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A Mayan calendar-inspired cyclical TRIZ approach: Enhancing systematic innovation and long-term problem-solving

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Abstract

This paper introduces the Mayan calendar-inspired cyclical theory of inventive problem solving (TRIZ) model, an innovative approach to systematic innovation (SI) that integrates the seven TRIZ pillars into a structured model consisting of "Tzolk'in" (short-term, adaptation), "Haab" (mid-term, harmonization), and "Long Count" (long-term, transformation) cycles. Unlike traditional linear innovation models, this cyclical model enables continuous adaptation, iterative refinement, and sustainable evolution. Each cycle addresses a different level of complexity: The adaptation cycle focuses on rapid, low-cost improvements using available resources. The harmonization cycle resolves deep-rooted contradictions to enhance system functionality. The transformation cycle drives strategic evolution by integrating intelligence and automation. This approach is validated through its alignment with trends of engineering system evolution, demonstrating that innovation naturally progresses through these phases. The model's practical applicability is illustrated through case studies on coffee machine design and automotive seat design, showing how short-term enhancements, mid-term optimization, and long-term transformation collectively contribute to sustainable evolution. By bridging systematic problem-solving with iterative adaptation, the cyclical TRIZ model provides a versatile and scalable SI model for industries seeking to achieve both immediate efficiency gains and long-term innovation resilience.

Keywords: Cyclical TRIZ Model, Mayan Calendar, Systematic Innovation, TRIZ

1. Introduction

Innovation is not just a straightforward journey from point A to point B. It often involves cycles of learning, feedback, and adaptation. This cyclical nature of progress can be seen in ancient philosophies, like the Mayan calendar (Fig. 1), which views time as a repeating cycle rather than a straight line.

The Mayan calendar consists of three main cycles: "Tzolk'in" (short-term), "Haab" (mid-term), and "Long Count" (long-term). Each cycle represents a layer of time that builds upon the previous one, emphasizing the importance of iteration, balance, and continuous growth. This concept of cyclicality not only promotes holistic understanding but also encourages adaptation over time, allowing for flexibility in the face of changing circumstances.

This idea of cycles aligns well with a systematic innovation process (SIP). Similarly, systematic innovation (SI) is not a purely linear process. While it provides a structured approach to problem identification, solution generation, and solution implementation, its effectiveness can be further enhanced by integrating cyclical elements.

Various SI models provide structured pathways to guide the process, typically moving from problem identification to solution implementation. These models often incorporate the theory of inventive problem-solving (TRIZ) tools to enhance creativity, improve idea generation, or manage knowledge transformation. While some focus on incremental problem-solving, others aim for strategic planning or interdisciplinary collaboration. However, a common limitation among these models is their linear

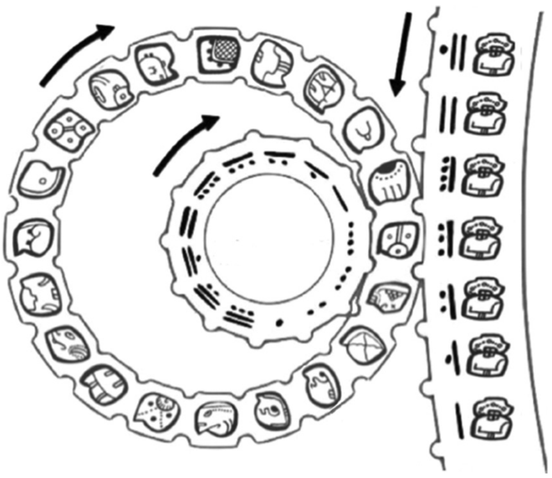

Fig. 1. A representation of the Mayan calendar cycle (adapted from Chanier, 2018)

progression, which lacks a mechanism for continuous feedback and adaptation.

A linear model may not fully support dynamic adaptation or long-term problem-solving. This study seeks to create a more adaptive SIP that can sustain both short-term problem-solving and long-term strategic growth. By integrating a cyclical approach inspired by the Mayan calendar, the TRIZ approach can become more iterative, allowing for continuous feedback and adaptation, which is essential for both short-term and long-term solutions.

The remainder of this paper is organized as follows: Section 2 reviews existing TRIZ-based SIPs. Section 3 presents the new cyclical TRIZ model, detailing its iterative and adaptive structure. Section 4 illustrates the model's application through a case study, showcasing its effectiveness in evolving scenarios. Sections 5-8 discuss the results, comparing the new model to traditional approaches and offering conclusions.

2. Literature Review

SI distinguishes itself from empirical, trial-and-error methods by providing a clear, step-by-step process that guides problem identification, solution generation, and implementation (Sheu & Lee, 2011). TRIZ is built on systematic principles that help identify contradictions in a system and generate inventive solutions. SI reduces the uncertainty and trial-and-error nature of traditional innovation by incorporating well-defined tools and strategies, often integrating principles from TRIZ.

