3. Rephrase and apply the question to different parts of the problem.
4. Move on to the next question when ideas slow down.
5. Skip questions that don't apply to your problem.

🔸 **Tip**: For ongoing projects, create your **own customized checklist** that suits your specific field or product.

⚠️ Limitations of Brainstorming:

- Brainstorming may **not overcome all mental and emotional blocks**.
- Can even worsen issues like:
    - **Fear of criticism**

- **Unease with chaos**
- **Holding on to incorrect assumptions**

✍️ Solution: Brainwriting

To reduce pressure and improve creativity:

- Conduct a **brainwriting** session **before** brainstorming.
- In **brainwriting**, individuals write down ideas **quietly and independently** before sharing with the group.
- This helps reduce judgment and encourages participation from **quieter team members**.

🧠 Quick Idea Generation Tools

Brainstorming is the most popular tool for generating creative ideas, but there are **other simple methods** that also support creativity. These tools help **trigger new thoughts** or **unblock stuck thinking** by asking **targeted questions** and encouraging **fresh perspectives**.

✴️ 1. Six Key Journalism Questions

Used by journalism students to explore all aspects of a story, these questions can also be applied to design problems:

Question	Purpose
Who?	Who uses it, wants it, or benefits from it?
What?	What happens if something changes? What caused success or failure?
When?	Can the process be faster or slower? Is timing important?
Where?	Where does the event or problem occur? Can it happen elsewhere?
Why?	Why is this done this way? Why did a failure or problem occur?
How?	How can it be done better, improved, or prevented?

🔹 These questions encourage you to **view the problem from all angles**, helping you **uncover hidden opportunities**.

✴️ 2. Five Whys Technique

A powerful tool for **root cause analysis**. It digs deeper into a problem by repeatedly asking **"Why?"**—usually five times.

📌 **Example:**

- **Why** did the machine stop? → A fuse blew due to fan overload.
- **Why** was there an overload? → Not enough lubrication.
- **Why** no lubrication? → The lube pump failed.
- **Why** did it fail? → Shaft was worn out.
- **Why** worn out? → No filter allowed debris inside.

🔸 Helps **identify the real issue**, not just the symptoms.

✴️ 3. Checklists

Checklists help in **stimulating creative thinking** by guiding the brain through **various possibilities**.

📝 Two types:

- **Idea generation checklists** – like Osborn's list for brainstorming.
- **Operational checklists** – used to remember steps in a process (e.g., in engineering or design projects).

📌 Example (from Table 6.2): A **"Technological Stretching" checklist** could ask:

- Can this be made stronger?
- Can it be used differently?
- Can we borrow ideas from other fields?

✴️ 4. Fantasy or Wishful Thinking

Encourages **imaginative and bold ideas** by freeing the mind from practical limitations like cost or feasibility.

🔹 Use **"invitational language"** to create a positive and open mindset.

🗣️ Example Questions:

- "Wouldn't it be nice if…?"
- "What I really want is…"

- "If cost didn't matter, I would…"
- "I wish we could…"

⚠️ **Avoid negative phrasing** like "This design is too heavy."
✅ Instead say: "How can we make the design lighter?"

💡 This approach promotes **innovation by removing mental filters**.

🛠️ Generating Design Concepts

Designing in engineering is not just about creating a single solution—it's about exploring a wide range of possible ideas and selecting the best one based on the design requirements. The process of **generating design concepts** is crucial in finding innovative and effective solutions to engineering problems.

🔍 What is Generative Design?

Generative design is a method that focuses on creating **multiple feasible alternatives** for a given design task. Instead of jumping to the first idea that comes to mind, this approach encourages designers to **systematically explore many options** to find the most effective solution.

The goal is to find **the best possible design** from a wide range of alternatives that meet the **Product Design Specification (PDS)**.

🌌 Understanding the Design Space

To visualize how many possible solutions there are, imagine an **n-dimensional design space**. Each dimension in this space represents a different design characteristic (like cost, size, weight, performance, etc.). Because there are many such factors, the space is **more than three-dimensional**—it's complex and vast.

- Think of it like a **solar system** where each planet or star represents a **unique design concept**.
- Some "planets" are well-known solutions; others are like **undiscovered ideas** still waiting to be explored.

