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A Proof-of-Concept for Parameter Manipulation in TRIZ: Automotive Case Study

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Abstract

This paper provides a proof-of-concept for using the Theory of Inventive Problem Solving (TRIZ) methodologies, focusing on parameter deployment and manipulation to solve physical contradictions in automotive seat design. While parameter deployment has been explored in theory, practical applications remain limited, and its potential has not been widely demonstrated. This study addresses this gap by showing how it can resolve the conflict between comfort during normal driving and safety during collisions. Two strategies are introduced: the Transfer-Oriented Approach (TOA) uses a single air bladder system to adjust seat firmness dynamically, ensuring comfort in regular driving and firmness during crashes. The Transfer-Oriented Approach with Adjustment (TOAA) extends this by combining air bladder systems for comfort and shape memory materials for safety, allowing both to work independently. These methods are innovative because they move beyond classical TRIZ principles by integrating external components, achieving dual functionality without compromising performance. This paper contributes to TRIZ literature by providing a practical example of how parameter deployment can be applied in automotive design. It also serves as a guide for engineers and researchers interested in using TRIZ to tackle similar design challenges. By validating the feasibility of this approach, the study opens up possibilities for exploring its use in other areas of automotive design such as climate control systems or crash energy management. The findings highlight how systematic innovation can transform theoretical methods into real-world solutions, offering practical insights for future applications within the automotive industry.

Keywords: Automotive seat design; Parameter transfer; TRIZ - Theory of inventive problem solving

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1. Introduction

Automotive seat design has long been challenged by the need to balance conflicting requirements such as comfort during regular driving and firmness for safety during collisions. As the automotive industry advances towards autonomous vehicles, this challenge becomes even more pronounced. Autonomous vehicles offer passengers more freedom of movement and create higher expectations for comfort due to passive travel. However, ensuring passenger safety simultaneously remains critical. Traditional designs often involve trade-offs where improvements in comfort result in reduced safety, or vice versa.

Altun et al. [1] addressed this problem by incorporating features such as rotating seats and integrated safety mechanisms like three-point seatbelts, aimed at achieving both comfort and safety in various seating configurations. Despite these efforts, achieving a comprehensive solution that addresses both comfort and safety without compromising either aspect remains a significant challenge in the field of automotive design.

Existing approaches to seat design primarily focus on enhancing comfort through material selection and structural improvements. To address issues related to the uneven distribution of contact pressure between the driver and the seat, innovative designs involving sponge materials with varying hardness levels have been developed to better accommodate body pressure distribution characteristics [2]. This adaptive material configurations allow the seat to respond more effectively to pressure points and provides enhanced comfort [3].

Furthermore, structural optimization approaches are employed to improve seat performance. Design areas are determined based on the shape and size requirements of the seat frame, taking into account actual seat-belt loading conditions. From these parameters, an optimized design model is established in [4]. With structural static stiffness maximization as a primary objective, the variable density method is applied for topological optimization. This process not only enhances the structural integrity of the seat but also contributes to improved safety and comfort.

While these methods contribute to improved comfort, they do not provide adequate adaptability to changing driving conditions or sudden impact events. Moreover, achieving safety during collisions often requires rigid structures that compromise comfort during normal driving.

In automotive vehicles, this issue becomes even more complex. The need for advanced seating systems that accommodate various user activities within automated driving vehicles has been highlighted in several studies. Specifically, Kim [5] explored functional options and design concepts for automated driving vehicle seats, emphasizing the importance of user comfort and safety in diverse operational scenarios.

Another recent study, Dillen et al. [6] emphasizes the importance of managing passenger comfort and anxiety in autonomous driving. They found that driving parameters such as acceleration significantly impact comfort, highlighting the need for adaptive seat designs. Additionally, Sauer et al. [7] demonstrated that cultural preferences influence design: Chinese passengers prefer luxury interiors, while German and U.S. passengers favor functional designs focused on safety. This cultural diversity underscores the necessity of adaptable seat designs that can meet both physical and cultural demands.

