

# **TRIZ: Generative AI Application**

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**To MATRIZ Official TMCC organization for TRIZ L5 application**

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## 1. Introduction.

The rapid advancements in Generative Artificial Intelligence (AI), a class of AI models capable of creating new, original content such as text, images, or code, particularly over the past two years, have transformed numerous industries and research fields.

Generative AI, especially in the form of Large Language Models (LLMs), has demonstrated remarkable capabilities in generating human-like text, automating tasks, and assisting in creative problem-solving. This transformation has opened up new opportunities for leveraging AI in enhancing established methodologies, one of which is the Theory of Inventive Problem Solving (TRIZ).

TRIZ, known for its systematic approach to inventive thinking, includes a suite of tools designed to resolve contradictions and facilitate innovation. These tools, while powerful, require expertise to be applied effectively, particularly in complex problem-solving scenarios.

In this thesis, the focus is on developing a systematic algorithm for integrating Generative AI with TRIZ tools, aiming to capitalize on the strengths of both technologies. TRIZ tools are invaluable for generating inventive ideas by systematically overcoming contradictions, and they are widely used in various fields of engineering and beyond. However, by augmenting these tools with the capabilities of Generative AI, we can streamline the learning and application processes, making TRIZ more accessible and adaptable across different domains.

The core of this research lies in the design of a systematic algorithm that allows for the seamless integration of AI with TRIZ tools. This algorithm facilitates the creation of effective prompts to communicate with Generative AI, enabling it to support the application of TRIZ tools in real-world scenarios. By leveraging this integration, users can enhance their ability to use TRIZ in multiple dimensions, including improving the learning process, accelerating problem-solving in real situations, and expanding the application of TRIZ beyond engineering disciplines. Furthermore, this approach opens up opportunities for the development of new TRIZ tools, driven by the generative capabilities of AI.

The positive impact of this integration is multifaceted. It improves learning accessibility by simplifying TRIZ training, allowing learners to interact with AI-generated examples and solutions. It also enhances the practical application of TRIZ by automating parts of the problem-solving process, enabling quicker responses to complex issues.

Additionally, the integration of Generative AI expands the potential use cases of TRIZ, making it applicable in fields that traditionally may not have utilized these tools. Finally, the AI-driven insights and data collection capabilities contribute to the ongoing evolution and creation of new TRIZ tools, ensuring that the methodology remains relevant and effective in a rapidly changing technological landscape.

**In conclusion**, this thesis proposes that the integration of Generative AI with TRIZ, through the development of a systematic algorithm, represents a significant advancement in the field of innovation and problem-solving. This integration not only enhances the usability and reach of TRIZ tools but also demonstrates the potential for AI to drive the creation of new tools and methodologies. While the research highlights several key benefits, it also underscores the importance of human expertise in guiding and validating AI-generated solutions to ensure their effectiveness in real-world applications.

## **2. Practical significance of the thesis topic.**

The practical importance of this thesis is its potential to change how TRIZ is learned, used, and grown. The new algorithm for combining AI with TRIZ tools can bring these benefits:

- **Easier AI Use:** The algorithm gives a clear and reliable way to add AI to TRIZ tools, making it easier for more people to use. The process of improving prompts, based on the algorithm and user feedback, makes AI-generated results better and more accurate.
- **Better TRIZ Tools:** Adding AI lets TRIZ tools do routine tasks automatically, analyze complex data, and come up with new ideas, making them better at solving problems and speeding up innovation. The case studies show that AI can give useful

information, find root causes, and suggest creative solutions, making different TRIZ tools more useful.

- **Faster Tool Creation and Wider Use:** The algorithm makes it easier to create new TRIZ tools, saving resources and time. It can be used with many TRIZ tools, so AI-powered problem-solving can be used in more areas and industries, helping with innovation and solving tough problems in different fields. The case studies show how AI-powered TRIZ tools can be used in areas like food production and social media, showing how widely they can be used.
- **Clear Evaluation:** The thesis stresses the need for clear ways to measure how well AI works with TRIZ and to compare results. Using numbers like time saved and user satisfaction shows the real benefits of AI-powered TRIZ tools. Case studies and user surveys also prove that the approach works in the real world and helps people solve problems.
- **Focus on New Ideas:** The thesis shows that AI can create truly new solutions by giving examples where AI suggests unique ideas that go beyond what we already know or combine ideas in new ways. The focus on creativity and using techniques like "Systematic Idea Generation" shows that AI can help us see problems in new ways.
- **Comparison with Others:** The thesis clearly explains how the new algorithm is different from other AI-TRIZ tools like AutoTRIZ, showing its unique features, better performance, or wider use in certain areas. The comparison in Case Study 3 also shows the strengths and weaknesses of different AI-TRIZ tools, helping users choose the right one.

### 3. Objectives.

#### Development of a Generative AI Application Algorithm for TRIZ Tools

- Develop a systematic algorithm to integrate Generative AI capabilities, particularly Large Language Models (LLMs), with TRIZ tools, enabling a consistent and effective application of AI to enhance problem-solving and innovation processes.

### 4. Literature Review.

#### 4.1 What is generative AI?

Generative AI, sometimes called *gen AI*, is artificial intelligence (AI) that can create original content—such as text, images, video, audio or software code—in response to a user’s prompt or request.

##### 4.1.1 A brief history of generative AI

The term “generative AI” exploded into the public consciousness in the 2020s, but gen AI has been part of our lives for decades, and today’s generative AI technology draws on machine learning breakthroughs from as far back as the early 20th century. A non-exhaustive representative history of generative AI might include some of the following dates

**1964:** MIT computer scientist Joseph Weizenbaum develops ELIZA, a text-based natural language processing application. Essentially the first chatbot (called a ‘chatterbot’ at the time), ELIZA used pattern-matching scripts to respond to typed natural language inputs with empathetic text responses.

**1999:** Nvidia ships GeForce 256 was marketed as “the world’s first ‘GPU’, or Graphics Processing Unit”, the first graphical processing unit. Originally developed to deliver smooth motion graphics for video games, GPUs had become the defacto platform for developing AI models and mining cryptocurrencies.

**2004:** Google autocomplete first appears, generating potential next words or phrases as users enter their search terms. The relatively modern example of generative AI is based on a Markov Chain, a mathematical model developed in 1906.

**2013:** The first variational autoencoders (VAEs) appear.

**2014:** The first generative adversarial networks (GANs) and diffusion models appear.

**2017:** Ashish Vaswani, a team at Google Brain, and a group from the University of

Toronto publish “Attention is All You Need,” a paper documenting the principles of transformer models, widely acknowledged as enabling the most powerful foundation models and generative AI tools being developed today.

**2019-2020:** OpenAI rolls out its GPT (Generative Pretrained Transformer) large language models, GPT-2 and GPT-3.

**2022:** OpenAI introduces ChatGPT, a front-end to GPT-3 that generates complex, coherent and contextual sentences and long-form content in response to end-user prompts. [1]

#### **4.2 LLM:**

What are LLMs? [2] Large Language Models (LLMs) have gained significant attention for their role in advancing generative AI and their widespread adoption across various business functions. While their public emergence seems sudden, companies like IBM have been integrating LLMs for years to enhance natural language understanding (NLU) and natural language processing (NLP) capabilities. This progress parallels advancements in machine learning, neural networks, and transformer models.

LLMs are foundational models trained on extensive data to drive multiple applications and tasks, contrasting with the cost-prohibitive and less efficient approach of developing domain-specific models. They represent a breakthrough in NLP and AI, accessible to the public through interfaces such as Open AI’s Chat GPT-3 and GPT-4, Meta’s Llama models, Google’s BERT/RoBERTa and PaLM models, and IBM’s Granite series on watsonx.ai.

Designed to understand and generate human-like text and other content forms, LLMs can infer context, generate coherent responses, translate languages, summarize text, answer questions, and assist in creative and coding tasks. Their ability to capture intricate language patterns through billions of parameters enables diverse applications, including chatbots, virtual assistants, content generation, research assistance, and language translation.

As LLMs continue to evolve, they are set to transform our interaction with technology and information, solidifying their role in the modern digital landscape.

#### **4.3 RAG**

**What is retrieval-augmented generation?** RAG is an AI framework for retrieving facts



from an external knowledge base to ground large language models (LLMs) on the most accurate, up-to-date information and to give users insight into LLMs' generative process.

Large language models (LLMs) can be inconsistent, sometimes providing accurate answers while at other times offering irrelevant or incorrect information. This is because LLMs understand statistical relationships between words, not their meanings.

RAG benefits LLM-based question-answering systems by ensuring access to current facts and enabling users to verify the sources of information. It reduces the likelihood of LLMs leaking sensitive data or generating incorrect information and diminishes the need for continuous model retraining, thus lowering computational and financial costs.

### **Potential Concerns with RAG**

While RAG offers significant advantages, it's important to acknowledge some potential challenges:

- **Misconception of Functionality:** Users familiar with traditional search engines may misunderstand RAG's capabilities, expecting it to function solely as an information retrieval tool. It's crucial to emphasize that RAG goes beyond simple search, synthesizing information to generate more comprehensive and insightful responses.
- **Insufficient Output Validation:** Despite grounding responses in external knowledge, the risk of errors or misleading information persists. Rigorous testing and validation of RAG-generated outputs are essential, especially in critical applications.
- **User Sensitivity to Errors:** Users are generally more tolerant of Type 1 errors (false negatives) in search, where relevant information might be missed. However, they are less forgiving of Type 2 errors (false positives) where the system fabricates information. RAG systems need to minimize both types of errors while recognizing the heightened sensitivity towards false positives.

RAG operates in two phases: retrieval and generation. In the retrieval phase, algorithms search for relevant information from external sources, which is then appended to the user's query. In the generation phase, the LLM synthesizes a response using both the augmented prompt and its internal data, producing personalized and verifiable answers.

By grounding responses in external knowledge, RAG allows for more accurate and reliable answers, reducing the chances of hallucinations or misinformation. This approach contrasts with traditional, script-based chatbots, which were limited by predefined answers and required frequent updates.

#### **4.4 Prompting**

What is prompt design and prompt engineering? [4]. Prompt design is the process of creating prompts that elicit the desired response from language models. Writing well-structured prompts is essential for ensuring accurate, high-quality responses. The iterative process of repeatedly updating prompts and assessing the model's responses based on predefined criteria such as accuracy, relevance, and coherence, often involving human-in-the-loop evaluation, is sometimes called "prompt engineering.

#### **4.5 Prompt Engineering:**

##### **Definition and Importance**

Prompt engineering is essential for improving the quality and relevance of outputs from generative AI systems, which produce outputs based on the quality of the provided prompts. It helps AI models interpret and respond effectively to a wide range of queries, ensuring more accurate and nuanced results. [5]

##### **Functionality**

Generative AI models, built on transformer architectures, process vast amounts of data and understand language intricacies through neural networks. Prompt engineering techniques, such as tokenization (breaking down text into smaller units), model parameter tuning (adjusting internal settings of the model), and top-k sampling (selecting from the most likely next words), mold the model's output to be meaningful and coherent. Effective prompt engineering bridges the gap between raw queries and meaningful responses, enhancing the quality of AI-generated content like text, images, code, and data summaries.

##### **Benefits**

The primary benefit of prompt engineering is achieving optimized outputs with minimal post-generation effort. It ensures AI-generated content aligns with desired goals, as articulated in the prompt, reducing the need for extensive post-processing. Prompt engineers tailor prompts to various AI models (e.g., OpenAI's GPT-4, Google Gemini,

Claude) to get the best results, guiding AI to create relevant, accurate, and personalized responses.

### **Applications**

Prompt engineering is crucial for leveraging generative AI in innovative ways beyond their initial design scope. Examples include AI systems that translate languages without parallel text, AI in games for responsive storytelling, and new insights into astronomical phenomena like black holes.

### **Skills Required**

Prompt engineers should be familiar with large language models, possess strong communication skills, programming expertise (especially in Python), and an understanding of data structures and algorithms. They need to comprehend vocabulary, context, and linguistics deeply. Additionally, knowledge in specific areas like coding principles, art history, or narrative styles can be crucial depending on the application.

*This may add to Appendix Due to Generative AI API, User able to adjust thiese parameters and it will effect to output Prompt engineering techniques, such as tokenization, model parameter tuning, and top-k sampling, mold the model's output to be meaningful and coherent.*

## **4.6 Elements of a Prompt [6]**

A prompt contains any of the following elements:

**Instruction** - a specific task or instruction you want the model to perform

**Context** - external information or additional context that can steer the model to better responses

**Input Data** - the input or question that we are interested to find a response for

**Output Indicator** - the type or format of the output.

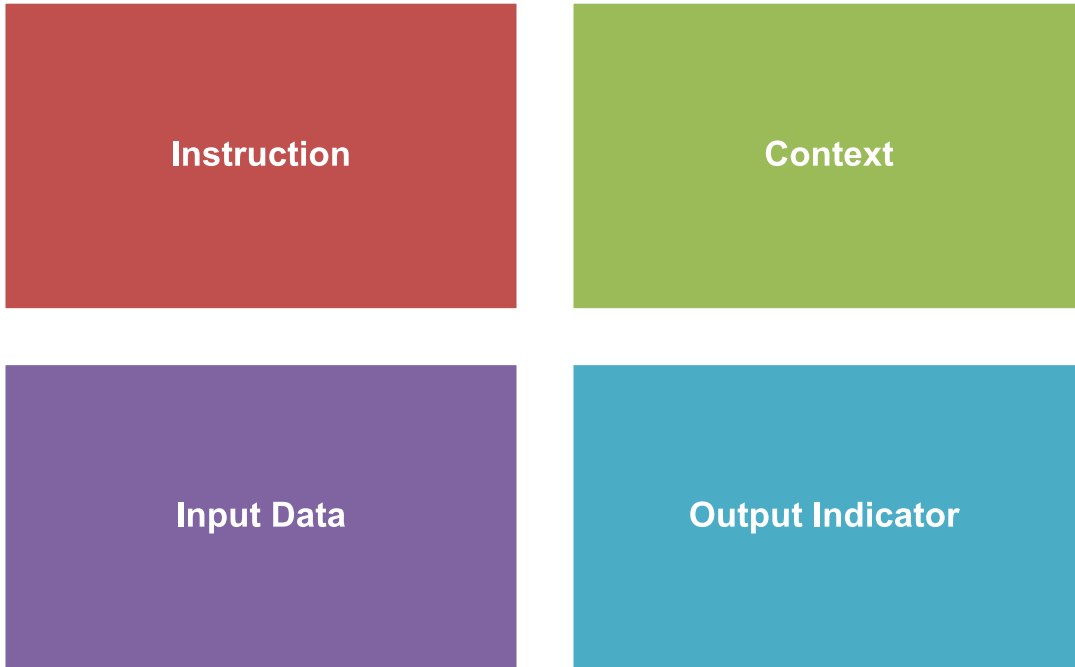


Figure 1: Elements of a Prompt.

#### **4.7 A Systematic Survey of Prompting Techniques [7]**

Schulhoff et al. (2024) conducted a comprehensive survey of prompting techniques used in generative AI. The authors defined key terminology in the field, including "prompt," "prompt engineering," and "prompt chain," to establish a standardized vocabulary. They identified 58 text-based prompting techniques and categorized them into six major groups: in-context learning, zero-shot, thought generation, decomposition, ensembling, and self-criticism. The study also explored multilingual and multimodal prompting techniques, as well as the use of agents and evaluation methods in prompting. The authors emphasized that while prompting is a powerful tool for interacting with generative AI, it is still an evolving field with challenges such as security and alignment that need to be addressed.

#### **4.8 LLM Accuracy [8]**

The OpenAI guide on optimizing LLM accuracy emphasizes the importance of context in improving model performance. It suggests techniques such as providing detailed instructions, using clear formatting, and offering relevant examples to enhance comprehension and accuracy. The accuracy of LLM outputs is typically assessed using metrics such as precision, recall, and F1-score (a balanced measure that combines

precision and recall), or through human evaluation. Additionally, it highlights the benefits of fine-tuning models on domain-specific data and iterating on prompts based on model feedback. The guide also underscores the need to evaluate outputs rigorously and adjust accordingly to maintain high standards of accuracy in various applications.

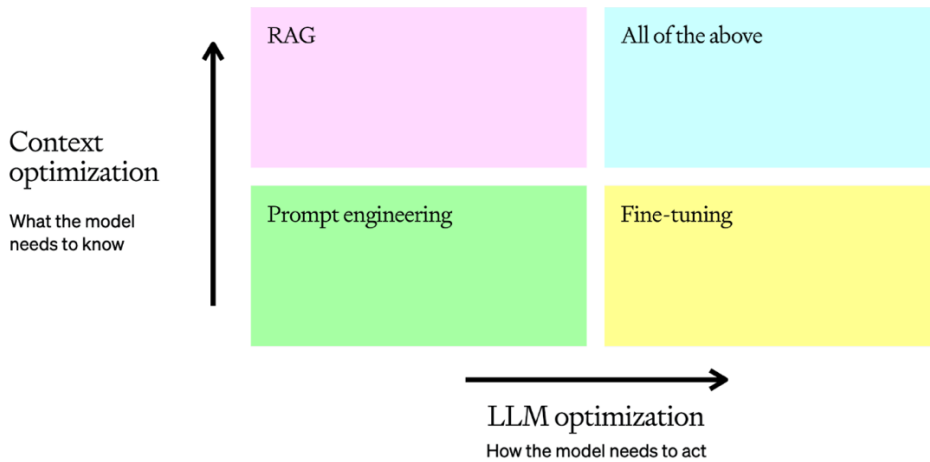


Figure 2: Diagram illustrating LLM optimization and context optimization.

Source: OpenAI

<https://platform.openai.com/docs/guides/optimizing-llm-accuracy/llm-optimization-context>

Used with permission.

#### 4.9 AI Hallucination

AI hallucinations refer to instances where AI systems, such as large language models, generate outputs that are misleading, factually inaccurate, or entirely fabricated. These hallucinations occur due to various factors, including overfitting, biases in the training data, and the inherent complexities of model algorithms. For instance, these models might produce nonsensical answers to prompts or claim to recognize objects in images that aren't present, which can sometimes resemble human misperceptions, like seeing shapes in clouds.

The risks associated with AI hallucinations are significant, particularly when these outputs are used in critical contexts. For example, in the legal field, reliance on incorrect AI-generated information could lead to the use of fictitious legal cases, as has happened, leading to professional and legal repercussions. Beyond individual

consequences, these inaccuracies can perpetuate misinformation, affecting broader societal trust in AI technologies. Moreover, businesses could face fines and reputational damage if their AI systems frequently generate and act on false information.

### **Transparency Concerns**

A major challenge in mitigating AI hallucinations is the lack of transparency regarding the training data used to develop these models. Users often have limited or no information about the sources, quality, and potential biases present in the data, making it difficult to assess the reliability and trustworthiness of AI-generated outputs.

To mitigate these risks, it's crucial to:

- **Advocate for increased transparency in AI model development:** Encourage the release of information about training data sources and methodologies, enabling users to better understand the potential limitations and biases of AI systems.
- **Use high-quality, diverse, and well-structured training data:** Strive to minimize biases and inaccuracies by carefully curating training data and ensuring it represents a wide range of perspectives and information.
- **Define clear objectives and limitations for AI models:** Clearly specify the intended use cases and boundaries of AI systems to reduce the likelihood of generating outputs that fall outside the expected scope.
- **Continuously test and refine AI systems:** Regularly evaluate and update AI models to adapt to new data and evolving contexts, ensuring they remain accurate and reliable.
- **Incorporate human oversight in validating and supervising AI outputs:** Implement human-in-the-loop processes to review and verify AI-generated content, particularly in critical applications where accuracy is paramount. [9]

### **4.10 Generative AI and Creative Problem Solving**

Boussioux et al. (2023) explore the potential of generative artificial intelligence (AI) in creative problem-solving through human-AI collaboration. The authors conducted a crowdsourcing challenge focused on sustainable, circular economy business ideas, comparing the novelty, value, and creativity of solutions from both human participants (HC) and those generated through human-AI collaboration (HAI). The study involved

125 human-generated solutions and 730 AI-generated solutions, evaluated by 300 individuals.

