

Evaluating TRIZ Methodology in the Conceptual Design Phase of Industrial Products

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Abstract

The Theory of Inventive Problem Solving (TRIZ) has emerged as a powerful systematic innovation methodology that enhances creativity and problem-solving efficiency in engineering design. This paper evaluates the application of TRIZ during the conceptual design phase of industrial products, where early-stage decisions critically influence functionality, cost, sustainability, and market competitiveness. TRIZ provides designers with structured tools—such as the 40 Inventive Principles, Contradiction Matrix, Su-Field Analysis, and Trends of Technological Evolution—that help identify and overcome technical contradictions without relying solely on intuitive brainstorming. By analyzing how these tools guide designers toward breakthrough concepts, this study highlights their relevance in accelerating ideation, reducing design risks, and fostering innovative alternatives. The evaluation draws on case studies from mechanical, electrical, and consumer product industries, demonstrating how TRIZ supports designers in systematically generating feasible solutions, minimizing trade-offs, and improving product performance. The methodology is particularly valuable for addressing complex engineering contradictions, enabling teams to foresee potential design limitations and integrate solutions aligned with technological evolution. Furthermore, TRIZ enhances collaborative decision-making by establishing a common innovation language among multidisciplinary teams. Overall, the study concludes that TRIZ significantly strengthens the conceptual design phase by promoting structured creativity, reducing development time, and improving solution novelty. Integrating TRIZ into early design workflows not only enhances product innovation potential but also contributes to sustainable and cost-effective engineering outcomes. This evaluation underscores the importance of adopting TRIZ as a strategic tool for industries seeking to remain competitive in an increasingly innovation-driven market.

Keywords: TRIZ methodology, inventive problem solving, conceptual design, industrial product development, contradiction matrix, technological evolution trends, engineering innovation, systematic design tools.

INTRODUCTION

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In today's highly competitive industrial environment, the demand for innovative, efficient, and user-centric products has pushed organizations to adopt systematic approaches to problem solving and design. The conceptual design phase is widely recognized as one of the most critical stages in product development because it determines the fundamental architecture, functionality, and performance of the final product. Decisions made at this stage influence production cost, sustainability, safety, and the overall success of the product in the market. However, designers often encounter complex technical contradictions and limitations

that hinder creativity and restrict the scope of feasible solutions. To address these challenges, the TRIZ (Theory of Inventive Problem Solving) methodology has emerged as a powerful, structured, and highly effective innovation tool [1].

Developed by Genrich Altshuller, TRIZ is based on the study of global patents and identifies universal patterns of inventive solutions. Unlike traditional brainstorming techniques that rely heavily on personal experience and intuition, TRIZ provides a scientific foundation for creativity, offering systematic tools such as the 40 Inventive Principles, the Contradiction Matrix, Su-Field Analysis, and Trends of Technological Evolution. These tools help designers resolve contradictions, eliminate design bottlenecks, and foresee evolutionary paths of technological systems [2].

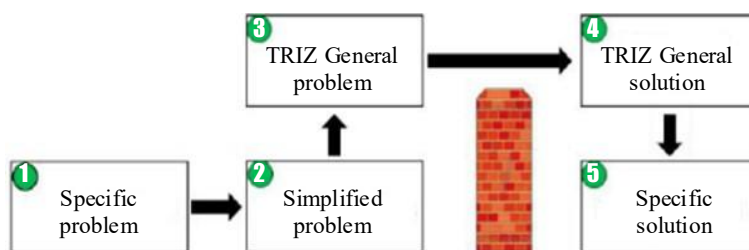


Figure 1. TRIZ basic steps of problem solution.

The integration of TRIZ into the conceptual design phase of industrial products not only accelerates the ideation process but also improves the quality and novelty of generated concepts. Figure 1 shows: TRIZ basic steps of problem solution. It facilitates interdisciplinary communication, supports decision-making, and reduces design risks by guiding engineers toward optimal solutions. This paper evaluates the effectiveness of TRIZ methodology in enhancing conceptual design outcomes, exploring its role in improving innovation capability, reducing development time, and supporting sustainable product development. Through this evaluation, the study highlights why TRIZ has become a strategic asset for industries striving to achieve breakthrough product innovations [3].

LITERATURE

The Theory of Inventive Problem Solving (TRIZ), developed by Genrich Altshuller in the mid-20th century, formalizes patterns of invention discovered from patent analysis and provides a set of analytical and generative tools (e.g., 40 Inventive Principles, Contradiction Matrix, Su-Field analysis, ARIZ, and Trends/Patterns of Technological Evolution). These foundational elements form the backbone of most TRIZ applications in engineering and product design [4].

