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Contradiction-oriented exploration: A dual-track methodology combining OTSM–TRIZ and the Six-Box Scheme

Koray Altun[1,2]*

[1]Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Bursa Technical University, Bursa, Turkey

[2]ARDiMER Digital Innovation Ltd, Bursa, Turkey

*Corresponding author E-mail: koray.altun@btu.edu.tr

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Abstract

Complex problems do not just ask for better answers; they ask for better ways of thinking. Accordingly, complex socio-technical design problems require integrated approaches that simultaneously address technical contradictions and human-centered processes. This study introduces contradiction-oriented exploration (COREX), a dual-track methodology designed to solve complex design problems involving both technical systems and human behavior. This approach combines two powerful tools: (i) The General Theory of Powerful Thinking–Theory of Inventive Problem Solving, which focuses on identifying and resolving system-level contradictions; and (ii) The Six-Box Scheme, which provides a user-centered, process-based framework for creative problem solving. By linking contradiction analysis with recursive exploration and real-world testing, this approach helps teams move from unclear user needs to structured innovations. The method was applied in a research and development setting focused on adaptive seat design. Participants followed a procedure that included problem modeling, contradiction identification, and inventive solution development. Results showed that COREX helped teams address design trade-offs more effectively than when using either method alone. The feedback cycles allowed for continuous improvement and system refinement. Overall, the methodology offers practical value for design teams working in emerging socio-technical domains by supporting both analytical thinking and creative ideation in an integrated process.

Keywords: Contradiction-Oriented Exploration, General Theory of Powerful Thinking–theory of Inventive Problem Solving, Six-Box Scheme

1. Introduction

General Theory of Powerful Thinking–Theory of Inventive Problem Solving (OTSM-TRIZ) excels in logical depth but is difficult to apply. In contrast, the Six-Box Scheme offers an intuitive, step-by-step process but lacks tools for handling contradictions. This reveals a core tension: Logic helps us go deep, while process helps us move forward, but each without the other remains incomplete.

The challenge mirrors a typical TRIZ contradiction (Fig. 1): increasing “ease of use” without reducing “complexity handling.” Suggested inventive principles include IP1 (segmentation), IP5 (merging), IP13 (the other way round), and IP24 (intermediary).

To resolve this, we propose contradiction-oriented exploration (COREX), a unified innovation methodology that combines OTSM-TRIZ’s contradiction reasoning with the Six-Box Scheme’s structured flow. COREX merges logic and process, making problem-solving both rigorous and intuitive. Its core contribution is bridging two complementary paradigms—analytical and procedural—into a scalable method for addressing complex technical and behavioral challenges. COREX enables deeper insight, focused ideation, and iterative learning. It is not only a tool but also a systematic way of thinking within complex systems.

This article proceeds as follows: Section 2 reviews contradiction-based and cognitive models.

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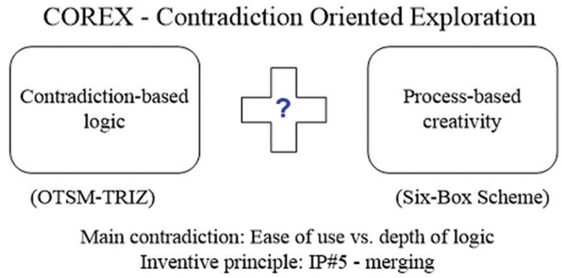

Fig. 1. Building blocks of the contradiction-oriented exploration
Abbreviations: OTSM-TRIZ: General Theory of Powerful Thinking–Theory of Inventive Problem Solving**.**

Section 3 introduces theoretical foundations. Section 4 presents COREX. Section 5 offers a case study. Section 6 compares results. Section 7 concludes with contributions and future directions.

2. Literature Review

Various systematic innovation processes (SIPs) have been proposed in the literature. Sheu and Lee (2011) introduced a phased SIP that integrates TRIZ and non-TRIZ tools, allowing structured transitions from opportunity discovery to implementation. Mann (2007) proposed the systematic creativity process, emphasizing the use of TRIZ tools across phases such a tool selection, idea generation, and evaluation. However, these models often address tactical rather than strategic innovation, and they typically lack recursive feedback mechanisms.

The W-model (Brandenburg, 2002) and the innovation value chain (Hansen and Birkinshaw, 2007) introduce strategic perspectives but fall short in problem-solving depth and contradiction resolution. Likewise, the accelerated innovation process, customer connection, and ecosystem of innovation (ACE) model incorporates big data analytics for dynamic product development but follows a linear process and lacks built-in adaptability (Zhan et al., 2017).

Some SIP models address emerging innovation needs more directly. Kruger et al. (2019) emphasize psychological factors such as inertia in problem solving. Roper et al. (2008) focus on knowledge transformation as a pathway to innovation, but both models lack mechanisms for contradiction resolution. In contrast, Sun et al. (2020) propose a TRIZ and OTSM-based SIP tailored for interdisciplinary research, offering recursive feedback and strong contradiction logic.

More recent models extend TRIZ applications further. Wang et al. (2024) propose the Radical Problem-Solving Model for breakthrough innovation, while Mann (2023) applies TRIZ to chaotic and high-risk environments using the "observe, orient, decide, and act" loop for rapid decision-making. These works highlight TRIZ's evolving flexibility, though most still rely on linear or semi-structured flows.

Recent developments such as cyclical TRIZ (Altun, 2025a) and TRIZ reverse (Dewulf et al., 2023; Cosgun and Altun, 2025) aim to address the limitations of linear thinking by introducing feedback loops, scenario-based learning, and layered innovation cycles. Cyclical TRIZ, inspired by the Mayan calendar, structures innovation into short-term, mid-term, and long-term cycles, allowing continuous strategic realignment. TRIZ reverse approaches contradictions retrospectively by analyzing how existing solutions emerged, thus offering insight into hidden design logic.

Recent efforts have also sought to enhance traditional TRIZ methodologies through hybrid approaches incorporating computational intelligence and environmental modeling. Notably, Mohammadi and Zeng (2025) proposed the environment-based design (EBD)-TRIZ-large language model (LLM) model, integrating TRIZ with EBD and LLMs to improve the generation and selection of inventive principles in context-aware scenarios. Their model systematically identifies environmental constraints and opportunities, enhancing the alignment between problem formulation and solution space exploration.

Classical TRIZ is often linear and focused on single-point contradictions, which limits its adaptability in complex and dynamic problem spaces. To overcome these limitations, OTSM-TRIZ was developed as a meta-level extension of TRIZ. It introduces problem networks, meta-contradictions, and fractal logic structures, enabling systemic exploration beyond isolated problems (Sun et al., 2020). OTSM-TRIZ supports recursive reasoning and predictive contradiction handling, but due to its formalism and abstraction, it often requires expert facilitation.

Meanwhile, the Six-Box Scheme proposes a process-oriented model that reflects natural human problem-solving behavior (Nakagawa, 2011, 2016a, 2016b, 2018). It divides the innovation process into six stages: From problem recognition to real-world implementation. This scheme is accessible and effective for interdisciplinary teams but lacks structural mechanisms to analyze contradictions or logical dependencies.