The TRIZ methodology, particularly parameter transfer developed by Sheu and Yeh [8], offers a systematic approach for resolving such physical contradictions. The fundamental principle of TRIZ is to move conflicting demands to external systems, thereby allowing designers to satisfy both objectives without compromising either.

For instance, air bladder systems provide comfort during regular driving, while shape memory materials ensure firmness during collisions. This method also aligns with modern optimization techniques, such as the lightweight design strategies demonstrated by Steinwall and Viippola [9], who achieved 27% reduction in seat weight through topology optimization without sacrificing safety. This separation of functions, which allows different systems to independently address conflicting requirements, is central to the TRIZ approach. However, despite its potential, the application of TRIZ-based methodologies, particularly parameter deployment and manipulation strategies, remains largely unexplored in the context of automotive seat design.

The primary aim of this study is to provide a proof-of-concept for TRIZ-based parameter manipulation methods in resolving the comfort-safety contradiction in automotive seat design. This research specifically focuses on demonstrating the applicability of two novel approaches: (*i*) TOA – Transfer-Oriented Approach, a strategy utilizing a single external component to address conflicting objectives simultaneously. (*ii*) TOAA – Transfer-Oriented Approach with Adjustment, a strategy involving two separate external components to handle conflicting objectives independently.

The rest of this paper is organized as follows: Section 2 provides a theoretical background, covering key concepts. Section 3 addresses the application of the parameter transfer strategies, specifically focusing on resolving the comfort-safety contradiction in automotive seat design through practical solutions like air bladder systems and shape memory materials. Section 4 discusses the results and implications of these methodologies, offering insights for both academic research and practical applications in the automotive industry, and concludes with recommendations for future research directions.

2. Theoretical background

2.1. Contradictions

In the world of product design and innovation, one of the most common challenges is dealing with contradictions. A "contradiction" is a condition where two conflicting demands are placed on a system, making it difficult to satisfy both at the same time. In TRIZ, contradictions are seen as the main obstacles to technical progress. The design of innovative technical systems is an ongoing process where contradictions are repeatedly resolved, allowing the system to evolve and improve over time [10].

TRIZ methodology distinguishes between three types of contradictions: administrative, technical, and physical contradictions [11], although administrative contradictions are often seen as a type of technical contradiction.

In TRIZ, the distinction between these three types of contradictions represents different levels of understanding and problem refinement. While administrative contradictions are broad and undefined, technical and physical contradictions are more specific and provide clearer paths toward innovation [12]. Administrative contradictions occur when there is a desired result or goal, but it is unclear how to achieve it. These contradictions are often vague and temporary, offering little heuristic value for problem-solving. They do not provide a clear direction and typically do not lead to immediate innovative solutions.

For example, the concept of mass customization, a business strategy that aims to produce individualized products on a large scale, exemplifies an administrative contradiction. Businesses strive to meet individual customer needs while maintaining the efficiency and scale of mass production, a challenge that requires innovative approaches to align adaptability with productivity [13]. Here, the challenge is not merely technical but involves broader strategic decision-making to balance these competing demands.

There are two primary types of contradictions: technical contradictions (TCs), where improving one part of a system negatively impacts another, and physical contradictions (PCs), where a single element must satisfy two opposing requirements. TRIZ emphasizes identifying and resolving these contradictions to drive innovation.

To illustrate this concept more clearly, Figure 1 is provided as an example. It visualizes the behavior of technical and physical contradictions. TCs involve situations where improving one parameter of a system negatively affects another. For example, increasing the speed of a process might lead to a reduction in precision. Addressing such contradictions often requires finding innovative ways to improve one aspect without sacrificing the other.

PCs, on the other hand, occur when a system requires conflicting conditions to exist simultaneously, such as needing a material to be both flexible and rigid. Resolving these contradictions typically involves finding a way to separate the conflicting requirements in time, space, or by using different conditions.