The theory of inventive problem-solving is a structured approach that aims to identify and solve contradictions in design and development. TRIZ traditionally adopts a linear problem-solving approach, focusing on one contradiction at a time. Although TRIZ tools are highly effective, applying the right tool at the right stage of the innovation process can be challenging (Ilevbare et al., 2013). This difficulty often arises due to the complexity and diversity of available TRIZ tools, as well as the need to adapt them to specific problem contexts.

Several SI models have been developed to provide structured pathways for innovation. These models aim to bridge the gap between problem identification and solution implementation, incorporating various tools, including TRIZ elements.

Mann's (2007) model, a systematic creativity process, emphasizes a clear sequence of steps: "Define," "Select Tool," "Generate Solutions," and "Evaluate." The approach integrates TRIZ tools to enhance creativity in problem-solving but primarily focuses on addressing specific problems rather than broader opportunities or strategic adaptation.

The W-model (Brandenburg, 2002) covers a continuous cycle of innovation from goal setting to implementation planning. It follows the stages of future analysis, idea generation, idea evaluation, concept detailing, and implementation planning. While effective in strategic planning, it often lacks practical tools for execution and does not emphasize feedback loops, making it less adaptable to evolving challenges.

The innovation value chain (Hansen & Birkinshaw, 2007) divides the innovation process into three distinct stages: idea generation, idea conversion, and idea diffusion. It focuses on moving ideas from concept to market but lacks specific tools for systematic problem-solving, making it more conceptual than operational.

Roper et al.'s (2008) model outlines innovation as a transformation of knowledge into business value, with stages of knowledge sourcing, transformation, and exploitation. While it emphasizes knowledge management as a driver of innovation, it lacks the structured tools necessary for resolving contradictions or implementing solutions systematically.

Sheu & Lee (2011) proposed a SIP that integrates both TRIZ and non-TRIZ tools to facilitate innovation across different phases. The SIP consists of structured stages that guide innovation from opportunity identification to solution generation, allowing for effective exploitation of developed technologies.

The ACE framework (Zhan et al., 2017) facilitates product innovation by shortening time-to-market, accelerating the understanding of customer needs, and reducing costs. The model uses big data analytics to accelerate innovation processes, enhance customer connection, and create an innovation ecosystem. It emphasizes the importance of faster innovation cycles and stronger customer feedback loops, making the product development process more dynamic and flexible. While this approach effectively uses big data to speed up innovation, it follows a linear process without built-in mechanisms for continuous adaptation or feedback.

Kruger et al. (2019) proposed a SI model that integrates TRIZ and creative problem-solving techniques to enhance innovation management. This model considers psychological factors, such as overcoming psychological inertia, to support creative thinking.

Sun et al. (2020) proposed a SIP specifically oriented toward interdisciplinary research. Their approach aims to solve complex problems by integrating insights from multiple disciplines, using TRIZ tools, the general theory of powerful thinking (OTSM), and patent databases. This process emphasizes both incremental and disruptive innovation, leveraging interdisciplinary collaboration to enhance creativity and generate high-quality solutions.

The radical problem-solving framework (Wang et al., 2024) aims to go beyond the limits of existing design methods to achieve more radical innovation. This model leverages TRIZ tools to drive more radical innovation, addressing some of the challenges associated with traditional TRIZ applications. While it provides a clearer guide for using TRIZ tools effectively, it follows a linear process that lacks built-in adaptation and continuous feedback.

Mann (2023) also proposed a SIP that applies TRIZ principles to chaotic situations, particularly in emergency response scenarios. The approach is based on TRIZ's concept, the "someone, somewhere, has already solved your problem," aiming to identify the most suitable solutions under unpredictable conditions. This process integrates TRIZ with the OODA Loop (a four-step process: observe, orient, decide, and act), suggesting that this combination allows for faster and more effective decision-making in complex environments. This model demonstrates the potential of TRIZ in managing complexity and asymmetric threats.

Existing SI models in the literature typically emphasize linear or mid-term problem-solving approaches, focusing on specific phases such as idea generation, evaluation, and implementation. While some models incorporate TRIZ tools, they often lack mechanisms for long-term adaptation and sustainability. In this study, the proposed Mayan calendar-inspired cyclical TRIZ approach addresses this gap by integrating short-term, mid-term, and long-term cycles, using the seven pillars of TRIZ (Sheu et al., 2020) to continuously navigate and refine solutions over time. This approach not only emphasizes long-term problem-solving but also aligns innovation strategies with enduring outcomes, ensuring more resilience in dynamic environments. It offers a more holistic approach by embedding iterative feedback and adaptability within each phase, bridging the gap between structured inventive problem-solving and sustainable innovation.

