Advanced and Sustainable Technologies
ASET
E-ISSN 2976-2294
Volume 4, No 2, December 2025 [443-458]

UDP-TRIZ for Inclusive SDG Innovation: A Quadruple Helix Approach

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Received 10 September 2025, Revised 12 October 2025, Accepted 28 October 2025

ABSTRACT

Inclusive innovation remains a critical gap in the implementation of the Sustainable Development Goals (SDGs), particularly for people with disabilities (PWDs). Existing frameworks often lack integration: Universal Design (UD) promotes equity but lacks structured problem-solving tools; TRIZ offers innovation methodologies but overlooks user diversity; and SDG strategies frequently operate in fragmented silos. This paper proposes UDP-TRIZ, a theoretical framework that combines UD principles with TRIZ innovation tools and embeds them within the Quadruple Helix model involving academia, industry, government, and civil society. The framework is developed through conceptual synthesis and strategic mapping to relevant SDG targets, offering a unified approach to inclusive innovation. It positions PWDs not only as users but as co-creators in design and policy processes. UDP-TRIZ serves as a scalable model to guide inclusive innovation practices across sectors such as education, employment, and urban development. While the framework awaits empirical validation, it offers a structured, interdisciplinary approach to bridging inclusion, innovation, and sustainable development.

Keywords: Inclusive Innovation, Universal Design Principle (UDP), TRIZ Methodology, Sustainable Development Goals, Quadruple Helix Model.

1. INTRODUCTION

The contemporary design landscape faces a growing imperative to address inclusivity, sustainability, and accessibility as interconnected challenges within the broader framework of global development. The advent of the United Nations' Sustainable Development Goals (SDGs) has emphasized the need for multidimensional strategies to ensure that no group, particularly persons with disabilities (PWDs), is left behind [1]. Despite progress in inclusive policy, design practice often remains disconnected from the transformative potential embedded in the SDG framework. The pressing question is how design methodologies can be innovatively realigned to serve as functional instruments for achieving these global objectives.

In response to this challenge, Universal Design Principles (UDP) have been widely advocated for their potential to facilitate access and equity in design outcomes. At the same time, the Theory of Inventive Problem Solving (TRIZ), a systematic innovation methodology developed from engineering practice, offers an underexplored opportunity to reinforce the operationalization of universal design through its logic-driven structure [2]. Yet, while each of these frameworks has demonstrated value in its respective domains, their integration remains largely theoretical, and their alignment with sustainable development agendas is conceptually underdeveloped.

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This paper addresses a significant research gap at the intersection of three key domains: Universal Design (UD), TRIZ methodology, and the SDGs. While UD is grounded in ethical inclusivity, it lacks a rigorous problem-solving protocol. TRIZ, in contrast, offers robust methodological tools but does not inherently account for the human-centred ethos critical to inclusive design. The disconnection between these paradigms results in a lack of strategic design frameworks that can both innovate and include. Furthermore, their combined contribution to the SDGs has yet to be clearly theorized, much less formalized within an integrative model.

To bridge this gap, the objective of this study is to propose a unified theoretical framework, UDP-TRIZ, that synthesizes the human-centred approach of Universal Design with the analytical robustness of TRIZ [3]. This framework is then situated within the Quadruple Helix Innovation Model, which emphasizes co-creation among four sectors: academia, industry, government, and civil society. By doing so, the paper positions the UDP-TRIZ framework not only as a methodological advance but also as a systemic innovation tool with direct relevance to SDG implementation. Figure 1 illustrates the UDP-TRIZ Framework.

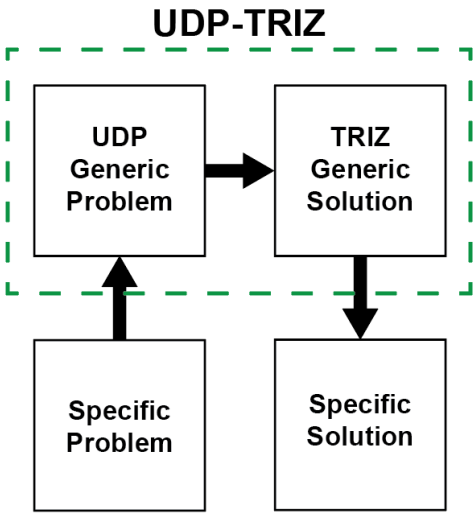

Figure 1: UDP-TRIZ Framework [3].

