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Evaluating the Effectiveness of Generative AI in TRIZ: A Comparative Case Study

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Abstract

The rapid advances in generative AI technologies have sparked a debate among researchers on their role in the innovation process, particularly regarding their problem-solving and idea-generation capabilities. While researchers theorise the potential of generative AI in conjunction with TRIZ (Theory of Inventive Problem Solving), evaluating its current state and understanding its practicality is equally critical. Hence, this paper provides evidence of generative AI's ability to offer solutions in real innovation projects. Our exploratory study compares the results of an actual innovation project in a professional consulting-like setting using traditionally applied modern TRIZ tools against generative AI-assisted results for the same customer-defined problem. The comparison focuses on the solutions' degree of similarity, depth, and breadth. Additionally, our research identifies the advantages, disadvantages, and feasibility of using generative AI in problem-solving and innovation projects. Our findings indicate that combining generative AI and TRIZ produces feasible, cross-domain preliminary conceptual directions with satisfactory scientific substantiation. Lastly, we recommend suitable use cases for innovation managers and TRIZ practitioners, highlighting how the TRIZ-GPT combination can save considerable time exploring preliminary concepts and idea generation during problem-solving.

Keywords: Generative AI, TRIZ, Case study, GPT.

1 Introduction

Past research on the theory of inventive problem-solving (TRIZ) has had an interesting evolutionary methodical transformation from a prominent problem-solving methodology to a globally recognised innovation-supporting toolkit and finally to an integrated part of broader innovation practices across several domains[1]. Fuller et al. state that artificial intelligence (AI) will play an essential role in the innovation pro-

cess, from exploring problems to selecting solutions [2]. The role of AI is expected to augment human creativity and automate specific parts of the problem-solving process. Other researchers also forecast that AI will become the key driver of innovation management, leading to more open and collaborative approaches and the emergence of new roles in innovation teams [3]. A recent evolutionary study by Brad, 2023 on the TRIZ methodology predicts that computer science, AI and its integration with TRIZ will be the next breakthrough in the problem-solving method. Moreover, the research also suggests that TRIZ will supposedly undergo seamless integration and rapid adoption due to the fast pace of artificial intelligence development [4].

While there has been an increase in academic publications on AI and TRIZ and thematic conferences inviting scientific journals, there remains a notable gap in research on the generative pre-trained transformer (GPT) AI models and TRIZ. The most recent study on TRIZ and GPT by Pheunguha and Adunka, 2024 focuses on prompt engineering for GPT technologies, applied in conjunction with TRIZ tools for better results. They attempt to address the issue of subjective prompts that lead to the high variability of results. Their work provides a systematic handbook that uses different structures of prompts engineered for specific purposes to enhance the problem-solving process [5]. However, they do not provide evidence of case studies showcasing their effectiveness in real projects. In this research, we aim to address this gap by providing evidence of the combination of TRIZ and generative AI and evaluating its practical applicability.

Therefore, in our exploratory study, we compare the results of generative AI chatbots with TRIZ against manually applied GENTRIZ methodology to solve the same customer-defined problem wherein the results were delivered to a client in a professional consulting-like environment [6]. We aim to determine the degree of alignment between the solutions delivered to the client and those generated by AI, demonstrating its feasibility, accuracy and robustness in real-world applications. This raises the following research question: 'Can the TRIZ-ChatGPT combination generate practical and usable solutions in real projects, potentially replacing modern TRIZ methods?'

2 Methodology

The research method used to select the case study is purposive sampling. The researchers selected this method because of its convenience and ease of data availability [7]. Additionally, the nature of the problem involves a limited number of system and super-system components that make it easy for a broad audience to understand. The methodology is divided into three sections: the case background, an overview of the GENTRIZ methodology, and the AI methodology used in the research.

2.1 Case Study Background

In this research, we selected a project in a professional consulting service-like environment completed in 2020 by a qualified TRIZ practitioner and his team. We made sure that the same researcher also performed the AI-assisted TRIZ later to standardise

human bias performed in both cases. The case involves a healthcare and life sciences company that produced pipettes and pipette racks for laboratory applications. The project aimed to "increase the sustainability of their pipette racks". Pipettes are small laboratory instruments typically used in chemistry or biology to move and measure liquids. Often, they have a removable attachment known as a pipette tip. The plastic box that holds the pipette tips is known as a pipette rack. Figure 1 below shows the pipette tips and the rack we refer to. As a part of the sustainability transition, the company switched its plastic material from polypropylene (PP) to fully recyclable thermoplastic polyethene terephthalate (PET), which resulted in less plastic and weight of the rack. The case, as described by the customer, is as follows.

"As a standard operating procedure, researchers and lab technicians are instructed to clean and sterilise the pipette racks in an autoclave machine at recurring intervals. An autoclave uses steam under pressure to kill harmful bacteria, viruses, and spores to sterilise the pipette rack at 120°C for approximately 30 minutes. The original material, PP, was thermally resistant to the autoclave machine; however, the problem occurred when the new recyclable material, PET, could not withstand the thermal load in the autoclave and crumpled due to heat. PET had inferior thermal resistance and functional and structural properties that did not meet the requirements. Therefore, PET racks became consumable and unsuitable for repeated use since they couldn't be sterilised. Thereby reducing its usable life significantly.