3. Proposed Model

According to Sheu et al. (2020), TRIZ is built on seven foundational pillars that guide SI (Table 1): (i) Ideality, striving for the most beneficial outcome with minimal costs; (ii) resources, maximizing the use of available and hidden resources; (iii) functionality-value (FV), enhancing system value by optimizing positive and negative effects; (iv) contradiction, resolving conflicts between system parameters; (v) space, time, domain, and interface (STDI), analyzing problems from spatial, temporal, and interface perspectives; (vi) system transfer, borrowing solutions from other fields; and (vii) system transition, evolving the system's structure or principles.

While these pillars offer a comprehensive foundation, traditional TRIZ is often applied in a linear manner, solving issues step-by-step without continuous feedback or adaptation.

The Mayan calendar-inspired cyclical TRIZ model integrates the seven foundational TRIZ pillars into three overlapping cycles: (i) Short-term (Tzolk'in), (ii) mid-term (Haab), and (iii) long-term (Long Count). Each cycle aims to refine solutions continuously, ensuring ongoing adaptation and sustainability. This model (Fig. 2) draws an analogy to the Mayan calendar, where each cycle represents a different time frame but works together for sustained progress.

Table 1. The theory of inventive problem solving's philosophies and tools (adapted from Sheu et al. 2020)

Philosophy	Practical tools
Ideality	Ideal final result
Resources	Harmful resource usage, DS-TPQ
Functionality-value	Patent regeneration
Contradiction	Separation principles, contradiction matrix, parameter deployment
STDI	Effect/resource database, STIC, smart little people, multi-screen viewpoints
System transfer	Feature transfer
System transition	Trends of engineering system evolution

Abbreviations: DS-TPQ: Demand-supply thought-provoking question; STDI: Space, time, domain, and interface; STIC: Space, time, interface, and cost.

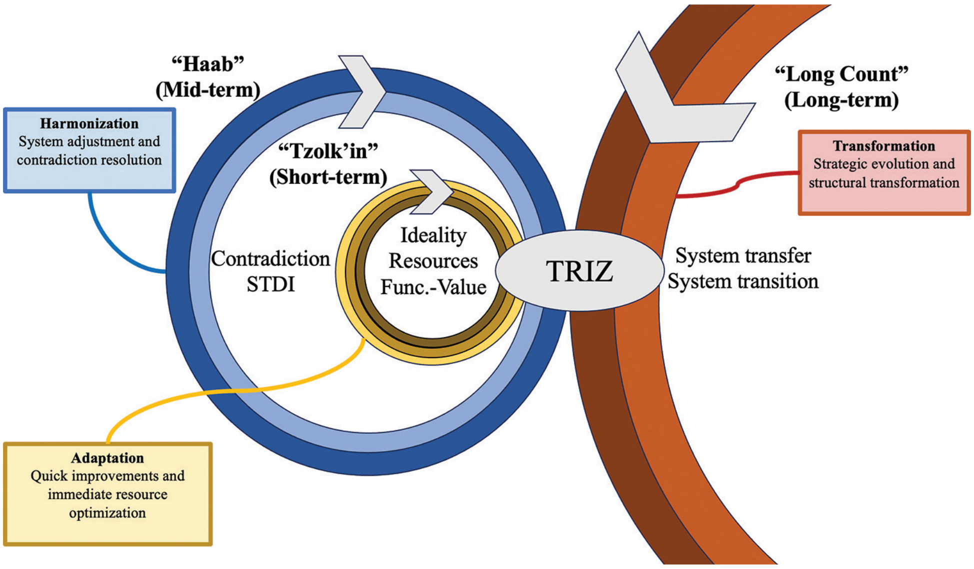

Fig. 2. An overview of the Mayan calendar-inspired cyclical TRIZ model
Abbreviations: Func.: Functionality; STDI: Space, time, domain, and interface;
TRIZ: Theory of inventive problem solving.

3.1. Cycle Overview of the Model

i. Short-term cycle (Tzolk'in)
Focus: Quick improvements and immediate resource optimization.
Theory of inventive problem solving's pillars used:
- Ideality: Implement the ideal final result to achieve immediate benefits with minimal costs.
- Resources: Apply tools, such as harmful resource usage analysis and demand-supply thought-provoking questions (DS-TPQ) to maximize existing resources.
- FV: Use patent regeneration to optimize functionality quickly.

Objective: To generate rapid solutions that enhance present performance and reduce inefficiencies.

ii. Mid-term cycle (Haab)
Focus: System adjustment and contradiction resolution.
Theory of inventive problem solving's pillars used:
- Contradiction: Use separation principles and the contradiction matrix (CM) to resolve conflicts between system parameters.
- STDI: Tools such as space, time, interface, and cost (STIC), smart little people (SLP), and the effect/resource database (ERD) help analyze problems from different perspectives.

Objective: To address contradictions and adjust system components for better integration.

iii. Long-term cycle (Long Count)
Focus: Strategic evolution and structural transformation.
Theory of inventive problem solving's pillars used:
- System transfer: Apply tools such as feature transfer to adapt successful solutions from other fields.
- System transition: Use trends of engineering system evolution (TESE) and multi-screen viewpoints to guide long-term transformation.