The core contribution of this work lies in its formulation of a comprehensive theoretical link between inclusive industrial design practices and sustainable development goals, operationalized through an interdisciplinary innovation lens. The UDP-TRIZ framework offers a structured pathway for integrating inclusive design strategies into real-world problem-solving, while the Quadruple Helix ensures that such innovation is co-produced across key societal sectors.

This paper proceeds by reviewing the historical development of UD and TRIZ, analysing their theoretical foundations and applications. It then elaborates the conceptual synthesis underpinning the UDP-TRIZ framework and maps its relevance to selected SDGs, notably SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10 (Reduced Inequalities) [1, 4]. The final sections assess how the framework facilitates knowledge exchange and collaboration across the Quadruple Helix domains and outline implications for design research, policy, and practice.

1.1 Contribution of the study

This study contributes a novel theoretical framework, UDP-TRIZ, that systematically integrates Universal Design Principles (UDP) with the structured innovation methodology of TRIZ, operationalized within the Quadruple Helix model of innovation ecosystems. It addresses a critical gap in the inclusive innovation literature by offering the first cohesive linkage between

design equity, technical problem-solving, and multi-stakeholder governance for achieving the Sustainable Development Goals (SDGs). Unlike existing approaches that treat inclusion, innovation, and policy as separate domains, this framework offers a unified model capable of generating scalable, inclusive solutions through cross-sector collaboration. The study also advances design theory by adapting TRIZ to accommodate human-centred variables and contextual complexity, particularly in the realm of disability-inclusive development. By mapping framework components to specific SDG targets and actor roles, the study provides a transferable and actionable model for policymakers, practitioners, and researchers seeking to embed inclusive innovation within national and local development agendas.

2. LITERATURE REVIEW

2.1 TRIZ and Universal Design Frameworks

The development of inclusive design strategies that simultaneously address social, technical, and accessibility challenges demands a robust theoretical foundation. Two prominent frameworks, Universal Design (UD) and the Theory of Inventive Problem Solving (TRIZ), have emerged as pivotal to design discourse, though traditionally treated as distinct domains. While UD focuses on equitable user experiences and access, TRIZ introduces systematic tools for resolving design contradictions and generating innovative solutions. This section reviews both frameworks and establishes the epistemological basis for their integration.

2.1.1 Universal Design

Originating from architectural accessibility principles, Universal Design has evolved into a comprehensive design philosophy aimed at ensuring usability, safety, and equity across the widest possible spectrum of users. The Center for Universal Design at North Carolina State University formally articulated seven UD principles, equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and appropriate size and space for approach and use [5]. These principles are increasingly recognized in global policy instruments, such as the United Nations Convention on the Rights of Persons with Disabilities (UN CRPD), as foundational to the creation of inclusive environments and products [6, 7].

In the context of industrial design, UD promotes solutions that accommodate users of different abilities without the need for later adaptation or specialized design. It aligns closely with SDG 10 (Reduced Inequalities) and SDG 11 (Sustainable Cities and Communities) by advocating inclusive infrastructure, accessible transportation, and socially equitable innovation. However, despite its normative strength, UD often lacks a methodological framework that supports systematic ideation, especially when navigating complex, multi-variable design constraints.

2.1.2 Theory of Inventive Problem Solving (TRIZ)

Developed by Genrich Altshuller in the mid-20th century, TRIZ is a methodology rooted in the analysis of millions of patent records to identify universal patterns of technical innovation [8, 9, 10]. TRIZ offers a structured approach to solving design and engineering problems, primarily through its 40 inventive principles, contradiction matrix, ideality concept, and trends of technical evolution. These tools allow designers to resolve design contradictions without compromising essential system parameters, thus fostering non-linear, high-impact innovations.