The results showed that HAI solutions matched the creativity of HC solutions, while providing more value in terms of strategic viability, financial and environmental value. However, HC solutions were found to be more novel. The authors conclude that incorporating AI into creative problem-solving can be a scalable and cost-efficient method for enhancing the early phases of innovation.

**Connection to TRIZ:** This aligns with the TRIZ process, which also emphasizes the early stages of problem identification and idea generation. The use of AI in generating creative solutions could potentially complement TRIZ tools used in these initial phases. The study's focus on the *early phases* suggests that AI might be particularly useful in assisting with problem definition, gathering information, and generating initial ideas, which are crucial steps in the TRIZ process.

#### **4.11 Comparing the Ideation Quality of Humans with Generative Artificial**

Joosten et al. (2024) investigate the potential of generative AI, specifically ChatGPT, in the ideation phase of the innovation process. It compares the quality of new product ideas generated by human professionals with those generated by ChatGPT. The results show that AI-generated ideas are significantly more novel and customer-beneficial, while their feasibility is similar to human-generated ideas. This finding, while contrasting with some previous studies (e.g., Boussioux et al., 2023) that found human ideas to be more novel, suggests that companies can benefit from integrating generative AI into their traditional idea-generation processes to enhance innovation outcomes. However, human expertise remains crucial in assessing and refining the feasibility of these innovative ideas. [11]

- **Addressing the Discrepancy:** The observation that AI-generated ideas were found to be more novel in this study might be attributed to the specific AI model used (ChatGPT), the nature of the ideation task (new product ideas), or the evaluation criteria employed. Further research is needed to explore these factors and reconcile the differing findings across studies. It is possible that AI excels at generating novel ideas in certain contexts or under specific conditions, while human creativity remains superior in others.

- **Complementary Roles of AI and TRIZ:** While AI can be a valuable tool for generating novel and customer-centric ideas, it's important to recognize that it doesn't replace the need for TRIZ training and human expertise. TRIZ provides a structured framework for problem-solving and innovation, and human practitioners bring critical thinking skills, domain knowledge, and contextual understanding to the process. AI can augment human capabilities in the ideation phase, but the evaluation, selection, and implementation of ideas still require human judgment and TRIZ expertise.

#### **4.12 AutoTRIZ**

Jiang and Luo (2024) introduce AutoTRIZ, an AI-powered tool designed to automate the Theory of Inventive Problem Solving (TRIZ) framework. TRIZ is a problem-solving methodology that identifies and resolves contradictions within engineering problems. AutoTRIZ leverages large language models (LLMs) to streamline the TRIZ process, making it more accessible to users. The tool guides users through problem identification, contradiction detection, and solution generation, ultimately producing a comprehensive report detailing the reasoning and solutions. The authors conducted experiments to evaluate AutoTRIZ's performance, demonstrating its consistency in identifying contradictions and its ability to generate feasible solutions comparable to those of human experts. [12]

#### **4.13 TRIZ and Generative AI V3.0**

Pheunghua and Adunka (2024) explored the integration of Generative AI into the Theory of Inventive Problem Solving (TRIZ) framework. They presented a collection of prompt examples designed to enhance the application of TRIZ tools with AI, particularly focusing on improving the learning and utilization of TRIZ methodology. The authors emphasized that Generative AI, while not a replacement for human expertise, can significantly reduce research time and enhance creative problem-solving when used in conjunction with TRIZ. They also highlighted the potential of Generative AI in various TRIZ applications, such as problem identification, technology forecasting, and tool integration. However, they cautioned that AI outputs should be critically evaluated due to their reliance on historical data and specific prompts. The authors proposed the development of an open platform for prompt engineering tailored to TRIZ, fostering



collaboration and knowledge exchange within the TRIZ community. [13]

### **Conclusion of Literature Review**

The literature review highlights the transformative potential of generative AI in various domains, including creative problem-solving and the TRIZ framework. The studies by Boussioux et al. (2023) and Joosten et al. (2024) demonstrate the ability of AI to generate novel and valuable ideas, potentially surpassing human capabilities in certain contexts. The development of tools like AutoTRIZ further showcases the integration of AI into established problem-solving methodologies, streamlining processes and enhancing accessibility. The exploration of prompt engineering in TRIZ by Pheunghua and Adunka (2024) underscores the importance of effective human-AI collaboration for maximizing the benefits of generative AI. The literature emphasizes that while AI can augment human creativity and problem-solving skills, it does not replace the need for human expertise and critical evaluation. The future of innovation lies in harnessing the power of AI in conjunction with human ingenuity and established frameworks like TRIZ.

### **5. Detailed Statement of the Problem.**

The Theory of Inventive Problem Solving (TRIZ) is a potent methodology for driving innovation. However, several limitations hinder its widespread adoption and full realization of its potential. These include the complexity and time-intensive nature of learning TRIZ, which often necessitates extensive training and experience, thus limiting its accessibility to a wider audience. Moreover, human problem-solving capabilities, even within the TRIZ framework, can be constrained by cognitive biases, limited knowledge domains, and a tendency towards incremental solutions, restricting the scope of TRIZ applications and the generation of breakthrough innovations. Additionally, the research, problem-solving, and idea generation processes within TRIZ can be slow and resource-intensive, demanding significant time, expertise, and access to specialized knowledge bases, particularly for complex problems that require multidisciplinary collaboration. Finally, while TRIZ has evolved over time, the development of new tools and methodologies remains slow and limited by available resources and expertise.

The emergence of Generative AI, particularly Large Language Models (LLMs) like GPT, presents a transformative opportunity to address these limitations and enhance the utilization of TRIZ. By leveraging the vast knowledge base, computational power, and creative capabilities of AI, this thesis aims to revolutionize how TRIZ is learned, applied, and expanded.

### **Main Problem Statement:**

TRIZ, renowned for its systematic approach to inventive thinking, encompasses a suite of tools designed to resolve contradictions and facilitate innovation. However, current TRIZ applications face several challenges: the difficulty and time required to master numerous tools, the ever-increasing pace of business problem-solving, the extensive time and expertise needed to search for and gather data supporting TRIZ tool usage (e.g., identifying root causes of problems or technologies from other industries), the limited human capacity for generating novel ideas (despite guidelines from Idea Generation tools such as 40 Principles), the constraints of TRIZ application in non-engineering fields, and the time-consuming nature of TRIZ tool research and development.

Generative AI, on the other hand, demonstrates capabilities in producing human-like text, automating tasks, and assisting in creative problem-solving. However, concerns about hallucination persist, necessitating the implementation of human-in-the-loop processes to review and verify AI-generated content, particularly in critical applications. While posing questions to Generative AI for quick answers is comparable to the trial-and-error thinking process, a more pressing concern is that humans may not recognize when an AI providing rapid responses is offering incorrect answers or responding based on hallucinations.

Combining the strengths of TRIZ tools with the exceptional support of Generative AI has the potential to significantly enhance the effectiveness of TRIZ methodologies.

## **6. Methodology.**

### **The Algorithm for Integrating Generative AI with TRIZ Tools**

The integration of Generative AI with TRIZ tools requires a systematic and structured approach to ensure the AI comprehends the specific tool, its objectives, and the desired

user outcomes. The proposed algorithm outlines a step-by-step process to guide this integration, facilitating effective and accurate AI-generated outputs.

The algorithm consists of the following key steps:

### **Phase 1: Prompt Preparation**

1. **Identification of TRIZ Tool and Objective:** The initial step involves a precise definition of the specific TRIZ tool to be employed and its intended purpose within the problem-solving context and desired outcome. This delineation enables the AI to grasp the contextual nuances and overarching goals of the analysis.
2. **Instruct the AI to Understand the Tool:** Provide the AI with a comprehensive explanation of the TRIZ tool, including its underlying principles, methodology, and expected outcomes. Use the common name of the tool if it exists (e.g., Function Analysis). If the tool has a specific name or acronym (e.g., CECA = Cause and Effect Chain Analysis), provide a clear explanation of the tool's purpose and methodology. This step is crucial for the AI to generate relevant and accurate responses.
3. **Specification of Traditional TRIZ Tool Usage Steps:** Outline the conventional steps involved in manually using the TRIZ tool. This helps the AI understand the logical flow and interdependencies of the process.
4. **Select and Craft Relevant Prompt Elements:** Carefully craft the prompt by incorporating essential elements such as context, objective, purpose, examples, and instructions. These elements provide the AI with the necessary information to generate meaningful responses.
  - **Problem Formulation/Analysis Tools:** For TRIZ tools used in problem formulation and analysis, ensure the prompt includes accurate scientific or engineering information relevant to the specific domain. This can be achieved by specifying the domain or using role prompting to guide the AI's response.
  - **Idea Generation Tools:** For TRIZ tools focused on idea generation, prioritize creativity in the prompt. Incorporate examples and role prompting to encourage the AI to generate diverse and innovative solutions.
  - **TRIZ Tools with Extensive Reference Content:** For tools like the 40 Principles, 76 Standard Solutions, or Scientific Effects, prepare the principle data and

examples as plain text before implementing Retrieval Augmented Generation (RAG) methods or similar techniques like knowledge files in custom GPT models. Due to token input limitations, consider having the AI focus on a limited number of principles (e.g., 5-10) at a time.

5. **Utilize Prompting Techniques:** Employ appropriate prompting techniques, such as Chain of Thought (CoT), Step-by-Step, or Role Prompting, to guide the AI's response generation and improve the accuracy and coherence of the output. Below are some basic prompt engineering techniques:

- **Zero-Shot Prompting:** Involves instructing the model to perform a task without providing any examples in the prompt. The model relies solely on its pre-trained knowledge and the given instructions to generate a response. This approach is useful when the model is expected to handle unfamiliar tasks or questions, drawing from its broad understanding to provide accurate answers.
- **Role Prompting:** Assigns a specific role or persona to the model, guiding it to produce responses consistent with that role. By framing the model as a particular character or professional (e.g., a doctor, teacher, or assistant), Role Prompting helps shape the style, tone, and content of the output to align with the expectations of that role, ensuring the response is contextually appropriate.
- **Step-by-Step Prompting:** Instructs the model to solve a problem or complete a task by breaking it down into a sequence of clear, ordered steps. This method encourages the model to follow a logical progression, ensuring that each part of the process is addressed before moving on to the next, thereby enhancing the accuracy and thoroughness of the response.
- **Chain of Thought Prompting:** Encourages the model to break down complex reasoning into a series of intermediate steps, demonstrating its thought process before arriving at a final answer. This helps the model produce more structured and coherent responses.
- There are also other prompting techniques [7], such as:
  - Few-Shot Prompting (In-Context Learning)
  - Self-Refinement (Self-Criticism)

- Least-to-Most Prompting (Decomposition)
  - Program-of-Thought Prompting (Decomposition)
  - Self-Verification (Self-Criticism)
  - Skeleton-of-Thought Prompting (Decomposition)
  - Rephrase and Respond (Zero-Shot)
6. **Definition of User Expectations from Generative AI:** Clearly define the desired output from the AI, whether it's generating novel ideas, identifying potential root causes from multiple perspectives, performing role-based prompting without specifying a role but using relevant scientific principles or expertise related to the problem statement, identifying contradictions, or providing solutions. This ensures that the AI's output aligns with the user's needs.
  7. **Determination of Necessary User Inputs:** A precise specification of the information required from the user, encompassing problem descriptions, system parameters, or desired outcomes, is essential. This ensures that the AI is equipped with the requisite data to undertake a comprehensive analysis.
  8. **Draft of Prompt:** Combine the information gathered from steps 1 through 7 to create a comprehensive prompt. This step involves synthesizing all the elements identified in the previous steps, including the tool identification, objectives, usage steps, relevant prompt elements, prompting techniques, user expectations, and required inputs. The goal is to construct a well-structured and effective prompt that will guide the Generative AI to produce the desired output for the TRIZ tool application.

### **Phase 2 : Prompt Refinement**

9. **Iterative Prompt Refinement:** Systematically experiment with different arrangements of prompt elements, informed by the understanding of the TRIZ tool, AI model capabilities, and user expectations, to identify the most effective prompt structure for eliciting the desired output. [14]

### **Phase 3 : Prompt Testing**

10. **Testing the Process with Diverse Problems:** Prior to the deployment of the AI-powered TRIZ tool in real-world scenarios, it is imperative to subject it to rigorous testing with a wide array of problems. This comprehensive evaluation serves to assess its performance and identify any potential limitations or biases.

### **Phase 1:**

#### **Prompt Preparation**

- **1. Identification of TRIZ Tool and Objective.**
- **2. Instruct the AI to Understand the Tool.**
- **3. Specification of Traditional TRIZ Tool Usage Steps.**
- **4. Select and Craft Relevant Prompt Elements.**
- **5. Utilize Prompting Techniques.**
- **6. Definition of User Expectations from Generative AI.**
- **7. Determination of Necessary User Inputs.**
- **8. Draft of Prompt.**

### **Phase 2 :**

#### **Prompt Refinement**

- **9. Iterative Prompt Refinement.**

### **Phase 3 :**

#### **Prompt Testing**

- **10. Testing the Process with Diverse Problems.**

Figure 3: Algorithm for Integrating Generative AI with TRIZ Tools.

The entire process stems from a review of the development process derived from example prompts for TRIZ Tools, which were created (as of April 2024) in the document "TRIZ and Generative AI - Example of Prompt" Version 3.0.

### Review of Developed TRIZ Tools Example of Prompt

TRIZ and Generative AI	Element of Prompt				Prompting Techniques						RAG methods or equivalents like Knowledge	Specific names or acronyms.
	Context	Objective or Purpose	Example	Instruction	Zero Shot, Few Shot	COT	Step by Step	Role Prompting or	Other			
1. IDEALITY *	X			X			X					
2. SYSTEM OPERATOR (9-SCREENS)	X	X	X	X			X					
3. FUNCTION ANALYSIS WITH COMPONENT INTERACTION ANALYSIS	X	X	X	X		X	X					
4. ROOT CAUSE ANALYSIS	X	X		X		X	X	X				
5. CAUSE AND EFFECT CHAIN ANALYSIS	X	X		X		X	X	X				X
6. TRIMMING AND TRIMMING RULES	X		X	X			X					
7. SCIENTIFIC EFFECT DATABASE	X			X			X				Recommend	
8. 40 INVENTIVE PRINCIPLES AND CONTRADICTION MATRIX	X	X	X	X			X				Recommend	

9.CONTRADICTION FORMULATION AND KEY PROBLEM	X	X	X	X			X				
10.PHYSICAL CONTRADICTIONS AND SEPARATION PRINCIPLES	X	X	X	X			X				
11. SUBSTANCE-FIELD ANALYSIS	X			X		X	X				
12. 76 STANDARD SOLUTIONS	X			X			X			Recommend	
13. MATCHEM	X	X	X	X			X				
14. FEATURE TRANSFER	X			X			X				
15. S-CURVE: TESE (TREND OF ENGINEERING SYSTEM EVOLUTION)	X	X		X		X					
16. TREND OF TRANSITION TO SUPER SYSTEM (MONO-BI-POLY):	X	X	X	X			X				X
17. TREND OF INCREASING DYNAMIZATION: TESE (TREND OF ENGINEERING SYSTEM EVOLUTION)	X	X	X	X			X				X
18. TREND OF INCREASING SYSTEM COMPLETENESS: TESE (TREND OF	X	X	X	X		X	X				



ENGINEERING SYSTEM EVOLUTION)											
19. SMART LITTLE PEOPLE	X	X	X	X			X				X
20. PATENT CIRCUMVENTION (CLAIM – ANALYSIS)	X			X			X				
21. FUNCTION-ORIENTED SEARCH (FOS)	X			X			X				
22. MFO: METHOD OF FOCAL OBJECT	X			X			X				
23. RESOURCES ANALYSIS	X	X	X	X			X				X
24. DERIVATIVE RESOURCES	X	X	X	X			X				X
25. MA: MORPHOLOGICAL ANALYSIS	X			X			X				
26. SYSTEM SEARCH, FUNCTION ANALYSIS	X			X			X				
27. EXTENSION FOS: MECHANISM-ORIENTED SEARCH (MOS)	X	X	X	X			X				
28. RESOURCES MODIFICATION	X	X	X	X			X				
29. FUNCTION REDIRECTION	X	X		X			X				
30. EXTENSION FOS: PROBLEM-	X			X			X				

ORIENTED SEARCH											
31. EXTENSION FOS: ROOT CAUSE-ORIENTED SEARCH	X			X			X				
32. RESOURCE FOR NON-ENGINEERING	X	X		X			X				
33. FUNCTION ANALYSIS: NON-ENGINEERS	X	X	X	X			X				
34. PROBLEM REVIEW AND DEFINITION	X	X		X			X				

Table 1: Element of TRIZ Tools Prompt.

**7. Results of the work performed**

**7.1 Implementation Details:**

To illustrate the practical application of the proposed method, we present two detailed examples that integrate Generative AI with TRIZ tools:

- 1) Function Analysis with Component Interaction Analysis.
- 2) Root Cause Analysis.

Each example outlines the step-by-step process of applying Generative AI.

**Example 1.**

**Function Analysis, Component Interaction Analysis with Generative AI.**

**1. Identification of TRIZ Tool and Objective:**

- o **Tool:** Function Analysis with Component Interaction Analysis.

- **Objective:** To understand how the components of a technical system interact by identifying the parts that serve as tools and the parts that are acted upon.

## 2. Instruct the AI to Understand the Tool:

- **Explanation:** Function Analysis examines the actions performed by components of a system to understand their interactions. Each component can be classified as a tool (performs an action), an object (acted upon), and the function (describes the interaction). The main function is the overall purpose of the system.

## 3. Specification of Traditional TRIZ Tool Usage Steps:

- **Steps:**
  1. Define the technical system.
  2. Conduct Component Analysis to identify all components.
  3. Perform Interaction Analysis to understand how components interact.
  4. Document the Function Analysis in a tabulated format.

## 4. Select and Craft Relevant Prompt Elements:

- **Context:** Use detail in Step 1, 2
- **Examples:**
  1. [Example 1]: The **main useful function** of the airplane is to **transport passengers and cargo efficiently from one geographic location to another** by generating lift and thrust, while maintaining stability, safety, and comfort throughout the flight.

The **Interaction Analysis** between each component identified in the **Component Analysis** of the airplane;

1. **Wings and Airflow:** The wings interact with the surrounding air to generate lift. The shape of the wings (airfoil) causes air to flow faster over the top than the bottom, creating a pressure difference that lifts the airplane.
2. **Engines and Thrust:** The engines (jet or propeller) generate thrust by expelling air or gas at high speed. This thrust propels the airplane forward, overcoming drag.

3. **Control Surfaces and Flight Stability:** Control surfaces (rudders, ailerons, elevators) interact with the air to change the airplane's orientation (pitch, roll, and yaw). Pilots use these to steer the plane and maintain stability.
4. **Fuselage and Aerodynamics:** The fuselage interacts with the air to reduce drag. It houses the passengers, cargo, and avionics and is designed to be aerodynamic.
5. **Landing Gear and Ground:** The landing gear provides support during takeoff and landing, interacting with the ground to absorb the impact and provide stability on the runway.
6. **Cockpit and Avionics System:** The cockpit contains the avionics system, interacting with both the airplane and external systems (air traffic control, navigation). The avionics system helps the pilot monitor and control the airplane's position, speed, altitude, etc.
7. **Hydraulic System and Control Surfaces:** The hydraulic system provides the necessary power to actuate control surfaces like ailerons, elevators, and the rudder.
8. **Fuel System and Engines:** The fuel system ensures a continuous supply of fuel to the engines, enabling them to generate thrust.

[Example 2]: The main useful function of the eraser is to **remove pencil marks from paper** by dislodging the graphite particles through friction, restoring the paper's original state.