This analogy helps us understand that there are **countless possible solutions**, and many of them haven't even been imagined yet.

🧭 Searching the Design Space

Once a designer finds one **feasible solution**, they can explore the **surrounding area of the design space** by tweaking or changing one or more characteristics. This is known as a **local search**.

- This method is useful if the first design is close to the best one.
- However, it can **limit creativity**, as the designer might miss out on solutions in **other distant parts** of the space.

To overcome this, **creative thinking and structured methods** are used to explore widely and generate more varied solutions.

🧠 The Role of Creative and Systematic Methods

While creativity can spark new and original ideas, it is not always reliable or structured. That's where **systematic methods** help. These are organized approaches that assist design teams in:

- Exploring **new areas** of the design space,
- Generating a **diverse set of ideas**,
- And considering **multiple alternatives** before selecting a final solution.

📚 Examples of Systematic Design Methods

1. **TRIZ (Theory of Inventive Problem Solving):**
   - Based on the analysis of **successful patents**.
   - Uses a **contradiction matrix** to resolve design conflicts and generate innovative ideas.
2. **Functional Decomposition and Synthesis:**
   - Breaks a design task into smaller, abstract **functions**.
   - Helps discover creative solutions by focusing on **what** needs to be done, rather than **how**.
3. **Biomimicry:**
   - Takes inspiration from **nature**.
   - Encourages solutions that mimic biological systems and processes.
4. **WordTree Technique:**

- Uses **semantic association** to trigger new ideas from words related to the problem.
- Helps expand thinking beyond the immediate problem.

🧩 Systematic Methods for Designing – Descriptive Notes

Systematic design methods are structured approaches used to **generate, analyze, and evaluate conceptual design solutions**. These methods are particularly helpful in mechanical design, where the complexity of engineering problems often demands a logical and repeatable process.

These systematic methods support creativity while adding **rigor and discipline** to the design process, ensuring **completeness, clarity, and effectiveness** in exploring possible solutions.

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1. 🔧 Functional Decomposition and Synthesis

- **Core Idea:** Break down a product or system based on the *functions it performs* rather than its physical components.
- **Purpose:** Understand what the system *does* (not how it does it), to spark creative alternatives.
- **How it Works:**
  - Identify overall function.
  - Decompose it into sub-functions.
  - Think of various ways to perform each function.
- **Why it's Useful:** Encourages thinking at an **abstract level**, which opens up room for **novel solutions** instead of focusing too early on known components or technologies.

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2. 🧮 Morphological Analysis

- **Core Idea:** Create a **morphological chart** to systematically explore combinations of sub-solutions.
- **Purpose:** Generate a **comprehensive list of possible designs** by listing all possible variations of components or functions.
- **How it Works:**
  - List required functions/subsystems in rows.

   - Fill each row with possible methods/components that can fulfill each function.
   - Mix-and-match different combinations across rows to form complete design concepts.
- **Why it's Useful:** Helps ensure no idea is overlooked and allows exploration of a **wide design space**.

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3. 🧠 TRIZ – Theory of Inventive Problem Solving

- **Origin:** Developed by **Genrich Altshuller** in Russia from the analysis of millions of patents.
- **Core Idea:** Technical problems follow patterns, and so do their solutions.
- **Purpose:** Apply **inventive principles** that have worked in the past to solve current design contradictions.
- **How it Works:**
   - Identify contradictions in the design (e.g., increasing strength without increasing weight).
   - Use a **contradiction matrix** and **40 inventive principles** to resolve conflicts innovatively.
- **Why it's Useful:** Encourages **breakthrough thinking** by drawing on proven problem-solving strategies.

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4. 🌳 WordTree Method

- **Core Idea:** Uses **linguistic association** and **design-by-analogy** to unlock fresh ideas.
- **Purpose:** Navigate through **semantically connected words** to find unexpected analogies and design inspirations.
- **How it Works:**
   - Start with a function word (usually a verb).
   - Use databases like **WordNet** to explore related words or actions in different domains.
   - Build a tree of related functions and discover new application areas.

- **Why it's Useful:** Helps designers **escape mental ruts** by moving into **new conceptual territory**.