Although widely applied in engineering, product development, and technical systems, TRIZ has had limited application in domains requiring empathetic, human-centred considerations such as inclusive design. Its strength lies in logical rigor and structured creativity, but it is traditionally

agnostic to user diversity, social equity, or participatory values. This methodological blind spot constrains TRIZ's utility in inclusive design contexts, particularly those aiming to serve marginalized or vulnerable populations such as persons with disabilities (PWDs).

2.1.3 Conceptual Misalignment and Integration Potential

At first glance, UD and TRIZ may appear epistemologically divergent, UD being grounded in ethics, equity, and user experience, and TRIZ in functionality, systems theory, and technical efficiency. Yet, their integration holds significant potential. TRIZ can offer the systematic tools UD lacks, while UD can embed the social relevance that TRIZ omits. For example, TRIZ's contradiction matrix can be repurposed to solve conflicts in user needs versus design constraints in UD scenarios (e.g., accessibility vs. aesthetic minimalism).

Integrating TRIZ and UD enables the development of design strategies that are not only innovative but also inclusive, addressing both functional contradictions and user diversity. This dual-focus approach offers a methodological pathway to achieve design solutions that are equitable, usable, and sustainable, ideals central to both inclusive innovation and the UN Sustainable Development Goals (SDGs) [11, 12].

This paper builds upon this alignment by proposing a UDP-TRIZ framework, a synthesis that draws on the structured innovation of TRIZ and the ethical imperatives of UD. This framework is further contextualized within the Quadruple Helix innovation model, ensuring multi-stakeholder collaboration among academia, industry, government, and civil society in advancing inclusive and sustainable design.

2.2 Role of Persons with Disabilities (PWD) in the Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs), adopted in 2015 by the United Nations as part of the 2030 Agenda, present a transformative vision for global development rooted in inclusion, equality, and sustainability. In contrast to the Millennium Development Goals (MDGs), which largely overlooked disability, the SDGs explicitly recognize persons with disabilities (PWDs) as stakeholders whose participation is essential to achieving the agenda's core principle to "leave no one behind" (UN, 2015). Figure 2 below shows the SDGs introduced by the UN.

Figure 2: Sustainable Development Goals [1, 4, 13].

Globally, an estimated 16% of the population, approximately 1.3 billion people, live with some form of disability, many of whom face intersecting barriers to education, employment, healthcare, and public participation [14, 15]. This marginalization results in a disproportionate representation of PWDs among those living in poverty, excluded from infrastructure planning, and left without access to basic services. As noted in the 2023 SDG Progress Report, only 15% of

the SDG targets are on track, while 48% show minimal progress, and 37% are regressing [16]. These figures signal a widening gap for vulnerable groups, including PWDs, especially in the wake of the COVID-19 pandemic and global economic disruptions.

Multiple SDGs are directly relevant to disability inclusion. Goal 4 (Quality Education) calls for "inclusive and equitable quality education" (Target 4.5), while Goal 8 (Decent Work and Economic Growth) demands "productive employment and decent work for all, including persons with disabilities" (Target 8.5). Goal 10 (Reduced Inequalities) explicitly targets "the social, economic, and political inclusion of all, irrespective of age, sex, disability" (Target 10.2). Meanwhile, Goal 11 (Sustainable Cities and Communities) emphasizes access to "safe, affordable, accessible and sustainable transport systems for all" (Target 11.2), including for those with disabilities [16, 17]

Despite this recognition, implementation remains uneven. The 2023 UNESCAP report on disability inclusion notes that data disaggregation by disability status remains weak, and most national policies lack systematic alignment with both the SDGs and the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) [18]. This institutional fragmentation hinders the operationalization of inclusive development goals, leaving many PWDs invisible in national statistics and excluded from decision-making processes. Design practice offers a powerful yet underutilized mechanism for addressing this gap. The United Nations Department of Economic and Social Affairs (UNDESA) has highlighted the need for design approaches that address the barriers faced by PWDs in everyday environments, technologies, and services [15]. However, as current design frameworks often operate within normative or aesthetic constraints, they fail to provide systematic solutions for complex inclusion challenges. As argued in this study, bridging this gap requires an integrated design methodology that is both ethically inclusive and technically innovative.