Objective: To achieve sustainable innovation by evolving the system's core principles.

3.2. Algorithm with Parametric Expressions

Phase 1: Initialize short-term cycle (Tzolk'in):
Objective: Achieve rapid improvements (*R*).
Inputs: Present system state (*S*), available resources (*Res*), immediate contradictions (*C1*)
Process:

Step-1: Apply Ideality (*I*):
- Target: Maximize beneficial outcomes and minimize costs.
- Formula: $R = max(I) - min(Cost)$

Step-2: Use resource optimization (*ResOpt*):
- Analyze and utilize available resources.
- Formula: $ResOpt = f(DS\text{-}TPQ, HarmfulUsage)$

Step-3: Implement *FV* improvements:
- Focus on rapid generation of functionality.
- Formula: $FV = f(PatentRegeneration)$

Outputs: Rapid improvements (*R*), refined resources (*Res*), improved value (*V*).

Feedback: Measure short-term impact and feed results (*F1*) to the next cycle.

Phase 2: Transition to mid-term cycle (Haab):

Objective: Address systemic contradictions and refine solutions (*Ref*).

Inputs: Refined system state (*S*), unresolved contradictions (*C2*), feedback (*F1*).

Process:

Step-1: Apply contradiction analysis (CA):

- Use separation principles (*Sep*), parameter deployment and manipulation (*PDM*), and *CM* to resolve conflicts between system parameters.
- Formula: *CA = f(Sep*, *PDM*, *CM)*

Step-2: Implement STDI analysis:

- Use STIC, *SLP*, *ERD*
- Formula: *STDI = f(STIC, SLP, ERD)*

Outputs: Refined solutions (*Ref*), reduced contradictions (*C*↓)

Feedback: Gather mid-term evaluation (*F2*) and feed results to the next cycle.

Phase 3: Advance to long-term cycle (Long Count):

Objective: Achieve sustainable solutions (*Sust*).

Inputs: Refined solutions (*Ref*), strategic goals (*G*), feedback (*F2*).

Process:

Step-1: Use system transfer (*SysTransfer*):

- Integrate features from other fields.
- Formula: *SysTransfer = f(FeatureTransfer)*

Step-2: Implement system transition (*SysTransition*):

- Adapt and evolve core principles.
- Formula: *SysTransition= f(TESE, MultiScreen)*

Outputs: Sustained solutions (*Sust*), evolved system structure (*E*).

Feedback: Establish long-term evaluation (*F3*) and inform the next short-term cycle to use feedback from the long-term cycle to refine initial solutions.

- Formula: *R = f(Sust, F3)*

4. An Illustrative Example

The design and improvement of a coffee machine provide an illustrative example of how the Mayan calendar-inspired cyclical model can be applied to an actual product development process. The coffee machine represents a typical engineering system that can benefit from ongoing refinement across short-term, mid-term, and long-term cycles.

4.1. Cycle Overview of the Example

i. Short-term cycle (Tzolk'in)

Objective: Achieve quick improvements that enhance the coffee machine's immediate performance and reduce costs.

Theory of inventive problem solving's pillars used:

- Ideality: The goal is to create a coffee machine that provides the optimal taste with minimal energy and water usage. Here, we can apply the ideal final result by identifying features that can be improved quickly. For example, optimizing the water heating system to use less energy while maintaining the ideal brewing temperature.
- Resources: To maximize the use of available resources, we can use tools like DS-TPQ for a deep search for technical and physical quantities. For example, utilizing residual heat from the brewing process to pre-heat the water for the next cycle can be a quick improvement.
- FV: By applying patent regeneration, we can analyze existing patents related to coffee machines and adapt features that enhance value, such as an adjustable pressure control for better extraction.

Output: Improved energy efficiency, better taste consistency, and faster brewing times. These short-term improvements are immediately tested and refined based on user feedback.

ii. Mid-term cycle (Haab)

Objective: Resolve contradictions and optimize system components to enhance the coffee machine's functionality over a medium time frame.

Theory of inventive problem solving's pillars used:

- Contradiction: One common contradiction in coffee machines is the balance between high pressure for espresso and lower pressure for drip coffee. Using separation principles and the CM, the system can be designed to separate the two pressure levels within the same unit. For example, a dual-pressure mechanism that adjusts based on the brewing mode can solve this contradiction.
- STDI: By analyzing the machine's spatial design and interface, we can identify areas where space can be better utilized. For example, using a more compact design for water reservoirs without compromising capacity. Tools such as STIC and SLP can help simulate user interactions and improve the design for a better user experience.