Although a variety of SIPs exist in the literature, a persistent gap remains: no single model fully integrates contradiction-based logic with a cognitive process structure in a recursive and scalable manner. To bridge this gap, COREX is proposed in this study. It introduces a dual-layered model: the inner layer, based on OTSM-TRIZ, structures and analyzes contradictions, while the outer layer, based on the Six-Box Scheme, provides a sequential and cognitively natural flow. This integration allows for both depth and usability.

As summarized in Table 1, COREX differentiates itself by enabling recursive learning, cognitive flow, and contradiction-centered exploration, making it a unique and integrated response to the limitations of existing SIP models.

3. Theoretical Foundations

3.1. OTSM-TRIZ

Classical TRIZ follows a largely linear approach, addressing one contradiction at a time (Altshuller, 1984, 1996). While effective for well-defined problems, this structure limits its adaptability in complex, multi-faceted situations where solving one contradiction often generates new, more intricate ones (Ilevbare et al., 2013). In complex systems, inventive design typically evolves non-linearly: resolving a contradiction may reshape the system and create additional conflicts. This increasing complexity presents significant challenges for classical TRIZ (Elmaraghy et al., 2012), as it typically addresses one contradiction at a time and lacks mechanisms to manage systemic interactions and layered networks of problems (NoPs) (Fiorineschi et al., 2015).

Recognizing this limitation, Altshuller proposed developing a more advanced methodology that could unify diverse problem types under a common problem-solving framework (Khomenko and

Table 1. A comparison of the existing SIP models/approaches

SIP model/approach	Process structure	Contradiction handling	Adaptability/ feedback	Innovation orientation
Classical TRIZ (Altshuller, 1984, 1996)	Linear	Focused on a single contradiction	Limited	Problem-solving
OTSM-TRIZ (Khomenko and Kucharavy, 2002)	Recursive/ fractal	Multi-level, networked contradictions	High	System transformation
Six-Box Scheme (Nakagawa, 2011, 2016a, 2016b, 2018)	Sequential	Absent	Moderate	Cognitive creativity
Cyclical TRIZ (Altun, 2025a)	Cyclical (3-tiered)	Embedded in each cycle	Built-in (short/mid/ long cycles)	Strategic and sustained
TRIZ reverse (Dewulf *et al*., 2023; Cosgun and Altun, 2025)	Inverse deductive	Extracted from solutions	Low	Retrospective learning
SIP (Sheu and Lee, 2011)	Phased	Moderate	Moderate	Cross-phase
Mann's systematic creativity (Mann, 2007)	Phased	Tool-driven	Low	Creative execution
W-model (Brandenburg, 2002)	Phased	Low	Low	Strategic planning
Innovation value chain (Hansen and Birkinshaw, 2007)	Linear	Absent	Low	Idea-to-market
Roper *et al*. (2008)	Phased	Absent	Low	Knowledge conversion
ACE model (Zhan *et al*., 2017)	Linear	None	Low	Data-driven cycles
Kruger *et al*. (2019)	Linear	Moderate	Low	Psychological enablers
IDR (Sun *et al*., 2020)	Recursive	Strong	High	Interdisciplinary
Radical TRIZ (Wang *et al*., 2024)	Linear	Strong	Low	Radical innovation
TRIZ-OODA (Mann, 2023)	Adaptive loop	Moderate	High	Crisis response
EBD-TRIZ-LLM (Mohammadi and Zeng, 2025)	Data-driven/ AI-supported	Context-aware contradiction suggestion via environment modeling	Moderate (via LLM-assisted iteration)	Environment-adaptive ideation
COREX (this study)	Dual-layered (process+logic)	Core mechanism (OTSM-enhanced)	Built-in recursion	Integrated thinking and systemic insight

Abbreviations: ACE: Accelerated innovation process, customer connection, and ecosystem of innovation; AI: Artificial intelligence; COREX: Contradiction-oriented exploration; EBD: Environment-based design; IDR: Interdisciplinary research; LLM: Large language models; OODA: Observe, orient, decide, and act; OTSM: General Theory of Powerful Thinking; SIP: Systematic innovation process; TRIZ: Theory of Inventive Problem Solving.

Ashtiani, 2007). This idea laid the groundwork for OTSM, a meta-level evolution of TRIZ introduced by Khomenko and Kucharavy in the 1980s (Khomenko and Kucharavy, 2002).

OTSM-TRIZ introduces several key conceptual tools, such as:

(i) NoP modeling to manage interdependent problems
(ii) Meta-contradiction analysis to reveal structural barriers to innovation
(iii) Fractal reasoning for recursive exploration of problem layers
(iv) Predictive evaluation to anticipate side effects of proposed solutions.

Cavallucci et al. (2015) applied OTSM-TRIZ in helicopter assembly processes to map system-wide decisions and anticipate the cascading impact of design choices. Khomenko et al. (2009) employed OTSM's NoP to support complex research and development (R&D) strategies in the energy sector, enabling interdisciplinary collaboration and long-term innovation planning.

Fiorineschi et al. (2015) compared OTSM-TRIZ with classical TRIZ in the conceptual design of a stratospheric gondola. Their study showed that OTSM-TRIZ's hierarchical decomposition of complex systems greatly improved the management of system-wide interrelations. Moreover, Borgianni et al. (2015) integrated OTSM-TRIZ with decision-making models to enhance the evaluation of design concepts in high-stakes innovation projects.

Together, these examples demonstrate that OTSM-TRIZ not only improves problem-solving efficiency but also strengthens strategic decision-making and innovation management across sectors.

3.1.1. Network of problems

The NoP framework maps the relationships between design parameters, intermediary parameters, and need parameters, forming a web of interactions where inconsistencies emerge as structural contradictions (Eltzer et al., 2006). These inconsistencies arise when the desired values of interconnected parameters conflict—improving one need parameter may compromise another. This systemic inconsistency constitutes the global problem, which cannot be resolved through linear reasoning alone (Fig. 2).

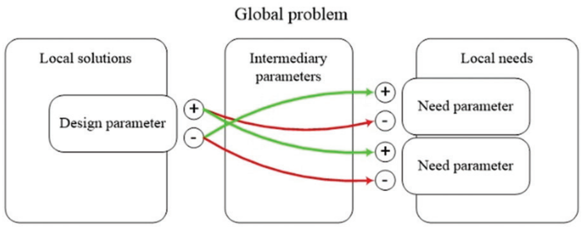

Fig. 2. Network of problems

The network of problems offers a structured way to represent and explore these contradictions. Each node in the network corresponds to a parameter or function, and each edge represents a dependency or influence.

Through this structure, designers can identify:

(i) Where contradictions emerge (e.g., conflicting design goals)
(ii) How changes in one part of the system propagate elsewhere
(iii) Where inventive principles or separation strategies could be applied.

Khomenko and Ashtiani (2007) emphasize that NoP transforms loosely defined or chaotic design challenges into a logically organized architecture of problems. By formalizing system behavior through parameter relationships, the NoP model supports systematic problem decomposition, enabling a clearer definition of sub-problems and meta-contradictions.