This paper responds to this challenge by conceptualizing the UDP-TRIZ framework, which integrates Universal Design Principles (UDP) with the Theory of Inventive Problem Solving (TRIZ). By doing so, it aims to provide a methodological foundation for resolving design contradictions in inclusive contexts. Furthermore, the framework is embedded within the Quadruple Helix innovation model, enabling multi-stakeholder engagement across academia, industry, government, and civil society. In this arrangement, PWDs are redefined not as passive recipients of policy but as co-creators of solutions that advance both design equity and SDG outcomes.

In essence, the role of PWDs in the SDG framework transcends statistical representation; it demands their full inclusion as design beneficiaries, knowledge contributors, and innovation stakeholders. Realizing this ambition requires methodologies, like UDP-TRIZ, that are deliberately structured to close the gap between global goals and localized, inclusive action.

2.3 Quadruple Helix and Innovation Systems

Achieving the Sustainable Development Goals (SDGs) requires not only innovative technologies but also innovation systems that are inclusive, collaborative, and socially responsive. The Quadruple Helix (QH) model offers a systemic framework that integrates four key stakeholder groups, academia, industry, government, and civil society, to drive inclusive innovation ecosystems. It extends the traditional Triple Helix model by explicitly incorporating the role of end users and communities, thereby strengthening participatory innovation and democratizing knowledge production [19].

The QH model is particularly relevant in the context of disability-inclusive development. It recognizes that knowledge generation and technological innovation are no longer the exclusive domain of formal institutions; instead, innovation is co-produced through multi-stakeholder collaboration. In the domain of inclusive design, this means that persons with disabilities (PWDs)

are not merely passive recipients of innovation but active contributors who shape design parameters, challenge existing norms, and enrich the innovation process with context-specific knowledge.

The United Nations acknowledges that achieving the SDGs depends on governance systems capable of fostering collaboration across sectors. As highlighted in the World Public Sector Report 2021, innovation for sustainable development should occur within ecosystems that bring together actors from diverse institutional spheres to align technological advancements with public value [20]. This principle is embodied in the Quadruple Helix framework, which supports the localization of SDG implementation by leveraging context-specific knowledge from civil society actors.

Within the UDP-TRIZ framework, the QH model serves as a bridge between innovation methodology and inclusive governance. The integration of UDP-TRIZ within the Quadruple Helix system thus fosters synergistic innovation: TRIZ contributes structured problem-solving tools, UD ensures equitable user focus, and the QH model coordinates stakeholder inputs across institutional domains. This arrangement enables the translation of inclusive design into actionable, scalable strategies for sustainable development.

As such, the QH innovation system not only supports technological advancement but also legitimizes inclusive design by embedding it within the collective intelligence and participatory mechanisms of society. In the context of disability inclusion, this ecosystemic model repositions PWDs as essential actors in innovation, thereby contributing to both innovation justice and SDG realization.

2.4 Limitations of Current Frameworks

Despite the widespread recognition of inclusive design and innovation as tools for sustainable development, existing frameworks such as Universal Design (UD), TRIZ, and the current structure of SDG implementation continue to operate in fragmented and isolated ways. Each contributes important elements to the advancement of inclusive development, yet each also suffers from significant structural and operational limitations that reduce their effectiveness in achieving SDG outcomes, particularly for persons with disabilities (PWDs).

2.4.1 Universal Design

Universal Design emphasizes the development of environments, products, and systems that are usable by all people, without the need for adaptation or specialized design. However, while UD is grounded in strong ethical and human rights foundations, it lacks a robust methodological system to address complex or conflicting design requirements. As noted in UNDESA (2023), the mainstreaming of accessibility remains limited in many countries, and UD is often applied only at the compliance level, producing outputs that fulfil minimal standards but lack innovation and systemic integration.