The **Interaction Analysis** between each component identified in the **Component Analysis** of the eraser; Eraser material acts by rubbing against the pencil marks, dislodging graphite particles from the paper. The result is the removal of pencil marks from the paper, fulfilling the function of cleaning the surface.

Grip or casing (if present) helps by providing a better grip to the user's hand.

This results in easier handling and control of the eraser, enhancing the user's ability to apply the eraser more effectively.

Frictional surface applies friction to the pencil marks, creating resistance that removes the marks. The result is an increase in the effectiveness of the eraser in removing the marks.

- **Instructions:** Step-by-step guidance for the user, and wait for User review in each step.
5. **Utilize Prompting Techniques:**
- **Technique:** Step-by-Step Execution to ensure clarity and coherence.
  - **Apply relevant to “Role prompting”** to provide detailed explanations through the introduction of scientific and engineering principles.
6. **Definition of User Expectations from Generative AI:**
- **Expectations:** A detailed analysis of the system, breaking down components into tools, actions, objects, results, and functions, and identifying the main useful function.
  - Refine the function table to align with the standard **verb-object** structure.
7. **Determination of Necessary User Inputs:**
- **Inputs:** A detailed description of the technical system and its components.
  - **User feedback:** Review input in each step
8. **Draft of Prompt:**
- **Combined Prompt:** Integrate all elements into a structured prompt.
9. **Iterative Prompt Refinement:** Test different arrangements of context, instructions, and examples to find the order that produces the most accurate and informative function analysis.
10. **Test with Diverse Problems:** Apply the refined prompt to various technical systems to assess the AI's ability to identify components, analyze interactions, and generate function tables. Evaluate the system's accuracy and efficiency. Ongoing testing is being conducted in fields such as automotive part manufacturing, wood drying processes, and with scientists and engineers from the food (meat), feed, and farming industries, as well as in agricultural engineering, paper production, and packaging processes.

**Generated Prompt: Function Analysis, Component Interaction Analysis**

*(This is 4th Prompt (September 2024): Full Transition to 10-Step Methodology)*

**Prompt:**

[Context]: Defining a Function

Function is an action performed by one Component to change or maintain a parameter of another Component. As shown in the following illustration, an object that performs a function is called the Function Carrier, while the object on which the function is performed is called the Object of the Function

[Example 1]: The main useful function of the airplane is **to transport** passengers and cargo efficiently from one geographic location to another by generating lift and thrust while maintaining stability, safety, and comfort throughout the flight.

The Interaction Analysis between each component identified in the Component Analysis of the airplane:

1. **Wings and Airflow:** The wings **generate** lift by interacting with the surrounding air. The shape of the wings (airfoil) causes air to flow faster over the top than the bottom, creating a pressure difference that lifts the airplane.
2. **Engines and Thrust:** The engines (jet or propeller) **generate** thrust by expelling air or gas at high speed. This thrust propels the airplane forward, overcoming drag.
3. **Control Surfaces and Flight Stability:** Control surfaces (rudders, ailerons, elevators) **change** the airplane's orientation (pitch, roll, and yaw) by interacting with the air. Pilots use these to steer the plane and maintain stability.
4. **Fuselage and Aerodynamics:** The fuselage **reduces** drag by interacting with the air. It houses the passengers, cargo, and avionics and is designed to be aerodynamic.
5. **Landing Gear and Ground:** The landing gear **provides** support during takeoff and landing by interacting with the ground to absorb the impact and provide stability on the runway.
6. **Cockpit and Avionics System:** The cockpit contains the avionics system, which **helps** the pilot **monitor and control** the airplane's position, speed, altitude, etc., by interacting with both the airplane and external systems (air traffic control, navigation).
7. **Hydraulic System and Control Surfaces:** The hydraulic system **actuates** control surfaces like ailerons, elevators, and the rudder by providing necessary power.

8. **Fuel System and Engines:** The fuel system **supplies** fuel to the engines, enabling them to generate thrust.

[Example 2]: The main useful function of the eraser is **to remove** pencil marks from paper by dislodging the graphite particles through friction, restoring the paper's original state.

The Interaction Analysis between each component identified in the Component Analysis of the eraser:

- **Eraser material dislodges** graphite particles by rubbing against the pencil marks, resulting in the removal of pencil marks from the paper, fulfilling the function of cleaning the surface.
- **Grip or casing** (if present) **provides** a better grip to the user's hand, resulting in easier handling and control of the eraser, enhancing the user's ability to apply the eraser more effectively.
- **Frictional surface applies** friction to the pencil marks, creating resistance that removes the marks, increasing the effectiveness of the eraser in removing the marks.

**[Instruction]:** Please follow instructions step by step.

Step 1: Ask the User "What is [Your interesting technical system]?" (Wait for User's Input).

Step 2: Identify scientific or engineering principles or technologies relevant to the interesting technical system. After this step, ask, "Do you need to add more details to the relevant principles?" to solicit user input (Wait for User input).

Step 3: [Component Analysis]: When analyzing the technical system, try to classify it into a super-system, technical system, and sub-system. By conducting a "**[Component analysis]**", could you please help me with the **[Component analysis]** of the **[Your interesting technical system]**? (Wait for User review).

Step 4: Analyze the "**[Interaction Analysis]**" between each component from the result of **[Component Analysis]**. Could you please help me analyze the "**interaction analysis**" of all the components that are part of the **[Your interesting technical system]**? (Wait for User review).

Step 5: In the **[Your interesting technical system]**, and its "**[Component Analysis]**"

and "[Interaction Analysis]", please write the **Function Analysis** of each component (by using information from Step 2, 3, and 4) where the **"Tool"** performs an **"Action"** to **"Object"** for [Your interesting technical system] in a tabulated format, including **"Tool," "Action," "Object," "Result,"** and **"Function."** Ensure that the **"Action"** column uses a **transitive verb ("to + transitive verb + object")** that clearly describes the physical action the **"Tool"** performs on the **"Object."**

Step 6: Conclusion of the **"Main Useful Function of [Your interesting technical system]."**

### **Previous Revision of Prompts Function Analysis, Component Interaction Analysis.**

#### **1<sup>st</sup> Prompt (May 2023)**

*When analyzing the technical system, I try to classify it into a super system, technical system, and sub-system. Additionally, I begin by conducting a 'component analysis.' Could you please help me with the component analysis of the Wood Pelleting machine?" Then, I try to analyze the interaction between each component: Feed Hopper, Conditioner, Pellet Mill (Die and Roller Assembly), Pellet Cooler, Pellet Sieve, Pellet Conveyor, Control System. Could you please help me analyze the 'interaction analysis' of all the components that are part of the Wood Pelleting machine Do you know "Wood Pelleting machine"? (wait for result, then next prompt)*

*In the "Pelletizing" process, Please write the function analysis ; ("Tool" action to "Object") for Wood pelleting Machine; in tabulated format including of "Tool" , "object", "The action between tool and object" and "Function of tool and object".*

#### **2<sup>nd</sup> Prompt (July 2023)**

##### **[Context]: Defining a Function**

*Function is an action performed by one Component to change or maintain a parameter of another Component. As shown in the following illustration, an object that performs a function is called the Function Carrier, while the object on which the function is performed is called the Object of the Function*

**[Example]:** *For example, the main function of a car is to move passengers and cargo.*

*The Targets of the car are passengers and cargo, and both belong to the Super-system.*

*The parameter change in the Targets is their physical location.*



*To identify the Targets of an Engineering System, first identify the main function by considering the main purpose for which that Engineering System is built. For example, a car may perform many functions, such as playing music or lighting the road, but its main function is to transport people and cargo from one place to another. The Targets are those components in the Super-system whose parameters change as a result of the main function.*

**[Example]:***For example, the main function of a toothbrush is to remove plaque from the teeth. Therefore, the Target of toothbrush is plaque and the parameter change in plaque is its location.*

**[Example]:***In the example of brushing teeth using a toothbrush, removing plaque qualifies as a function because: Both the toothbrush and the plaque are material objects There is interaction between the toothbrush and plaque The location of the plaque, which is a parameter value of plaque, is changed./*

**[Instruction] : Please following instruction step by step;**

*Component Analysis; When analyzing the technical system, I try to classify it into a super system, technical system, and sub-system. Additionally, I begin by conducting a “Component analysis” Could you please help me with the component analysis of the “Coffee Brewing Machine”? In the “Coffee Brewing Machine” and its “Component”, Please write the function analysis which the “Tool” action to “Object” for “Coffee Brewing Machine”; in tabulated format including of “Tool”, “Action”, “Object”, “Result” and “Function”.*

### **3rd Prompt (April 2024)**

**[Context]: Defining a Function**

*Function is an action performed by one Component to change or maintain a parameter of another Component. As shown in the following illustration, an object that performs a function is called the Function Carrier, while the object on which the function is performed is called the Object of the Function*

**[Example 1]:***the main function of an airplane is to transport passengers and cargo over long distances. The Targets of the airplane are the passengers and cargo, and both belong to the Super-system. The parameter change in the Targets is their geographic location. To identify the Targets of an Engineering System, first identify the main function*

by considering the main purpose for which that Engineering System is built. For example, an airplane may perform many functions, such as providing in-flight entertainment or serving meals, but its primary function is to move people and cargo from one geographic location to another efficiently. The Targets are those components in the Super-system whose parameters change because of the main function.

**[Example 2]:** the main function of an eraser is to remove pencil marks from paper. Therefore, the Target of the eraser is the pencil marks, and the parameter change in pencil marks is their visibility.

**[Example 3]:** In the example of using an eraser, removing pencil marks qualifies as a function because; Both the eraser and the pencil marks are material objects, there is interaction between the eraser and the pencil marks, The location of the pencil marks, which is a parameter value of the marks, is changed.

**[Instruction]: Please follow instructions step by step.**

- Step 1: Ask the User What is **[Your interesting technical system]**? / (Wait for User's Input).
- Step 2: [Component Analysis]; When analyzing the technical system, try to classify it into a super system, technical system, and sub-system. By conducting a "[Component analysis]" Could you please help me with the [Component analysis] of the **[Your interesting technical system]**?
- Step 3: Analyze the [Interaction Analysis] between each component from the result of [Component Analysis], Could you please help me analyze the "interaction analysis" of all the components that are part of the **[Your interesting technical system]**?
- Step 4: In the **[Your interesting technical system]**, and its "Component Analysis] and [Interaction Analysis],", Please write the function analysis which the "Tool" action to "Object" for **[Your interesting technical system]** in a tabulated format including of "Tool", "Action", "Object", "Result" and "Function".

### **Analysis of Prompt Development:**

(Remark: Prompt after April 2024: Transitional Phase – Shift Toward 10-Step Methodology)

### **Function Analysis, Component Interaction Analysis**

### **1. From Simple Guidelines to Structured Function Analysis:**

The development of the "Function Analysis with Component Interaction Analysis" prompt shows a clear progression from the "Think Before Prompt" guideline to the structured, process-driven 10-step methodology. In the 1st Prompt (May 2023) and 2nd Prompt (July 2023), the prompts were simplistic, providing basic instructions for component analysis and function description without comprehensive guidance or structure. By the 3rd Prompt (April 2024), in response to feedback, the transition begins toward more rigorous function analysis, with a clearer definition of interactions and a structured format for "Tool-Action-Object." The 4th Prompt (September 2024) fully embraces the 10-step methodology, incorporating detailed steps, engineering principles, and a focus on the main useful function, bringing depth and rigor to the analysis.

### **2. Addressing Feedback on Format and Detail:**

After the release of the 2nd Prompt, feedback highlighted an issue with the wrong format of Tool-Act-Object and insufficient detail in the function analysis. These problems stemmed from the lack of clarity in how the AI should structure its analysis. The 3rd Prompt (April 2024) addressed this by refining the structure, adding a step-by-step breakdown for function analysis, and ensuring that the AI correctly follows the Tool-Action-Object format. The 4th Prompt (September 2024) built upon this by introducing a final step to identify the system's main useful function, providing users with a more comprehensive and accurate analysis.

### **3. Scientific and Engineering Principles Integration:**

The early prompts (May and July 2023) lacked specific guidance on incorporating scientific or engineering principles into the function analysis. Feedback from testing across industries, particularly in the IT sector, revealed that the lack of these principles led to incorrect or incomplete function analysis. In the 4th Prompt (September 2024), this gap is addressed by explicitly instructing the AI to incorporate scientific and engineering principles relevant to the system. This improves the accuracy and applicability of the analysis, grounding the AI's output in domain-specific knowledge and making the function analysis more robust.

### **4. Expanding Testing and Scope:**

The early versions of the prompt were tested primarily within industries like Automotive part manufacturing and Agricultural engineering equipment, food processing and packaging, which may have contributed to narrow feedback. As testing expanded in the 3rd Prompt (April 2024) to sectors like IT, new insights emerged about the wrong details in function analysis. This feedback loop led to the integration of engineering principles and the addition of a final step defining the main function. The broader scope of testing ensured that the prompt could handle diverse technical systems and address the varying needs of different industries.

### **5. Human-in-the-Loop Feedback and Continuous Refinement:**

In the 3rd Prompt (April 2024), human feedback became a more prominent part of the process, as engineers and users from different sectors could interact with the AI and provide real-time feedback, particularly on format and detail issues. This human-in-the-loop approach enabled continuous refinement of the prompts. Engineers could test the AI's analysis in real-world scenarios (e.g., in wood drying processes or agricultural machinery), provide corrections, and see improvements in the subsequent versions. This feedback loop is crucial for refining complex analyses like function and component interaction.

### **Example 2. Root Cause Analysis with Generative AI.**

#### **1. Identification of TRIZ Tool and Objective:**

- **Tool:** Root Cause Analysis (RCA)
- **Objective:** To systematically identify the underlying causes of an engineering problem, enabling the user to implement effective solutions to prevent recurrence.

#### **2. Instruct the AI to Understand the Tool:**

- **Explanation:** Root Cause Analysis is a systematic process used to identify the fundamental cause of a problem or fault. By understanding the root cause, organizations can address these issues effectively and prevent them from occurring in the future.

#### **3. Specification of Traditional TRIZ Tool Usage Steps:**

- **Steps:**

1. Define the engineering problem.
  2. Identify relevant scientific or engineering principles.
  3. Determine the necessary expertise to analyze the problem.
  4. Analyze potential root causes.
  5. Provide investigation guidelines.
  6. Suggest containment, corrective, and preventive actions.
4. **Select and Craft Relevant Prompt Elements:**
    - **Context:** Clear definition of the problem and steps for RCA.
    - **Examples:** Provide illustrative examples to clarify each step.
    - **Instructions:** Step-by-step guidance for the user.
  5. **Utilize Prompting Techniques:**
    - **Technique:** Step-by-Step Execution to ensure clarity and coherence.
    - **COT:** Use result of previous step 1,2,3 as input of step 4,5,6 / Use result of step 4 as input of step 5, 6.
    - **Role Prompting;** Use detail of “problem statement” to indicate “relevant principles and expertise”.
  6. **Definition of User Expectations from Generative AI:**
    - **Expectations:** A detailed Root Cause Analysis, identifying the primary cause of the problem and suggesting corrective actions.
    - **Investigation guideline** for “Human in a Loop” and re-analysis by investigation data.
  7. **Determination of Necessary User Inputs:**
    - **Inputs:** A comprehensive description of the engineering problem, including observations and initial investigation results.
  8. **Draft of Prompt:**
    - **Combined Prompt:** Integrate all elements into a structured prompt.
  9. **Iterative Prompt Refinement:** Test different arrangements of context, instructions, and examples to find the order that produces the most accurate and informative Root Cause Analysis.

10. **Test with Diverse Problems:** Apply the refined prompt to various engineering problems, assessing the AI's ability to identify root causes and suggest corrective actions. Evaluate accuracy, efficiency, and practicality of solutions.

**Generated Prompt:**

**[Context]: Root Cause Analysis (RCA)**

(This is 3rd Prompt (April 2024): Transitional Phase to 10-Step Methodology)

**[Context]** Root Cause Analysis (RCA) is a systematic process used to identify the underlying causes of a problem or fault, allowing an organization to address those causes effectively. The main goal of RCA is to determine why a problem occurred in the first place and how to prevent it in the future.

**[Instruction]** The process involves key steps, Following Step-by-Step;

**Step 1.** Ask the User for What is **[Your Interesting Engineering Problem]?**, (Wait for User's Input). *(Note to User: Providing more detailed explanations of the problem, clearly identifying relevant observations, and including the results of your investigation will lead to a well-analyzed outcome.)*

**Step 2.** Identifying scientific or engineering principles relevant to the observed problem or defect. After this step, then ask, "Do you need to add more details to the relevant principles?" to solicit user input, (Wait for User input).

**Step 3.** Determining the expertise required to analyze the problem effectively. Upon completing this step, then ask "Do you need to add more expertise?" allowing the user to contribute further information, (Wait for User input)]

**Step 4.** Analyzing potential root causes from the perspective of the "identified principles" and "expertise". Present its findings in a tabulated format for clarity and comprehensive analysis.

**Step 5.** Investigation Guidelines: To aid in the validation of potential root causes, provide guidelines for conducting detailed investigations, In a tabulated format. These include methods for collecting and analyzing data (Frequency and quantity if possible), testing hypotheses, relevant tools or specific analysis equipment, relevant investigation procedures, and documenting evidence. After presenting these

guidelines, Ask, "Do you have additional methods or tools to suggest?" to integrate user expertise further.

**Step 6.** Provide containment actions, and corrective and preventive actions from the analyzed potential root causes and present its findings in a tabulated format for clarity and comprehensive analysis.

### **Previous Revision of Prompts Function Analysis, Component Interaction Analysis.**

*1<sup>st</sup> Prompt (May 2023)*

*Prompt:*

*We found the warping problem of corrugated board which use for corrugated-box. Between the process of corrugated board and waiting for printing. The stack of corrugated-board is placed on the floor of the factory. Mostly warping corrugated-board are on top of stacking around 10 percent of the corrugated board. Could you please explain what are the potential root causes of this problem?*

*2<sup>nd</sup> Prompt (July 2023)*

*Prompt:*

*[Problem Statement]*

*The PCB is composed of several layers:*

- 1. Polyamide*
- 2. Copper*
- 3. Nickel*
- 4. Gold*

*The nickel and gold layers are applied through a plating process. At the customer's request to reduce costs, the nickel-plating process was eliminated. After a month of storing the product before production, the customer discovered an issue with the PCBs that did not undergo nickel plating. The surface of the gold layer exhibited what appeared to be rust. Upon investigation, the engineering team used a spectrometer to analyze the particles and determined that the substance was copper, not rust. The engineer informed the customer that the issue was due to copper migrating through the gold surface, as copper was layered between the polyamide and gold.*

*[Instruction #1]*

*Which scientific principles or theories should we apply to investigate the defect?*

*[Instruction #2]*

*Analyze the potential root causes from the perspectives of:*

- 1. Chemical Engineer*
- 2. Mechanical Engineer*
- 3. Metallurgist*

### **Analysis of Prompt Development:**

*(Remark: Prompt after April 2024: Transitional Phase – Shift Toward 10-Step Methodology)*

### **Root Cause Analysis (RCA)**

1. From Simple Guidelines to Structured RCA: The evolution from "Think Before Prompt" to the 10-step methodology shows a transition from loosely defined problem-solving prompts to structured, process-driven RCAs. The initial versions lacked the depth and methodological guidance needed for complex problems, while the 3rd version begins to address these shortcomings.
2. Handling Hallucination: Feedback from the 1st prompt indicated that hallucination was a problem, likely due to the lack of structured guidance for identifying relevant scientific principles. In the 3rd version, this issue is mitigated by prompting the user for more detailed information and principles, ensuring a more grounded analysis.
3. Expertise and Scientific Principles: In the 2nd prompt, the introduction of expertise from multiple disciplines improved the depth of analysis, but the AI still lacked guidance in selecting the correct principles. In the 3rd prompt, the AI asks for relevant principles and allows for further refinement based on user feedback, leading to more accurate and applicable insights.
4. Human-in-the-Loop: By incorporating human involvement in the 3rd prompt, the process becomes more dynamic. Engineers can interact with the AI in a continuous loop, investigating on the ground and refeeding observations back to the AI. This enhances the reliability of the analysis and prevents the AI from operating in isolation.