Within the COREX methodology, NoP plays a central role in structuring problems and mapping contradictions. It forms the analytical backbone that enables teams to move beyond surface-level symptoms and uncover deeper logical tensions. This elevates COREX from a toolset to a comprehensive thinking system capable of structuring and transforming complex design challenges.

3.1.2. Meta-contradiction analysis

In many innovation scenarios, contradictions do not exist independently; they stem from deeper systemic constraints within the problem structure. Meta-contradictions refer to these higher-order conflicts that arise when multiple local contradictions interact or when a problem resists simplification into a single conflict (Khomenko and Ashtiani, 2007).

In OTSM-TRIZ, meta-contradiction analysis provides a strategic mechanism for identifying what makes a system inherently resistant to innovation. These contradictions often reflect competing system-level goals (e.g., maximizing customization while minimizing production complexity). Unlike classical TRIZ, which focuses primarily on technical or physical contradictions, OTSM-TRIZ uses meta-contradiction trees and problem parameter hierarchies to locate deeper innovation barriers.

This concept allows designers to go beyond direct contradiction resolution and target the root structural limits of the system. Fiorineschi et al. (2015) highlight that identifying meta-contradictions was essential in managing the layered constraints of high-altitude aerospace design. Thus, meta-contradiction analysis not only guides problem-solving but also redefines the boundaries of innovation.

3.1.3. Fractal reasoning

A major strength of OTSM-TRIZ is its use of "fractal reasoning" to handle complex, layered problem spaces (Khomenko and Kucharavy, 2002). In this approach, each problem is viewed as part of a larger system and may itself contain subsystems and nested contradictions. This mirrors the structure of complex real-world problems, where solving one issue often reveals a cascade of related sub-problems.

Rather than stopping after solving a single contradiction, OTSM-TRIZ promotes recursive exploration: testing solutions for hidden contradictions and tracing their implications across system layers. This principle reflects the non-linear nature of innovation, which is better understood as the ongoing reconfiguration of system constraints and opportunities.

3.1.4. Predictive evaluation

Predictive evaluation is based on cause–effect chain analysis and future scenario modeling (Khomenko et al., 2009). These tools help anticipate potential side effects and verify whether a solution resolves the core problem or merely shifts it elsewhere.

In the context of energy systems, Cavallucci et al. (2015) demonstrated how predictive analysis within OTSM-TRIZ/Inventive Design Method-TRIZ improved long-term decision robustness in helicopter assembly planning. Using NoP-based propagation models, they identified secondary contradictions before implementation.

3.2. Six-Box Scheme

The Six-Box Scheme, proposed by Toru Nakagawa as the foundation of his broader Creative Problem-Solving framework, offers a systematic structure for navigating the stages of inventive thinking. While classical TRIZ and many scientific problem-solving models rely on the Four-Box Scheme (specific problem, abstract problem, abstract solution, and specific solution), the Six-Box Scheme expands this into a more process-aware structure. As shown in Fig. 3, it provides a comprehensive map of the creative thinking journey, from initial problem recognition to real-world implementation (Nakagawa, 2011, 2016a, 2016b, 2018).

Unlike conventional flowchart-based approaches, which focus primarily on the order and execution of procedures, the Six-Box Scheme is based on a dataflow philosophy (Nakagawa, 2011). This means that the model emphasizes the types of information to be

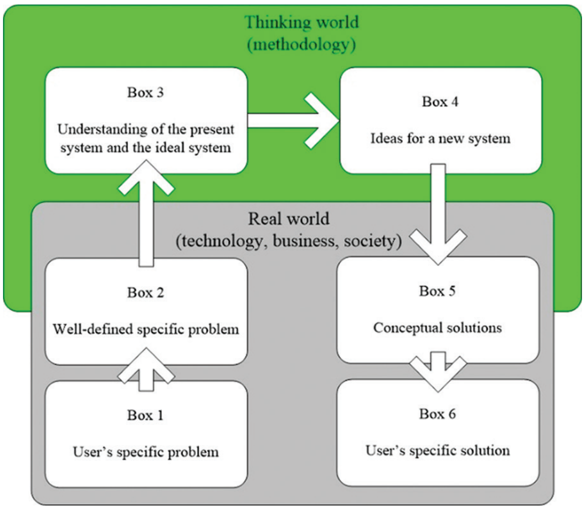

Fig. 3. The Six-Box Scheme

obtained, transformed, and delivered at each stage. Traditional flowcharts concentrate on "what to do and when," often losing sight of "what to know and why." In contrast, the Six-Box Scheme views innovation as an information-centered transformation process: from vague real-world observations to well-defined problems, from system analysis to idea generation, and from conceptual design to implementation. Each box corresponds not only to a step in the innovation journey but also to a knowledge state defining the type of insight that must be achieved at that stage (Nakagawa, 2016a).

3.2.1. A dual domain perspective

A key conceptual advancement in the Six-Box Scheme is its separation of the innovation process into two cognitive domains:

(i) The "real world," where problems originate, and solutions are ultimately implemented (Boxes 1, 2, and 6),
(ii) The "thinking world," where abstract analysis and creative reasoning take place (Boxes 3, 4, and 5).

In this structure: Box 1 captures the user's initial complaint or observation. Box 2 formulates a well-defined problem. Boxes 3–5 reflect the process of structured idea development within the thinking world. Finally, Box 6 delivers actionable outputs back into reality.

This separation encourages practitioners to temporarily step away from immediate pressures and constraints and enter a focused, reflective mode of creative exploration. In collaborative environments, it also supports group ideation sessions, workshops, and structured co-creation.

3.2.2. The three macro processes

Nakagawa (2011) further identifies three macro-level processes within the Six-Box Scheme:

(i) Problem definition process (real world)
- Recognizing the user's concern (Box 1),
- Framing a solvable, structured problem (Box 2)

(ii) Creative problem-solving process (thinking world)
- Analyzing the present and the ideal system (Box 3)
- Generating new ideas (Box 4)

(iii) Constructing conceptual solutions (Box 5)
- Solution implementation process (real world)

(iv) Deploying the solution into actual systems or products (Box 6).

This clear division of phases enhances the clarity, teachability, and transferability of the model. Each stage aligns with a specific cognitive goal, allowing for modular adaptation across various real-life innovation workflows.

4. Proposed Methodology

4.1. A Dual-layered Structure

In COREX, OTSM-TRIZ serves as the logical engine responsible for mapping contradictions, modeling problem networks, and reasoning through recursive system behavior. Specifically, OTSM-TRIZ contributes to the proposed methodology in the following ways:

(i) Problem structuring (Box 2): The user's problem is not only redefined but also modeled through the NoP, enabling the identification of systemic inconsistencies and the decomposition of complex design goals

(ii) System analysis (Box 3): The present system and ideal system are explored through meta-contradiction analysis, fractal modeling, and parameter dependency mapping, providing structured abstraction and insight into the root logic of the problem

(iii) Idea generation (Box 4): Contradictions identified in earlier steps are resolved using inventive strategies drawn from TRIZ principles, enhanced by OTSM's predictive and recursive logic.

By embedding these mechanisms into COREX, contradiction handling becomes a continuous, feedback-driven process, rather than a single-point resolution effort.