In practical terms, UD tends to be adopted as a design philosophy rather than a structured process, making it difficult to scale or replicate across different sectors. Without tools for structured problem-solving, UD struggles to navigate trade-offs, for instance, between cost-efficiency and inclusive usability, or aesthetic design and physical accessibility. As highlighted in your draft, while UD addresses the question of “why” inclusion matters, it often falls short in answering “how” to implement inclusion systematically in real-world technical scenarios.

2.4.2 TRIZ

TRIZ, or the Theory of Inventive Problem Solving, provides a highly structured and systematic methodology for resolving contradictions and generating innovative solutions. However, it is fundamentally an engineering-driven model that does not take into account social factors such as accessibility, user diversity, or inclusive development goals. As emphasized in your manuscript, TRIZ does not naturally incorporate emotional, cognitive, or socio-cultural dimensions of user experience. This limits its direct applicability in inclusive design or policy-making contexts.

Although TRIZ offers tools like the 40 Inventive Principles and the Contradiction Matrix, these tools were developed from patent analysis and industrial design problems, thus reflecting a technocentric orientation. When applied without adaptation, TRIZ may solve mechanical or functional challenges while unintentionally ignoring critical human-centred requirements such as usability for people with physical or cognitive impairments. This gap in TRIZ's conceptual framework necessitates a modification or integration with inclusion-focused methodologies, such as UD, to align with SDG priorities.

2.4.3 Sustainable Development Goals (SDGs)

The 2030 Agenda explicitly includes disability in several of its targets, such as 4.5, 8.5, 10.2, and 11.2. Yet, the actual integration of disability into SDG implementation remains slow and fragmented. According to the UN SDG Progress Report 2023, only 15% of the SDG targets are on track, while 48% show moderate progress, and 37% have regressed or stagnated [16]. These figures indicate that global development remains off course, particularly for vulnerable populations like PWDs.

Moreover, many governments have yet to adopt or institutionalize multi-sectoral coordination mechanisms to implement inclusive development. As stated in the ESCAP (2023) report, although more than 40 countries in the Asia-Pacific region have ratified the UNCRPD, only a minority have strategies that align disability inclusion with SDG frameworks. The absence of technical methodologies that combine social inclusion with innovation processes further exacerbates this shortfall. Policies often emphasize "what" must be done (e.g., ensure accessibility), but lack guidance on "how" to design solutions in a replicable and collaborative manner [18].

2.4.4 Need for Integration

In summary, UD provides ethical direction but lacks process tools; TRIZ offers structured innovation but lacks inclusivity; and the SDG framework sets out strategic goals but lacks grounded methodologies for inclusive implementation. This disconnection between vision, method, and practice constitutes a major barrier to effective inclusive innovation.

To address these gaps, this paper proposes the UDP-TRIZ framework as an integrated model that combines the inclusive intent of UD with the structured problem-solving approach of TRIZ. By embedding this framework within the Quadruple Helix model, which promotes collaboration between academia, industry, government, and civil society, it becomes possible to design inclusive, scalable solutions that advance SDG outcomes, particularly for marginalized groups such as persons with disabilities.

3. THEORETICAL FRAMEWORK

3.1 Structure of the UDP-TRIZ Framework

The UDP-TRIZ framework is constructed as a hybrid model that combines the inclusive ethos of Universal Design Principles (UDP) with the structured problem-solving mechanisms of the TRIZ methodology, forming a dual-layered innovation model. This integration is essential for advancing solutions that are both functionally inventive and socially inclusive.

At its foundation, Universal Design offers seven core principles, such as equitable use, flexibility in use, simple and intuitive design, and perceptible information. These principles guide the development of environments and products accessible to all, especially those with disabilities. However, as discussed earlier, UD lacks operational tools for resolving complex contradictions or competing demands in a design context.