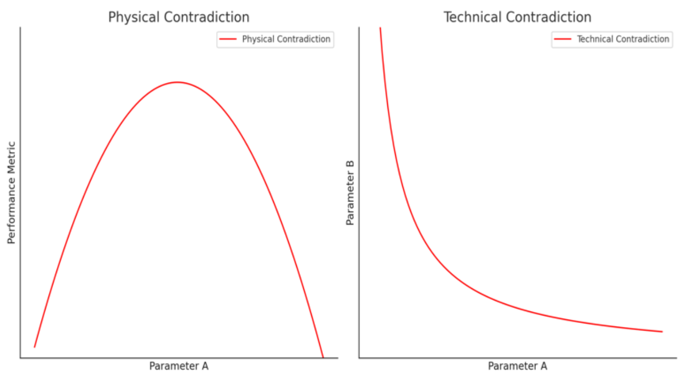

Figure 1. Graphical characteristics of the contradictions (adapted from Mann and Stratton [14])

TRIZ provides several tools to help identify and resolve these contradictions systematically. The main goal is to find solutions that do not involve compromises but instead satisfy both conflicting demands.

2.2. Separation principles

Separation principles are at the heart of resolving physical contradictions, and TRIZ suggests four main separation strategies [15,16]:

(*i*) Separation in time: Satisfying contradictory requirements at different times. For instance, an object can be flexible when stored but rigid when used.
(*ii*) Separation in space: Fulfilling different needs in different parts of the system. One part can be soft for comfort, while another part is hard for strength.
(*iii*) Separation based on condition: Contradictory properties can be achieved under different conditions. For example, a material might behave differently under varying temperatures.
(*iv*) Separation between parts and the whole: A specific part of the system can satisfy one need, while another part meets the opposite requirement.

The discussion on separation principles aligns with fundamental TRIZ concepts, emphasizing the importance of different separation strategies like time, space, condition, and parts-whole dynamics. However, Sheu's work offers a more structured approach to parameter deployment and manipulation, which could deepen the analysis here. Specifically, Sheu [17] highlights the need to address the problem point through precise parameter manipulation, beyond the general strategies of time and space.

For example, while TRIZ suggests using time-based separation to meet different needs at different times, Sheu [17] and Sheu and Yeh [8] introduce the concept of "parameter transfer" to external elements. This means that instead of only changing parameters within the system over time, you can also bring in external solutions to address conflicts. Additionally, these ideas about "inter-parameter separation" and "cross-parameter separation" help clarify how to use space-based solutions. These ideas provide a more specific way to handle conflicting requirements across different parts of a system.

Sheu [17] also critiques the traditional TRIZ methods of separation. He suggests that just dividing properties in time or space might not fully solve a contradiction. Instead, he focuses on making precise adjustments to parameters, which can balance conflicting needs more effectively. This approach is more detailed than the broad categories of TRIZ and focuses on finding a better balance between different requirements.

3. Parameter deployment and manipulation

Sheu [17] and Sheu and Yeh [8] highlight several key limitations in the separation principles for resolving physical contradictions.

(*i*) The main issue is that separation principles, such as those based on space, relationship, direction, time, and system levels, operate independently without a unified approach or synergy.
(*ii*) These methods focus on separating the conflicting parameter ($+P/-P$) into different aspects like space or time to resolve contradictions. However, they fail to address the separation of the underlying contradictory objectives (O_1/O_2) directly.
(*iii*) Additionally, these methods, including strategies like satisfying contradictions or using system transitions, rely on a few inventive principles without offering a structured, step-by-step process for problem-solving.
(*iv*) Moreover, they do not consider using unrelated external resources to find solutions, which limits their effectiveness.

Sheu [17] and Sheu and Yeh [8] propose three main approaches for dealing with physical contradictions: (*i*) parameter deployment, (*ii*) parameter separation, and (*iii*) parameter transfer. Here's a more detailed explanation of each, with their formulations and examples:

3.1. Parameter deployment

This approach focuses on analyzing and manipulating parameters at the local system level. This means looking closely at the components that directly contribute to a conflict and adjusting their parameters accordingly. The goal is to identify and adjust the parameters that influence conflicting objectives, making it possible to balance these objectives.