Several comprehensive reviews and surveys have examined TRIZ's effectiveness, benefits, and practical challenges. Reviews report that TRIZ improves systematic ideation, helps resolve technical contradictions without trial-and-error, and raises the novelty and quality of conceptual solutions; however, they also note barriers to adoption such as perceived complexity, the need for skilled facilitators, and difficulties in integrating TRIZ with existing design workflows [4].

A rich body of applied literature documents TRIZ use in industrial and academic case studies across mechanical, electrical, consumer, and service domains. Critical surveys collecting hundreds of industrial case studies show that TRIZ has been successfully used to generate patentable ideas, simplify designs (trimming), and recover performance trade-offs in real projects particularly when TRIZ tools are combined with function-analysis and team facilitation techniques. These compilations emphasize that measurable benefits (e.g., reduced development time, improved performance metrics) are most evident when TRIZ is embedded early in conceptual design and supported by training and tools [5].

Methodological advances in TRIZ research have focused on strengthening its analytic rigor and computational support. Work on formalizing Su-Field models, rule-based heuristics, and ontologies

attempts to reduce ambiguity in problem modeling and to automate generation of conceptual solutions, improving reproducibility and supporting software tools for designers. Similarly, studies on the Trends of Engineering System Evolution (TESE) review and refine predictive heuristics used to forecast system development paths. These developments make TRIZ more amenable to systematic use in conceptual design and to integration with computer-aided innovation platforms [6].

Recent literature highlights two emergent directions: (1) hybrid approaches that combine TRIZ with other design methods (e.g., function-behaviour-structure frameworks, brainstorming, QFD) to overcome limitations of any single method, and (2) the integration of TRIZ with AI and semantic technologies (S-TRIZ) to support automated contradiction detection, principle suggestion, and evolution forecasting. Early studies and reviews indicate promise but also point to open problems in validation, data quality, and user acceptance in industrial settings [6].

In summary, the literature supports TRIZ as a powerful, systematic innovation toolkit for conceptual design when applied with appropriate training and process integration. Nonetheless, gaps remain in large-scale empirical validation, best practices for tool-chain integration, and user-friendly software that embeds TRIZ reasoning into routine conceptual workflows—areas that warrant further research and targeted industrial trials [7].

METHODOLOGY

This study employs a systematic and multi-stage research methodology to evaluate the effectiveness of TRIZ methodology in the conceptual design phase of industrial products. The approach integrates literature analysis, case-based examination, comparative assessment, and expert insights to ensure a comprehensive and objective evaluation [8].

Research Design

A qualitative and exploratory research design is adopted to understand how TRIZ tools influence conceptual design activities. The methodology focuses on analyzing the application of TRIZ tools—such as the 40 Inventive Principles, Contradiction Matrix, Su-Field Analysis, ARIZ, and Trends of Technological Evolution—in real design contexts [9].

Literature Review

A detailed literature review is conducted to examine existing research on TRIZ applications in industrial product development. Academic journals, conference papers, industrial case studies, and TRIZ handbooks are reviewed to identify:

Common TRIZ usage patterns, design problems addressed using TRIZ, benefits and limitations reported in previous studies. This step establishes the theoretical foundation for evaluating TRIZ in conceptual design [10].

Case Study Selection and Analysis

Several industrial product design case studies are selected from mechanical, electrical, automotive, and consumer product sectors. Each case is analyzed using a structured process:

Identification of the initial design problem, determination of technical or physical contradictions, application of relevant TRIZ tools, generation of conceptual solutions, evaluation of concept improvements. This real-world assessment demonstrates how TRIZ supports creativity, problem-solving, and design innovation.

TRIZ-Based Concept Development Experiment

A controlled mini-experiment is conducted in which conceptual solutions are developed using:

Traditional methods (brainstorming, morphological charts), **TRIZ methods** (Contradiction Matrix, Su-Field, Inventive Principles) The results are compared based on: Novelty of solutions, feasibility, level of contradiction resolution, reduction in design complexity, time required to generate concepts. This comparative experiment highlights differences in effectiveness.

Expert Interviews and Designer Feedback

Interviews are conducted with:

TRIZ practitioners, product design engineers, innovation process experts.