Fig. 1. Representative figure of Pipette racks with Pipette tips

Project Goal: Find alternative materials for pipette tip racks within the constraints of the following requirements.

1. Can be produced in the same or similar form factor to the current racks
2. Low-cost
3. Robust- capable of support tips during loading and withstand shipping and handling
4. Clean and sterilisable (no contamination on the tips)- steam autoclave built for 20 minutes at 120°C for ten cycles and gamma radiation resistant

5. Chemical compatibility similar to PP.”

The company's original problem statement suggests finding alternative materials as the direction of the solution.

2.2 Overview of the application of Modern TRIZ on the case.

This section summarises the manually applied GENTRIZ approach, project logic, TRIZ tools applied, key problems, and conceptual directions for the case employed by the TRIZ team. The section also briefly overviews the key problems and their emerging conceptual directions. Due to confidentiality reasons, the researchers decided not to reveal any detailed solutions in this study. Several iterative discussions with the company led to the scope refinement and allowed the TRIZ practitioners to transform the initial problem into key problems by applying TRIZ tools. The project objective was refined to “identify cost-effective technical solutions that allow existing recyclable racks to be autoclavable.”

The TRIZ team benchmarked existing systems and performed preliminary patent landscaping, function analysis, and cause-and-effect chain analysis for the problem identification stage, resulting in key disadvantages and key problems in line with the GENTRIZ methods [6]. This is followed by the problem-solving stage, which includes generating conceptual directions and concept substantiation. Figure 2 illustrates the project logic followed by the TRIZ team using the GENTRIZ approach.

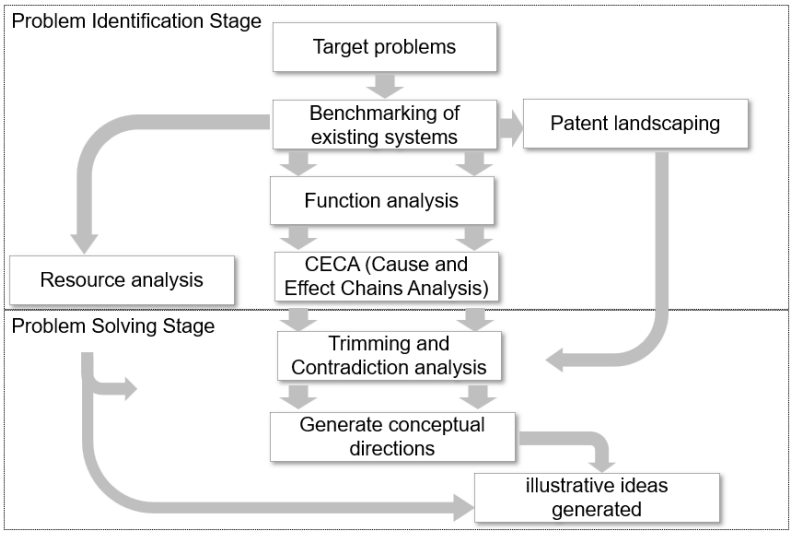

Fig. 2. Project logic with GENTRIZ approach[6]

In this case, trimming was not performed since the scope to trim the component was limited. Figure 3 illustrates the key problems and their respective general conceptual directions in which specific solutions were developed. However, the researchers

have omitted specific solutions in the conceptual directions for reasons of confidentiality.

#	Key Problem	Conceptual direction
1	How to eliminate Key Disadvantage "Excessive Temperature of steam"?	CD1: Alternate methods for Sterilization or changing autoclave mechanisms
2	How to eliminate Key Disadvantage "Insufficient Thickness of the material"? How to increase "Glass transition temperature" of plastic?	CD2: Creating Stronger Materials/structures and alternate materials
3	"Rack Should be thin In order to have low weight BUT Rack Should be thick In order to resist heat"?	CD3: Dynamization of the rack
4	How to eliminate Key Disadvantage "Material Holds heat"?	CD4: Movement of heat
5	How to eliminate Key Disadvantage "steam contacts rack directly"?	

Out of scope directions | From Cause-and-Effect Chain Analysis | From Contradiction Analysis

Fig. 3. Key problems and conceptual directions formulated by the TRIZ team

Five key problems were revealed during the problem identification stage. Conceptual direction one (CD1) was out of scope since changing sterilisation machines is a supersystem element that the company did not control and was not pursued in detail. The analysis found three key problems from cause-and-effect chain analysis and one key problem from contradiction analysis. Post the problem identification stage, the researchers formulated several contradictions for each conceptual direction and developed solutions that allowed the company to meet its requirements. Some solutions recommended alternative materials as substitutes whilst meeting all the customer requirements. Several solutions were directed towards better functional strength and dynamisation of the pipette racks, resolving the contradiction in key problem four. Lastly, a group of solutions was directed towards moving heat away from the plastic in the operation zone during the operation time, which required minimal changes to the existing racks. In total, the TRIZ team delivered 20+ promising solutions offered to the client. We will use these delivered solutions to compare them with the AI-generated solutions.