Formulation:

The objectives (O_1: Eq.1 and O_2: Eq.2) are represented as functions of various parameters:

$$O_1 = fn(P_1^1 \uparrow, \dots; E_1^1 \uparrow, \dots; Z_1^1 \downarrow, \dots;) \quad (1)$$

$$O_2 = fn(P_1^2 \downarrow, \dots; E_1^2 \uparrow, \dots; Z_1^2 \downarrow, \dots;) \quad (2)$$

$P_1^1 \uparrow, P_1^2 \downarrow$: Conflicting parameters

$E_1^1 \uparrow, E_1^2 \uparrow$: Exclusive parameters

$Z_1^1 \downarrow, Z_1^2 \downarrow$: Compatible parameters

The formulation involves three types of parameters: conflicting parameters, exclusive parameters, and compatible parameters. Conflicting parameters, like flexibility and strength, have opposing effects on the objectives. Exclusive parameters are specifically adjusted to satisfy one objective, such as using a waterproof coating to ensure water resistance. Compatible parameters can be adjusted without creating new conflicts, such as modifying the weight of a material. These parameters work together in a function that describes how they interact to achieve the desired outcomes. For instance, by using special composite materials and adjusting characteristics like thickness and permeability, a device can be optimized to achieve both waterproofing and effective heat dissipation.

3.2. Parameter separation

This is a method used to solve physical contradictions by dividing the conflicting requirements into different aspects, such as time, space, or conditions, so that they can be managed separately. This approach allows each conflicting need to be satisfied without interfering with the other, making it easier to balance both sides of the contradiction.

There are two main types of parameter separation:

Within-parameter separation: This method involves adjusting a single parameter in different ways depending on the situation. The parameter is not changed entirely but is allowed to vary based on conditions like time or environment. Imagine a material that needs to be flexible when being stored but rigid when in use. This can be achieved by making the material behave differently at different temperatures. When the temperature is low, it remains flexible for easier storage (O_1). When the temperature increases, it becomes rigid, making it strong enough for practical use (O_2). This way, the same material can fulfill both needs by adjusting its properties based on temperature.

Cross-parameter separation: This method further divides into two strategies: Inter-parameter separation and Parameter splitting.

Inter-parameter separation assigns different needs to separate parameters, allowing each one to focus on a specific requirement. In a shoe design, the sole could be made from a soft material to provide comfort (O_1), while the outer part is made from a hard material to provide durability (O_2). Here, the softness and hardness are separated into different parts of the shoe, each fulfilling a different need.

Parameter splitting divides one conflicting parameter into two parts, each adjusted to satisfy a specific requirement. Consider a valve that needs to be watertight for sealing (high pressure) but also easy to open and close (low pressure). Instead of using the same pressure throughout, the valve could have a mechanism that switches between high pressure to maintain the seal (O_1) and low pressure for easy operation (O_2).

3.3. Parameter transfer

The key idea of parameter transfer is to find external parameters or components that can take over part of the work, allowing the original system to focus on the remaining requirements. This approach can make problem-solving more flexible and creative because it opens up possibilities beyond the limits of the current system.

Formulation:

Eq.3 indicates that an external parameter, like a cooling system or a flexible coating, is used to satisfy both objectives without altering the core system.

$$Sol = (ExternalParameterA \rightarrow O_1/O_2) \quad (3)$$

Different strategies [17] for how parameter transfer methods can be applied to address contradictory objectives. Following each strategy provides a way to manage the objectives and parameters effectively, depending on the specific requirements of the problem.