Output: More versatile brewing options, improved user interface, and reduced space requirements. Mid-term solutions focus on resolving deeper issues and adapting the design based on accumulated user feedback.

iii. Long-term cycle (Long Count)
Objective: Evolve the coffee machine's core principles and introduce long-term sustainable innovations.
Theory of inventive problem solving's pillars used:

- System transfer: Borrow solutions from other fields to introduce advanced features. For example, adopting feature transfer from smart appliances to include Internet of Things (IoT) capabilities, allowing the coffee machine to connect to a smartphone app for remote control and personalized brewing preferences. For another example, some functions of the coffee machine can be integrated with other kitchen appliances to create a new product category (e.g., combining a coffee machine with a water filter).
- System transition: By applying TESE, the machine can be designed to evolve from a manual operation to a fully automated, artificial intelligence (AI)-driven coffee maker that learns user preferences over time. This can include features such as self-cleaning, auto-refill, and predictive maintenance based on sensor data.

Output: A smart, adaptable coffee machine that is capable of evolving with user needs and technological advancements. Long-term solutions ensure the machine remains relevant and competitive in the market.

The short-term cycle focuses on quick wins and immediate efficiency improvements. The mid-term cycle targets more complex contradictions and system integration issues, making the machine more versatile and user-friendly. The long-term cycle drives strategic evolution and sustainable innovation, making the product future-proof. This cyclical approach ensures that short-term improvements, mid-term adjustments, and long-term evolution are interconnected, creating a continuous loop of SI that adapts to changing user needs and technological trends.

4.2. Algorithm with Parametric Expressions

Phase 1: Initialize short-term cycle (Tzolk'in):
Objective: Achieve rapid improvements (*R*) in the coffee machine's performance and efficiency.

Inputs: Present system state (*S*), available resources (*Res*), immediate contradictions (*C1*)
Process:
Step-1: Apply Ideality (*I*):

- Formula: *R = max(I) – min(Cost)*
- Application: Optimize the water heating system for energy efficiency.
- Example: Implement a feature to reuse residual heat for pre-heating, reducing energy consumption.
- *R = f(IdealHeatUsage, min(EnergyCost))*

Step-2: Use resource optimization (*ResOpt*):

- Formula: *ResOpt= f(DS-TPQ, HarmfulUsage)*
- Application: Maximize available resources, such as the water used in brewing cycles.
- Example: Use DS-TPQ to identify underutilized heat or pressure that can be optimized.
- *ResOpt = f(WaterPressure, HeatResidual)*

Step-3: Implement FV improvements:

- Formula: *FV = f(PatentRegeneration)*
- Application: Adapt existing patents to enhance functionality.
- Example: Adjust pressure control to optimize extraction for better taste.
- *FV = f(OptimalPressure, ExtractionTime)*

Outputs: Rapid improvements (*R*), optimized resources (*Res*), and enhanced value (*V*).

Feedback (F1): Measure energy savings, brewing speed, and taste improvement.

Phase 2: Transition to mid-term cycle (Haab):
Objective: Address systemic contradictions (*C*) and refine components for better system integration (*Ref*).
Inputs: Refined system state (*S*), unresolved contradictions (*C2*), feedback (*F1*).
Process:
Step-1: Apply CA:

- Formula: *CA = f(Sep, PDM, CM)*
- Application: Resolve the contradiction between high pressure for espresso versus low pressure for drip coffee.
- Example: Implement a dual-pressure system that adjusts automatically.
- *C = f(high, low) → Resolved C*

Step-2: Implement STDI analysis:

- Formula: *STDI = f(STIC, SLP, ERD)*
- Application: Analyze space and interface for better user experience.
- Example: Redesign the water reservoir to save space while maintaining capacity.
- *Space = f(ReservoirDesign, Compactness)*

Outputs: Refined solutions (*Ref*), reduced contradictions ($C\downarrow$).

Feedback (*F2*): Evaluate usability, versatility, and system adjustments.

Phase 3: Advance to long-term cycle (Long Count):

Objective: Achieve sustainable solutions (*Sust*) by evolving core features and principles.

Inputs: Refined solutions (*Ref*), strategic goals (*G*), feedback (*F2*).

Process:

Step-1: Use system transfer (*SysTransfer*):

- Formula: *SysTransfer = f(FeatureTransfer)*
- Application: Integrate features from other smart appliances.
- Example: Add IoT capabilities for remote operation and customization.
- *Sust = f(AppIntegration, UserPreferences)*

Step-2: Implement system transition (SysTransition):

- Formula: *SysTransition=f(TESE, MultiScreen)*
- Application: Evolve from a manual to an AI-driven machine.
- Example: Use predictive maintenance to notify users about potential issues.
- *AI-Transition = f(MaintenancePred., Adapt.)*

Outputs: Sustained solutions (*Sust*), evolved system structure (*E*).

Feedback (*F3*): Assess long-term sustainability, user adaptation, and technological integration.