While OTSM-TRIZ structures the internal reasoning process, the Six-Box Scheme forms the external procedural and cognitive structure through which users interact with the problem-solving journey. It does so by:

(i) Providing a stage-wise process flow aligned with human creative cognition, making COREX accessible to non-experts and cross-functional teams

(ii) Guiding practitioners through problem definition (boxes 1 and 2), structured analysis and creativity (boxes 3–5), and real-world implementation (Box 6) in an iterative fashion

(iii) Ensuring that each logical insight from OTSM-TRIZ is cognitively processed and practically translated into action within a broader innovation workflow.

The Six-Box Scheme allows COREX to function not merely as a logical tool but as a "thinking environment," supporting decision-making, team collaboration, and strategic innovation deployment.

4.2. Algorithm of the Proposed Methodology

Table 2 presents the COREX implementation algorithm, describing each phase, its function, and the tools involved. The approach is designed for real-world innovation teams seeking both conceptual clarity and logical depth when addressing complex, contradiction-rich challenges.

In this methodology, steps 1 and 2 are carried out primarily in the real world, reflecting direct user needs and constraints. Steps 3–5 occur within the thinking world, where abstraction, contradiction modeling, and ideation are guided by OTSM-TRIZ reasoning. Steps 6 and 7 transition back to the real world, where implementation and validation take place. Step 8 represents the recursive structure of COREX, allowing for continuous refinement and adaptation—an essential feature for complex and evolving systems.

5. Case Study

To illustrate the practical value of the COREX methodology, this section applies it to a real-world design challenge in the context of autonomous vehicles (Altun et al., 2022; Altun, 2023; Altun, 2025b; Kim, 2021). As driver responsibility decreases, the vehicle cabin must evolve to support new expectations of comfort, flexibility, and usability. However, these demands often introduce contradictions, especially between passenger comfort and system safety. The following use case illustrates how COREX can be applied step-by-step to structure, analyze, and resolve such contradictions.

5.1. Step 1 – Capture the Initial Problem (Box 1)

User observations and feedback from autonomous vehicle prototypes indicate a recurring concern: "I want to relax and recline fully during the ride, but I'm not sure if I will be safe in case of an accident."

This vague concern reflects a contradiction between comfort and safety (Fig. 4). Although no explicit failure has occurred, the user's hesitation signals an unresolved design problem. The goal at this step is to capture the user's discomfort and translate it into a design challenge suitable for structured exploration.

5.2. Step 2 – Define the Problem Structure (Box 2)

In this step, the vague user concern is transformed into a well-defined and analyzable design problem. To achieve this, the team applies NoP modeling to systematically map interactions among design parameters, intermediary parameters, and need parameters.

Table 2. Step-by-step contradiction-oriented exploration methodology

Steps	Six-Box ref.	Cognitive objective	Tool (s) used
Step 1: Capture the initial problem	Box 1	Recognize vague user concern	- Informal observation - User feedback
Step 2: Define the problem structure	Box 2	Formulate a well-defined and measurable problem	- NoP modeling - Parameter mapping
Step 3: Analyze present and ideal systems	Box 3	Explore both current and desired system states	- Meta-contradiction analysis - Fractal reasoning
Step 4: Identify core contradictions	Box 3 (continued)	Reveal systemic conflicts and inconsistencies	- TRIZ contradiction matrix - Root conflict analysis
Step 5: Generate inventive solutions	Box 4	Produce ideas to resolve core contradictions	- TRIZ inventive principles - Separation strategies
Step 6: Construct conceptual solutions	Box 5	Organize ideas into feasible concepts	- Constraint analysis - Predictive evaluation
Step 7: Implement and validate	Box 6	Deploy the solution in a real context	- Evaluation criteria (business/technical) - Feedback loop
Step 8: Recursive feedback loop	(Back to Box 1)	Reframe the problem if unresolved or evolving	- Recursive OTSM modeling - NoP update

Abbreviations: NoP: Network of problems; OTSM: General Theory of Powerful Thinking; TRIZ: Theory of Inventive Problem Solving.

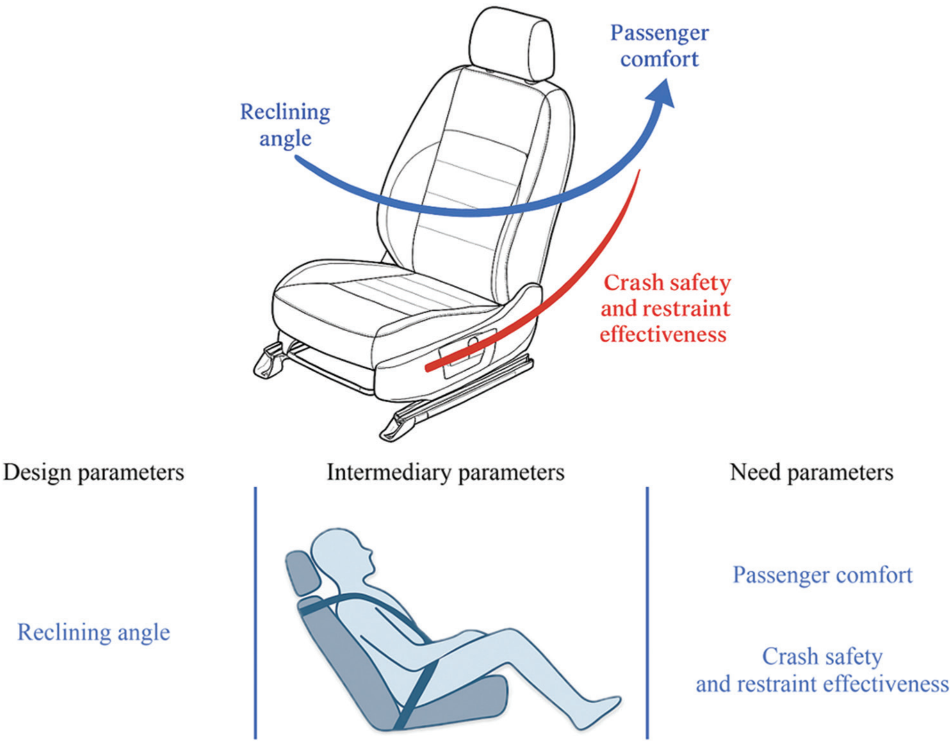

Fig. 4. Initial contradiction between comfort and safety

As illustrated in Fig. 5, the NoP of an automotive front-seat system reveals a complex web of interdependencies. Design parameters such as reclining angle, seat shape, headrest design, and seatbelt configuration influence intermediary attributes, including seat-back shape, foam density, and anchor points. These intermediary attributes, in turn, contribute to various need parameters such as comfort, safety, ergonomics, durability, and adjustability.

In the specific case of the reclining seat problem:

- Design parameter: Reclining angle
- Need parameters: Passenger comfort (positively affected), restraint system safety (negatively affected)
- Intermediary parameters: Seatbelt anchor position, headrest geometry, seat adjustability mechanism, seat foam density, and seat-back angle.

An increase in reclining angle improves comfort but compromises the alignment and effectiveness of seatbelt and airbag systems, thus reducing safety. This trade-off leads to a structural contradiction: optimizing one need parameter (comfort) degrades another (safety), with the conflict propagated through intermediary parameters.