2.3 AI methodology and assumptions

The section elaborates on the artificial intelligence-related methodology followed during the research. Pheunguha and Adunka highlight the importance of prompt engineering in their study and summarise six different prompt design techniques that users can employ for better GPT results [5]. Similarly, in our case, the input prompts are incredibly critical for productive output. However, given the human subjectivity, the input prompts provided to the GPT will be highly subjective and variable. Therefore, to resolve this problem, we used a commercially available Advanced Innovation Design Approach (AIDA) automatic idea and IP generator version 2.09 software to create standardised and consistent prompts [8, 9]. The AIDA software is commercially

available and developed by Tris Europe Innovation Academy, founded by Professor Pavel Livotov and his team. This Microsoft Excel-based software provides a feature for generating a prompt structure that can be copied and pasted into any generative AI-powered chatbots without needing any iterative prompt engineering. The software was created primarily for audiences with TRIZ knowledge, which brings us to our first assumption: users should have a basic understanding of TRIZ to use the AIDA software effectively. Figure 4 shows the landing page of the AIDA software and its AI prompt generation feature. In this case, we selected AI prompter 2, specifically utilised for developing product concepts.

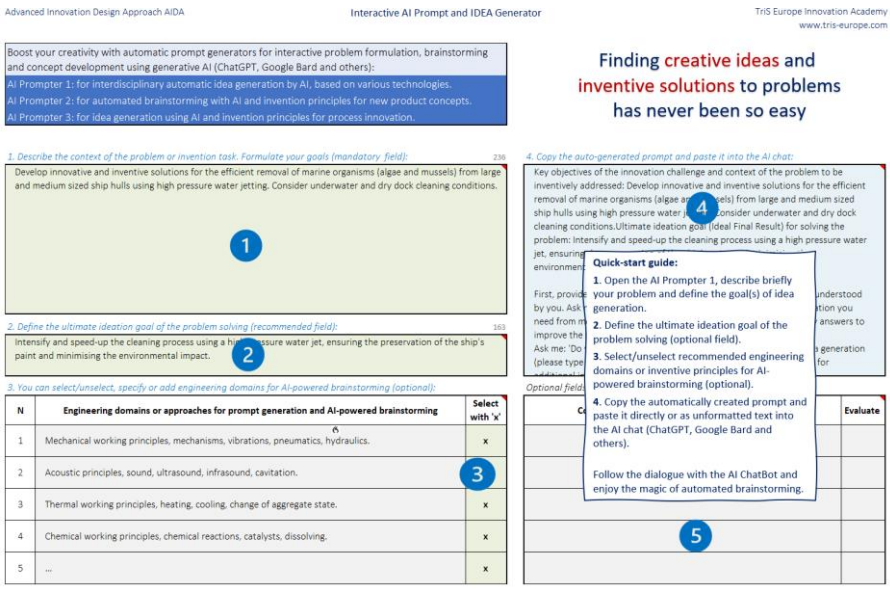

Fig. 4. Screenshot of AIDA software V2.09 interface and steps in the prompt generation (Tris-Europe Innovation Academy)

The software uses a specific structure to model any problem description into a pre-defined prompt that does not require constant human refinement. We will describe each step briefly and provide justifications for how it was used for this research.

Step 1. The user inputs the context of the problem or the invention task.
Our research aims to determine if generative AI can resolve the problem described in the company's initial problem description. Therefore, we used the company's unchanged description and entered it into the prompt generator. The prompt was the same as described in the case study background section and the formulated goals below.

"As a standard operating procedure, researchers and lab technicians are instructed to clean and sterilise the pipette racks in an autoclave machine at recurring intervals. An autoclave uses steam under pressure to kill harmful bacteria, viruses, and spores to

sterilise the pipette rack at 120°C for 30 minutes. The original material, PP, was thermally resistant to the autoclave machine; however, the problem occurred when the new recyclable material PET could not withstand the thermal load in the autoclave and crumpled due to heat. PET material also had inferior thermal resistance and functional and structural properties that did not meet the requirements. Therefore, PET racks became consumable and unsuitable for repeated use since they couldn't be sterilised. Thereby reducing its usable life.

Find alternative materials for pipette tip racks within the constraints of the following requirements. 1. Can be produced in the same or similar form factor to the current racks 2. Low-cost 3. Robust- capable of providing support tips during loading and withstanding shipping and handling. 4. Clean and sterilisable (no contamination on the tips)- steam autoclave built for 20 minutes at 120°C for 10 cycles and gamma radiation resistant 5. Chemical compatibility similar to PP."