- TOPA - Transfer-Oriented Parameter Approach: In this method, parameter *P* satisfies either O_1 or O_2, while the other need (O_2 or O_1) is managed using an external parameter.
- TOAP – Transfer-Oriented Approach with Parameter: Similarly, parameter P is used to satisfy one objective (O1 or O2), with an external parameter taking care of the remaining objective.
- TOEA – Transfer-Oriented Exclusive Approach: This method uses an exclusive parameter for O1 while employing an external parameter to satisfy O2.
- TOAE – Transfer-Oriented Approach with Exclusive Parameter: In this approach, an exclusive parameter is used for O2, with an external parameter managing O1.
- TOAA – Transfer-Oriented Approach with Adjustment: This method involves using two separate external parameters to satisfy O1 and O2 individually. Each objective is managed by a different external element.
- TOA – Transfer-Oriented Approach: A single external parameter is used to meet both O1 and O2 simultaneously. This external parameter balances the needs of both objectives at once.
- TOAV – Transfer-Oriented Approach with Variable Settings: The same external parameter is used, but it operates within two different ranges to satisfy O1 and O2. It adjusts

its behavior based on the situation, allowing it to meet both needs with variable settings.

4. Solving design contradictions

To systematically address the comfort-safety contradiction in automotive seat design, two distinct TRIZ-based parameter transfer strategies are proposed: TOA and TOAA. Each strategy employs a unique methodology to resolve the conflicting objectives of comfort during normal driving and firmness for safety during collisions. Figure 2 illustrates the progression of the methodology, demonstrating how each approach targets the conflicting objectives through unique mechanisms.

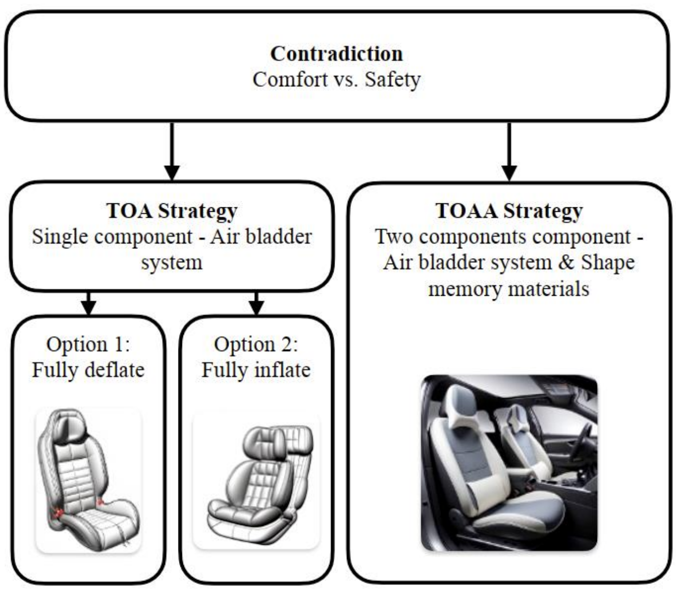

Figure 2. Flow of the contradiction resolution

4.1. Use of parameter transfer approach (TOA)

Automotive seat design faces a critical physical contradiction: the need for comfort during regular driving and the need for increased firmness to ensure safety during collisions. This contradiction arises because a seat that is too firm may cause discomfort to occupants during daily use, while a seat that is too soft may fail to provide adequate support in the event of a crash.

To solve this physical contradiction, the parameter transfer methodology proposed by Sheu [17] and Sheu and Yeh [8] is applied using the TOA strategy. This method uses a single external parameter, the air bladder system, to adapt to different conditions, providing both comfort and safety when required.

Formulation:

O_1: Comfort during normal driving.

O_2: Firmness during collisions for safety.

The solution uses one external component:

A: Air bladder system,

which can adjust its pressure to be either deflated or inflated to provide firmness.

$$Solution = (A \rightarrow O_1/O_2) \quad (4)$$

This formula (Eq.4) indicates that the air bladder system (A) is used to meet both objectives (O_1 and O_2) by adjusting its pressure. It can either reduce pressure for comfort during normal driving or increase pressure to enhance firmness during a crash.

Application of the strategy:

Air bladder system (A): The air bladder system integrates adjustable air chambers into the seat, which can be controlled to adjust the seat's firmness.

During regular driving conditions, the air bladder system lowers the pressure in the chambers, allowing the seat to be softer and more comfortable, thus directly addressing the comfort requirement (O_1).

In the event of a collision, the air bladder system can either:

(i) Fully deflate, allowing the seat to quickly absorb impact energy by adapting its shape (Figure 3).