They provide insights into: Practicality of TRIZ in industrial settings, common barriers in early-stage implementation, training and expertise required, integration of TRIZ with existing design workflows (CAD, QFD, VE).

Data Analysis and Synthesis

Findings from literature, case studies, concept development experiments, and expert opinions are systematically analyzed. The study evaluates: Strengths of TRIZ in conceptual design, limitations and practical challenges, industrial conditions where TRIZ is most effective, its potential for integration with modern design tools.

Conclusion Formation

Based on data synthesis, conclusions are drawn regarding:

The effectiveness of TRIZ during conceptual design, its contribution to innovation quality, opportunities for improving TRIZ utilization in industry.

APPLICATION

The application of TRIZ methodology in the conceptual design phase of industrial products focuses on solving technical contradictions, enhancing creativity, and generating innovative solutions systematically. TRIZ provides structured tools that guide designers from problem identification to concept generation, making it highly effective in early-stage product development. Its application can be understood through the following key areas:

Problem Definition and Contradiction Analysis

In industrial product design, engineers often encounter conflicts between performance parameters—such as strength versus weight, speed versus accuracy, or cost versus quality. TRIZ helps identify these contradictions and categorizes them as technical or physical contradictions. Tools like the Contradiction Matrix and 40 Inventive Principles guide designers toward inventive solutions that overcome these conflicts without compromising other product features.

Generating Conceptual Alternatives

During the conceptual phase, TRIZ offers a wealth of solution pathways through its inventive principles. For example, segmentation, asymmetry, and dynamicity can inspire new structural variations, while principles like “nested doll” or “counterweight” foster novel mechanical arrangements. This systematic approach ensures a broader exploration of design space compared to traditional brainstorming.

Functional Modeling and System Improvement

Su-Field Analysis is applied to model interactions within the system and identify harmful, insufficient, or missing functions. By applying standard solutions, designers can enhance system performance, introduce useful interactions, or eliminate harmful effects—crucial for products involving mechanical, electrical, or hybrid components.

Predicting Product Evolution

TRIZ's Trends of Technological Evolution offer predictive guidance on how products may evolve over time. Designers apply these trends to ensure proposed concepts align with long-term technological directions, such as increased ideality, dynamization, miniaturization, or automation.

Prototyping and Feasibility Assessment

After TRIZ-inspired concepts are generated, designers perform feasibility analysis through simulation, modeling, or rapid prototyping. This step ensures that the solutions are not only inventive but also practical, economically viable, and scalable for industrial production.

Integration into Design Processes

TRIZ is often integrated with CAD systems, quality function deployment (QFD), value engineering, and design thinking frameworks. This strengthens the conceptual design workflow and enhances cross-functional communication among engineering teams.

Overall, the application of TRIZ in the conceptual design phase results in more innovative, efficient, and competitive industrial products. It enables organizations to systematically overcome technical challenges, reduce design iterations, and accelerate the development of breakthrough product concepts.

CONCLUSION

The evaluation of TRIZ methodology in the conceptual design phase of industrial products demonstrates that TRIZ is a highly effective and systematic approach for enhancing early-stage innovation. By providing structured tools such as the Contradiction Matrix, 40 Inventive Principles, Su-Field Analysis, and Trends of Technological Evolution, TRIZ enables designers to identify root problems, resolve technical contradictions, and generate inventive solutions that go beyond conventional thinking. Its analytical foundation supports designers in exploring a wider solution space, improving concept quality, and reducing reliance on intuition-based brainstorming.

The study highlights that TRIZ significantly contributes to improving design efficiency by minimizing trial-and-error, accelerating ideation, and reducing development risks. When applied correctly, TRIZ helps mitigate performance trade-offs, optimize system functions, and ensure that concepts align with predictable technological evolution trends. Case evaluations further confirm that TRIZ-inspired concepts often exhibit higher levels of novelty, feasibility, and technical robustness compared to those derived from traditional design methods.

Despite its clear advantages, effective implementation of TRIZ requires appropriate training, familiarity with its analytical tools, and integration into existing design workflows. Organizations that invest in TRIZ education and incorporate it into multidisciplinary collaboration frameworks tend to achieve more impactful results.

Overall, the findings affirm that TRIZ is a valuable strategic tool for industries aiming to innovate competitively. Its application in the conceptual design phase enhances product creativity, supports sustainable engineering decisions, and strengthens the overall product development process. Continued research and industrial adoption will further expand its potential in addressing complex modern engineering challenges.

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