This form of contradiction is non-local, meaning that it does not reside within a single parameter but emerges from cross-linked dependencies. As such, it cannot be resolved through linear optimization or isolated improvement. Instead, it requires multi-parametric adjustment and inventive restructuring, which COREX supports through its recursive and logic-based exploration process.

Using the NoP structure, as shown in Fig. 5, the design team is able to: (i) Make hidden parameter relationships visible, (ii) Identify and quantify the tension points within the system, and (iii) Prepare a structured basis for contradiction modeling in the following COREX step.

Although Fig. 5 visualizes the internal structure of the NoP, the resulting contradictions extend beyond isolated parameter interactions and form a hierarchical structure consistent with OTSM-TRIZ logic. At the first level, local contradictions arise between directly linked parameters. For example, increasing the reclining angle improves comfort but misaligns the seatbelt anchor, while softer foam density enhances pressure distribution but reduces structural stability. As these tensions propagate through intermediary attributes (such as seat-back shape, foam density, and anchor positioning), they evolve into technical contradictions, where improving one engineering attribute worsens another (e.g., increased adjustability reduces long-term durability; improved cushioning decreases crash stiffness). Some tensions span functional domains and become non-local

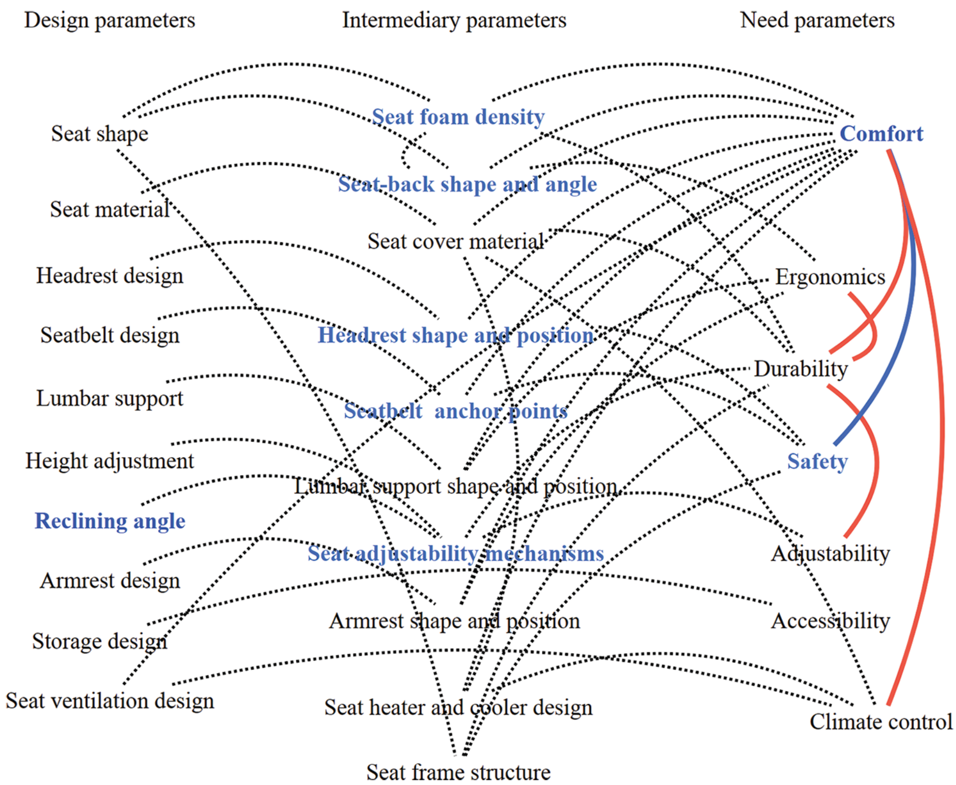

Fig. 5. Network of problems structure for front-seat systems in automotive design. Solid black arcs represent direct parameter dependencies; red arcs indicate aggregated conflict areas between key need parameters; blue elements represent the main influential parameters of the case study

contradictions, such as enhanced ergonomic contouring requiring additional sensors and thus increasing privacy intrusion. These accumulated tensions converge into a system-level meta-contradiction, as illustrated in Fig. 5 by the diverging need-parameter curves: Comfort requires softness, adaptability, and spatial freedom, whereas safety and durability require rigidity, reliable alignment, and controlled posture.

This layered structure clarifies how parameter-level dependencies within the seat system give rise to higher-order conflicts. The contradictions in this case can be grouped as follows:

(i) Local contradictions
- Reclining angle versus seatbelt anchor alignment
- Foam density/seat shape versus pressure distribution stability

(ii) Technical contradictions:
- Improved adjustability mechanisms reduce long-term durability
- Increased foam softness lowers crash stiffness
- Improved climate responsiveness increases energy use

(iii) Non-local contradictions
- Enhanced ergonomic shaping increases privacy intrusion (due to added sensing)
- Automated posture correction reduces perceived autonomy
- Improved deformation recovery reduces vibration comfort

(iv) Meta contradiction
- The comfort subsystem (e.g., reclining angle, foam softness, adaptability) conflicts with the safety-durability subsystem (e.g., structural rigidity, alignment stability, restraint geometry)

Similar multi-layered tensions were demonstrated in a previous OTSM-TRIZ-based front-seat design study (Altun, 2025c), reinforcing the relevance of network-driven contradiction mapping for automotive seating systems. Making these hierarchical relationships explicit strengthens the connection between the NoP structure in Fig. 5 and the contradiction modeling performed in the subsequent steps.

It should be noted that several contradictions discussed later (e.g., structural rigidity vs. flexibility; personal freedom vs. system control; sensor feedback vs. crash response time) represent higher-level abstractions derived from the combinations of the design and intermediary parameters, as shown in Fig. 5, rather than new or independent parameters.

5.3. Step 3 – Analyze Present and Ideal Systems (Box 3)

The present system is based on conventional seat designs optimized for upright posture, where seatbelts and airbags operate reliably. The ideal system would allow passengers to rest in any desired posture without compromising safety.

At this stage, meta-contradiction analysis is applied. The root contradiction lies not only between comfort and safety but also in the shared spatial domain: both demands are imposed on the same physical structure (the seat). Using fractal reasoning, the contradiction is decomposed into:

(i) Constraint conflicts within the seat design (structural rigidity vs. flexibility),
(ii) System-level conflicts (personal freedom vs. system control),
(iii) Cross-domain dependencies (sensor feedback vs. crash-response time).

This layered analysis allows the design team to reframe the problem beyond surface symptoms.

To clarify how the three conflict types emerge, a simplified root conflict analysis for the reclining-seat problem was conducted. The key issue—loss of restraint-system alignment during deep recline—was traced back to several first-level causes: fixed seatbelt anchor geometry, posture-dependent changes in headrest and airbag positions, and reduced structural stability when the backrest moves far from upright. All mechanisms point to a common root conflict: current safety systems are designed for a fixed posture, while comfort demands wide and dynamic posture variability. This explains the first conflict category: structural rigidity versus flexibility.