(ii) Increase air pressure, making the seat more rigid to provide additional support and protection during the impact (Figure 4).

This ensures the seat maintains the structural integrity required for occupant safety, satisfying the firmness requirement (O_2).

The TOA strategy is particularly effective here because it uses the adaptability of the air bladder system to meet both comfort and safety needs through simple adjustments in pressure.

For comfort (O_1), the system reduces the air pressure, creating a softer seating experience for everyday driving.

For safety (O_2), the system either fully deflates or increases its pressure during a crash, providing the necessary firmness or adaptability to protect the occupants.

Figure 3. Air bladder system in a deflated state, allowing the seat to adapt its shape for impact absorption during a collision.

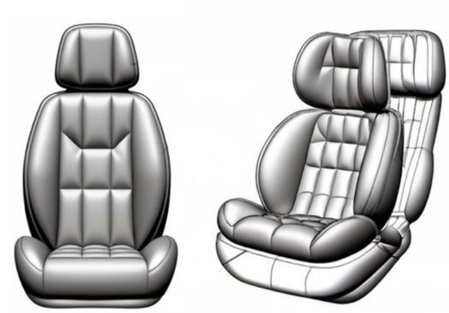

Figure 4. Air bladder system in an inflated state, providing increased firmness to ensure occupant safety during a collision.

This approach allows the automotive seat to dynamically adjust to different scenarios, solving the contradiction between comfort and safety without the need for multiple external components. It offers a straightforward and efficient solution that is both responsive and effective in adapting to changing conditions.

4.2. Use of parameter transfer approach (TOAA)

TOAA strategy involves using two separate external parameters, one for comfort and another for safety, to manage each need independently.

Formulation:

O_1: Comfort during regular driving.

O_2: Firmness during collisions for safety.

The solution involves two external components:

A_1: Air bladder system, which is designed to provide adjustable comfort during normal driving.

A_2: Shape memory materials, which provide rigidity and support specifically during crashes.

$$Solution = (A_1 \rightarrow O_1) + (A_2 \rightarrow O_2) \quad (5)$$

This formula (Eq.5) indicates that A_1 (air bladder system) is used exclusively to satisfy the comfort requirement (O_1), while A_2 (shape memory materials) is used to meet the firmness and safety requirement (O_2) during a collision. Each external parameter is focused on a different objective, avoiding direct interference between them.

Application of the strategy:

Air bladder system (A_1): The air bladder system consists of adjustable air chambers built into the seat. These chambers can be inflated or deflated to control the seat's softness, allowing it to adapt to the comfort preferences of the driver and passengers during everyday driving.

During normal conditions, this system makes the seat soft and comfortable, directly addressing the comfort objective (O_1).

The air bladder system operates independently of the seat's structural firmness, ensuring that comfort is managed without affecting the rigidity needed for safety.

Shape memory materials (A_2): Shape memory materials are embedded in the seat structure and are designed to become rigid when a collision occurs. These materials react to the impact forces, changing their state to provide the necessary firmness and support to protect the occupants.

When a crash happens, the shape memory materials automatically harden, ensuring the seat offers the structural integrity required for safety, satisfying the firmness objective (O_2).

This external solution operates independently of the air bladder system, ensuring that the safety requirements are met only when needed during a collision.

The TOAA strategy is effective here because it separates the functions of comfort and safety into two distinct external systems, allowing each one to be optimized for its specific role. The air bladder system (A_1) is dedicated to maintaining comfort, providing flexibility in everyday use without compromising the seat's softness. The shape memory materials (A_2) are focused solely on safety, becoming active only during high-impact events to ensure rigidity and protection.

The air bladder offers adjustable softness during daily use, while the shape memory materials provide increased firmness during collisions (see Figure 5).

Figure 5. Automotive seat design utilizing air bladder system for comfort and shape memory materials for safety.

By using these separate parameter transfer solutions, the automotive seat design resolves the physical contradiction between comfort and safety. This approach ensures that the seat can provide a comfortable experience during regular driving and become rigid during a collision, offering a tailored response to both situations without compromising either requirement.