5. Application in Various Industries

The cyclical TRIZ model introduced in this study extends beyond consumer products, such as coffee machines, and can be effectively applied in automotive engineering. One of the key challenges in automotive seat design is achieving an optimal balance between comfort, safety, durability, and energy efficiency while meeting consumer expectations and regulatory standards.

Through the application of cyclical TRIZ principles, automotive seats can be systematically improved by addressing contradictions and developing adaptive, smart seat functions for both conventional and autonomous vehicles.

Phase 1: Adaptation/short-term optimization (Tzolk'in)

Objective: To improve comfort and energy efficiency using existing materials and minor design changes.

Examples:

- Breathable seat materials that dynamically regulate airflow based on external temperature and body sweat levels.
- Passive seat ventilation that does not require additional power but improves air circulation to prevent discomfort.

Innovation impact:

- These low-cost improvements offer immediate functional benefits without requiring complex redesigns.
- They align with TRIZ principles of FV optimization, ensuring better comfort without energy waste.

Phase 2: Harmonization/mid-term contradiction resolution (Haab)

Objective: To resolve contradictions between comfort, durability, and ergonomics while enhancing seat functionality.

Examples:

- Active lumbar support systems that automatically adjust based on driving conditions and driver fatigue.
- Pressure-sensitive seat cushions that dynamically redistribute weight to prevent discomfort during long-distance driving.

Innovation impact:

- These solutions apply TRIZ contradiction resolution principles, improving both comfort and durability.
- The implementation of adaptive support mechanisms enhances seat ergonomics while maintaining long-term structural stability.

Phase 3: Transformation/long-term system innovation (Long Count)

Objective: To introduce intelligent and autonomous seat functions for future mobility solutions.

Examples:

- A smart posture detection system that adjusts the seat position automatically based on the driver's or passenger's body alignment.
- Artificial intelligence-driven personalized comfort settings, using biometric sensors to analyze fatigue levels and stress, adapting temperature, lumbar support, and massage functions accordingly.

Innovation impact:

- This cycle applies TRIZ system transition and transfer principles, ensuring that seat design evolves with future autonomous vehicle needs.
- Artificial intelligence-based comfort management integrates real-time user feedback to create a fully personalized seating experience.

The cyclical TRIZ approach effectively structures the automotive seat innovation process, providing a clear roadmap for short-term optimizations, mid-term contradiction resolution, and long-term transformations.

6. Validation of the Proposed Approach

Validation is essential to establish the scientific credibility and real-world applicability of the cyclical TRIZ model. While a retrospective validation using patent analysis is still in progress, which will be published in a separate study, this section demonstrates that the model is already verifiable within TRIZ itself.

By integrating the TESE, it is shown that the cyclical TRIZ phases naturally align with how engineering systems evolve over time. This ensures that the model is not just a conceptual framework but a structured reflection of real innovation processes.

6.1. TESE: Its Relevance to Validation

The TESE is a systematic methodology that explains how technological systems develop over time through specific evolutionary stages. TESE is an extension of TRIZ and provides a scientific basis for predicting innovation pathways by identifying patterns in system development.

The TESE defines multiple trends that describe how engineering systems evolve (Ghane et al., 2022; Mann, 2003; Sheu and Chiu, 2017), including:

- Increasing ideality: Systems improve functionality while reducing cost and complexity
- Resolving contradictions: Successful systems find ways to eliminate trade-offs between opposing requirements
- Dynamization and adjustability: Systems evolve to become more flexible and adaptable
- System transition: Systems undergo structural and functional transformations into new generations over time
- Integration of intelligence and automation: The highest stage of evolution, where AI and self-learning systems replace manual processes.

By aligning our cyclical TRIZ phases with TESE trends, we provide a strong theoretical foundation for the validity of the model.

6.2. Mapping Cyclical TRIZ Phases to TESE

Each phase of the cyclical TRIZ model aligns with specific TESE evolutionary trends, confirming its consistency with real-world engineering advancements.

Table 2 summarizes that each cyclical phase corresponds to a specific TESE trend, provided that the model follows established evolutionary laws in engineering.

In the adaptation cycle (Tzolk'in), systems evolve by maximizing functionality while minimizing complexity and costs, which aligns with the TESE principle of "increasing ideality." This phase focuses on quick and low-cost improvements that enhance efficiency without requiring major structural changes. In addition, the "resource utilization" principle is evident as early innovations rely on better use of existing materials and functions before undergoing significant modifications. In coffee machines, this is seen in improved water heating efficiency and thermal insulation, while in automotive seats, breathable seat materials and passive ventilation enhance comfort without additional energy consumption.

The harmonization (Haab) cycle corresponds to TESE's "resolving contradictions" principle and "dynamization and adjustability" principles. Engineering systems do not merely optimize existing solutions but instead eliminate inherent trade-offs to improve overall performance. A key example is adaptive lumbar support in automotive seats, which resolves the contradiction between comfort and stability by dynamically adjusting to driver posture and fatigue levels. Similarly, coffee machines evolve to brew different coffee types within the same system, eliminating the trade-off between versatility and efficiency. Over time, systems become more flexible and adaptable, as demonstrated by pressure-sensitive automotive seats that redistribute weight in real time to enhance user comfort.