Fractal reasoning clarifies the remaining two conflict categories. At the system level, increasing recline freedom reduces the predictability required for safety systems—thus, personal freedom versus system control. At the cross-domain level, sensor quality, posture-detection accuracy, and required crash-response timing interact, creating reliability issues when posture deviates from the standard. These repeating tensions across physical structure, user behavior, and system timing show that the comfort–safety contradiction recurs at multiple scales. This confirms that the problem is systemic, requiring multi-level restructuring rather than isolated adjustments.

5.4. Step 4 – Identify Core Contradictions (Box 3 Continued)

The key contradiction is defined between “ease of use (comfort)” and “loss of information or system complexity” (safety systems handling crash data). The contradiction matrix suggests inventive principles (IPs): IP1 – Segmentation; IP24 – Intermediary; IP3 – Local quality; and IP13 – The other way round. Root conflict analysis further reveals that existing safety systems are built for static configurations and lack adaptability.

5.5. Step 5 – Generate Inventive Solutions (Box 4)

Several inventive ideas are generated based on the contradiction logic:

(i) IP24 – Intermediary: Introduce an active support module beneath the seat surface (Fig. 6A). When a crash is imminent (detected via sensor data), the module stiffens and repositions load-bearing regions (e.g., lumbar, side wings) to brace the passenger

(ii) IP3 – Local quality: Embed shape-memory alloys or air-cell actuators in selective contact zones (Fig. 6B), allowing local flexibility while maintaining rapid, localized rigidity

(iii) IP1 – Segmentation: Divide the seat into independently adjustable/lockable modules (e.g., headrest, torso, hip, leg) responding to real-time posture and crash dynamics (Fig. 6C)

(iv) IP13 – The other way round: Instead of adapting the seat to fixed safety systems, redesign the seatbelt and airbag geometry to follow the user's posture (Fig. 6D).

These concepts are not random ideation but systematically derived from the contradiction analysis conducted in prior steps.

5.6. Step 6 – Construct Conceptual Solutions (Box 5)

The most promising concepts are selected and integrated into a system-level solution:

(i) A smart seat system with posture sensors, real-time crash-prediction algorithms, shape-adaptive materials, and repositionable airbags

(ii) Constraint analysis ensures feasibility across mechanical, electrical, and timing domains

(iii) Predictive evaluation uses simulations to test the activation time of support modules relative to average crash speed and occupant behavior.

This stage yields a functional concept ready for prototyping and validation.

5.7. Step 7 – Implement and Validate (Box 6)

The solution is implemented in a concept vehicle cabin. Validation includes: (i) Crash simulations across seating positions, (ii) comfort assessments in prolonged autonomous travel scenarios, and (iii) evaluation of cost, weight, and manufacturability.

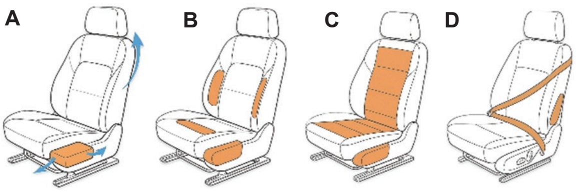

Fig. 6. Conceptual ideas generated based on the contradiction logic. (A) Active intermediary support; (B) Local adaptive contact zones; (C) Segmented modular seat structure; (D) Reversed safety adaptation (seatbelt–airbag following posture)

Results show increased comfort with crash-dummy injury metrics remaining within acceptable thresholds.

5.8. Step 8 – Recursive Feedback Loop

Even after implementing the smart-seat solution, new contradictions emerge, indicating that the innovation process is ongoing. This step captures these emerging concerns and guides the system back into a new COREX cycle.

As adaptive systems gain autonomy, contradictions that arise are no longer confined to technical or ergonomic trade-offs but extend into the ethical domain, where values such as autonomy, privacy, consent, and trust frequently collide. In these situations, safety-enhancing automated actions may diminish perceived user control; data-driven personalization may improve comfort while raising concerns about monitoring and psychological acceptability. Treating these tensions as socio-technical contradictions allows COREX to articulate and formalize them (e.g., increasing automated intervention improves safety but reduces perceived autonomy) and convert them into new needs and intermediary parameters such as transparency, consent logic, or user override mechanisms. This ensures that ethical considerations are incorporated into the structured reasoning process rather than added informally, aligning the methodology with contemporary perspectives in design ethics and responsible innovation.

However, two major contradictions appear:

(i) User autonomy vs. system control – "What if I don't want the seat to move automatically?" This reflects a tension between user privacy and freedom, and the automatic system overrides required for safety

(ii) Ethical tension: Passive consent versus forced adjustment – raising the question of whether the system should forcibly adjust a passenger's posture prior to a crash, even if the user resists or is unaware. This introduces broader ethical considerations related to consent, trust, and the psychological acceptability of automated interventions.

Thus, the original comfort–safety contradiction evolves into behavioral and ethical contradictions. The problem must be reframed with new need parameters (user control, transparency, trust) and new intermediary parameters (consent logic, user override interface, behavior-prediction modules).

This reframing brings the process back to Box 1, where the updated problem can be captured as a new user concern. From here, a second iteration of COREX begins, applying the same step-by-step method but now targeting a different dimension of the challenge: not only technical performance, but human–system interaction. This recursive structure is what enables COREX to adapt to evolving systems—technically, socially, and ethically.

Although the COREX logic supports multiple recursive cycles, the present simulation study did not extend the process beyond the first loop. The aim of this work was not to exhaustively explore all possible iterations, but to compare methodological behavior under identical conditions. Given that the initial cycle already revealed a shift from a technical contradiction (comfort vs. safety) to a socio-technical one (autonomy, consent, and system control), the primary objective, demonstrating how COREX uncovers deeper layers of the problem, was achieved. In practice, a new COREX cycle is initiated only when emerging contradictions introduce new needs or intermediary parameters that alter the structure of the problem. If subsequent contradictions merely refine existing parameters without reshaping the conflict architecture, the process is considered converged, and further iterations are unnecessary.

6. Comparison of the Methodologies

To demonstrate how the proposed COREX methodology addresses complex design challenges more effectively than existing approaches, all three methods (OTSM-TRIZ, the Six-Box Scheme, and COREX) were applied to the same design problem: the development of an adaptive seat system for autonomous vehicles. This problem was intentionally selected due to its multi-domain nature.

To evaluate the practical performance of the methods, an empirical simulation study was conducted within the R&D department of a tier-1 automotive seat supplier. The purpose of this exercise was not to build an actual seat system but to assess and compare the methodologies under realistic design conditions. The teams worked with persona-based scenarios, system constraints, and structured design discussions. Thus, the insights presented here reflect methodological behavior rather than engineering feasibility testing.

The design task confronted the teams with multiple conflicting requirements. Passengers expected superior comfort, adaptive postural support, and temperature responsiveness during extended autonomous trips. These expectations conflicted with constraints related to structural durability, energy efficiency, manufacturability, and cost. Such tensions made the problem an ideal test bed for contradiction-oriented methods.

Table 3 presents a comparative overview of how each methodology approached the same problem and the specific steps taken during its application.