## 7.2 Case Study.

The following case studies demonstrate the practical application of prompts generated by the "Algorithm for Integrating Generative AI with TRIZ Tools." These examples underscore the effectiveness of this approach in enhancing problem-solving analyses, root cause investigations, and systems analyses:

- Case Study 1: Application of Function Analysis to a Texturizer in a plant-based food production facility.
- Case Study 2: Investigation of soldering defects (voids) using Root Cause Analysis.

In addition, further case studies will be presented, highlighting other key areas of the integration:

- Case Study 3: Generation of novel ideas through resource enhancement, leveraging the 40 Inventive Principles tool.
- Case Study 4: Identification of inventive resources in communication-related tasks, with potential applications extending beyond engineering fields.
- Case Study 5: Exploration of adjacent markets through inventive problem-solving techniques.
- Case Study 6: Function Redirection: Solving problems or generating ideas by breaking down main goal or target into smaller auxiliary functions and identifying alternative or creative ways to achieve it.

Each case study emphasizes the integration of Generative AI capabilities with either traditional TRIZ tools or methodologies grounded in TRIZ principles.

*(In the [Case Study], the presented prompt result was artificially generated using Generative AI.)*

**Case Study 1.** Application of Function Analysis to a Texturizer in a plant-based food production facility.

**Problem Statement:** The seller, with limited experience, must thoroughly understand both the overall function of the texturizer machine and its individual components to accurately meet the specific equipment requirements of a plant-based food production factory. Ensuring the equipment delivers the necessary functionality and performance is

crucial for producing plant-based products that replicate the texture of meat or other desired textures.

**Prompt : Function Analysis, Component Interaction Analysis (Refer Prompt to 7.1)**

**User Input :** “Texturizer machine in plant-based” in Step 1

**Result :**

The key scientific and engineering principles involved include:

- **Extrusion technology:** The machine uses a combination of heat and mechanical forces to change the physical structure of plant proteins.
- **Thermodynamics:** Control of temperature is essential to ensuring the correct texture formation.
- **Shear forces:** These are used to align proteins in the desired structure, which gives the final product a meat-like texture.
- **Material science:** Understanding the behavior of plant proteins under these conditions helps in selecting the right ingredients for texturization.
- This table outlines how each component (the "Tool") performs its specific action on the relevant "Object" in the texturizer machine, resulting in specific outcomes that contribute to the overall function of producing plant-based food products.

<b>Tool</b>	<b>Action</b>	<b>Object</b>	<b>Result</b>	<b>Function</b>
Feeding system	To transport ingredients	Raw plant-based materials	Continuous supply of ingredients	Ensures consistent input of raw materials for processing
Heating system	To heat	Plant-based ingredients	Proteins denature and become flexible	Prepares proteins for further processing by denaturing them
Screw conveyor (extruder)	To move and shear	Heated ingredients	Proteins are aligned, forming fibrous texture	Mechanically aligns proteins for meat-like structure
Pressure system	To apply pressure	Extruding material	Proteins take on dense, meat-like consistency	Helps in protein structuring through compression
Cooling system	To cool	Extruded product	Solidifies the structure of the product	Stabilizes the final texture of the product

Control panel	To regulate	Machine systems	Monitors and adjusts temperature, pressure, etc.	Maintains consistent operational parameters
Discharge system	To release	Final processed material	Final product exits for packaging or further use	Ejects the processed plant-based material

The main useful function of the texturizer machine in plant-based food production is to transform raw plant-based proteins into a meat-like texture through the combined application of heat, pressure, and mechanical shear. This process creates a structured, fibrous product that mimics the texture of animal meat. The machine achieves this by denaturing and aligning plant proteins, stabilizing the texture through controlled cooling, and ensuring the processed material is ready for further packaging or consumption. The machine enables efficient production of high-quality plant-based meat alternatives with desirable texture, consistency, and structure.

**Observation** for Function Analysis, Component Interaction Analysis.

Generative AI offers significant time savings, but expert review remains crucial. While experts may not directly operate these systems, they can rigorously assess them using scientific and engineering principles. Even with Generative AI capable of linking results to automatic diagram creators, there's a risk of human oversight in analyzing interesting system aspects. Manual diagram creation is still recommended by the author.

**Case 2.** Investigation of soldering defects (voids) using Root Cause Analysis.

**Problem Statement:** The company needs to identify and resolve the root causes of soldering defects (Void) in electronic circuit board assembly to improve product reliability and production efficiency.

**Prompt : Root Cause Analysis** (Refer Prompt to 7.1)

**User Input : Step 1: Define the Engineering Problem**

**“Engineering Problem:** The company is experiencing soldering defects, specifically voids, in electronic circuit board assemblies. These voids compromise the reliability and performance of the final products. The problem is observed during the manufacturing process and has been linked to various potential factors. Preliminary findings suggest

that the voids may be due to issues such as improper solder paste application, inadequate heating profiles, contamination, or improper board design.

**Observations:**

- Increased frequency of solder voids in recent production batches.
- Voids detected through X-ray inspection of assembled boards.
- Affected boards exhibit intermittent connections and performance issues.
- Voids are observed in various locations, not confined to specific components.

**Context:**

- Occurs in a high-volume electronic manufacturing environment.
- Production involves automated solder paste application, pick-and-place of components, and reflow soldering.”

*(To convert the "problem statement" into a well-defined "Engineering Problem," utilize the following prompt: "Problem Review and Definition" [Appendix 1])*

**Result :**

**Potential Root Cause**

Potential Root Cause	Description	Relevant Principles	Expertise Involved
<b>Improper Reflow Temperature Profile</b>	Insufficient or uneven heating during reflow may result in incomplete outgassing or improper wetting.	Thermal Transfer, Reflow Soldering, Surface Tension in Molten Solder	Thermal Engineering, Process Engineering
<b>Contamination on PCB or Components</b>	Presence of contaminants (dust, oil, moisture) can prevent proper solder wetting and result in voids.	Contamination, Solder Paste Chemistry, Surface Tension	Contamination Control, Materials Science, Quality Control
<b>Inconsistent Solder Paste Application</b>	Solder paste applied unevenly or in excess can lead to trapped flux or air, forming voids.	Solder Paste Chemistry, Surface Tension, Outgassing	SMT Process Engineering, Materials Science
<b>Improper Solder Paste Composition</b>	Incorrect flux or paste composition may affect the reflow process, leading to poor solder joint formation.	Solder Paste Chemistry, Outgassing, Flux Behavior	Materials Science, Process Engineering
<b>Improper</b>	Poor design features like pad	PCB Design, Thermal	PCB Design

<b>PCB Design (Pad/Via Placement)</b>	geometry or via location can trap air or cause uneven heating.	Transfer, Reflow Profile	Engineering, Process Engineering
<b>Flux Insufficiency or Inactivation</b>	Inadequate flux or improper flux activation can result in poor surface cleaning and outgassing, causing voids.	Flux Behavior, Outgassing, Solder Paste Chemistry	Materials Science, SMT Process Engineering
<b>Reflow Oven Malfunction or Calibration</b>	Reflow oven not functioning correctly or miscalibrated, causing inconsistent heating profiles.	Thermal Transfer, Reflow Soldering	Thermal Engineering, Process Engineering
<b>Moisture in the PCB or Solder Paste</b>	Excess moisture absorbed in PCBs or solder paste can turn to steam during reflow, creating voids.	Contamination, Outgassing, Solder Paste Chemistry	Contamination Control, SMT Process Engineering

### Investigation guidelines

Investigation Step	Description	Method/Tool	Frequency	Documentation
Analyze Reflow Profile	Verify if the reflow oven temperature profile matches the required specifications.	Temperature profiling tool (thermocouples)	Measure for multiple batches	Document reflow profiles with temperature data
Inspect for Contamination	Check PCBs and components for signs of contamination (e.g., dust, oils, moisture).	Visual inspection, ion chromatography	Inspect batches before soldering	Document contamination levels and cleaning procedures
X-Ray Inspection of Solder Joints	Use X-ray inspection to measure the size, location, and frequency of voids in solder joints.	X-ray machine	Random sample of boards	Capture X-ray images and analyze void patterns
Evaluate Solder Paste	Measure solder paste volume and consistency	3D SPI (Solder Paste)	Random samples	Log paste volume data

Application	across boards to ensure uniform application.	Inspection)	during application	and report inconsistencies
Test Solder Paste Composition	Check for any inconsistencies in the solder paste formulation, including flux content.	Solder paste analysis lab tests	Test paste samples from affected lots	Record test results and compare with manufacturer specs
Check PCB Design for Layout Issues	Review PCB layout (pads, vias, trace spacing) to identify design flaws that may cause voids.	PCB design software and physical inspection	Review design documents for affected boards	Document layout issues and design feedback
Verify Reflow Oven Calibration	Ensure that the reflow oven is correctly calibrated and functioning as expected.	Calibration tools, reflow oven diagnostic tools	Check calibration regularly	Record calibration logs and maintenance records
Moisture Testing in PCBs and Solder Paste	Test for moisture content in PCBs and solder paste, especially if boards are stored improperly.	Moisture analysis (TGA or humidity test)	Test affected lots	Record moisture levels and storage conditions
Investigate Flux Activation	Verify that flux activation temperature and time are appropriate for cleaning and outgassing.	Thermal profiling with flux analysis	Test during reflow	Document flux activation findings and temperature curves

**Observation** for Root Cause Analysis.

In the development of the Root Cause Analysis prompt, it became apparent that the quality of the AI-generated response was highly dependent not only on the prompt itself, but also on the clarity and specificity of the problem description provided by the user.

This recognition led to the creation of the "Problem Review and Definition" prompt, designed to assist users in formulating a more refined and precise problem statement.

However, it's important to emphasize that the process of root cause analysis, including both the initial problem definition and the subsequent investigation, remains a task best suited for human execution. This aligns with the principles of TRIZ (Theory of Inventive Problem Solving), which stresses the importance of thoroughly defining and analyzing a problem before attempting to generate solutions. In the TRIZ framework, a well-structured problem statement is considered a prerequisite for effective problem-solving and innovation.

**Case Study 3:** Generation of novel ideas through resource enhancement, leveraging the 40 Inventive Principles tool.

**The concept of this tool** is to modify resources (substance, field, time, space, information, and function) in an existing system by applying idea generation techniques (using the 40 principles) to address a goal, key problem, or contradiction

**Problem Statement:** The production of pelletized animal feed involves a cutting process that generates dust. While this dust is typically recycled by mixing it back into the raw materials, this practice leads to quality issues. Feed pellets made from these dust-containing raw materials exhibit poor adhesion, increased brittleness, and a tendency to break easily. These characteristics result in a product that falls short of customer expectations and quality standards.

**Prompt :** See Appendix 1. Prompt : Systematic Idea Generation

**User Input :**

1. Problem Statement and
2. Modification Goal = **Key Problem of Technical Contradiction:**

How can we recycle dust into the raw materials to **increase material efficiency** without causing **poor adhesion and brittleness** in the feed pellets?

**Result :**

**Modifying Resources Using TRIZ Principles**

Resource Category	Resource/ Component or Parameter	TRIZ Principle	Modified Result
Substance Resources	Dust particles	Principle 1: Segmentation	Modify dust to smaller particle sizes, allowing them to integrate better with the

			raw materials without affecting the final product's brittleness.
		Principle 35: Parameter changes	Adjust moisture content of the dust to match raw material moisture for improved adhesion and strength.
	Binders	Principle 5: Merging	Introduce a secondary binding agent specifically for dust particles, improving adhesion without affecting the main material's properties.
	Raw materials	Principle 29: Fluidity	Pre-treat raw materials and dust together in a fluid-like mixture before pelletizing, ensuring better integration and adhesion.
<b>Field Resources</b>	Mechanical force (compression)	Principle 3: Local quality	Apply increased compression at specific stages when dust is mixed in to enhance adhesion of dust particles without damaging the main structure.
<b>Time Resources</b>	Pelletizing time	Principle 10: Prior action	Extend the pre-mixing time of dust and raw materials to ensure better integration before pelletizing, improving pellet cohesion.
<b>Space Resources</b>	Mixing chamber	Principle 17: Another dimension	Modify the location or angle where dust is mixed with raw materials in the chamber to enhance the uniformity of the mixture.
<b>Information Resources</b>	Recipe/formula for raw materials	Principle 28: Mechanics substitution	Develop an automated system to measure and adjust dust-to-raw material ratios based on quality feedback in real time.
<b>Functional Resources</b>	Binding agent application	Principle 13: The other way round	Instead of adding binder to the raw material, apply binder directly to the dust before mixing to improve the cohesion of dust particles.

**Observation** for Systematic Idea Generation (Modifying Resources).

We can integrate the capabilities of Generative AI with the TRIZ methodology to serve as an assistant in team efforts for generating novel ideas. This approach does not rely on random text generation from Large Language Models (LLMs) directly. Instead, it



leverages the outcomes of two primary TRIZ tools: Resources and the 40 Inventive Principles.

**Case 4** Identification of inventive resources in communication-related tasks, with potential applications extending beyond engineering fields.

**The concept of this tool** : adapt the principles of TRIZ (a problem-solving methodology originally developed for engineering) for non-engineering domains. It focuses on identifying resources that can be leveraged in areas such as nursing, education, communication, or personnel management.

**Problem Statement:** Social Creative Media Business: This enterprise focuses on generating ideas to transform harmful news into useful content. They aim to identify sources of inventive resources from a media business perspective.

**Prompt** : See Appendix 1. Prompt : Resource for Non-Engineering

**User Input** : “Social Creative Media Business” or Use Problem Statement as input

**Result** :

**Types of Resources in Social Creative Media Business**

Type of Resource	Definition	Examples
<b>Content</b> (Substance in TRIZ)	All forms of information, media, and raw materials (like news articles, reports, images, videos, and social posts) that can be transformed into new, meaningful content.	- News reports of crises repurposed into informative articles highlighting positive community responses.
		- Harmful social media trends re-contextualized to promote awareness and solutions.
<b>Audience Attention</b> (Field in TRIZ)	The engagement, attention span, and emotional response of the audience, which can be harnessed to amplify positive messages.	- Using interactive formats (polls, videos) to engage users in a discussion about how to respond to divisive issues.
		- Analyzing audience emotional triggers and steering content that

		resonates in constructive ways.
<b>Platform Space</b> (Space in TRIZ)	The digital environments or channels where content is distributed, such as social media platforms, websites, or apps. Maximizing visibility and interaction on these platforms.	- Using specific social media algorithms to target users with positive content.
		- Creating spaces (forums, social media groups) for discussions that shift negativity into solution-focused conversations.
<b>Time</b>	The timing of content creation and distribution, which impacts how well the content is received and shared. Timing is key in transforming harmful news into timely, useful content.	- Posting content that transforms negative news into actionable advice immediately after a crisis.
		- Scheduling inspirational posts during peak engagement times when audiences are more receptive to positive messaging.
<b>Audience Feedback and Interaction</b> (Information in TRIZ)	The data gathered from audience reactions, comments, likes, and shares that can be analyzed to improve future content. This resource can provide insights into what types of messages resonate.	- Tracking which posts on sensitive topics generate the most constructive conversation.
		- Using feedback loops (surveys, polls) to shape content strategies, ensuring harmful news is reframed into useful formats.
<b>Creative Talent</b> (Functions in TRIZ)	The skills, creativity, and perspectives of content creators, writers, designers, and social media managers who transform harmful news into meaningful content.	- A creative team that brainstorms solutions-focused news angles.
		- Writers who specialize in reframing negative stories into positive case studies or thought-provoking op-eds.

Table 7: Resource for Non-Engineering : Social Creative Media Business

**Observation** for Resource for Non-Engineering.

This prompt can help apply the concept of resources in TRIZ to fields beyond engineering, assisting in the identification of resources to generate new ideas.

**Case Study 5:** Exploration of adjacent markets through inventive problem-solving techniques.

**The concept of this tool :** Explore new business opportunities by identifying adjacent markets for their products or services. It uses a method called *Function-Oriented Search (FOS)*, which focuses on defining the core function of a product or system and abstracting it to explore how similar functions are performed in other industries.

**Problem Statement:** A construction materials manufacturing company with a highly capable maintenance engineering department wants to expand its business but is unsure of the industry to target. The company seeks to identify potential industries where its advanced maintenance engineering capabilities can be leveraged for business expansion, understanding market needs, and competition.

**Prompt :** See Appendix 1. Prompt : Adjacent markets by leveraging the Function Oriented Search (FOS)/ Reversed Function-Oriented Search (RFOS).

**User Input :** Define the Core Function by refer to “Problem statement”

**Result :**

**Recommend for Adjacencies**

Industry/Domain	Specific Function Similarity	Key Technologies/Methods Employed	Core Operating Principles/Science Utilized
Aerospace	Maintaining and optimizing aircraft systems for safety, reliability, and longevity	Predictive maintenance, AI-driven diagnostics, advanced materials	Aerodynamics, materials science, reliability engineering
Automotive Manufacturing	Ensuring optimal performance of production lines and vehicle maintenance	Robotics maintenance, IoT sensors, data analytics	Lean manufacturing, robotics engineering, production line optimization
Energy (Oil & Gas,	Maintaining power	Remote monitoring,	Energy management,

Power)	generation and distribution systems	preventive maintenance, condition-based monitoring	mechanical engineering, thermodynamics
Healthcare/Medical Devices	Ensuring the reliability of medical devices for patient care	Equipment calibration, real-time monitoring, maintenance protocols	Biomedical engineering, quality control, device reliability
Railway/Transportation	Maintaining rail and transport systems for safety and performance	Real-time diagnostics, remote monitoring, automated repair systems	Transportation engineering, predictive maintenance, system safety
General Manufacturing	Maintaining industrial machinery for smooth production	Condition monitoring, predictive analytics, lean maintenance	Mechanical engineering, production efficiency, system monitoring
Mining	Ensuring heavy machinery performance for continuous operation	Heavy equipment diagnostics, wear-and-tear monitoring	Industrial mechanics, earth-moving engineering, heavy equipment reliability
Data Centers/IT	Maintaining IT infrastructure for uninterrupted service	Environmental monitoring, server diagnostics, maintenance automation	IT operations, cooling system management, hardware diagnostics

**Observation** for Adjacent markets by leveraging the Function Oriented Search (FOS). While this approach leverages expertise to identify new market opportunities, it remains primarily a qualitative assessment. Although it involves measuring market size, which has a partly quantitative aspect, and evaluating the potential for applying expertise, the overall process is largely subjective. Nevertheless, it can serve as a valuable tool for idea generation. Further development is possible by incorporating AI prompts, particularly those that retrieve real-time, quantitative data.

**Case Study 6: Function Redirection:** Solving problems or generating ideas by breaking down main goal or target into smaller auxiliary functions and identifying alternative or creative ways to achieve it.

**The concept of this tool :** Using AI analyze the main function and identify auxiliary functions or sub-tasks that could help achieve the main goal through a "redirection of function" approach.

**Problem Statement:** A company wants to reduce the drying time for high-moisture natural materials to achieve a dry state. The company needs to optimize the drying process of natural materials with high moisture content to minimize drying time while maintaining material quality.