TRIZ, in contrast, supplies a toolbox for overcoming contradictions and generating creative alternatives through mechanisms such as the contradiction matrix, 40 inventive principles, trends of technical evolution, and ideal final result (IFR). Traditionally applied in technical engineering contexts, TRIZ can transform abstract problems into general solution patterns.
The UDP-TRIZ framework synthesizes these two paradigms by:

- Interpreting each of the UD principles through TRIZ contradiction-solving mechanisms (e.g., reconciling “low physical effort” with “system complexity” through Principle 10: Preliminary Action).
- Translating inclusive design objectives into TRIZ-compatible functional parameters, thus enabling structured ideation and system-level optimization.
- Embedding emotional, social, and cognitive variables (as required by UD) into TRIZ’s abstraction logic, thereby adapting TRIZ for inclusive contexts.

This layered integration provides a bridge between inclusive goals and technical innovation, enabling systematic design processes that respond to human diversity while maintaining technical performance.

3.2 Mapping the UDP-TRIZ Framework to the Sustainable Development Goals (SDGs)

The UDP-TRIZ framework directly supports the implementation of multiple SDGs, particularly those focused on accessibility, equity, and innovation. Based on the synthesized analysis in Tables 1 and 2, specific alignment is established between UDP-TRIZ outputs and selected SDG targets. This mapping in Table 3 reveals that the UDP-TRIZ framework is multi-dimensional, capable of addressing both technical innovation challenges and societal inclusion objectives, in alignment with global development priorities.

3.3 Application of the Framework through the Quadruple Helix Innovation Model

The Quadruple Helix (QH) innovation model provides the ecosystem structure through which the UDP-TRIZ framework is applied and scaled. Table 4 below shows how the QH model integrates four sectors, academia, industry, government, and civil society and their role into a co-creative and collaborative innovation process.

As visualized in Figure 2, the UDP-TRIZ sits at the core of this innovation ecosystem, serving as the operational toolset that each QH actor uses to drive inclusive SDG-related outcomes. The QH model ensures that innovations are not only technically sound and socially inclusive, but also institutionally embedded, thereby increasing the likelihood of real-world implementation and systemic change.

This ecosystemic perspective transforms innovation from a linear pipeline into a distributed, collaborative process, with each sector contributing expertise, legitimacy, and feedback. The UDP-TRIZ framework thus benefits from continuous validation and refinement through real-world stakeholder input, making it a practically actionable and policy-relevant model for disability-inclusive development.

Table 1: UDP-TRIZ Contribution to SDGs.

SDG	Relevant Targets	UDP-TRIZ Contribution
SDG 3 – Good Health & Well-being	3.8 (access to healthcare), 3.d (resilience for vulnerable groups)	Design healthcare tools/devices that are universally usable and technically optimized.
SDG 4 – Quality Education	4.5 (eliminate gender/disability disparities), 4.a (inclusive learning environments)	Enables the development of inclusive educational tools and learning spaces.
SDG 9 – Industry, Innovation & Infrastructure	9.1, 9.4 (inclusive, sustainable infrastructure)	Applies TRIZ principles to inclusive industrial design and sustainable technologies.
SDG 10 – Reduced Inequalities	10.2 (inclusion of all), 10.3 (equal opportunity)	Supports removal of systemic design barriers for marginalized populations.

Table 2: Integration of role in UDP-TRIZ with QH Model.

Actor	Role in UDP-TRIZ Ecosystem
Academia	Conducts research on inclusive design and TRIZ adaptation; provides training and evaluation.
Industry	Integrates inclusive innovation into product development; applies TRIZ to optimize functionality.
Government	Supports policy frameworks, accessibility standards, and funding for inclusive innovation.
Civil Society	Offers lived experience; evaluates usability; participates in co-design processes, especially PWD communities.