Step 2. The user describes the ultimate ideation goal of problem-solving.
This is an optional but recommended field for the user to fill in in the AIDA software and is also known as an ideal final result (IFR), wherein some examples provided by the software follow the structure of "improve the useful action XXX, eliminate the harmful effect XXX, resolve the contradiction XXX". This step requires the user to demonstrate basic TRIZ knowledge and formulate an IFR. Therefore, we provided the most suitable IFR for the initial problem in the recommended format: Eliminate the Harmful effect of "steam melting the PET pipette rack."

Step 3. The user is asked to select/unselect inventive solution principles for AI-powered brainstorming.
This step is optional but important in the solutions generated. The AIDA software consists of several elementary solution principles and applies them to the working tool, target object, workpiece affected by the working tool, to the main function or the undesired function as identified in steps 1 and 2 [10]. These elementary solution principles go well beyond the forty inventive principles. Eighty-eight such elementary solution principles exist; however, we left it in its default condition with ten elementary solution principles selected. Some examples of the solution principles described are "use Work Tool in other aggregate states: change it to solid, liquid, gas, or plasma." Most elementary solution principles are variations and structured specifically for the working tool. Therefore, human oversight over generative AI is critical to validate whether the working tool and the target object were identified appropriately.

Step 4. Copying the auto-generated prompt.
Next, we copy the single prompt automatically generated in the Excel sheet and paste it into the Open AI ChatGPT 4o chatbot. We noticed a discrepancy concerning this step that can create a variation in outcomes. We notice that the overall output of the conceptual directions remains similar, with minor but acceptable differences. In some cases, while testing for repeatability, the generative AI fails to understand and follow the instructions, making it inconvenient for the user. Therefore, the user must repeat

this step. Lastly, step five is a feature in the AIDA software that allows users to take notes of ideas in the software.

2.4 Selection of the GPT model and AIDA prompt generator

This section justifies the generative AI model selected and the prompt output structure. We selected ChatGPT 4o, OpenAI's latest state-of-the-art flagship model behind the generative AI-powered chatbot capable of image recognition and generation, the latest available model as of July 2024. It provided reliable and more repeatable results than Google Gemini and Anthropic Claude. Gemini and Claude produced outcomes that took an excessively creative stance and were not considered. However, it was noted that GPT4o provides the most comprehensive and consistent response, following the user instructions on repeated trials of the prompt. All chat history has been recorded and saved for research purposes using the link in the appendix section.

Figure 5 illustrates the GPT4o logic diagram and its interaction, highlighting the key stages where user input is required. The logic below directly corresponds to the AIDA software prompt and its working principle. Problem-solving with ChatGPT happens in two distinct stages. Firstly, the user is asked to refine the prompt iteratively and provide an output to confirm and verify the initial problem. Moreover, GPT can ask relevant additional questions to clarify the context and request user input. In this stage, the structure of the AIDA software forces ChatGPT to define the initial problem situation and the working tool. It also outputs the main useful function, the target object and the user's desired IFR. If the user confirms and verifies all the above, the GPT provides a revised, improved output and requests the user to proceed to the idea generation stage.

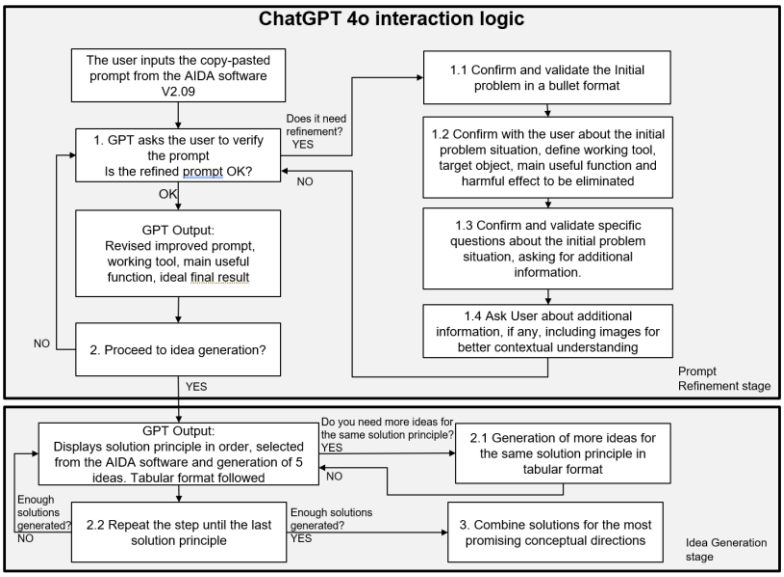

Fig. 5. ChatGPT 4o logic interacting with the user input

In the idea generation stage, user-predefined solution principles from the AIDA prompt are used to generate the top five ideas in a tabular format for each selected solution principle. Note that these are not inventive principles in TRIZ but solution principles. At its core, they are segmented into specific variations and versions of inventive principles that mostly apply to the working tool. Ten solution principles specified in the AIDA software were selected by default; therefore, at least fifty ideas will be generated. However, TRIZ practitioners can choose the most relevant solution principles based on the description provided in the AIDA software, which modifies the initial prompt and, therefore, the output of GPT. During the idea generation process, the GPT provides the idea name, ID description, implementation example (some scientific justification) and the solution principle used in the idea. If the user is satisfied with the number of ideas generated, it moves on to the following principle. Post-idea generation, the AIDA software consists of a prompt that combines several ideas and provides integrated complementary ideas to provide robust and effective solutions. Lastly, ChatGPT generates and displays five complementary integrated conceptual directions in a tabular format following the structure.