**Prompt :** See Appendix 1. Prompt : Function Redirection

**User Input :** Define the Core Function by refer to “Problem statement”

**Result :**

<b>Auxiliary Function</b>	<b>Description</b>	<b>Resources Required</b>
<b>1. Pre-treatment of materials</b>	Reduce initial moisture by mechanical means (e.g., pressing, centrifuging) to shorten drying time.	Presses, centrifuges, mechanical drying equipment
<b>2. Optimize airflow and heat distribution</b>	Use uniform airflow and precise heat control to avoid over-drying or uneven moisture removal.	HVAC systems, smart temperature sensors, fans
<b>3. Divide materials into smaller batches or layers</b>	Drying smaller quantities in thin layers helps reduce drying time and ensures uniform moisture reduction.	Drying trays, batch processing units
<b>4. Utilize energy-efficient heating techniques</b>	Implement methods like microwave drying or infrared drying to speed up moisture removal without compromising material quality.	Microwave heaters, infrared lamps
<b>5. Monitor real-time moisture content</b>	Use sensors to track moisture levels continuously and adjust drying parameters accordingly.	Moisture sensors, smart controllers
<b>6. Control humidity of drying environment</b>	Maintain lower humidity to increase drying efficiency by enhancing evaporation rates.	Dehumidifiers, environmental control systems

<b>7. Alternate drying methods (vacuum, freeze drying)</b>	Consider advanced drying methods like vacuum drying to maintain quality by reducing drying time and preserving the structure of materials.	Vacuum dryers, freeze dryers
<b>8. Implement recirculation of drying air</b>	Recirculate hot air to maintain efficient drying temperatures while minimizing energy usage.	Air recirculation systems, heat exchangers

Table 8: Function Redirection: drying process

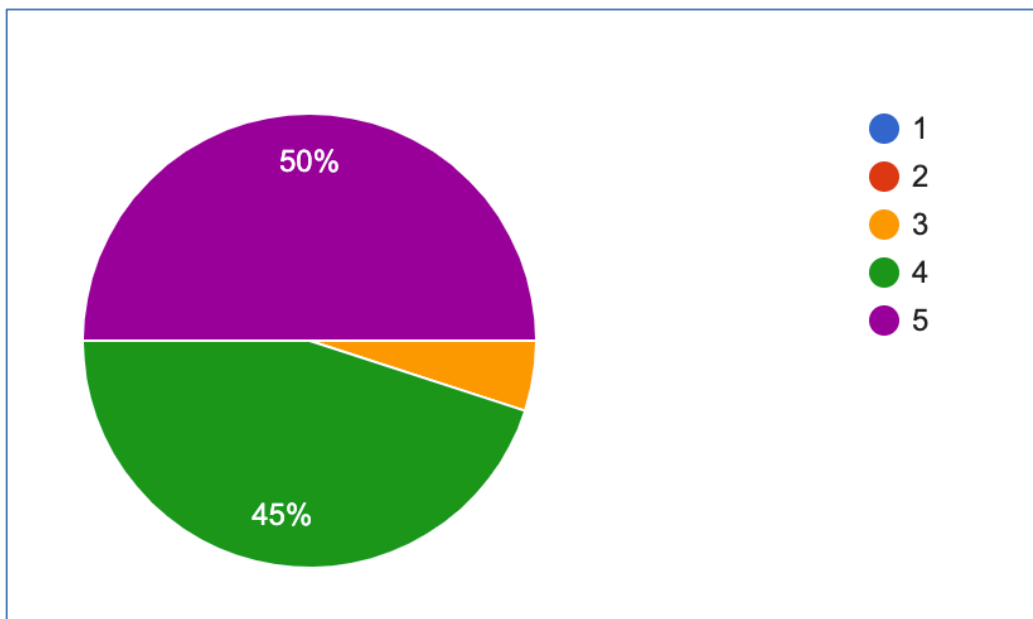
**Observation** for Function Redirection.

This idea represents an initial development that can be applied and further enhanced. Before the era of Generative AI, significant time was spent compiling a database of Auxiliary Functions that interact with other Auxiliary Functions, both in the context of diverse thinking and invention resources. However, AI-generated results must always be verified for accuracy and feasibility.

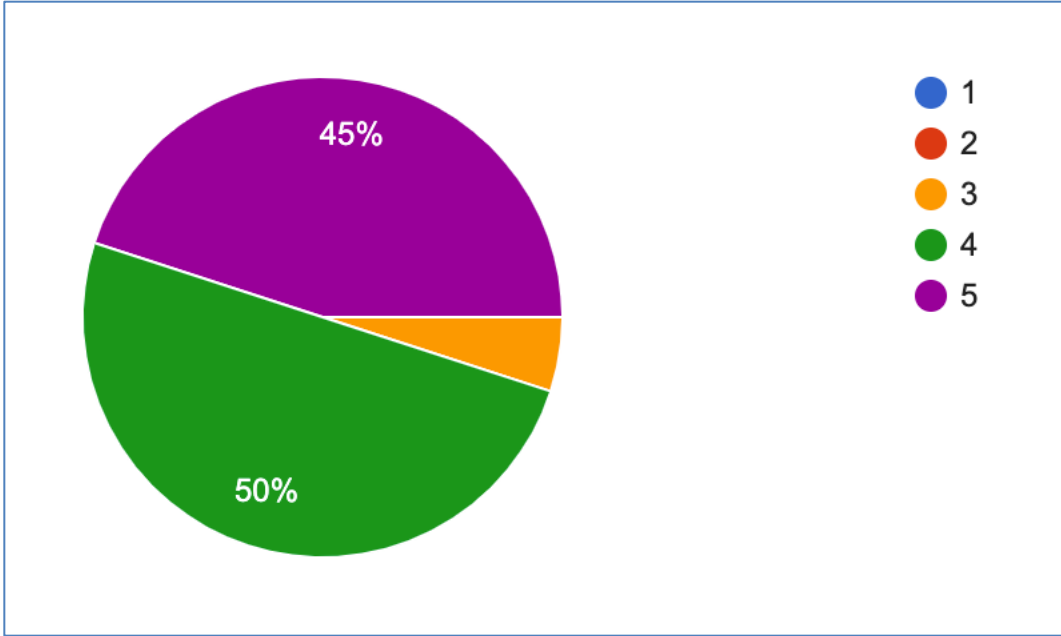
### 7.3 Survey Results.

These 2nd questionnaires were designed for individuals with selected TRIZ experience and familiarity with Generative AI, from 3 companies and 1 faculty of nursing, that have employed both TRIZ and Generative AI assistance since last year. We received 20 responses out of a target of 40. The respondents have already tested the TRIZ Prompts to provide deeper insights into how different user groups perceive and interact with AI-powered TRIZ tools.

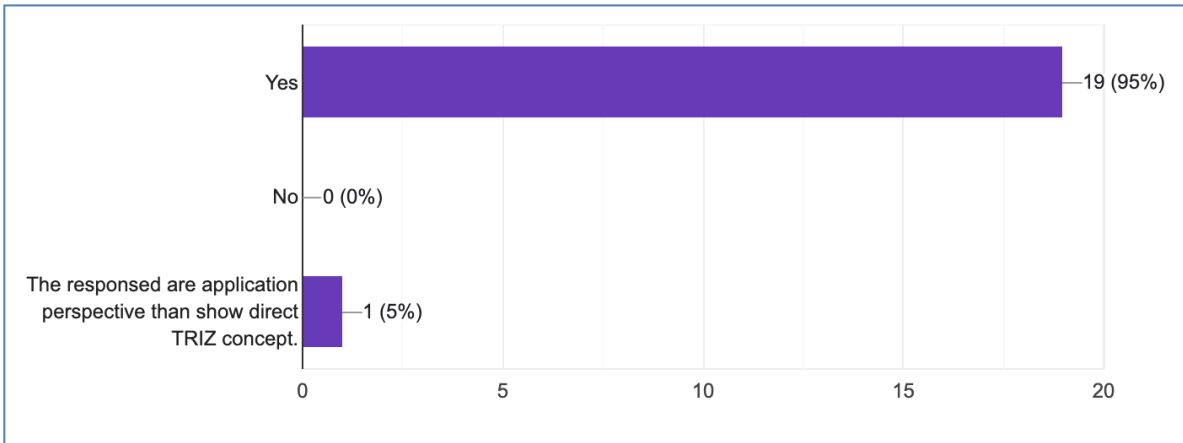
1. To what extent did the AI's output directly address the core function or objective of the TRIZ tool? (Scale: 1-5, 1 being not at all, 5 being completely).



2. How well did the AI's output tailor to the specific problem context presented in the case study? (Scale: 1-5).

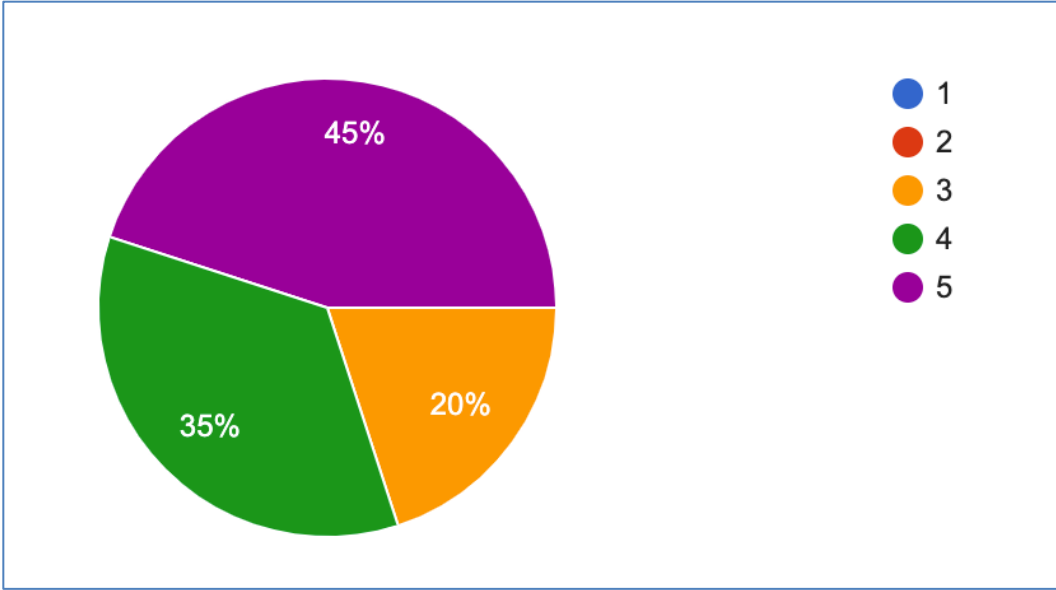


3. Did the AI's output demonstrate an understanding of the underlying principles and concepts of the TRIZ tool? (Yes/No, with space for elaboration).

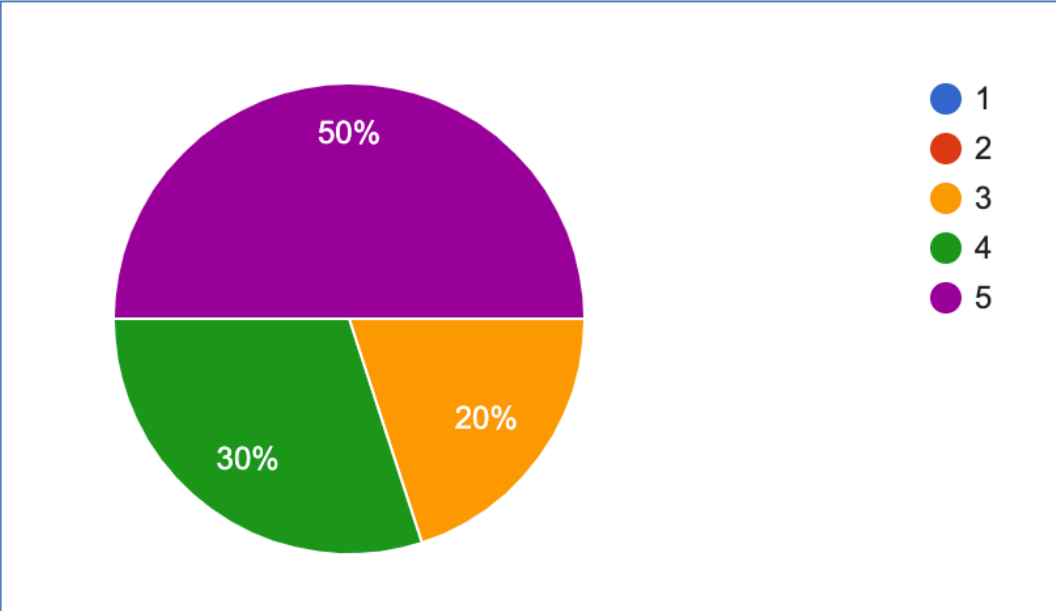


4. How technically feasible and realistic were the AI-generated solutions or insights within the given constraints? (Scale: 1-5).

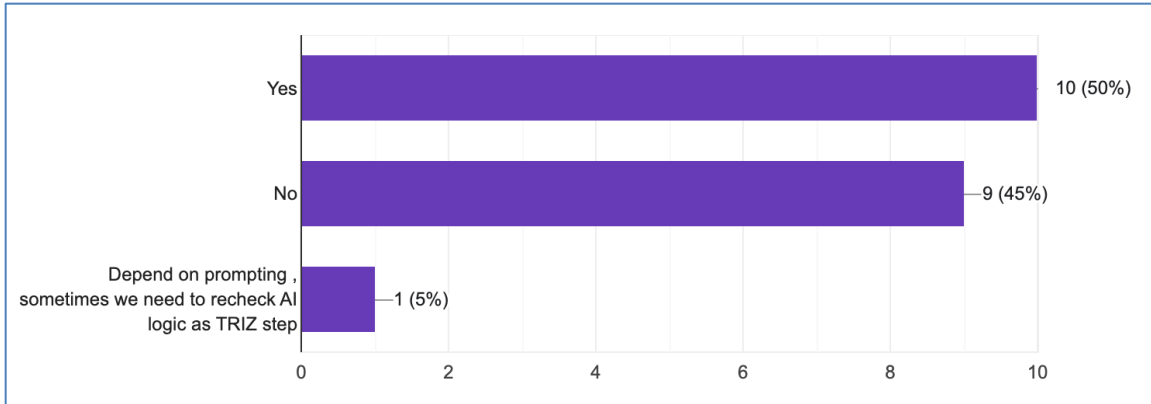




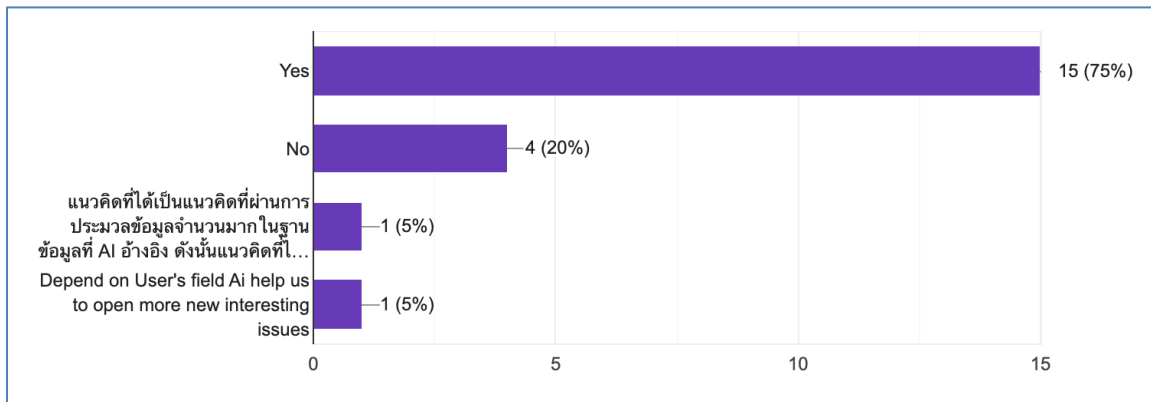
5. To what extent did the AI's output align with established engineering knowledge and best practices? (Scale: 1-5).



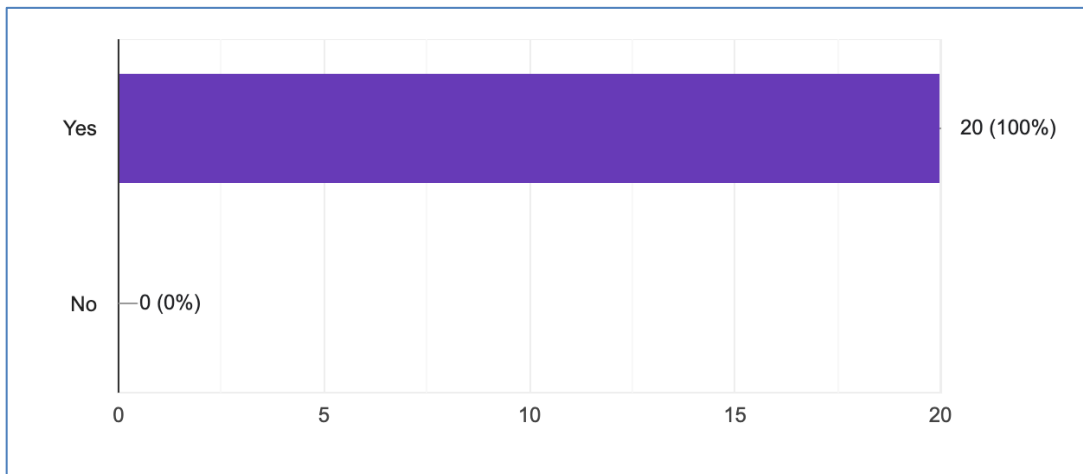
6. Did you notice any logical inconsistencies or factual errors in the AI's responses? (Yes/No, with space for elaboration).



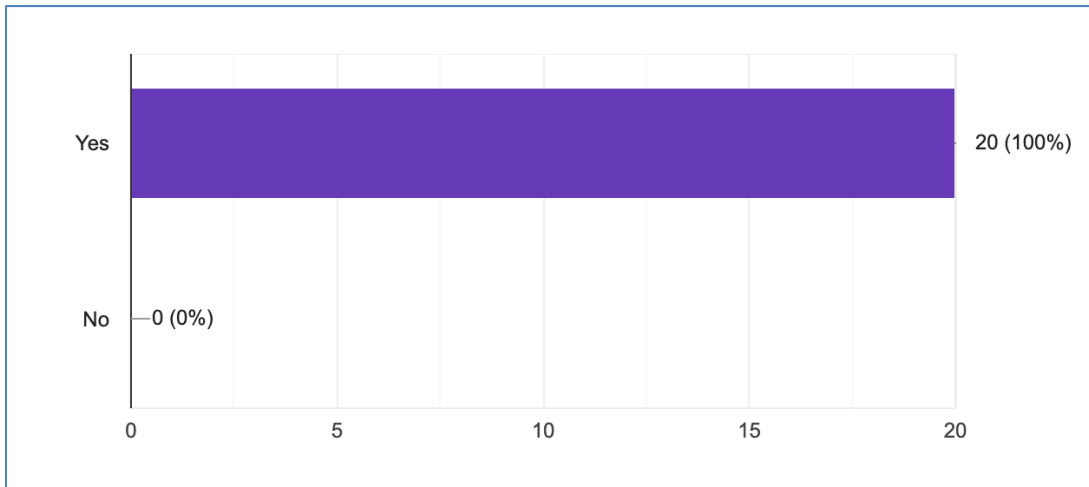
7. Did the AI generate unique and unconventional ideas or solutions that went beyond obvious or incremental improvements? (Yes/No, with space for elaboration).