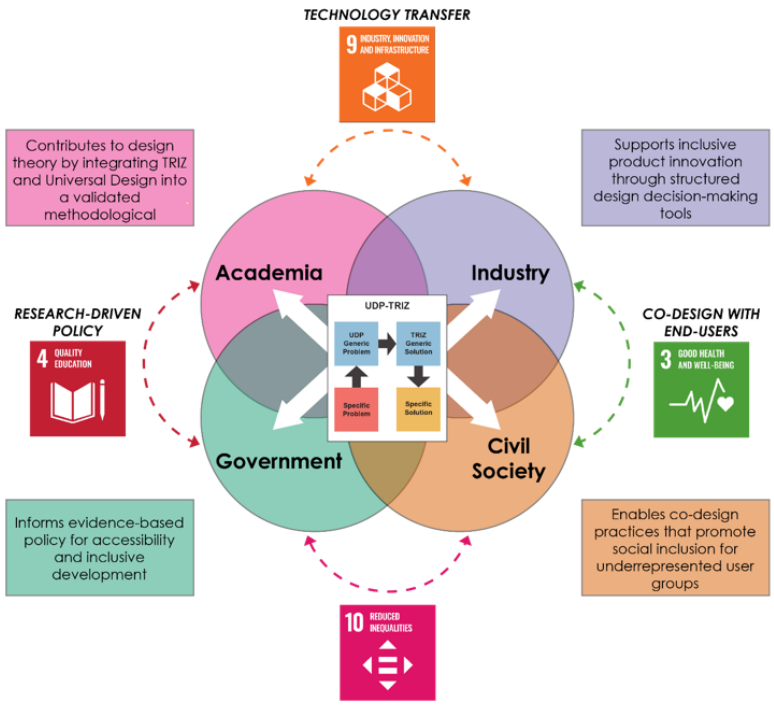

Figure 2: UDP-TRIZ Methodology Framework Contribution Across the Quadruple Helix and SDGs.

4. Conceptual Framework Development

The development of the UDP-TRIZ conceptual framework emerges from the synthesis of three interdependent knowledge domains: (1) Universal Design Principles (UDP), (2) the TRIZ methodology for structured innovation, and (3) the Quadruple Helix (QH) innovation system. Each of these contributes a unique dimension, ethical inclusivity, technical problem-solving, and institutional co-creation, respectively, forming an integrated foundation to support inclusive innovation aligned with Sustainable Development Goals (SDGs), particularly for persons with disabilities (PWDs).

4.1 Foundational Integration Logic

The conceptual framework responds to the limitations identified in existing approaches (Section 2.5). While UD ensures inclusive intent, it lacks structured innovation tools. Conversely, TRIZ provides robust problem-solving mechanisms but is not oriented toward user diversity or inclusion. The SDG framework articulates goals but lacks operational design methods. The UDP-TRIZ framework bridges these gaps by applying TRIZ to resolve design contradictions within inclusive design objectives, guided by UD principles and scaled through the Quadruple Helix model.

This framework is grounded in a logic model that integrates:

- The "what" – Inclusive outcomes defined by SDG targets (e.g., accessibility, equity, innovation).
- The "how" – TRIZ-driven inventive problem-solving adapted to support UD goals.
- The "who" – Actors in the QH model who contribute to and validate the process (academia, industry, government, civil society).

4.2 Framework Structure and Interaction

As illustrated in Figure 2 of the above, the conceptual framework is structured around a three-tier logic:

1. Input Layer: Includes societal needs (e.g., disability inclusion), institutional mandates (e.g., UNCRPD), and SDG targets.
2. Process Layer: Represents the hybridization of UDP and TRIZ. Inclusive design challenges are translated into TRIZ-compatible functional contradictions and addressed using adapted TRIZ tools (e.g., contradiction matrix, inventive principles). These tools are framed within the ethical boundaries defined by UD principles.
3. System Layer: Operationalizes the process through the QH model, ensuring that knowledge, resources, and legitimacy are co-created across sectors. It emphasizes feedback loops from civil society (particularly PWD communities) to validate design usability and inclusiveness.