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5. ⚖️ Axiomatic Design

- **Developer:** Introduced by **Nam P. Suh**.
- **Core Idea:** Base the design process on **first principles (axioms)** to ensure quality and simplicity.
- **Purpose:** Maintain **functional independence** and reduce **information complexity** in the design.
- **Key Axioms:**
    1. **Independence Axiom** – Each functional requirement should be met without affecting others.
    2. **Information Axiom** – Minimize the amount of information (complexity) in the design.
- **Why it's Useful:** Converts abstract customer needs into measurable **functional requirements**, and then into physical design parameters, all while ensuring **logical consistency**.

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6. 📈 Design Optimization

- **Core Idea:** Treats design as an **engineering science problem** using **optimization algorithms**.
- **Purpose:** Find the **best possible design** within a defined set of constraints and goals.
- **How it Works:**
    - Use objective functions (e.g., minimize cost, maximize strength).
    - Apply optimization strategies (e.g., gradient-based, genetic algorithms, multi-objective optimization).
- **Types of Models:**
    - **Deterministic:** Based on fixed inputs.
    - **Stochastic:** Involves randomness or uncertainty.
    - **Hybrid:** Combines both approaches.

- **Why it's Useful:** Helps refine designs for **maximum performance and efficiency**, especially in later design stages.

⚖️ Decision Making and Concept Selection

📘 7.1 Introduction

The engineering design process is fundamentally a **decision-making process**—a journey filled with judgments, often made under **uncertainty** and with **incomplete information**.

While technical knowledge, **creativity**, and **information gathering** are crucial, effective decision-making also demands:

- Awareness of **psychological factors** influencing the designer,
- A deep understanding of **trade-offs** among alternatives,
- An ability to manage the **uncertainty** inherent in choosing between competing concepts.

🔄 Divergent and Convergent Thinking in Design

The process of concept development and selection follows a **cyclical pattern** of divergent and convergent thinking, as shown in **Figure 7.1** (Concept Generation and Selection Process):

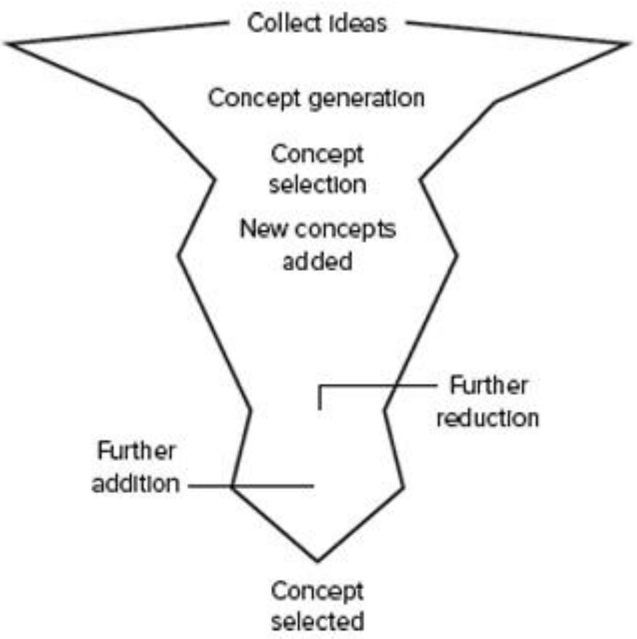


Figure 7.1 : Concept generation and selection, viewed as alternating divergent and convergent processes.

🔹 **Divergent Thinking:**

- The design net is "spread wide."
- Gather as much information as possible from:
  - Customers
  - Industry sources
  - Market trends
- Use **creative and systematic methods** (like those in Chapter 6) to develop a **broad range of design concepts**.
- Think **outside the box**, exploring multiple directions.

🔸 **Convergent Thinking:**

- Begin **narrowing down** the wide set of generated ideas.
- Evaluate each idea using established **selection criteria**.
- Reject clearly inferior or impractical concepts.
- Refine and combine ideas as necessary.
- This may spark **new divergent thinking** as new insights emerge from evaluation and recombination.

🔁 **Repeat the divergent–convergent cycle** to gradually converge on a small number of strong concepts.

📊 **Controlled Concept Evolution**

- Each cycle of concept generation and refinement should be **guided by the design specification criteria**, which stem from:
  - The **House of Quality** (a structured way to define customer requirements)
  - **Design sponsor input**
  - **Regulations and standards**
  - **Market and competitive demands**
- Controlled iterations ensure that concepts **improve over time** in alignment with real-world constraints and expectations.