Table 3. Comparison of the methodological approaches

Stage	OTSM-TRIZ	Six-Box Scheme	COREX
Problem identification	Uses NoP to link discomfort to design parameters (seat hardness, thermal adaptation, load-bearing)	User complaints are framed in Box 1 and translated into clarified needs in Box 2	Integrates user discomfort from boxes 1 and 2 with NoP mapping to trace contradictions across physical and psychological needs
Problem modeling	Constructs a parameter network including design parameters, intermediary parameters, and need parameters	Performs present-vs-ideal system analysis (Box 3) for thermal and ergonomic mismatches	Runs NoP modeling and Box 3 analysis in parallel to capture layered, real-world tensions
Contradiction analysis	Identifies a meta-contradiction (e.g., adjustable softness reduces durability) and applies meta-level resolution tools	Contradictions are inferred from user needs but are not addressed through a systematic resolution process	Maps the contradiction matrix (e.g., speed vs. energy consumption) and augments it with meta-level insights added through structural contradiction mapping
Solution generation	Uses fractal reasoning and abstraction to propose concepts such as shape-memory foams or layered materials	Box 4 brainstorming produces ideas, including air-cushion systems and AI-controlled morphing surfaces	Applies inventive principles (e.g., IP35: parameter change; IP28: mechanical substitution) to develop adaptive layered structure
Evaluation	Predicts system impact via NoP updates, though real-world feedback mechanisms are limited	The transition from boxes 5 to 6 focuses on concept translation toward prototyping	Uses predictive evaluation tools and real-world constraints; identified failure points feed back into boxes 1 and 2 for recursion

Abbreviations: AI: Artificial intelligence; COREX: Contradiction-oriented exploration; NoP: Network of problems; OTSM-TRIZ: General Theory of Powerful Thinking–Theory of Inventive Problem Solving.

6.1. Study Design and Evaluation

This empirical study was conducted in collaboration with the R&D department of a tier-1 automotive seat supplier. Three interdisciplinary design teams were formed, each consisting of four members with complementary expertise in engineering design, ergonomics, and design thinking. Each team was assigned and formally trained in one of the three innovation methodologies evaluated in this study: OTSM-TRIZ, the Six-Box Scheme, and COREX. All teams worked on the same design problem: developing an adaptive seat system for autonomous vehicles capable of balancing comfort, safety, and energy efficiency.

The evaluation followed a structured four-step procedure:

(i) Step 1: A common scenario and design brief were introduced to all teams to ensure comparable starting conditions
(ii) Step 2: Teams applied their assigned methodology in a controlled setting over a four-hour design session
(iii) Step 3: Design outcomes were documented, including sketches, assumptions, contradiction formulations, intermediate models, and proposed system concepts
(iv) Step 4: Upon completion, each participant completed a structured assessment survey evaluating the methodology they used.

The assessment was based on six criteria reflecting both analytical and human-centered aspects of innovation work:

(i) Clarity of problem modeling – Ability to represent the design problem and contradictions
(ii) Contradiction resolution – Effectiveness in identifying and resolving systemic conflicts
(iii) Creativity and feasibility – Novelty and implementability of proposed concepts
(iv) User-centeredness – Degree to which user needs, personas, and scenarios informed the solution
(v) Cognitive load – Perceived mental effort required to apply the method
(vi) Integration capability – Ability to synthesize perspectives across domains (e.g., ergonomics, mechanics, materials, and user requirements).

Each criterion was rated individually on a 1–5 Likert scale (1 = very low, 5 = very high). Table 4 provides the ratings. To statistically examine differences between methods, a nonparametric analysis was conducted using Kruskal–Wallis omnibus tests followed by Mann–Whitney U post-hoc comparisons (Table 5). These analyses revealed significant methodological differences across most criteria, particularly in contradiction resolution, integration capability, user-centeredness, and cognitive load.

The results indicate that COREX combines the systemic depth of OTSM-TRIZ with the human-centered clarity of the Six-Box Scheme. COREX received the highest evaluations in contradiction resolution and integration—two key capabilities for socio-technical systems such as autonomous vehicle seating. While the Six-Box Scheme supported creativity and user-focused reasoning, it lacked analytical depth. OTSM-TRIZ exhibited strong modeling capability but required higher cognitive effort and provided limited support for user-integrated iteration. COREX therefore achieved a functional balance between analytical rigor and design usability, although future research may

Table 4. Evaluation scores across innovation methodologies

Model	Participant	Problem modeling	Contradiction resolution	Creativity	User-centeredness	Cognitive load	Integration
OTSM-TRIZ	O1	4	4	4	3	2.5	4
	O2	5	5	4	3	2	4
	O3	4	4	3	2	2	3
	O4	4	5	3.5	3	2.5	4
Six-Box Scheme	S1	4	3	4	5	4	3
	S2	3	3	4.5	5	4	4
	S3	3.5	2.5	4	4	4.5	3.5
	S4	3.5	3	4	4.5	4	3
COREX	C1	5	5	5	5	4	5
	C2	5	5	4	5	4	5
	C3	4.5	4	4	4.5	4	5
	C4	5	5	5	4	3.5	4.5

Note: "Cognitive load" was reverse-coded for clarity (higher = easier use).
Abbreviations: COREX: Contradiction-oriented exploration; OTSM-TRIZ: General Theory of Powerful Thinking–Theory of Inventive Problem Solving.

Table 5. Kruskal–Wallis and Mann–Whitney U test results across the three methodologies

Criterion	Comparison	Median difference	W	*p*-value	Adjusted *p*	Interpretation
Problem modeling *Kruskal–Wallis H (df=2): 8.17 p (adj): 0.017**	COREX vs. OTSM	1.0	23.5	0.0745	0.0569	Marginal (COREX > OTSM)
	COREX vs.Six-Box	1.5	26.0	0.0152	0.0128*	Significant (COREX > Six-Box)
Contradiction resolution *Kruskal–Wallis H (df=2): 8.36 p (adj): 0.015**	COREX vs.OTSM	0.0	20.0	0.3325	0.3042	No difference
	COREX vs.Six-Box	2.0	26.0	0.0152	0.0114*	Significant (COREX > Six-Box)
Creativity *Kruskal–Wallis H (df=2): 4.95 p (adj): 0.084*	COREX vs.OTSM	1.0	24.0	0.0562	0.0443	Slightly significant (COREX > OTSM)
	COREX vs.Six-Box	0.25	21.0	0.2352	0.2023	Not significant
User-centeredness *Kruskal–Wallis H (df=2): 7.82 p (adj): 0.020**	COREX vs.OTSM	2.0	26.0	0.0152	0.0128*	Significant (COREX > OTSM)
	COREX vs.Six-Box	0.0	18.0	0.5000	0.5000	No difference
Cognitive load (inv.) *Kruskal–Wallis H (df=2): 9.02 p (adj): 0.011**	COREX vs.OTSM	1.5	26.0	0.0152	0.0123*	Significant (COREX easier)
	COREX vs.Six-Box	0.0	14.5	n.s.	n.s.	No difference
Integration *Kruskal–Wallis H (df=2): 8.38 p (adj): 0.015**	COREX vs.OTSM	1.0	26.0	0.0152	0.0114*	Significant (COREX > OTSM)
	COREX vs.Six-Box	1.5	26.0	0.0152	0.0128*	Significant (COREX > Six-Box)

Note: *indicates $p<0.05$.
Abbreviations: adj: Adjusted; COREX: Contradiction-oriented exploration; df: Degree of freedom; inv.: Inverted; n.s.: not significant; OTSM: General Theory of Powerful Thinking.

explore tool support or training aids to further reduce cognitive load.