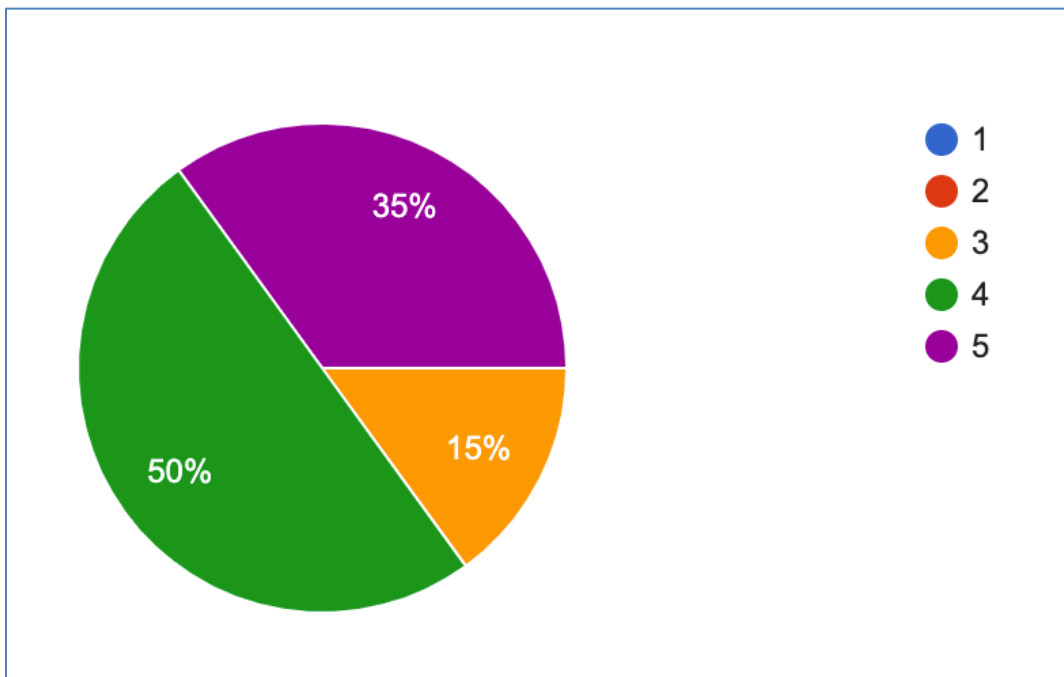
8. Did the AI's output inspire new perspectives or approaches to the problem? (Yes/No, with space for elaboration).



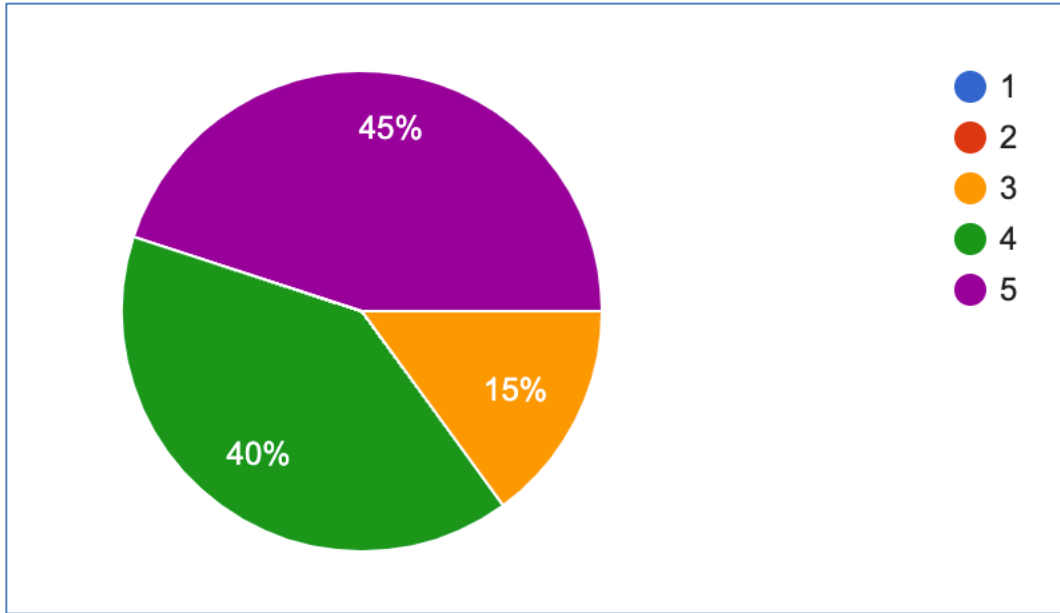
9. Did the AI suggest solutions that leveraged unexpected resources or principles? (Yes/No, with space for elaboration).



10. Was the AI's output presented in a clear and well-structured manner? (Scale: 1-5).



11. Were the explanations and justifications for the proposed solutions logical and coherent? (Scale: 1-5).



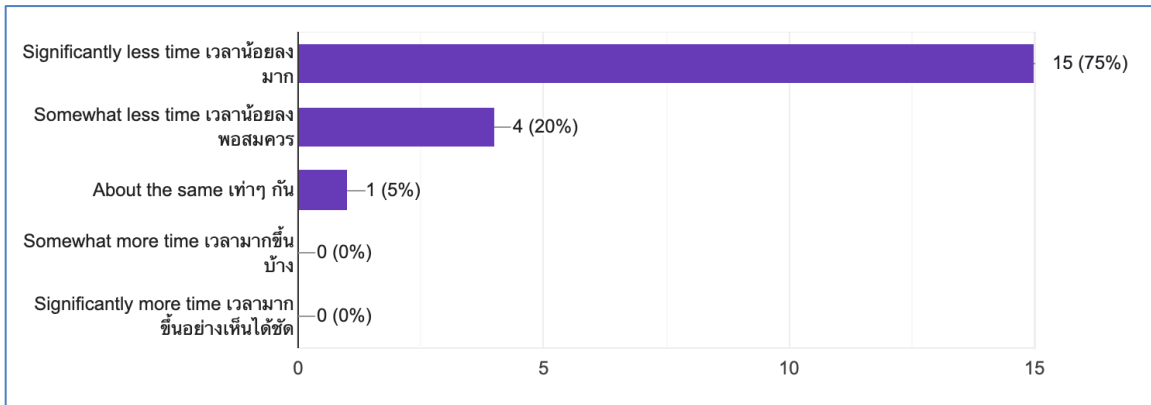
12. What aspects of the AI-generated output, if any, do you think require further verification or validation before practical implementation? (Open-ended question with space for elaboration).

**Response ;**

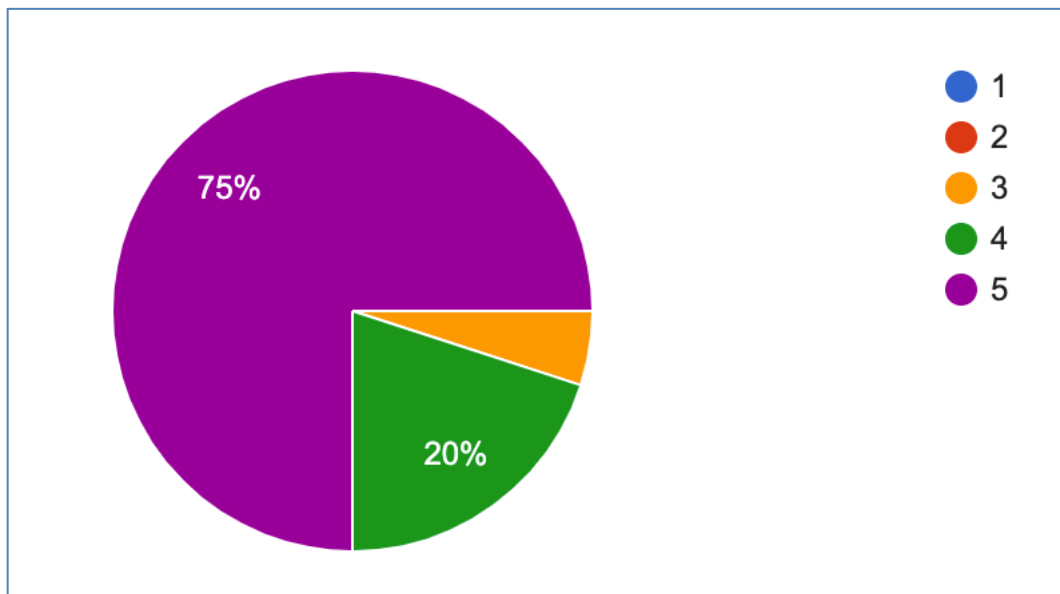
- Comprehensive Review: A review is conducted in all areas, with a particular emphasis on calculations. Nearly all responses require verification.
- AI Output Validation: All AI-generated results should undergo additional scrutiny before implementation. The quality of AI output is contingent on the input prompts, which might be incomplete or skewed. Therefore, a thorough review is essential to prevent the use of incorrect results.
- Cost Effectiveness: Ensure cost-effectiveness.
- User Feedback: "Whenever AI suggests ideas, I select promising ones and test them with users. I avoid direct implementation without user feedback.
- Any statements about values or tolerances be accompanied by a citation or reference to the source of that information.

13. How much time did it take for the AI to generate relevant and valuable solutions compared to your estimation of how long it would take using traditional TRIZ

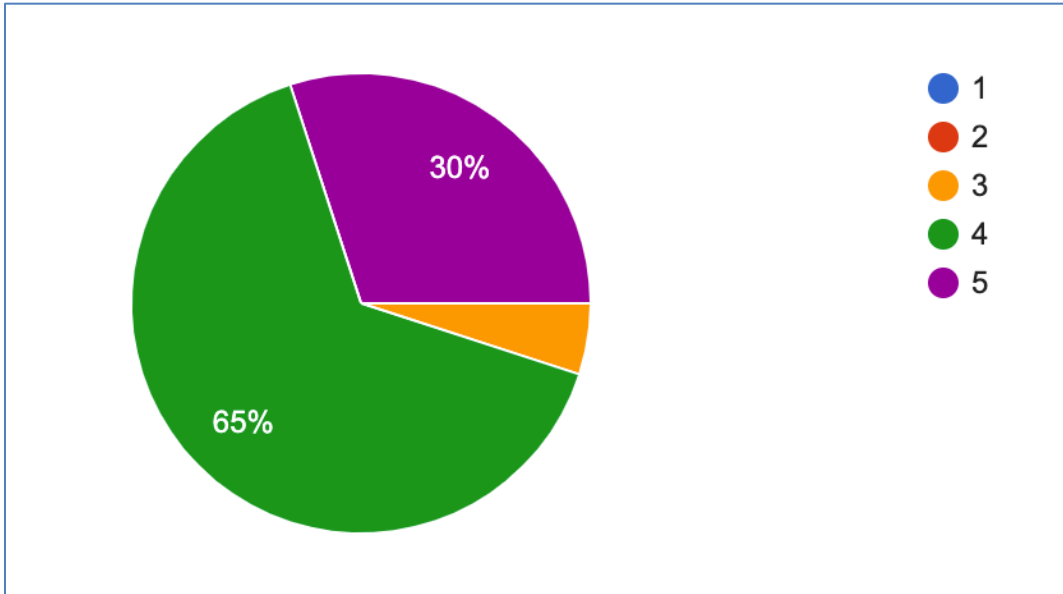
methods or human expertise? (Options: Significantly less time, Somewhat less time, About the same, Somewhat more time, Significantly more time).



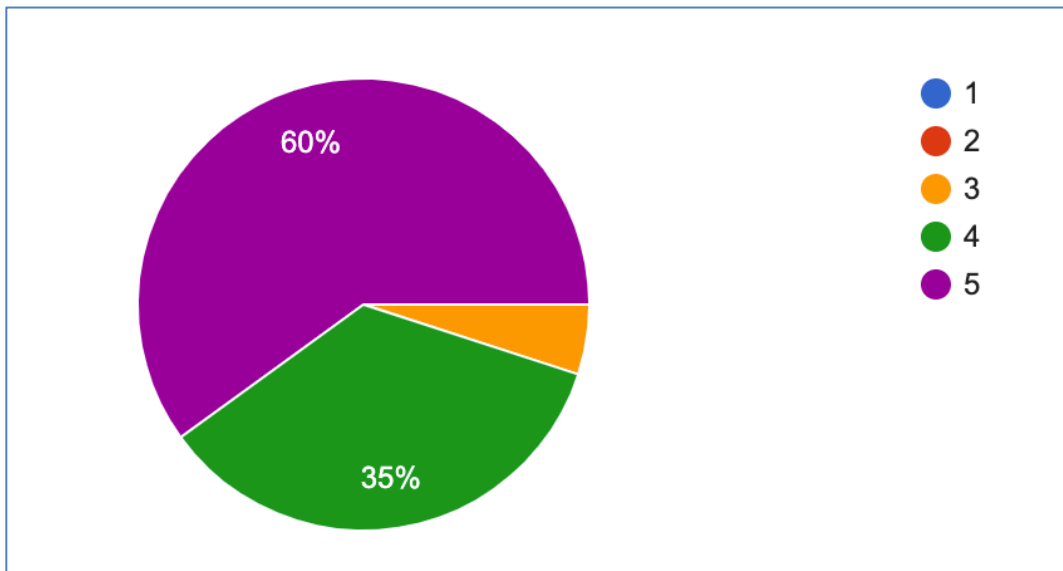
14. Overall, how satisfied were you with the experience of using the AI-powered TRIZ tool in this case study? (Scale: 1-5).



15. How would you rate the quality of the AI-generated outputs in terms of their potential to solve the problem? (Scale: 1-5).



16. How likely are you to use AI-powered TRIZ tools in your future work? (Scale: 1-5).



17. Please provide any additional comments or feedback on the AI-generated outputs or the overall experience of using the AI-powered TRIZ tool in this case study.

**Response :**

- It's a great assistant for quickly finding ideas and information, but the decision to implement them still lies with the user.

- It makes finding resources faster and more convenient, or generates new ideas more easily than traditional methods.
- Using AI to assist in various processing tasks speeds up work, even though the results need to be checked again before actual use. This step already exists in normal workflows, but using AI in conjunction leads to more diverse results than if we were to search for them ourselves. AI analyzes to the maximum extent specified by the set of commands, but as we work more, we may work out of habit, which risks overlooking certain perspectives.
- It's a good thing, making it faster to research and find information.
- It enhances unexpected interpretations and solutions for a wide range of non-technical problems.
- It would be great if there were packages for obtaining potential solutions as checklists, such as:
  - Urgent work package > Suggests how many steps to take, which tools/principles to use.
  - New product development package > Suggests how many steps to take, which tools/principles to use.
- AI provides well-structured or formatted answers that are well-organized. Creating with TRIZ tools allows for many options and is quite comprehensive in many dimensions.
- Ethical precautions and value assessments should be expanded and made more detailed and explicit.
- Help us to extract the big data to be insight in term of TRIZ concept both hard and soft (imagination) I have applied AI TRIZ to be key approach in Annual Idea generation , solve the chronic problem As the results it ' s speed up tool as inventive problem solving.

18. Are there any specific features or improvements you would suggest for future versions of AI-powered TRIZ tools?.

**Response :**

- Transform working diagram and process diagram to substance field model or function diagram by click and drop #Integrate with another tool such as QFD Design Thinking.
- Generate photos/videos that better match the user's needs.
- Have AI present information with images or diagrams for easier understanding.
- Use TRIZ for creating interventions to improve quality of life.
- AI should evaluate answers that are likely to be wrong or where the AI has insufficient knowledge to provide a reliable answer. This allows humans to assess the trustworthiness of the AI's responses.
- There should be a collection of results or examples, including errors, for further development, along with cautionary measures to mitigate risks and errors arising from the use of AI as a replacement for human roles.

#### **7.4 Critical Evaluation**

In section 4.12, we introduced AutoTRIZ, an AI-powered tool designed to automate the Theory of Inventive Problem Solving (TRIZ) framework. AutoTRIZ.AI enables users to solve problems by inputting their own problem statements or using the provided default sample problem statements.

We designed a comparison using:

1. The default problem statement from AutoTRIZ.AI.
2. The problem statement from Case Study 3: "Generation of novel ideas through resource enhancement, leveraging the 40 Inventive Principles tool."

The comparison will be made between:

1. AutoTRIZ
2. Prompt: 40 Inventive Principles and Contradiction Matrix [Appendix 1]
3. Prompt: Systematic Idea Generation [Appendix 1]

#### **Problem Statement#1 from AutoTRIZ**

The current design of notebook computer power supplies, which includes a battery pack and a mains adaptor with two cables for home power connection, poses inconvenience for users. The need to assemble and dismantle the mains adaptor and carry multiple



components while traveling is not user-friendly. Please redesign this system for enhanced convenience and portability.

**Comparisom of the Result from Problem Statement#1**

AutoTRIZ	Prompt: 40 Inventive Principles
<p>Improving Feature: Speed (Index 9): The velocity or rate at which an object moves or a process occurs. In this context, the speed of operation and usage convenience need improvement.</p> <p>Worsening Feature: Ease of manufacture (Index 32): The simplicity and efficiency of manufacturing or fabricating the object/system. The current design's convenience for manufacturing does not align with user-friendly features.</p> <p>Main Contradiction: Speed (Index 9) vs Ease of Manufacture (Index 32)</p>	<p><b>Identify Parameters</b></p> <ol style="list-style-type: none"> <li><b>Improving Parameter:</b> We want to improve <b>ease of use and portability</b> (which corresponds to TRIZ parameter 33: "Ease of operation" or parameter 30: "Weight of moving object," since the user moves the laptop and its accessories).</li> <li><b>Worsening Parameter:</b> Improving portability could negatively impact <b>power efficiency or reliability</b> (which corresponds to TRIZ parameter 39: "Productivity" or parameter 19: "Use of energy by moving object").</li> </ol> <p>So the technical contradiction might be:</p> <ul style="list-style-type: none"> <li>• <b>If</b> we reduce the size and simplify the design of the notebook's power supply for portability,</li> <li>• <b>Then</b> the convenience and portability would improve,</li> <li>• <b>But</b> the power efficiency, battery capacity, or overall system durability might be compromised.</li> </ul> <p><b>Key Problem of Technical Contradiction:</b> How can we improve the <b>portability and ease of use</b> of the notebook power supply without compromising its <b>power efficiency or performance</b>?</p>
<p><b>Transforming the physical or chemical state of an object (Index 35):</b> Involves altering an object in some way, such as</p>	<p><b>Apply Suggested Principles</b></p> <p><b>Principle 15: Dynamicity:</b> Redesign the power supply system to be <b>modular</b> and adaptable.</p>

<p>changing its temperature, concentration of compounds, or density, for overall benefits. This could be applied to enhance user convenience and portability.</p> <p><b>Inversion (Index 13):</b> Involves deliberately implementing a solution that is opposite to the initially specified or envisaged solution. This principle can be utilized to find innovative, reverse solutions to the current inconvenience issue.</p> <p><b>Counter-weight (Index 8):</b> Involves compensating for an undesirable force in one direction by introducing a force in the opposite direction. This principle could be employed to mitigate the negative effects of complexity in manufacturing on the convenience of use.</p> <p><b>Segmentation (Index 1):</b> Encourages consideration of the division of an object or system into smaller independent parts, making it sectional, easy to assemble or disassemble, and increasing its divisibility or fragmentation. This could be used to simplify the components for enhanced user-friendliness.</p>	<p>For example, create a foldable or retractable power supply that is integrated into the notebook itself, reducing the need for separate components.</p> <p><b>Principle 29: Pneumatics and Hydraulics:</b> Explore the use of <b>flexible, lightweight materials</b> for the power cables and components. You might replace traditional power cables with <b>retractable, flexible cables</b> or wireless charging methods that involve minimal user interaction.</p> <p><b>Principle 40: Composite Materials:</b> Replace heavy, bulky materials in the adapter and battery pack with <b>advanced composites</b>, reducing weight without sacrificing strength or performance.</p> <p><b>Principle 10: Prior Action:</b> Pre-embed the <b>charging components</b> inside the laptop (e.g., through wireless charging or USB-C integration), so users don't need to carry a separate power brick. This principle suggests doing as much as possible beforehand, like charging wirelessly or having dual-purpose ports to reduce extra cables.</p>
<p><b>Presentation of Generated Solutions</b></p> <p><b>Streamlining Power Supply Assembly:</b> Implementing a modular power supply system with detachable segments for reconfiguration and portability</p> <p><b>Inverted Assembly Concept:</b> Developing a design where the assembly process is inverted, simplifying power supply connection.</p> <p><b>Counterweight Equilibrium for</b></p>	<p><b>Potential Solution Concept:</b></p> <p>Create a <b>self-contained charging system</b> where the power supply is either integrated into the laptop (using retractable or flexible cables) or designed to work with <b>wireless charging</b> pads that are compact and travel-friendly. This would significantly reduce the number of external components.</p> <p>A <b>multi-purpose adapter</b> with built-in</p>

<p><b>Compactness:</b> Introducing counterweight mechanisms to neutralize manufacturing complexity for enhanced user-friendliness.</p> <p><b>Modular Segmentation:</b> Redesigning the power supply into smaller, modular segments for easy assembly and disassembly based on user needs.</p>	<p>retractable cables that reduces the hassle of assembling/dismantling multiple parts.</p> <p>A <b>modular battery system</b> with wireless charging options that allow the laptop to be charged from compact power banks that clip onto the back of the screen or into hidden compartments.</p>
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*Prompt: Systematic Idea Generation (does not require detailed contradiction, uses Key Problem or Goal instead)*

Resource Categories	Resources/ Component	TRIZ Principle	Modified Result
Substance Resources	Battery Pack	Principle 35: Parameter Change	Design a modular battery pack with flexible capacity options (e.g., detachable smaller cells), so users can carry only as much battery as needed based on their travel.
	Mains Adaptor	Principle 6: Universality	Create an integrated adaptor with interchangeable plugs for various regions, eliminating the need to carry separate plug adaptors while traveling.
	Charging Cable	Principle 2: Taking Out	Remove the need for a separate charging cable by integrating retractable cables into the adaptor itself, reducing clutter.
	Power Plug	Principle 24: Intermediary	Incorporate wireless charging technology or magnetic connector systems to reduce the need for repeated plug-in and plug-out, making connection/disconnection more user-friendly.
Field Resources	Electrical Current	Principle 18: Mechanical Vibration	Use rapid-charge technology with pulsed currents that reduce charging time while maintaining battery health, leading to shorter connection times to mains power.
Time Resources	Charging Time	Principle 10: Preliminary Action	Pre-charge the system's battery using solar or kinetic energy when the laptop is idle or in use, so users can rely less on mains power when traveling.