3 Results

The results present ChatGPT 4o generated 50 ideas and five integrated conceptual descriptions that we will compare against the solutions to the ones delivered by the TRIZ team. Firstly, Table 1 shows the top five conceptual directions that ChatGPT generated. The table shows the AI-generated concept name, conceptual description, idea ID numbers, and implementation examples.

As shown in Table 1, the AI output typically consists of the conceptual description, which provides the general action principle. For example, CD1 and its AI-generated concept description suggest materialistic changes. This conceptual direction is aligned with material science and polymer chemistry action principles. Next, the AI result provides an implementation example, which dives deeper and provides more specific answers. For instance, high-performance temperature-resistant polymers, such as PEEK, are the specific material for use with some scientific justification. We added the similarity and depth column to compare the AI-generated and the manual results. The similarity column marks a “Yes” if the solutions generated by AI are similar or the same as compared to the GENTRIZ method and a “No” if found otherwise. Next, the depth column marks a “yes” if the solution description and implementation example have sufficient details to develop a feasible solution for the problem solver and a “no” if found otherwise.

Table 1. The AI-generated result in comparison to results from the TRIZ team

CD	AI- Concept Name	AI-Concept Description	AI- Implementation Example	Similarity	Depth
1	Composite Material Approach	Utilise a high-temperature composite material combining	Develop a pipette rack using a blend of PET and high-temperature-	Yes	Yes

		PET with other polymers and granules to enhance thermal resistance and structural integrity.	resistant polymers like PEEK, reinforced with thermally resistant granules such as silica or alumina, to create a composite material that with-stands autoclaving without deformation.		
2	Modular and Dismountable Design	Design the pipette rack with inter-changeable and dismountable modules that can be easily assembled and disassembled for cleaning and autoclaving.	Create a pipette rack consisting of modular, snap-together parts that can be assembled into smaller components for autoclaving and reassembling afterwards. If damaged, each part can be individually replaced, reducing waste and cost.	No	No
3	Advanced Coating and Surface Treatments	Apply various coatings and surface treatments to enhance PET racks' thermal resistance and durability during autoclaving.	Coat the PET racks with nanocomposite materials and thermal-resistant chemical layers, such as silicone or ceramic-based coatings, to protect the underlying PET from heat damage and improve overall thermal stability.	No	No
4	Phase Change and Cooling Integration	Incorporate phase change materials and cooling inserts within the rack design to absorb excess heat during autoclaving and prevent deformation.	Integrate phase change materials that absorb and store thermal energy within the rack and design cooling inserts with high thermal conductivity materials to dissipate heat, ensuring the PET material remains below its melting point during sterilisation.	Yes	Yes
5	Granular and Fillers Enhanced Structure	Develop the rack using a composite structure with granules and fillers that enhance thermal resistance and mechanical strength.	Create a pipette rack using PET material reinforced with thermally stable granules and fillers, such as glass beads or silica particles, uni-	Yes	Yes

	formly distributed throughout the structure to improve thermal resistance and prevent deformation during autoclaving.

We will use the original solutions delivered to the client as the control group to benchmark the GPT-generated solutions and compare them against each other based on the following:

3.1 Similarity of action principles

As our first step in comparing the TRIZ team's results with the AI-generated ones, we compare the action principles of both solutions from AI and the TRIZ team. If they match, with approximately the same level of detail described by the GPT, we can consider that their general solution directions are similar. Here, we refer to the AI-concept descriptions.

In our case, three conceptual directions provided by the AI were similar in terms of the action principle delivered by the TRIZ team. They are marked as "YES" in column two, i.e. CD 1, 4 and 5. They use composite materials, phase change materials, and the integration of cooling channels and granular and filler materials, which enhance structures for effective thermal resistance and mechanical strength. The TRIZ team did not deliver CD2 and CD3 and were therefore marked as "NO". These directions include modular and dis-mountable designs and advanced coating and surface treatment operations and did not match with the AI.

While the GPT generates the top five conceptual directions, the user can request that it create more. Therefore, the number of conceptual directions matching the TRIZ team is not an effective comparison.

3.2 Depth of the solutions

To structure our assessment method, we evaluated the depth of the directions in a two-step method. First, we assessed the first output generated in the concept description and the implementation example column. Second, we qualitatively analysed the AI-generated description of an explicit "elaboration request" on one of the conceptual directions, asking Chat GPT4o to explain the response in more detail.