The transformation (Long Count) cycle aligns with "system transition" and "integration of intelligence and automation" in TESE. At this stage, systems undergo fundamental structural changes, marking a transition from traditional mechanical designs to intelligent and autonomous systems. Coffee machines have evolved from manual brewing methods to AI-powered devices that self-adjust brewing parameters, while automotive seats incorporate smart posture detection systems that autonomously configure seating positions based on biometric data. This trend culminates in AI-driven, self-learning solutions, where both coffee machines and automotive seats dynamically adapt to user preferences and external conditions, ensuring maximum efficiency and personalization.

By mapping the cyclical TRIZ model to TESE evolutionary trends, we demonstrate that the proposed approach is not only conceptually valid but also systematically structured according to engineering system evolution principles. This alignment reinforces

Table 2. Mapping three phases of the proposed cyclical theory of inventive problem-solving model to trends of engineering system evolution (TESE)

Phases	Objective	Relevant TESE trend	Example: Coffee machine design	Example: Automotive seat design
Adaptation (Tzolk'in)	Quick, low-cost improvements using available resources.	"Increasing ideality" "Resource utilization"	Optimizing water heating efficiency. Reducing energy waste using thermal insulation.	Breathable seat materials that adapt to humidity. Passive ventilation improves comfort.
Harmonization (Haab)	Resolving functional contradictions to balance efficiency and performance.	"Resolving contradictions" "Dynamization and adjustability"	Dual brewing system for multiple coffee types. Adjustable pressure control for different flavors.	Active lumbar support adapts to driver fatigue. Pressure-sensitive cushions optimize comfort.
Transformation (Long Count)	Fundamental innovation and future-ready system evolution.	"System transition" "Integration of intelligence and automation"	AI-powered coffee makers that adjust brewing settings automatically. IoT-enabled self-learning coffee machines	AI-based seat adjustment using biometric sensors. Fully autonomous seat modes for different driving conditions.

Abbreviations: AI: Artificial intelligence; IoT: Internet of things.

the scientific legitimacy of the model and its applicability across multiple industries.

7. Comparative Analysis against Existing Models

To critically evaluate the cyclical TRIZ model, a comparison with relevant TRIZ-based methodologies is necessary. However, not all SI models are directly comparable. Instead, we selected three models that best align with the core characteristics of the cyclical TRIZ model in terms of problem-solving approach, adaptability, and sustainability. The chosen models, the classical TRIZ, OTSM, and Sheu and Lee's (2011) SIP, were included for the following reasons.

The classical TRIZ, developed by Genrich Altshuller, is the origin of SI methodologies. It is the baseline for all SI models. It provides a reference point to demonstrate the improvements made by the cyclical TRIZ in terms of iterative adaptability and sustainability.

The OTSM is an extension of the classical TRIZ to handle complex, multi-variable problems (Cavallucci et al., 2015; Khomenko & Ashtiani, 2007; Khomenko & Kucharavy, 2002). It introduces problem networks and system-level problem-solving, making it a useful benchmark for evaluating whether the cyclical TRIZ offers a more structured iterative process. Unlike the OTSM, the cyclical TRIZ emphasizes evolutionary, time-dependent problem-solving rather than static network modeling.

Sheu and Lee's (2011) SIP is a structured, phase-wise approach to innovation that incorporates both TRIZ-based tools and non-TRIZ methodologies. This model was selected because it represents an industry-oriented innovation framework with business and technology considerations. Comparing it to the cyclical TRIZ demonstrates how our model enhances adaptability and long-term sustainability beyond structured stage-wise innovation.

This section compares these models against the cyclical TRIZ, focusing on:

- Efficiency: How well the model optimizes resources and eliminates contradictions
- Adaptability: The model's ability to handle evolving innovation challenges dynamically
- Sustainability: How the framework supports long-term innovation processes.

7.1. Efficiency

Unlike the classical TRIZ, which operates in a single problem-solving cycle, the cyclical TRIZ model (i) enables continuous optimization at multiple levels, (ii) feeds short-term improvements into mid-term contradiction resolution to ensure deeper refinements, and (iii) ensures that long-term transformation integrates past refinements into future design improvements.

For example, in automotive seat design, the classical TRIZ can optimize seat adjustability using inventive principles. Meanwhile, the OTSM can model complex interactions between comfort, safety, and cost. On the other hand, Sheu and Lee's (2011) SIP provides a structured process to integrate both TRIZ and non-TRIZ methodologies. In contrast, the cyclical TRIZ continuously refines seat design across multiple innovation cycles, ensuring progressive and sustainable improvements.