4.3. Comparative analysis of TOA and TOAA

The TOA and TOAA strategies offer distinct approaches to resolving the comfort-safety contradiction in automotive seat design. Each strategy applies the TRIZ parameter transfer methodology in different ways, which affects their technical performance, adaptability, and overall practicality.

The TOA strategy employs a single external component, specifically an air bladder system, to address air chambers. During normal driving, the air pressure is reduced to provide a softer, more comfortable seating experience. During a collision, the system either fully deflates to absorb impact energy or increases air pressure to enhance structural firmness.

The ability to adjust air pressure in real-time makes TOA strategy particularly effective for scenarios where immediate transitions between comfort and safety are required. Utilizing a single external component makes the system more compact and easier to integrate within existing seat structures. The system's effectiveness is inherently limited by the performance range of the air bladder. Achieving optimal performance for both objectives simultaneously may be difficult, especially during high-impact collisions where rapid pressure adjustments are required. Reliability concerns may also arise due to potential air leakage or mechanical wear over time.

On the other hand, the TOAA strategy utilizes two independent external components, an air bladder system for comfort and shape memory materials for safety to achieve greater specialization and effectiveness.

Unlike the TOA strategy, the TOAA approach assigns each external component to a specific objective. This separation ensures that modifications to enhance comfort do not interfere with the safety mechanism and vice versa.

Shape memory materials provide a robust safety mechanism due to their inherent resilience and ability to react precisely during collisions. The air bladder system, meanwhile, maintains comfort without compromising safety. The introduction of two separate systems increases complexity, manufacturing costs, and space requirements. Additionally, ensuring proper integration between components can be challenging.

The selection between these strategies depends on the specific design requirements and performance criteria of the application. For scenarios where adaptability and responsiveness are prioritized, the TOA strategy may be more suitable. Conversely, where specialization and robust safety mechanisms are essential, the TOAA strategy may provide a more reliable solution.

5. Concluding remarks

This paper provides a proof-of-concept for applying TRIZ methodologies, specifically parameter deployment and manipulation, to solve physical contradictions in automotive seat design. While this approach has been explored in theory, practical applications are rare, and its effectiveness has not yet been widely demonstrated. This study addresses the comfort-safety contradiction, a common challenge in automotive design, to validate the proposed methods.

The study presents two approaches: the TOA strategy employs a single air bladder system that dynamically adjusts seat firmness, ensuring comfort during regular driving and safety during collisions. The TOAA strategy further innovates by combining air bladder systems for comfort and shape memory materials for safety, allowing each system to work independently. These methods go beyond traditional TRIZ separation principles by integrating external components, achieving dual functionality without compromise.

The improvements achieved through these strategies include enhanced adaptability and responsiveness in the TOA strategy, which demonstrates the ability to transition seamlessly between comfort and safety requirements through real-time pressure adjustments. Additionally, the TOAA strategy provides increased specialization and reliability by dedicating separate components to comfort and safety, thereby optimizing performance for each objective. Both strategies contribute to improved structural integrity and user satisfaction by addressing comfort and safety requirements without compromising either aspect.

The primary goal of this paper is to serve as a proof-of-concept, demonstrating the feasibility of parameter deployment and its potential for inventive solutions. The proposed methods are aligned with inventive approaches seen in patents such as CN 114340945B, WO 2018114723, CN 108297819B, and CN 210083007, which use similar airbag technologies to address occupant safety challenges. It should be noted here that these patents are utilized as supportive references to assess existing technological approaches related to airbag devices and occupant protection mechanisms. While these patents provided valuable insights into the technological landscape, the proposed TOA and TOAA strategies were independently developed through a TRIZ-based parameter transfer methodology. The conceptualization of these strategies is not derived from patented mechanisms but rather aims to address identified gaps and limitations within the existing solutions.

Potential future outcomes include experimental validation of the proposed methodologies through prototyping and empirical testing, integration of advanced sensing technologies to enhance adaptability and responsiveness, and exploration of hybrid approaches that combine the strengths of TOA and TOAA for optimized performance. Moreover, the methodologies proposed in this study could be applied to broader contexts, such as aerospace seating systems and public transportation, where comfort-safety contradictions are also significant.