📌 Three Essentials of Design Decision Making

To make informed and effective decisions in design, the following are essential:

1. **Design Selection Criteria**
    - These are the **metrics or goals** the design must meet.
    - Examples: cost, reliability, safety, manufacturability, user-friendliness, sustainability.
2. **Set of Alternatives**
    - A pool of design concepts that are believed to satisfy the criteria.
    - Alternatives can be fully formed concepts or partially developed ideas.
3. **Evaluation Strategy**
    - A **method or process** for comparing alternatives.
    - Must match the **phase of design** and the **level of detail** available.
    - Can range from rough qualitative judgments to detailed quantitative models.

🧭 Where This Fits in the Design Process

As seen in **Figure 7.2 (Steps in the Design Process)**:

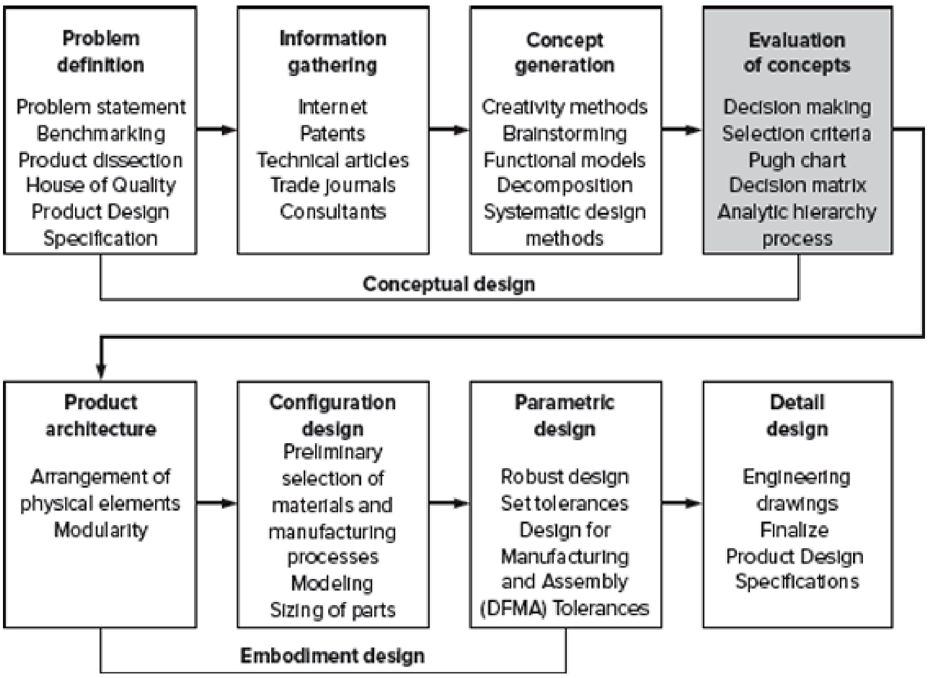


FIGURE 7.2: Steps in the design process, showing evaluation and selection of concepts as the completing step in conceptual design.

- **Concept evaluation and selection** is the **final step in the conceptual design phase**.
- It leads directly into **embodiment design**, where the selected concept is detailed out and engineered for real-world implementation.

📈 Usage Throughout the Design Process

- Although initially emphasized during **concept selection**, these decision-making methods apply at **many points** throughout the design process.
- What varies is:
    - The **amount of information available**
    - The **level of detail** of the models and criteria
    - The **complexity** of the alternatives being compared

🧠 Behavioral Aspects of Decision Making

🧍 Human-Centered Nature of Design Decisions

Design decisions are **primarily human activities** influenced by psychology, experience, and the pressure of uncertainty. Unlike purely technical problems, design decisions often must be made with:

- **Incomplete or uncertain information**
- High **risk of failure** or **loss**
- Pressure to protect one's **reputation and self-esteem**

This stress can cloud judgment and lead to **decision-making errors**.

😨 Sources of Psychological Stress in Decision Making

Psychological stress during design decisions is primarily due to:

1. **Fear of loss**: Both material (e.g., time, cost, resources) and social (e.g., peer approval, job performance).
2. **Reputation risk**: Designers may feel that their competence or status is being judged based on the outcome.