6.2. Validity and Reliability of the Evaluation

To ensure the methodological soundness of the empirical comparison, particular attention was given to the validity and reliability of the evaluation process. The assessment involved 12 participants, organized into three independent design teams trained respectively in OTSM-TRIZ, the Six-Box Scheme, and COREX. Each team received the same design brief, scenario, and constraints, and all sessions were conducted in a controlled environment. Ratings were collected individually and anonymously immediately after task completion to minimize social desirability and conformity biases.

Construct validity was supported through the use of six well-defined evaluation criteria, each aligned with theoretical constructs widely used in innovation, design, and TRIZ research. To assess internal reliability, Cronbach's alpha was calculated across the six criteria, resulting in $\alpha = 0.699$. Considering the small sample size and the exploratory nature of design-team studies, this level of internal consistency is regarded as acceptable. Because Likert-scale data are ordinal and sample sizes were modest, inferential validity was strengthened through the use of nonparametric statistical analyses. Accordingly, Kruskal–Wallis omnibus tests and Mann–Whitney U *post hoc* comparisons were applied to identify significant differences among the three methodologies.

Potential sources of bias (e.g., varying familiarity with specific methods or individual cognitive differences) were mitigated through standardized training, consistent timing, homogeneous team structure, and independent evaluation rather than consensus-based scoring. Together, these measures reinforce the validity and reliability of the evaluation framework and support the robustness of the comparative findings as reported in Table 5.

6.3. OTSM-TRIZ

The OTSM-TRIZ method focused on constructing an NoP, mapping user discomfort to underlying design parameters such as foam stiffness, thermal regulation, and deformation memory.

It effectively identified a key meta-contradiction: "To improve comfort, the seat must be soft and adaptive; but to ensure durability, it must be firm and stable." This insight enabled the generation of high-level concepts (e.g., memory foams or adaptive materials). However, the approach remained largely abstract, lacked structured evaluation steps, and did not easily connect with user feedback loops or iterative prototyping stages.

6.4. Six-Box Scheme

The Six-Box Scheme structured the innovation process as a linear, intuitive flow. The user problem was first captured as a complaint (Box 1), then refined into a specific need (Box 2), and finally through a present-vs.-ideal system comparison (Box 3).

Creative brainstorming in Box 4 yielded concepts such as artificial intelligence (AI)-controlled morphing surfaces or air-cushion systems. While this approach supported ideation and facilitated team creativity, it lacked analytical tools to identify or resolve deep contradictions. In particular, it provided no formal mechanism to explain why certain needs conflicted or how trade-offs could be resolved systematically.

6.5. COREX

The COREX approach combined the strengths of both systems. It began by mapping user discomfort (boxes 1 and 2) into a structured NoP model, linking design parameters such as padding softness, thermal response, and pressure distribution.

In Box 3, COREX applied both the TRIZ contradiction matrix and meta-contradiction analysis to identify conflicts, including: "increased adjustability reduces long-term reliability" and "comfort vs. safety during crash scenarios."

Using IPs—specifically IP35 (parameter change) and IP28 (mechanics substitution)—the team generated a multi-layered adaptive seat system comprising a durable memory-foam base layer, a gel-based comfort top layer, and smart fabrics for climate control.

These concepts were validated using predictive evaluation tools (boxes 5 and 6) and tested through user scenarios. The solution improved comfort while maintaining energy consumption within targets. Importantly, real-world feedback (e.g., insufficient neck support limitations for older users) was fed back into Box 1 for system-level adjustments, demonstrating COREX's recursive power.

6.6. Critical Comparison and Theoretical Implications

The OTSM-TRIZ method and the Six-Box Scheme represent two distinct but incomplete approaches to early-stage problem structuring. OTSM-TRIZ provides rigorous tools for identifying systemic contradictions, yet its high level of abstraction and representational complexity limit its ability to incorporate user perspectives and scenario-based insights. In contrast, the Six-Box Scheme excels at capturing user needs and guiding intuitive reasoning but lacks formal mechanisms for navigating technical contradictions or linking user complaints to parameter-level trade-offs. These complementary limitations illustrate why neither approach, when used in isolation, is fully adequate for contemporary socio-technical design challenges.

Recent TRIZ developments exhibit similar patterns. Radical TRIZ (Wang et al., 2024) offers deep functional decomposition but requires extensive data processing and provides limited support for user integration. Cyclical TRIZ (Altun, 2025a) emphasizes iterative refinement without specifying how abstraction transitions should be managed. AI-assisted extensions such as EBD-TRIZ-LLM (Mohammadi and Zeng, 2025) broaden the search space but depend heavily on the quality of the underlying problem model and do not inherently resolve contradictions. COREX responds to these theoretical gaps by combining the structured contradiction modeling of OTSM with the user-grounded clarity of the Six-Box Scheme. This integration provides a balanced framework that maintains analytical depth while remaining cognitively accessible, offering a coherent methodological pathway for complex design problems.

7. Conclusion

This research contributes to the field of systematic innovation by demonstrating how classical contradiction-based logic can be integrated with cognitive innovation models. It supports a hybrid methodology that addresses both technical contradictions and human-centered needs, and it extends the application of meta-contradictions and predictive reasoning in early-stage design.

For R&D and innovation managers, COREX offers a practical roadmap for guiding complex projects. It helps teams to navigate ambiguity, clarify user and system needs, and generate solutions with reduced risk of early-stage failure. Its structured steps and recursive flow also improve cross-functional collaboration, particularly in industries where user–system interactions pose significant design challenges.

This study was conducted as a simulation within a real R&D setting. Although team discussions and feedback resembled authentic development conditions, neither market testing nor long-term adoption fell within the scope of investigation. The evaluation therefore focused on methodological effectiveness rather than engineering performance, leaving real-world validation of the final concepts as an open direction for future research.

Future studies may apply COREX in other industries and with more diverse teams. Integrating digital tools (e.g., AI-enhanced contradiction detection or simulation-based user testing) could further strengthen the methodology. Longitudinal research may also examine how COREX shapes innovation cycles and contributes to product success over time.

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Conflict of Interest

The author declares no competing interests.

Author Contributions

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Availability of Data

Data related to the study are available from the corresponding author upon reasonable request.

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AUTHOR BIOGRAPHIES

Koray Altun is an assistant professor of industrial engineering at TU Bursa and a research collaborator at Glorad. He is also the founder and manager of a startup focused on digital innovation and software consultancy. He holds a Ph.D. and a B.Sc. degree in industrial engineering from Gaziantep University and Erciyes University, respectively. He has published papers in well-respected journals and has led consulting engagements in reputable companies with a focus on research and development (R&D), technology, and innovation management. His recent research interests include the innovation excellence model, systematic innovation, technology and innovation management, and R&D management.