A. The first raw output generated and its level of detail.

As we see in Table 1, the ChatGPT generates a reasonably accurate concept description of the action principle used behind the solution, although at an abstract level. This level of detail is not enough to carry the idea further in the innovation process. The concept description lacks any specific detail, elaboration, and know-how to de-

velop the solution and is generally insufficient to develop the idea into concrete solutions. However, the implementation examples (column 3) for the respective concept descriptions provide more specific examples, such as the name of the material and categorisation of materials, and more generic know-how that approximately describes the potential of the solution to meet the constraints.

In the researcher's opinion, these implementation examples are satisfactory for triggering specific solution ideas (if domain knowledge is available). These descriptions may be worth investigating and researching with the help of subject matter experts. For example, at this stage, a mechanical engineer can investigate high-temperature resistant polymers, such as PEEK, to create composites or research on thermally stable granules and filler particles used in thermoplastics. We will call this phase the "general research phase" starting point. Subject matter experts can discuss, develop, and begin general research in the proposed conceptual directions. However, the implementation examples are still at the general level and not enough to be called a complete solution. For example, the CD4 description of the ChatGPT does not explain where the cooling inserts should be placed, which specific phase change materials can be used, how much quantity is needed or how the rack design can be changed to accommodate the inserts.

B. Elaboration on the raw output and its level of detail

Considering CD1 in Table 1, we asked ChatGPT to elaborate more on the solution. ChatGPT now provides an elaborate conceptual description with three sections: key elements, implementation examples, and benefits. The key elements included the specific polymer needed for creating the blend, such as polyetheretherketone(PEEK) and polyphenylene sulfide(PPS), which is scientifically appropriate. Secondly, it suggests thermally resistant granules such as silica and alumina. And lastly, ChatGPT compares these solutions against the original constraints the user provides. We found this behaviour very interesting since, during the idea generation phase, the output of the chatbot does not substantiate or give any indication of the feasibility of these ideas against the user-defined constraints. However, upon elaboration, it automatically suggests that, in theory, it could meet the requirements specified by the user.

Next, in the elaborated implementation example, ChatGPT divides its output recommendation into three parts: how to prepare the material, the suitable manufacturing process, and the performance validation. The material preparation does not provide a specific ratio or substantiation but some generic considerations for researchers to calculate the required ratio. Secondly, injection moulding or extrusion is recommended to form the composite into the desired shape for manufacturing. In this case, this is correct since the original racks are injection moulded, but the user never provided any input on the manufacturing process of the current racks.

ChatGPT also generates descriptions for conducting quality control tests with repeated autoclave cycles to simulate usage conditions. Lastly, performance validation provides some testing-related general guidelines. The first level of elaboration from ChatGPT ends with the "benefits" section that compares the original constraints of the problem and tries to justify the same. For example, in our case, ChatGPT generated "Cost-Effective: By achieving a balance between material costs and performance, the

composite material can meet the target cost of $0.60 per rack at high production volumes."

Overall, the output of the first request to elaborate on the solution remains generic, with partial justification and substantiation that can help researchers and R&D experts navigate the uncertainty and brainstorming needed to find suitable material, especially if they are not subject matter experts. It provides a satisfactory starting point for research and a preliminary conceptual direction that can be investigated in detail. That is better than traditionally substantiating using trial and error, web scraping, and researching potential solution directions, saving valuable time for TRIZ consultants and practitioners.

However, they are conceptual directions, not final solutions, and must not be taken at face value. They should be verified, examined, and investigated to develop into complete solutions. To explore further, we asked ChatGPT to provide a cost estimate and breakdown of the proposed idea. To our surprise, it provided material costs, estimated manufacturing costs, and several other costs to approximate if the conceptual direction could meet the requirements defined by the user. Moreover, it provides the cost sources and the potential manufacturers of the suggested materials, typically saving TRIZ consultants valuable time in narrowing down research areas. Of course, these estimates are most likely inaccurate and depend heavily on other factors, but GPT provides an approximate estimate rather quickly and conveniently. Thanks to its web access, GPT can provide data sources, translating to a starting point for the substantiation phase that TRIZ consultants perform at the end of a full-blown project. For example, ChatGpt 4o provided the material pricing from chemical and engineering news market reports, plastics technology magazines and supplier websites such as Sigma-Aldrich, Polyone and Sabic. Manufacturing costs were provided by the American Injection Moulding Institute(AIM), the Plastic Industries Association reports, the Trade Association publications, and industry benchmarks. In such cases, specific answers significantly reduce the time spent researching suppliers instead of using a search engine, which overloads humans with information.

3.3 Breadth of the solutions.

The earlier section elaborated on the integrated conceptual directions provided by ChatGPT 4o; however, in this section, we comment on the overall experience and the breadth of solutions it covers. Utilising generative AI for problem-solving can generate potentially infinite cross-domain ideas that humans cannot explore otherwise due to time constraints, knowledge constraints or lack of competence. We wanted to examine the potential opportunities and domains missed by the TRIZ team that the AI was able to generate. This criterion can directly correspond to the number of action principles used by the AI compared to the TRIZ team within the default prompt provided by the AIDA software. Conversely, we also investigate if there were solutions, action principles or domains that the TRIZ team developed and missed by the AI.