This emotional tension contributes to poor choices unless consciously managed.

🧩 Five Decision-Making Patterns (Only One is Healthy)

People typically fall into **five behavior patterns** under decision stress. Only the last one—**vigilance**—is recommended.

1. **Unconflicted Adherence**
   - Stick with the current plan.
   - Ignore new or conflicting information.
   - **Problem:** Ignores possible risks and needed adjustments.
2. **Unconflicted Change**
   - Jump to the most recommended action without critical thought.
   - **Problem:** Lacks evaluation and personal judgment.
3. **Defensive Avoidance**
   - Delay or avoid the decision.
   - Shift responsibility or ignore warning signs.
   - **Problem:** Leads to inaction and missed opportunities.
4. **Hypervigilance**
   - React frantically to find an immediate solution.
   - **Problem:** Decisions are rushed and often poorly thought out.
5. **Vigilance (Recommended)**
   - Carefully search for and evaluate relevant information.
   - Weigh evidence in an **unbiased** way before deciding.
   - **Advantage:** Most likely to lead to a sound, well-informed decision.

🧠 Best Practices for Vigilant Decision Making

- **Base decisions on real facts**—not assumptions or pressure.
- **Evaluate biases**—make sure the facts are relevant and accurate.
- **Ask the right questions**—focus on solving the right problem, not just getting the right answer.

- **Seek advice**—learn from experienced peers and past examples.
- **Use others' experience**—even if failures are rarely documented, tap into shared knowledge.

🎯 Decision Context: Four Action Aspects

Every decision/action situation can be framed using four aspects:

1. **Should** – What ought to be done, assuming no constraints. Reflects the **ideal goal**.
2. **Actual** – What **is currently happening**. Reflects the real-world state of affairs.
3. **Must** – The **non-negotiable requirements**. These are essential constraints or minimum acceptable standards.
4. **Want** – Desirable but **negotiable goals**. These can be ranked and prioritized but are **not absolute**.

Understanding these distinctions helps structure decisions clearly and systematically.

📋 Steps to Making a Good Decision

A structured, logical approach helps reduce stress and improve decision quality:

1. The objectives of a decision must be established first.

2. The objectives are classified as to importance. (Sort out the musts and the wants.)

3. Alternative actions are developed.

4. The alternatives are evaluated against the objectives.

5. The choice of the alternative that holds the best promise of achieving all of the objectives represents the tentative decision.

6. The tentative decision is explored for future possible adverse consequences.

7. The effects of the final decision are controlled by taking other actions to prevent possible adverse consequences from becoming problems and by making sure that the actions decided on are carried out.

🧪 Evaluation Processes

✅ What is Evaluation in Design?

Evaluation is a **systematic process** used to assess and compare **design alternatives** based on how well they meet certain criteria or standards. It is closely tied to decision making but focuses specifically on **judging the merit or worth** of the options available.

Where decision making involves **choosing**, evaluation involves **analyzing and comparing**.

📊 Purpose of Evaluation

- To **assess each concept** against a standard or design requirement.
- To **rank or score** design alternatives.
- To **identify the best choice** based on logical and structured criteria.

🔁 Where Evaluation Happens

Evaluation is **not restricted** to the conceptual design phase. It is important across the entire design process, including:

- **Conceptual Design** – Comparing full product/system concepts.
- **Embodiment Design** – Choosing between component versions, configurations, or materials.
- **Detail Design** – Selecting from among precise dimensions, tolerances, etc.