Conflict of Interest Statement

The author declares that there is no conflict of interest in the study.

References

[1] Altun, K, Özcan Berber, R, Kurt, R, Bektaş, E, Turan, S, Korkmaz, V. Front seat development for autonomous driving: A case of innovative product development. Journal of the Faculty of Engineering and Architectures of Gazi University. 2022; 37 (3), 1441–1452. https://doi.org/10.17341/gazimmfd.936325

[2] Mistarihi, MZ, Al-Omari, AA, Al-Dwairi, AF. Designing and simulation assessment of a chair attachment air blowing method to enhance the safety of prolonged sitting. Biomimetics. 2023; 8, 194. https://doi.org/10.3390/biomimetics8020194

[3] Mitsuya, R, Kato, K, Kou, N, Nakamura, T, Sugawara, K, Dobashi, H. Analysis of body pressure distribution on car seats by using deep learning. Applied Ergonomics. 2019; 75, 283-287. https://doi.org/10.1016/j.apergo.2018.08.023

[4] Jiang, X, Meng, X. A structural design of a child seat based on morphological elements and ergonomics. Comput. Intel. and Neuroscience. 2022, 1-8. https://doi.org/10.1155/2022/1792965

[5] Kim, D. Analysis of automotive seating systems in automated driving vehicles according to the changes of the interior environment. Master thesis of public administration. Graduate School of Engineering Practice, Seoul National University. 2021; Seoul, South Korea.

[6] Dillen, N, Ilievski, M, Law, E, Nacke, LE, Czarnecki, K, Schneider, O. Keep calm and ride along: Passenger comfort and anxiety as physiological responses to autonomous driving styles. In Proceedings of the 2020 CHI conference on human factors in computing systems. 2020; 1-13.

[7] Sauer, V, Mertens, A, Groß, S, Heitland, J, Nitsch, V. Designing automated vehicle interiors for different cultures: Evidence from

China, Germany, and the United States. Ergonomics in Design. 2022; 30(3), 16-22. https://doi.org/10.1177/1064804620966158
[8] Sheu, DD, Yeh, R. Parameter Deployment and Separation for Solving Physical Contradictions. 18th TRIZ Future Conference. Springer International Publishing. 2018; Strasbourg, France.
[9] Steinwall, J, Viippola, P. Concept development of a lightweight driver's seat structure and adjustment systems: Combining optimization and modern product development methods to achieve a lightweight design. Master thesis in Product Development. Chalmers University of Technology. 2014; Gothenburg, Sweden.
[10] Altshuller, G. And suddenly the inventor appeared: TRIZ, the theory of inventive problem solving. Worcester: Technical Innovation Center. 1996.
[11] Terninko, J. Systematic Innovation: An introduction to TRIZ (Theory of Inventive Problem Solving). 1998; Boca Raton: CRC Press.
[12] Coatanéa, E, Nosiri, S, Mokammel, F, Christophe, F, Calonius, O, Ryynänen, L. Contradiction graph search: A tool for discovering for physical contradictions. Proceedings Tools and Methods of Competitive Engineering TMCE. 2014; 993-1006.
[13] Mann, D., Domb, E. Business Contradictions: 1) Mass Customization. TRIZ Journal. 1999; December.
[14] Mann, D, Stratton, R. Physical contradictions and evaporating clouds. TRIZ Journal. 2000; April, 1-12.
[15] Gadd, K. TRIZ for engineers: Enabling inventive problem solving. John Wiley & Sons. 2011; United Kingdom.
[16] Sheu, DD, Chiu, MC, Cayard, D. The 7 pillars of TRIZ philosophies. Computers & Industrial Engineering. 2020; 146, 106572.
[17] Sheu, DD. Parameter deployment and manipulation: An overarching approach for identifying and solving contradictions. The 15th International Conference & Global Competition on Systematic Innovation (ICSI & GCSI). 2024; Bursa, Turkey.