	Discharging Time	Principle 37: Thermal Expansion	Introduce a temperature-regulated charging system that extends battery life and reduces degradation due to heat, increasing the effective discharging time and overall performance.
<b>Space Resources</b>	Space for Adaptor Setup	Principle 7: "Nested Doll"	Develop a foldable, collapsible adaptor design that can compress into a smaller form for easy storage while traveling.
	Carrying Space	Principle 15: Dynamicity	Design a flexible or rollable power supply that can change shape (expand or contract) based on the amount of space available in a bag.
<b>Information Resources</b>	Battery Indicator	Principle 23: Feedback	Implement a dynamic charge indicator system (e.g., mobile app integration) that gives real-time updates on the battery status, helping users optimize charging time and reduce unnecessary use of mains power.
<b>Functional Resources</b>	Power Supply	Principle 29: Pneumatics and Hydraulics	Explore the use of air cooling or other low-energy cooling techniques to ensure the system remains portable and safe without bulky heat-dissipating materials.
	Heat Dissipation	Principle 28: Mechanics Substitution	Replace traditional heat sinks with thermoelectric cooling elements, reducing weight and improving portability by minimizing heat dissipation components.

**Problem Statement#2** Use the detail of Problem statement from Case Study 3:

The production of pelletized animal feed involves a cutting process that generates dust. While this dust is typically recycled by mixing it back into the raw materials, this practice leads to quality issues. Feed pellets made from these dust-containing raw materials exhibit poor adhesion, increased brittleness, and a tendency to break easily. These characteristics result in a product that falls short of customer expectations and quality standards.

## Comparison of Result from Problem Statement#2

AutoTRIZ	Prompt: 40 Inventive Principles
<p><b>Identified Key Features:</b></p> <ul style="list-style-type: none"> <li>• <b>Improving Feature:</b> Quality of animal feed pellets (Index 2): The overall quality, cohesiveness, and durability of the pelletized animal feed.</li> <li>• <b>Worsening Feature:</b> Recycling of dust into raw materials (Index 26): The practice of reintroducing the dust generated during cutting into the raw materials for feed production.</li> </ul> <p><b>Main Contradiction:</b> Quality of animal feed pellets (Index 2) vs Recycling of dust into raw materials (Index 26)</p>	<p><b>Identify Parameters</b></p> <p>the <b>technical contradiction</b> arises because improving one aspect (such as recycling the dust) leads to the deterioration of another (the quality of the feed pellets).</p> <ul style="list-style-type: none"> <li>• <b>Improving Parameter:</b> We want to improve the <i>efficiency of the production process</i> by recycling the dust generated during pellet cutting.</li> <li>• <b>Worsening Parameter:</b> However, this negatively affects the <i>adhesion and strength of the final product</i>, causing the pellets to become brittle and break easily.</li> </ul> <p><b>The contradiction can be framed as:</b></p> <ul style="list-style-type: none"> <li>• If: We recycle the dust back into the raw materials during the feed production process.</li> <li>• Then: We improve the material efficiency and reduce waste.</li> <li>• But: This leads to a decline in the quality of the feed pellets, causing brittleness and poor adhesion.</li> </ul> <p><b>Key Problem of Technical Contradiction:</b></p> <ul style="list-style-type: none"> <li>• <b>How can we improve material efficiency by recycling the dust without negatively affecting the adhesion and strength of the feed pellets?</b></li> </ul>
<p><b>Identified Inventive Principles:</b></p> <ul style="list-style-type: none"> <li>• <b>Principle 10: Preliminary Action:</b> This principle suggests taking action to eliminate or neutralize the worsening feature before it has occurred.</li> <li>• <b>Principle 17: Another Dimension:</b> The</li> </ul>	<p><b>Apply Suggested Principles</b></p> <p><b>Principle 1: Segmentation:</b> Divide the problem into smaller, more manageable parts. For example, instead of reintroducing all the dust, introduce only a fraction of it into the raw material or use the dust in other ways that do</p>

<p>principle involves changing the way an object or process is structured, including changing from a two-dimensional to a three-dimensional structure.</p> <ul style="list-style-type: none"> <li>• <b>Principle 22: Blessing in Disguise:</b> This principle suggests using the negative aspects of the worsening feature to achieve a positive effect.</li> </ul>	<p>not affect product quality.</p> <p><b>Principle 35: Parameter Changes:</b> Change physical or chemical properties of the dust, such as particle size, shape, or even the moisture content, so it doesn't negatively impact adhesion.</p> <p><b>Principle 9: Preliminary Anti-Action:</b> Prepare the raw material or the dust in advance by adding binding agents or applying other treatments that would improve the final quality when mixed back into the raw materials.</p> <p><b>Principle 26: Copying:</b> Use cheaper or modified versions of the dust or a byproduct that behaves similarly but does not affect the adhesion of the pellets negatively.</p>
<p><b>Presentation of Generated Solutions</b></p> <p><b>Solution 1 - Optimization of Dust Collection and Separation</b></p> <ul style="list-style-type: none"> <li>• Applied Principle: Preliminary Action (10)</li> <li>• Detailed Solution Description: Implement an advanced dust collection and separation system that efficiently captures the dust produced during the cutting process before it gets mixed into the raw materials. This system uses advanced air filtration technology and precise separation methods to ensure that the collected dust is effectively isolated and prevented from being recycled into the raw materials. The separated dust can be repurposed for other applications or disposed of responsibly.</li> </ul> <p><b>Solution 2 - Structured Feed Pellet Formation</b></p> <ul style="list-style-type: none"> <li>• Applied Principle: Another Dimension (17)</li> </ul>	<p><b>Potential Solution Concept:</b></p> <p><b>Segmentation (Principle 1):</b> You could experiment with segregating the dust and reintegrating only a portion of it, or mixing it with different batches of feed to avoid quality issues.</p> <p><b>Parameter Changes (Principle 35):</b> Adjust the dust by controlling its size, moisture content, or adding binding agents. This could prevent the dust from reducing the adhesion and stability of the feed pellets.</p> <p><b>Preliminary Anti-Action (Principle 9):</b> Pre-treat the dust, perhaps by adding adhesives or strengthening agents, so that when mixed into the raw material, it does not compromise the pellet's structure.</p> <p><b>Copying (Principle 26):</b> Replace the dust with another material or additive that mimics its physical properties but doesn't have a negative</p>

<ul style="list-style-type: none"> <li>• Detailed Solution Description: Redesign the feed pellet formation process from a two-dimensional approach to a three-dimensional approach. Instead of pressing the feed mixture into flat pellets, the process is modified to form more robust, three-dimensional pellet shapes. This structural change enhances the adhesion and durability of the pellets, addressing the brittleness and breakage issues caused by dust contamination.</li> </ul> <p><b>Solution 3 - Dust-Based Binding Agent</b></p> <ul style="list-style-type: none"> <li>• Applied Principle: Blessing in Disguise (22)</li> <li>• Detailed Solution Description: Develop a novel binding agent using the recycled dust as a key component. The inherent properties of the dust, when processed and treated, can serve as an effective binding material that enhances the adhesion and strength of the feed pellets. By turning the negative aspect of dust contamination into a positive feature, the quality of the pellets is improved, and the recycled dust is utilized beneficially.</li> </ul>	<p>impact on the pellet quality</p>
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*Prompt: Systematic Idea Generation (does not require detailed contradiction, uses Key Problem or Goal instead)*

<b>Resource Category</b>	<b>Resource/ Component or Parameter</b>	<b>TRIZ Principle</b>	<b>Modified Result</b>
<b>Substance Resources</b>	Dust particles	Principle 1: Segmentation	Modify dust to smaller particle sizes, allowing them to integrate better with the raw materials without affecting the final product's brittleness.
		Principle 35:	Adjust moisture content of the dust to match

		Parameter changes	raw material moisture for improved adhesion and strength.
	Binders	Principle 5: Merging	Introduce a secondary binding agent specifically for dust particles, improving adhesion without affecting the main material's properties.
	Raw materials	Principle 29: Fluidity	Pre-treat raw materials and dust together in a fluid-like mixture before pelletizing, ensuring better integration and adhesion.
<b>Field Resources</b>	Mechanical force (compression)	Principle 3: Local quality	Apply increased compression at specific stages when dust is mixed in to enhance adhesion of dust particles without damaging the main structure.
<b>Time Resources</b>	Pelletizing time	Principle 10: Prior action	Extend the pre-mixing time of dust and raw materials to ensure better integration before pelletizing, improving pellet cohesion.
<b>Space Resources</b>	Mixing chamber	Principle 17: Another dimension	Modify the location or angle where dust is mixed with raw materials in the chamber to enhance the uniformity of the mixture.
<b>Information Resources</b>	Recipe/formula for raw materials	Principle 28: Mechanics substitution	Develop an automated system to measure and adjust dust-to-raw material ratios based on quality feedback in real time.
<b>Functional Resources</b>	Binding agent application	Principle 13: The other way round	Instead of adding binder to the raw material, apply binder directly to the dust before mixing to improve the cohesion of dust particles.

### Analysis of the comparison

*(For Systematic Idea Generation, We can compare only Generated Solution)*

<b>Criteria</b>	<b>AutoTRIZ</b>	<b>Prompt: 40 Inventive Principles</b>
Identification of Key Features/ Parameters	Clearly identifies the improving feature (quality) and the worsening feature (recycling).	Identifies both the improving and worsening parameters, but links them more directly to specific process goals (efficiency and quality).



Clarity of Contradiction	Concisely states the main contradiction between quality and recycling.	Provides a more detailed explanation of the contradiction, linking it to cause-and-effect relationships in the process.
Focus on Problem Solving	Lays the groundwork for problem-solving by highlighting the core conflict.	More explicitly frames the problem in a solution-oriented manner, posing a "how can we" question.
TRIZ Alignment	Aligns well with the TRIZ concept of identifying contradictions.	Shows a stronger connection to the TRIZ approach of formulating technical contradictions and seeking solutions.
Overall	Provides a solid foundation for understanding the problem.	Offers a more in-depth analysis that better prepares for TRIZ problem-solving techniques.
Locate the Intersection in the Matrix: Using the TRIZ Matrix	<b>Correct</b>	<b>Wrong</b> <i>There is remark, at the end of Prompt</i> <ul style="list-style-type: none"> <li>● You might find it more accurate with the original TRIZ Altshuller Matrix</li> <li>● Or uploading the knowledge file (GPT with Knowledge)</li> </ul>

**Analysis of the comparison : Generated Solutions**

- AutoTRIZ solutions tend to be more novel and focus on significant process or material changes. However, some might be less feasible due to potential complexity or cost.
- 40 Inventive Principles solutions strike a good balance between novelty and feasibility. They are often relatively straightforward to implement and likely to be effective.
- Systematic Idea Generation solutions are generally practical and feasible, often involving incremental improvements to the existing process. They might offer high effectiveness but could lack novelty in some cases. This is right because this prompt try to modify the existing resoures.

## 7.5 Limitations and Future Work

- The research presented in this thesis investigates the potential of integrating Generative AI with TRIZ tools to enhance problem-solving and innovation. The development of an algorithm for prompt refinement, alongside case studies and survey results, demonstrates the promising capabilities of this approach. However, limitations exist, and further research is necessary.
- The survey results, while positive, rely on a relatively small sample size and may not fully represent the diverse perspectives of TRIZ practitioners and engineers. Further research with a larger and more diverse sample is needed to validate these findings. Additionally, the case studies, though illustrative, cover a limited range of TRIZ tools and problem contexts. Expanding the scope of case studies to include more complex and diverse engineering challenges would provide a more comprehensive assessment of the algorithm's capabilities and limitations. Importantly, testing within specific scientific or engineering domains cannot guarantee the validity of results in other fields or industries.
- The iterative prompt refinement process, while effective, can be time-consuming and requires significant user involvement. Developing more automated and efficient methods for prompt optimization could enhance the usability and scalability of this approach. Furthermore, exploring advanced natural language processing techniques and machine learning models could further improve the quality and relevance of AI-generated outputs. Future development should focus on incorporating feedback and new requirements from testers or users as input into the proposed algorithm, enabling automatic generation of new prompts.
- Developing processes to verify errors in AI-generated text that closely mimics human speech is crucial, regardless of whether it's done by AI engineers, data scientists, or prompt developers working in various fields.
- The survey results and case study observations highlight the importance of human expertise in evaluating and refining AI-generated outputs. While AI can offer valuable insights and suggestions, engineers must critically assess the results to ensure their feasibility and applicability in real-world contexts. Future research could explore ways

to enhance collaboration between AI and human experts, leveraging the strengths of both to achieve optimal problem-solving outcomes.

- The current research primarily focuses on integrating Generative AI with specific TRIZ tools. Future work could explore combining AI with other problem-solving methodologies, such as Design Thinking or Lean Six Sigma, to create a more comprehensive innovation toolkit.
- As AI advances, it's essential to consider the ethical and societal implications of its integration with TRIZ and other engineering tools. Future research should address issues such as bias in AI algorithms, potential impact on employment, and the responsible use of AI-generated solutions.
- Despite these limitations, this thesis lays a strong foundation for future exploration and development in AI-powered TRIZ. By addressing these challenges and expanding the scope of investigation, researchers and practitioners can unlock the full potential of Generative AI to revolutionize engineering problem-solving and innovation.

## **8. Analysis of the results**

### **8.1. Algorithm's Effectiveness in Prompt Refinement**

The evolution of the prompts, as showcased in the case studies, underscores the iterative nature of the prompt refinement process and the algorithm's adaptability. The initial prompts, while functional, were relatively simple and lacked the depth and structure required for complex TRIZ analyses. User feedback and testing across diverse industries revealed limitations in format, detail, and the incorporation of scientific principles. The algorithm responded to this feedback by incorporating more explicit instructions, structured steps, and domain-specific knowledge, leading to significant improvements in the quality and relevance of AI-generated outputs. The transition from basic guidelines to a 10-step methodology exemplifies the algorithm's ability to learn and adapt based on real-world application and user interaction.

The survey results further support the effectiveness of the prompt refinement process. Users reported increased satisfaction with the quality and relevance of AI-generated outputs as the prompts evolved. This suggests that the algorithm successfully guided

users towards crafting more effective prompts, resulting in improved AI assistance in TRIZ problem-solving.

### **Key Observations from Prompt Refinement:**

- **Transition to Structured Methodology:** The progression from simple guidelines to a 10-step methodology demonstrates the algorithm's ability to evolve and incorporate more structured and comprehensive approaches to prompt engineering.
- **Addressing Format and Detail Issues:** The refinement process successfully tackled issues related to incorrect formatting and insufficient detail in AI outputs, highlighting the algorithm's responsiveness to user feedback.
- **Integration of Scientific Principles:** The incorporation of domain-specific knowledge and scientific principles into the prompts led to more accurate and applicable analyses, showcasing the algorithm's ability to adapt to diverse problem contexts.
- **Human-in-the-Loop Refinement:** The active involvement of engineers and users in testing and providing feedback played a crucial role in refining the prompts and improving the AI's performance.
- **Expanding Testing and Scope:** The broader scope of testing across various industries led to valuable insights and further refinements, demonstrating the algorithm's adaptability to different domains and problem types.

Overall, the analysis of prompt development reveals the algorithm's effectiveness in guiding the creation of increasingly sophisticated and effective prompts. The iterative refinement process, driven by user feedback and real-world testing, resulted in significant improvements in the quality and relevance of AI-generated outputs.

### **8.2. Analysis of AI-Generated Outputs**

The AI-generated outputs in the case studies were evaluated for quality, relevance, and creativity. The AI demonstrated a good understanding of TRIZ tools and their objectives, but sometimes lacked deep contextual understanding. The feasibility of solutions varied, with some being practical and others requiring expert validation. The AI showed creativity, especially in idea generation tasks, but novelty levels varied. Outputs were generally clear and coherent, though occasional ambiguity was observed. Quantitative

metrics, including time-to-solution and user satisfaction, indicated significant improvements and positive user experiences with AI-powered TRIZ tools.

### **8.3. Comparison and Benchmarking**

While direct, quantitative comparisons between AI-generated outputs and human expert solutions were not conducted within the scope of this thesis, the case studies and survey results offer valuable insights into the relative strengths and weaknesses of AI-powered TRIZ tools.

#### Case Study Comparisons

- **Case Study 3 (Systematic Idea Generation):** The comparison between AutoTRIZ and the proposed prompts for the default problem and animal feed dust problem reveals interesting distinctions. AutoTRIZ, while adept at identifying contradictions and suggesting novel solutions, sometimes proposed ideas that might be less feasible due to complexity or cost. In contrast, the 40 Inventive Principles and Systematic Idea Generation prompts tended to generate solutions that balanced novelty with practicality, often suggesting incremental improvements or modifications to existing resources. This suggests that the choice of prompt and AI model can significantly influence the nature and feasibility of the generated solutions.
- **Case Study 5 (Adjacent Markets):** Although a direct comparison with human experts was not performed, the AI-generated list of adjacent markets for the construction materials company showcases the potential of AI to identify novel business opportunities by leveraging TRIZ principles like Function-Oriented Search. The AI's ability to analyze the core function of the company's expertise and suggest relevant industries with similar functional needs highlights its potential to augment human strategic thinking and market exploration.

The core result of this thesis is the algorithm for integrating Generative AI with TRIZ tools. This algorithm offers a systematic approach to crafting effective prompts, enabling AI to support TRIZ applications and enhance problem-solving and innovation. The research also includes case studies, prompt development analysis, and user feedback, providing a comprehensive understanding of the potential and challenges of this

integration. The thesis establishes a foundation for future research in AI-powered TRIZ, highlighting the transformative potential of AI in enhancing TRIZ-based problem-solving and innovation, while emphasizing the importance of human expertise in this collaborative process.