🧩 Evaluation Steps and Figure 7.3

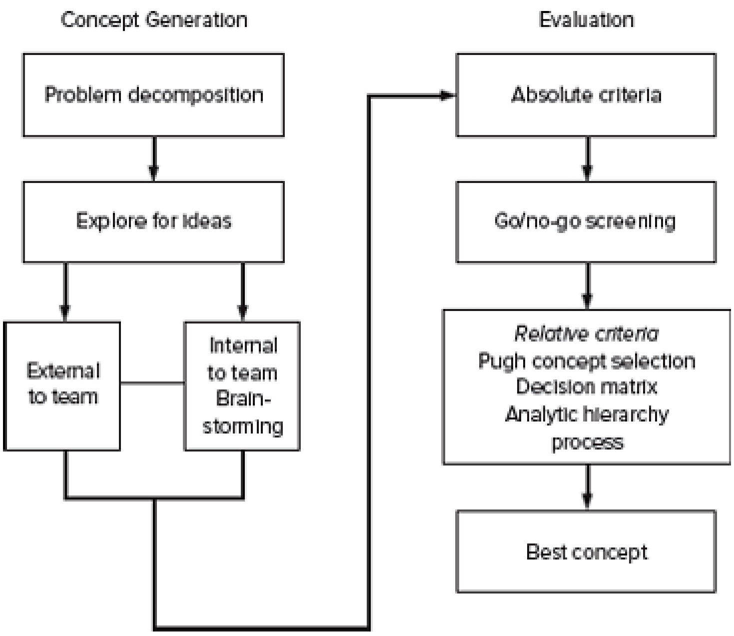


FIGURE 7.3 Steps that are involved in concept generation and its evaluation.

Figure 7.3 illustrates the **two main stages**:

1. **Concept Generation**
   (Explored in Chapter 6 – includes ideation methods like functional decomposition, morphological analysis, etc.)
2. **Concept Evaluation**
   (Steps that follow generation, involving selection criteria, comparison techniques, and decision-making tools.)

These steps help reduce a large number of ideas to a few **high-potential candidates** that best meet the design goals.

🆚 Absolute vs. Relative Comparison

📐 Absolute Comparison

- A design is evaluated **against fixed, known standards**, like:
  - Product Design Specification (PDS)
  - Regulatory codes
  - Engineering constraints
- Example: Does the design weigh less than the 20 kg limit defined in the PDS?

⚖️ Relative Comparison

- Alternatives are **compared with one another** using performance metrics.
- No fixed benchmark; evaluation is based on **ranking** among the set.
- Example: Which concept has the **lowest estimated weight** among all candidates?

Both types of comparison are useful, and often used **together**.

🏀 Example – Concept Evaluation

Figure 7.4 depicts **five design concepts** for an **automated basketball return device**. These alternatives likely differ in:

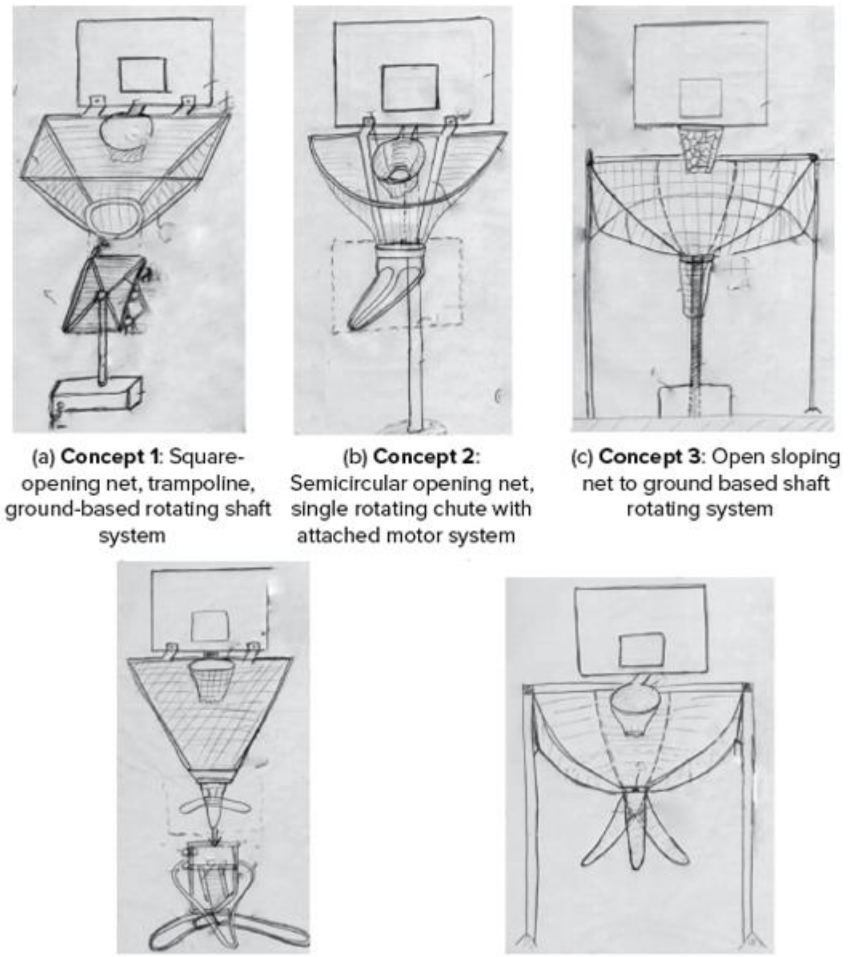
- Mechanism
- Size and weight
- Cost and materials