Example in automotive seats:

- Short-term adaptation cycle: Optimized ventilation efficiency in seat cushions

Table 3. Comparison table of the proposed model and selected models

Model	Problem-solving approach	Efficiency	Adaptability	Sustainability
Classical TRIZ	Linear contradiction resolution using 40 IPs	High (Effective contradiction elimination)	Low (Does not inherently support iterative adaptation)	Low (One-time problem resolution without built-in iteration)
OTSM	Network-based problem-solving for complex, multi-layered systems	High (Handles interconnected problems well)	Medium (Uses problem flow modeling but lacks cyclical iteration)	Medium (Provides structured knowledge mapping but no built-in renewal mechanisms)
Sheu and Lee's (2011) systematic innovation process	Stage-wise systematic innovation process, integrating TRIZ and non-TRIZ tools	High (Structured phases improve efficiency)	Medium (Stepwise adaptability but lacks cyclical iteration)	High (Integrates business opportunity exploration and cross-industry application)
Cyclical TRIZ model	Iterative cycles for short-term optimization, mid-term contradiction resolution, and long-term transformation	High (Leverages existing TRIZ tools for continuous improvement)	High (Ensures adaptive problem-solving through iterative cycles)	High (Facilitates continuous innovation/evolution rather than static problem-solving)

Abbreviations: IP: Inventive principle; OTSM: General theory of powerful thinking; TRIZ: Theory of inventive problem-solving.

- Mid-term harmonization cycle: Resolving contradictions between comfort and durability
- Long-term transformation cycle: AI-driven smart seating systems that dynamically adjust based on real-time biometric data.

7.2. Adaptability

Most existing TRIZ methodologies, including Sheu and Lee's (2011) SIP, follow a linear, stage-wise structure. While these approaches provide clear problem-solving pathways, they lack built-in iterative mechanisms.

The cyclical TRIZ model ensures (i) short-term improvements feed into mid-term refinements, making it highly adaptive, and (ii) innovation is not a one-time process but a continuous, self-improving loop.

For example, in coffee machine design, Sheu and Lee's (2011) SIP identifies innovative business opportunities but treats problem-solving as a stepwise approach. In contrast, the cyclical TRIZ continuously iterates through adaptation, harmonization, and transformation cycles, ensuring sustained technological evolution (e.g., from manual espresso machines to AI-driven smart coffee systems).

7.3. Sustainability

Unlike the classical TRIZ and OTSM, which focus on single-instance problem resolution, the cyclical TRIZ model provides a mechanism for continuously refining past solutions and structures innovation into a long-term iterative model, ensuring continuous renewal.

For example, in automotive seat design, Sheu and Lee's (2011) SIP provides a structured method to evaluate contradictions but does not inherently recycle improvements into future iterations. The cyclical TRIZ incorporates a continuous refinement mechanism, ensuring that past advancements dynamically influence future designs.

Table 3 presents a comparison table. The comparative analysis confirms that the cyclical TRIZ model provides superior adaptability and sustainability compared to traditional TRIZ methods while maintaining high efficiency. The key advantages of the proposed approach include:

- A structured, iterative approach to innovation that continuously refines solutions
- Higher adaptability than the classical TRIZ, OTSM, and Sheu and Lee's (2011) SIP
- A long-term sustainable innovation model that ensures continuous learning and adaptation.

8. Conclusion

The Mayan calendar-inspired cyclical TRIZ model represents a significant advancement in the field of SI, offering a structured and flexible approach that ensures both short-term efficiency and long-term adaptability. Unlike traditional TRIZ applications, which often focus on solving individual contradictions in a linear manner, this model emphasizes a continuous feedback loop, ensuring that each phase builds upon and refines previous innovations: (i) Short-term cycle (adaptation) allows for quick wins by maximizing available resources and making low-cost optimizations; (ii) mid-term cycle (harmonization) targets more complex contradictions, enabling system-wide improvements and integration; and (iii) long-term cycle (transformation) ensures sustainable innovation by aligning product evolution with future technological advancements.

The practical effectiveness of this model is demonstrated through its application in coffee machine design and automotive seat design, where each cycle contributes to a progressive and self-sustaining improvement process. Furthermore, the alignment of these cycles with TESE principles confirms that the proposed model is not only theoretically sound but also practically validated through real-world technological evolution.

By providing a dynamic and adaptive problem-solving approach, the cyclical TRIZ model extends beyond conventional TRIZ applications, making it an effective tool for industries requiring SI. This model bridges the gap between structured problem-solving and sustainable innovation, offering a scalable solution for industries seeking both rapid improvements and long-term strategic evolution.

Future research should focus on retrospective validation through patent analysis to quantify the model's effectiveness. Previous studies have successfully employed such analysis to validate technological evolution patterns (Rahim & Iqbal, 2023). Future research could also further explore its application across various industries, examining its effectiveness in more complex systems and diverse contexts.

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