Firstly, the GPT generated 50 ideas by default. This was without using the different eighty-eight elementary solution principles optionally available in the AIDA software. The quality of the ideas GPT generates may be questionable, but even for the best

TRIZ practitioners, developing concepts, ideas, and integrated solutions takes considerable time. However, the time saved in exploring multiple conceptual directions from scratch can be saved considerably for problem-solving and acts as a platform to provide initial triggers for inventive solutions.

Secondly, it is possible to generate ideas and solutions based on several action principles infinitely depending on the prompt. These generative AI models can help researchers, scientists, and TRIZ practitioners blur the boundary by generating different possible solutions to provide a holistic landscape of ideas that could have been completely missed due to a person's psychological inertia. For example, in our case, the TRIZ team was comprised primarily of mechanical engineers and suggested several strong solutions in the mechanical engineering domain despite utilising a function-oriented search during problem-solving [11]. However, ChatGPT 4o generated ideas based on acoustics, magnetics and electromagnetic properties, textured surface designs, and foaming of thermoplastics by itself. The researchers did not prompt ChatGPT to produce these ideas. The TRIZ team was unaware of this and did not have sufficient expertise to substantiate it during their problem-solving process. While the answers generated may not be practical, directly usable, or sometimes wholly off-topic, we found that sometimes they enhance the understanding of the problem solver and add value to their individual knowledge to improve their ideas, allowing them to visualise several solution possibilities based on theoretical scientific principles. In some instances, several inventive solutions were also generated, such as heat dissipation channels, cooling inserts, and aerogel coatings that solved the key problem of moving heat.

On the other hand, the TRIZ team also generated several specific solutions based on sustainable material-based solutions and modular thermoplastics that ChatGPT did not generate and missed. This may be because of the inherent bias of the historical pre-trained data or the lack of it in its training models. Despite the problem description being unrefined and directed towards finding alternative materials, the AIDA software-generated prompt performed excellently, redirecting the idea direction of ChatGPT and pushing it to solve the appropriate key problems. The AIDA software develops good one-time structured prompts without much human intervention that guide the generative AI in the correct direction, which aligns with TRIZ knowledge for effective results. In several cases, the results are theoretically feasible preliminary conceptual directions that provide enough information for research and investigation.

4 Discussions

This section discusses the various aspects of using generative AI against traditionally applied modern TRIZ and weighs its pros and cons to conclude by answering our research question. Our study demonstrates an experiment comparing a traditionally applied modern TRIZ in a professional consulting project against a standalone TRIZ-generative AI combination to solve the same problem and to evaluate their outcomes. This study is the first to explore such a radical emerging topic, in which we expected the outcomes to be sub-par. In contrast, the results of the study are positive and prac-

tical and can be used by TRIZ practitioners and other problem solvers alike. This section showcases the advantages and disadvantages of generative AI approaches for practical problem-solving. We divide our discussions into three sections: the advantages of combining TRIZ and ChatGPT or AI chatbots and their potential applications, the disadvantages, and the conclusions and limitations of the study.

4.1 Advantages of using TRIZ and generative AI combinations

ChatGPT 4o or any other generative AI model may not possess logical reasoning and understand the problems and how humans do, but they are extremely fast in providing specific solutions to specific requests [12]. This ability makes it valuable for TRIZ consultants to significantly reduce “time to solution” during problem-solving processes. While they cannot be relied upon and trusted, they mostly provide a satisfactory conceptual direction that may be worth examining or exploring depending on the nature of the problem. We may think of the TRIZ and GPT combination as an extended R&D global knowledge database that spits out specific answers and is available to us at any time during the problem-solving process. Given the overload of data and information produced by search engines, generative AI can act as a supportive mechanism to narrow down research areas and aid in problem-solving through its arguments.

TRIZ and GPT combination is best utilised in the preliminary idea generation phase for tasks requiring maximal opportunity exploration, such as technology forecasting, innovation portfolio analysis and future product roadmaps [5, 13, 14, 15, 16]. Projects that require the TRIZ consultant and practitioner to explore several preliminary conceptual directions in the fuzzy front end of innovation need TRIZ-GPT combinations to cover as many cross-domains as possible[17, 18, 19]. For example, developing several future directions for hundreds of products and product lines is necessary for complex project types such as innovation portfolio analysis. This task is time-consuming and requires significant effort from TRIZ practitioners and consultants. In this case, generative AI aided product portfolio development wherein ideas and concepts that are approximately acceptable, provide a holistic product portrait, meet the voice of the product and the customer, could provide faster results [13]. These tasks do not require specific solutions but a general direction of the product's future evolution. Secondly, using generative AI may also be useful in patent circumvention to visualise all possible directions of the product trend of development and protect the intellectual assets accordingly. Our research findings support Pheunghua and Adunka, wherein generative AI provides conceptual directions that often require human oversight for verification to assess and adapt the solutions proposed critically [5].