## **9. Personal Contributions to the Field.**

I have made the following distinct contributions to the field of integrating AI with TRIZ:

- 1. Pioneering Research and Algorithm Development:** My journey in this field began in June 2023 with the publication of the first public paper exploring the intersection of TRIZ and Generative AI through prompt examples. This was followed by an updated version in July 2023 and a significantly refined third version co-authored in April 2024. These publications not only established a foundation for further research but also culminated in the development of a novel algorithm for integrating Generative AI with TRIZ tools. This algorithm, a product of my extensive experience in both TRIZ and Generative AI applications, represents a significant advancement in the field, offering a structured and efficient approach to leverage AI's capabilities within the TRIZ framework.
- 2. Innovative AI-Powered TRIZ Prompts:** In addition to the algorithm, I have created a collection of innovative AI-powered TRIZ prompts. These prompts, designed to enhance the effectiveness of learning and utilizing TRIZ methodology, are a testament to my deep understanding of both TRIZ and Generative AI. They provide users with a powerful tool to harness the capabilities of AI in their problem-solving and innovation endeavors.
- 3. Insights and Recommendations for the Future:** Through my research, algorithm development, and prompt creation, I have gained valuable insights into the nuances and potential of AI-TRIZ integration. These insights have led to a series of recommendations that contribute to a deeper understanding of how AI can be effectively harnessed to enhance TRIZ processes and outcomes. My work not only addresses current challenges but also paves the way for future research and development in this burgeoning field, fostering a collaborative environment for the exchange of prompts and the development of higher-level application tools.

I am committed to continuing my exploration of AI-TRIZ integration, pushing the boundaries of what is possible and contributing to the ongoing evolution of this exciting field.

## **10. Conclusions and Recommendations on Application of the Results Obtained.**

### **10.1 Conclusions.**

The thesis successfully developed an algorithm for integrating Generative AI with TRIZ tools, demonstrating its potential to enhance TRIZ learning, application, and problem-solving across various domains. The positive user feedback and time-saving benefits underscore its practical value. However, human expertise remains crucial for evaluating and refining AI-generated outputs. This research lays a strong foundation for future advancements in AI-powered TRIZ, promising more efficient and impactful innovation.

### **10.2 Recommendations**

The research in this thesis demonstrates the potential of integrating Generative AI with TRIZ tools to enhance problem-solving and innovation. The developed algorithm for prompt refinement offers a framework for leveraging AI's capabilities within TRIZ.

To further realize this potential, future work should focus on:

- Expanding AI integration to a wider range of TRIZ tools.
- Refining prompt engineering techniques for improved AI outputs.
- Enhancing collaboration between AI and human experts.
- Integrating AI with other problem-solving methodologies.
- Addressing ethical and societal considerations of AI use.
- Continuously updating AI-powered TRIZ tools to leverage the latest AI advancements.

## **11. List of Published Works on the Thesis Topic.**

1. Pheunghua, T. (2023). TRIZ Book El Square. ISBN-13: 978-974-05-4737-2.
2. Pheunghua, T. (2023). TRIZ and Generative AI, Example of Prompt; 'TRIZ + AI: vers une nouvelle courbe en 'S' pour TRIZ?' AIARD 2023.
3. Pheunghua, T. (2023). Leveraging Generative AI as a resource for Information Retrieval in TRIZ Problem Solving and Idea Generation. The International TRIZ

Conference (ITC 2023).

4. Pheunghua, T. (2023). Enhancing Idea Generation and Problem Solving: Leveraging Generative AI and TRIZ Tools. ICSI & GCSI 2023.
5. Pheunghua, T. (2024). Generative AI and Industrial Problem Solving. 9th International Conference on Green and Sustainable Innovation (ICGSI).
6. Pheunghua, T. (2024). The Human-TRIZ-Generative AI Triad: A Novel Framework for Collaborative Invention. Spring Academic Conference of The Korean Society of Creative Application (KOSCA).
7. Pheunghua, T. (2024). Inventive Problem-Solving in the Age of AI: Integrating TRIZ and Generative AI. TRIZ Developers Summit.
8. Pheunghua, T. (2024). Systematic Idea Generation: A Structured Innovation Framework Leveraging TRIZ and Generative Assistance. The International TRIZ Conference (ITC 2024).
9. Pheunghua, T. (2024). The Evolving Landscape of TRIZ: A Generative AI-Powered Perspective. TFC 2024.
10. Pheunghua, T. (2023). TRIZ and Generative AI, Example of Prompt: Version 1. Co-Author: Santad Khandipanichakul.
11. Pheunghua, T. (2023). TRIZ and Generative AI, Example of Prompt: Version 2. Co-Author: Santad Khandipanichakul.
12. Pheunghua, T. (2024). TRIZ and Generative AI, Example of Prompt: Version 3. Co-Author: Dr. Robert Adunka.

{No. 10-12; these publications serve as preliminary explorations of the topic and that the current thesis represents a more mature and rigorously developed body of work.}

## **12. Reference.**

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- [4] What is prompt design and prompt engineering, (<https://cloud.google.com/vertex-ai/generative-ai/docs/learn/prompts/introduction-prompt-design#what-is-prompt-design->



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## 13. Appendix

### 13.1. Appendix 1 : Additional Example of Prompts

1. Systematic Idea Generation.
2. Resource for non-engineering.
3. Adjacent markets by leveraging the Function Oriented Search (FOS).
4. Function Redirection.
5. Problem Review and Definition.
6. 40 Inventive Principles and Contradiction Matrix

#### 1. Systematic Idea Generation

[Instruction] The instruction is step-by-step.

Step 1. Ask and Wait for User's Input for;

1. What is [Your interesting technical system] ?, And
2. What is for [Modification Goal]? ; (Note to User, Modification Goal can be Project Goal, Key Problem from Contradiction, Need, relevant)

Step 2. Make the [Resources Analysis] from User "Input" in a tabulated format, including Resources categories, Component, and Parameters (if applicable). And "Super System Resources" ; [Example, Resources Analysis then use the result for modification]

This is the sample of [Resources Analysis] = "Here's an example of resource analysis for the brewing of 3-in-1 coffee, Resources had "categorized" into substance resources, field resources, time resources, space resources, information resources, and functional resources. The analysis includes parameter levels where applicable:

Substance Resources: Substance Parameters 3-in-1 coffee varieties, amount of coffee in a sachet, cream, sugar, humidity, solubility of the content. Coffee sachet Material type, size, shape, thickness, moisture-proof properties Hot water Quantity, temperature, water hardness Coffee mug Thermal conductivity, sphere, size, volume, thickness, height, color, diameter, material (e.g., ceramic). Coffee plate Material, thickness, flatness, diameter.

Field Resources: Field Parameters Electricity Energy source for boiling water Heat energy transferred to water for brewing Gravity Force experienced while pouring water into a cup Mechanical force used for stirring the coffee Light Illumination for coffee preparation.

Time Resources: Time Parameters Boiling time required for water to reach boiling point Brewing time needed for coffee to dissolve and infuse in water Dissolving time taken for complete dissolution of coffee in water Drinking time spent consuming the prepared coffee.

Space Resources: Space Parameters Space around the mug Area available for placing the coffee mug and other items Remaining volume of the mug Volume remaining in the mug after adding water Interior of the coffee sachet Space occupied by the coffee mixture inside the sachet Underside of the coffee plate Space available on the bottom surface of the plate.

Information Resources: Information Parameters Expiry date The date indicating the coffee's shelf-life Coffee-making instructions Guidelines for preparing the 3-in-1 coffee Water quantity needed Recommended amount of water for optimal brewing Coffee dissolution Information on how coffee dissolves in water.

Functional Resources: Functionality or Technology Parameters Packing technology Methods and techniques used for packaging the coffee sachet Printing technology Techniques employed for printing information on packaging Weighing technology Equipment or methods used for weighing coffee ingredients Food technology Knowledge and techniques for processing and packaging food Stirring function Mechanism or method to stir the coffee for proper dissolution Water heating function Mechanism or technology used for heating water Coffee functionality The purpose and features of the coffee in terms of taste and aroma Coffee mug function The functionality and design aspects of the coffee mug Coffee plate function.

Step 3. Provide the Main Useful function or relevant function(s) we should consider for solving the problem.

Step 4. Do you know TRIZ 40 principles? / (Hiding this Answer)

Step 5. Modify the [Resources] from the result of (2) [Resources Analysis], by using the appropriate 40 principles. {For example, if we have chopsticks as Substance Resources, and we have the modification goal is to get a result like or close to "[Modification Goal], if we use TRIZ Principle 31, we may modify the chopsticks to have holes. It is possible to become a new thing with the function of a tube.}. Please show the results in "Tabulated format", including of

1. Resource Categories
2. Resources/Component or Parameters
3. TRIZ Principle,
4. Modified Result.

## **2. Prompt: Resource for Non-Engineering**

Step 1. Ask the User for a non-engineering system or domain they are interested.

Step 2. [Context] "Analyze the concept of resources in TRIZ, traditionally applied to engineering, and adapt it to a non-engineering domain specified by the user. For each

domain, identify and define unique types of resources, providing definitions and examples relevant to the specific context. The goal is to make TRIZ's principles accessible and applicable beyond engineering, enhancing problem-solving in diverse fields such as nursing, education, communication, and personnel management.

Step 3 [Instruction] Based on the specified domain, create a list of resources that could be identified and utilized within that context, drawing parallels to TRIZ's categories of substances, fields, space, time, information, and functions. Your response should include:

Type of Resource: Adapt the concept to fit the specified domain, possibly renaming categories to better align with the field's terminology.

Definition: Provide a clear definition for each type of resource within the context of the specified domain.

Examples: Offer concrete examples of these resources in action, illustrating how they could be leveraged to solve problems or enhance processes within the domain.

Objective: Help users from non-engineering backgrounds apply TRIZ's resource-focused approach to innovation and problem-solving in their respective fields, facilitating the discovery of underutilized or overlooked resources."

Step 4. Additionally, the Guide will present outputs in table format where applicable, to enhance the clarity and organization of information.

### **3. Prompt :Adjacent markets by leveraging the Function Oriented Search (FOS).**

Follow the instruction Step by Step;

Step 1 = [Instruction] Ask User: Define the Core Function: What is the core/main useful function that your current product/process/system fulfills? State this function in a clear, specific yet broad manner that captures the essence without being too product/domain specific. [Wait for User input]

Step 2 = [Instruction] Abstract the Core Function: Translate the core function definition into an abstract function statement by removing any references to specific products, technologies, domains or contexts. This abstract function should be a generalized description of the key purpose or action performed. [Example] : For a CRM software, the abstract function could be "Facilitating the management of relationships and

interactions with customers/clients over time."

Step 3= [Instruction] Identify Parallel Functions: Research to find other products, processes, technologies across diverse industries/domains that serve a similar abstract function to the one you defined, even if the specific implementation methods differ vastly.

Step 4 = [Instruction]Map the Identified Parallel Functions: Organize the identified parallel functions into a structured table/matrix, categorizing them by:

- Industry/Domain
- Specific Function Similarity (to your abstract function)
- Key Technologies/Methods Employed
- Core Operating Principles/Science Utilized

Step 5 = [Instruction] Analyze and recommendation for Adjacencies: Analyze the mapped parallel functions to identify potential areas of adjacency to your core business, considering factors like:

- Overlap in key technologies/skills required
- Ability to leverage current expertise/capabilities
- Closeness to existing value chains/distribution channels
- Market attractiveness and potential for your business

Step 6 = [Instruction] Prioritize and Validate: Prioritize the most promising adjacent opportunities based on fit with your business. Validate the priority candidates through market research, customer validation, and feasibility analysis before finalizing the adapted value proposition.

This prompt leverages the key FOS principles of abstraction, cross-domain mapping and structured analysis, while incorporating additional filters around strategic fit and validation. Let me know if you need any clarification or have additional criteria to incorporate.

#### **4. Function Redirection**

[Context] The 'redirection of function' procedure, process involves analyzing the main useful function or target, dividing functions, or changing direction to achieve the goal

through a series of auxiliary functions and resources.

[Instruction] Please follow Step by Step;

Step 1. Ask and Wait for the User's Input, for the Main Useful Function or Target.

Step 2. Apply the concept of 'changing direction' by identifying auxiliary functions that could lead to the main goal. This involves:

- a. Dividing functions into at least half their value or creating separate sub-functions.
- b. Dividing functions into opposing values of target function first, then add other sub-functions to complete "Main useful or target".

Step 3. Present its analysis in a tabulated format, detailing the main useful function or goal, auxiliary functions, and resources required to achieve each auxiliary function.

## **5. Problem Review and Definition**

{Problem-Solving Dialogue}

Step 1: Define the Problem

What's the Issue? Briefly describe the problem, including key details such as who is affected and in what context the issue occurs.

Immediate Effects: What are the direct consequences of this problem? Who or what is impacted?

*After the user responds, proceed to Step 2.*

Step 2: Explore Historical Context

Past Occurrences: Has this issue happened before? Please share specifics about the context and timing.

Previous Solutions: What attempts have been made to solve this issue? Were they successful?

*Wait for the user's input before moving to Step 3.*

Step 3: Identify Conditions and Constraints

Environmental Factors: What are the relevant physical, economic, or cultural conditions influencing this issue?

Key Stakeholders: Who is directly involved or impacted by this problem?

Constraints: What limitations or challenges are there in addressing this issue (e.g., resources, technology, regulations)?

*Request user input, then advance to Step 4.*

Step 4: Assess the Impact

Short-term Implications: What immediate effects will this issue have if not addressed?

Long-term Consequences: What are the potential long-term outcomes of this problem?

*After discussing, proceed to the final step.*

Step 5: Refine the Problem Definition

Based on our discussion, let's refine the problem statement. Please summarize the issue, its scope, the affected parties, and any significant conditions or constraints that will influence the solution approach.

## **6. 40 Inventive Principles and Contradiction Matrix**

[Instruction of how to apply the 40 Principles and Contradiction Matrix]

Step 1. Ask the user for a "Problem Statement", (Wait for the User's Input)

Step 2. Identify Technical Contradiction, (If there is Technical Contradiction, go to Step 3 but If there is not, recommend to the User for alternative way)

Step 3.:

1. Identify the Improving Parameter: This is the aspect you want to improve, e.g., the Strength of the smartphone screen.
2. Identify the Worsening Parameter: This is the aspect that gets negatively affected when you try to improve the first parameter, e.g., the Weight of the smartphone.
3. Rendering the Contradiction Statement with "Key Problem of Technical Contradiction " or "Key Problem of Physical Contradiction".

Step 4. Apply TRIZ Contradiction Matrix (Altshuller's Matrix)

4. Locate the Intersection in the Matrix: Using the TRIZ Matrix, find the intersection of the improving parameter (Strength) and the worsening parameter (Weight of Stationary Object), (Ask the User to "Please confirm the locate result" with Original Matrix or Use the relevant GPT with include Matrix detail as knowledge)
5. Apply Suggested Principles: The matrix will suggest one or more of the 40 Inventive Principles to resolve this contradiction.

[Context of Contradiction] Identify and analyze Engineering (Technical) contradictions in Engineering systems using TRIZ methodology. At the heart of TRIZ lies the concept of

contradiction, which is crucial for understanding and applying this methodology. Let's delve into the details:

## 1. Contradiction in TRIZ

- **General Concept:** In TRIZ, a contradiction occurs when an attempt to improve one aspect of a system leads to the degradation of another aspect. This is a fundamental concept in TRIZ, reflecting the idea that inventive problems often stem from these conflicting requirements or desires.
- **Role in Problem Solving:** Identifying and resolving contradictions is key to finding innovative solutions. By focusing on the contradiction, TRIZ practitioners aim to break free from traditional trade-offs and find a solution that enhances all aspects.

## 2. Technical Contradiction

- **Definition:** A technical contradiction in TRIZ is when improving one technical characteristic causes the deterioration of another. This is the most common type of contradiction encountered in engineering and design problems.
- **Example:** Consider a car tire. Increasing the tire's durability might decrease its grip on wet surfaces. Here, the improvement in one characteristic (durability) leads to a decline in another (grip).
  - The "If, Then, But" analysis is directly related to analyzing and resolving contradictions in TRIZ. Here's how it connects:

Contradictions arise when an "If-Then" relationship has an undesirable "But" side-effect or result.

[Technical Contradiction Example]:

I give you the context following; The process of cooking rice has important factors such as amount of rice, amount of water, and cooking time. Let's assume that we have a purpose. "Want to reduce the cooking time of rice" We can write the form of the contradiction as follows.

*If = [Specific action on the technical system]*

*Then = [Positive change of a typical parameter of the technical system]*

*But = [Negative change of a typical parameter of the technical system]*

So, If = We cook rice by halving the time.



Then = shorter cooking time

But = uncooked rice and we can write the

“Key Problem of Technical Contradiction” sentence as follows: How can we solve the problem to improve [Positive change of a typical parameter of the technical system] without [Negative change of a typical parameter of the technical system]?”

In the case of rice cooking,

"Key Problem of Technical Contradiction" = How can we cook rice in a "shorter time" without "undercooked rice"?

[Instruction to Retrieve from 40 Principles and 39 Parameters]

Step 1. List of 40 Inventive Principles of TRIZ

Step 2. List of 39 engineering parameters

Step 3. Retrieve the Contradiction Matrix by G. Altshuller

[Example Scenario]

Imagine you are designing a smartphone, and you face a contradiction where you need to increase the Strength (parameter 14) of the smartphone screen to prevent breakage, but without increasing the Weight of the Stationary Object (parameter 2), which in this case refers to the overall weight of the phone.

Steps to Use the TRIZ Matrix

1. Identify the Improving Parameter: This is the aspect you want to improve, e.g., the Strength of the smartphone screen.
2. Identify the Worsening Parameter: This is the aspect that gets negatively affected when you try to improve the first parameter, e.g., the Weight of the smartphone.
3. Locate the Intersection in the Matrix: Using the TRIZ Matrix, find the intersection of the improving parameter (Strength) and the worsening parameter (Weight of Stationary Object).
4. Apply Suggested Principles: The matrix will suggest one or more of the 40 Inventive Principles to resolve this contradiction.

Example Output from the Matrix

In a typical TRIZ Matrix, if you look at the intersection of Strength (14) and Weight of Stationary Object (2), you might find principles like:

- Principle 1. Segmentation - Divide an object into independent parts.

- Principle 26. Copying - Use cheaper, simpler copies instead of an inaccessible, expensive, fragile object.
- Principle 27. Cheap Short-Living Objects: Replace an expensive, durable object with a multitude of inexpensive, disposable objects.
- Principle 40. Composite Materials: Change from uniform to composite materials.

#### Applying the Principles

- Principle 40 might lead to the use of advanced composite materials like Gorilla Glass or sapphire glass, which provide high strength without significantly increasing the weight.

#### *Remark;*

- *You might find it more accurate with the original TRIZ Altshuller's Matrix*
- *Or uploading the knowledge file (GPT with Knowledge).*

## **Appendix 2 Experiment with parameter values**

Some generative AI providers allow users to adjust the AI parameters.

*Refer: <https://cloud.google.com/vertex-ai/generative-ai/docs/learn/prompts/adjust-parameter-values>*

### **Temperature**

The temperature is used for sampling during response generation, which occurs when topP and topK are applied. Temperature controls the degree of randomness in token selection. Lower temperatures are good for prompts that require a less open-ended or creative response, while higher temperatures can lead to more diverse or creative results. A temperature of 0 means that the highest probability tokens are always selected. In this case, responses for a given prompt are mostly deterministic, but a small amount of variation is still possible.

If the model returns a response that's too generic, too short, or the model gives a fallback response, try increasing the temperature.

Each model has its own temperature range and default value.

### **Top-K**

Top-K changes how the model selects tokens for output. A top-K of 1 means the next selected token is the most probable among all tokens in the model's vocabulary (also

called greedy decoding), while a top-K of 3 means that the next token is selected from among the three most probable tokens by using temperature.

For each token selection step, the top-K tokens with the highest probabilities are sampled. Then tokens are further filtered based on top-P with the final token selected using temperature sampling.

Specify a lower value for less random responses and a higher value for more random responses.

### **Top-P**

Top-P changes how the model selects tokens for output. Tokens are selected from the most (see top-K) to least probable until the sum of their probabilities equals the top-P value. For example, if tokens A, B, and C have a probability of 0.3, 0.2, and 0.1 and the top-P value is 0.5, then the model will select either A or B as the next token by using temperature and excludes C as a candidate.

Specify a lower value for less random responses and a higher value for more random responses.