- Reliability

The evaluation process would assess each based on:

- Design criteria (e.g., speed of return, accuracy, portability)
- PDS constraints (e.g., maximum weight, budget)

Each concept would be **scored or ranked**, and the top performer(s) would be selected for further development.



(a) **Concept 1**: Square-opening net, trampoline, ground-based rotating shaft system

(b) **Concept 2**: Semicircular opening net, single rotating chute with attached motor system

(c) **Concept 3**: Open sloping net to ground based shaft rotating system

(d) **Concept 4**: Square funnel non-rotating director and multiple chutes

(e) **Concept 5**: Open sloping net to pivot a single guide to multiple positions

FIGURE 7.4

Shot-Buddy concepts generated by design team.[1]

🧠 Design Selection Based on Judgment and Experience

🎯 Why Use Judgment Early in Evaluation?

Before applying detailed evaluation methods (like scoring matrices or decision trees), it's practical to eliminate **clearly unworkable concepts** through early screening. This avoids wasting time on ideas that:

- Will obviously not work,
- Rely on unavailable technology,
- Violate critical design constraints.

🧰 Three Early Filters for Concept Evaluation

These filters apply **absolute selection criteria** based on **expert judgment and practical feasibility**.

1️⃣ Functional Feasibility Screening

Evaluate whether the design **can work at all**, even without full technical detail.

- Categorize each concept:
    - (a) ❌ *Not feasible* – Will never work.

Don't discard immediately—ask why. It may reveal new insights.

-
    - (b) ⚠️ *Conditionally feasible* – Might work if certain technologies become available or components are developed.
    - (c) ✅ *Feasible* – Appears workable and worth developing further.

Tip: When unsure, err on the side of keeping the concept rather than prematurely eliminating it.

2️⃣ Technology Readiness Assessment

Avoid relying on technologies that require **significant R&D**. Instead, use **mature technologies** that are ready for implementation.

- Ask:
    - Can it be manufactured with current processes?

  - Are the critical parameters well-understood?
  - Do we know the safety range and sensitivity?
  - Have failure modes been identified?
  - Does hardware exist that proves feasibility?

Design teams should not try to do research while designing. R&D belongs in a different phase.

3️⃣ Go/No-Go Constraint Screening

Once a design passes functional and technological filters, evaluate whether it meets **key constraints**:

- Weight
- Size
- Cost
- Safety
- Performance thresholds

The goal here is not detailed analysis but to eliminate clearly non-compliant designs.

🏀 Shot-Buddy Example Analysis (Figure 7.4)

Concept Overview:

- A semicircular catch net guides the ball to a pivoting ramp aimed at the shooter.
- The ramp is supposed to return the ball using its kinetic energy.
- The pivot mechanism is unspecified.

Evaluation Result:

- ❌ **Functionally Infeasible** due to:
  - Unsupported catch net → can't hold required shape.
  - Guide ramp lacks rigidity → cannot consistently direct the ball.
  - Needed supports would obstruct gameplay → violates user constraints.

Conclusion: This version of Shot-Buddy is not viable as designed, but components like the pivoting guide may still be worth exploring.

🔁 Iterative Use of Filters

Even if a concept gets some “no-go” responses, **don’t discard it too quickly**:

- Weak areas might be improved by **borrowing ideas** from better designs.
- The analysis might **spark new hybrid concepts**.

📌 Summary

- Use **judgment and experience** to quickly eliminate clearly flawed concepts.
- Apply **three filters**:
    1. Functional feasibility
    2. Technology readiness
    3. Constraint compliance
- These filters save time and guide the team toward the **most promising solutions**.
- Some elements of a rejected design may still inspire useful ideas.