Moreover, the AIDA idea IP generator is an excellent driving force behind the generative AI prompt for conveniently providing a satisfactory output and allowing researchers to explore directions they may have neglected, were unaware of, or missed out on. The software can save precious time and resources for iterative prompt engineering and refinement needed for effective AI-generated answers [8].

4.2 Disadvantages of TRIZ and generative AI combinations

Data privacy, specifically on innovation projects and sensitive information, is a known disadvantage of using any generative AI related to data ethics [3, 5, 12, 20]. Adhering to legal frameworks is necessary for standard ethical practices concerning copyrights, trade secrets, and scientific research. On the other hand, we have already stated that the unreliable and inaccurate information provided by the generative AI cannot be taken at face value and requires human oversight to ensure the accuracy and applicability of its answers. Moreover, historical pre-trained data of the GPT that is unknown to the users can create biases that harm its application and adoption [2].
However, in the researcher's opinion, human beings' critical thinking and problem-solving abilities are hampered when using generative AI, which concerns us the most. While there are research papers arguing that generative AI has the potential to heighten and not diminish argument creativity, we believe that utilising it in a standalone mode may not be beneficial for the upcoming TRIZ practitioner generation [21]. Originally, TRIZ aimed to eliminate brainstorming and develop an individual's ability to solve inventive problems. TRIZ thinking and knowledge of ARIZ have proven to develop highly activated brain regions that indicate neurocognitive differences and improve thinking [3]. Several TRIZ tools, specifically problem formulation tools such as function analysis, cause-and-effect chain analysis and trimming, require strong scientific and logical thinking developed over time through practice. However, in this experiment, a standalone use case of generative AI and TRIZ, starting from the problem definition until the output, there was no use of problem formulation tools, contradiction analysis, or problem-solving. One can safely say that there was no TRIZ involved other than the initial prompt (which included TRIZ words and predefined structures) developed by the AIDA software. This harms our ability to formulate the appropriate key problems, which does not develop strong crucial thinking skills. Therefore, we believe that more research is required on the impact of generative AI on the problem-solving ability of humans and TRIZ.

5 Conclusions and limitations

To answer our initial research question, we provide evidence that TRIZ-based prompts generated by the AIDA software and utilising the state-of-the-art ChatGPT 4o model cannot replace modern GENTRIZ methods or provide direct and complete concrete solutions to real projects. However, surprisingly, they generate relevant practical preliminary conceptual directions, with scientific justification and potentially cross-domain ideas, reducing the significant time required for research areas for the problem solver. The outcome of generative AI heavily depends on the prompt, which requires prompt engineering techniques to be precise and robust for its effectiveness. Given the AIDA software’s effectiveness in generating the prompt, we found it one of the most convenient and effective commercially available software for prompt generation. It provides a structured prompt and allows the generative AI to produce several practical, relevant and satisfactory preliminary ideas with acceptable detail. Generative AI reduces the considerable effort needed to explore ideas and perform pre-

liminary substantiation. However, the generated outputs often lack specific know-how and require adaptations to transform their output into complete and concrete solutions. Moreover, we experimented with the Dall-E image generator available with Chat GPT 4o to develop an illustrative image of the idea it generates. However, it does not provide any usable results, so it was omitted from this paper.

With the current state of generative AI models, using them as a standalone problem-solving methodology may not provide satisfactory results. However, a hybrid combination of generative AI and TRIZ can provide quick ideas and broader conceptual directions in projects and tasks requiring extensive exploratory work. For example, technology forecasting, protection of intellectual property and patent families, innovation portfolio analysis and preliminary idea generation. We recommend using generative AI as a supplementary tool after identifying the key problems for maximal effectiveness. The role of AI will be to support the problem solver and ensure that all potential strong conceptual directions are explored and examined, thereby increasing the effectiveness of innovation. The future scope of work for generative AI and TRIZ may heavily depend on integrating problem formulation tools, wherein logical reasoning and scientific thinking of the generative AI may be able to produce relevant key disadvantages and key problems through the initial prompt.

Lastly, some of this study's limitations include its lack of generalizability because it examines a single case with the addition of AI bias and discrepancy in repeatability based on the chatbot's response. These research outcomes may not be generalisable since they heavily depend on the historical data of the generative AI, and therefore, results may vary on a case-by-case basis. However, it provides an important foundation for more exploration and research on AI-assisted TRIZ mechanisms for researchers. Lastly, repeatedly providing the same prompt to ChatGPT 4o does not yield the same results. We noticed that sometimes there were instructions in the prompt which were not completely followed, or the results and solutions varied slightly from each other. However, given that this case study is experimental and exploratory, its results and findings may vary depending on the selected case study.

Appendix

The link provides the entire Open AI ChatGPT 4o history to be used for research purposes and review for audiences- https://chatgpt.com/share/a126c1f5-b433-4bed-b23c-ceb4b90459ab

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