This triadic structure ensures that inclusive innovation is:

- Ethically grounded (via UD)
- Technically structured (via TRIZ)
- Systemically scalable (via Quadruple Helix)

4.3 Operational Domains and SDG Alignment

The framework enables cross-sectoral application by aligning TRIZ-adapted design strategies with specific SDG targets. For instance:

- Resolving contradictions in accessibility vs. cost in public infrastructure design contributes to SDG 11.2.
- Developing inclusive assistive technologies aligns with SDG 3.8 and SDG 9.1.
- Creating adaptive learning platforms for diverse learners supports SDG 4.a and SDG 10.2.

Although the framework has not yet undergone empirical validation, it is grounded in comparative analysis, theoretical synthesis, and mapping to validated global targets (SDGs). Future research will apply this framework in live pilot settings to assess usability and design efficacy. These mappings demonstrate the transformative potential of the framework, positioning design not only as a technical practice but as a social intervention mechanism for equity and empowerment.

4.4 Feedback and Validation Mechanisms

The conceptual framework incorporates iterative feedback loops, a core element of the Quadruple Helix model. Civil society, especially PWD representatives, are positioned as evaluators and co-creators, not merely end-users. Their lived experiences shape refinement cycles, ensuring that solutions are not only technically effective but socially accepted and contextually relevant.

This participatory validation ensures:

- Legitimacy of design outcomes
- Practical feasibility in policy contexts
- Continuous adaptation to emerging needs and constraints

In conclusion, the conceptual framework developed in this study is not merely a theoretical proposition but a functioning innovation model. It offers a replicable approach for integrating inclusion, creativity, and sustainability into design processes and policy systems—thereby enabling real progress toward the SDGs for marginalized populations, particularly persons with disabilities.

5. DISCUSSION

5.1 Positioning UDP-TRIZ within Inclusive Innovation for the SDGs

The development of the UDP-TRIZ framework responds to a multi-layered problem space in inclusive innovation: the methodological gaps in Universal Design, the social limitations of TRIZ, and the implementation inefficiencies in current SDG frameworks. The discussion in this section situates UDP-TRIZ as a novel theoretical and practical model that addresses these gaps through hybrid integration and ecosystem application.

5.1.1 Theoretical Contribution

This study contributes to the theoretical development of design and innovation frameworks by offering a composite model that unifies ethical inclusivity with systematic creativity. The integration of Universal Design Principles (UDP) into TRIZ enables the latter to transcend its traditional technical constraints and expand into social and policy-relevant domains. At the same

time, TRIZ lends UD a methodological structure, enabling it to move beyond normative guidelines into resolvable design contradictions and iterative solution-building.

In doing so, UDP-TRIZ fills a critical void in existing literature, namely, the lack of design-based methodologies that are capable of operationalizing inclusion within structured innovation ecosystems. This hybridization reinforces arguments in inclusive innovation theory that call for co-productive, participatory, and context-sensitive innovation models (UNDESA, 2021).

5.1.2 Practical Relevance for SDG Implementation

The UDP-TRIZ framework aligns directly with several core Sustainable Development Goals, including SDG 4 (education), SDG 8 (employment), SDG 9 (industry), SDG 10 (inequality), and SDG 11 (cities and communities). The mapping of TRIZ-driven design interventions to specific SDG targets (as presented in Tables 2 and 5.2) demonstrates the operational potential of the framework to translate global development agendas into localized, inclusive solutions.

Moreover, the application of the Quadruple Helix model ensures that innovation is not siloed within a single institutional domain, but rather co-developed across academic, industrial, policy, and civic actors. This model addresses a key weakness in SDG delivery mechanisms, fragmentation, and supports systemic impact through distributed responsibility and iterative feedback [16].

5.1.3 Reframing the Role of Persons with Disabilities (PWDs)

A central innovation of this framework lies in its repositioning of PWDs as active contributors in the innovation process. Instead of designing "for" persons with disabilities, UDP-TRIZ, especially through the Quadruple Helix lens, advocates designing with them. This reorientation reflects the human rights approach emphasized in the UN Convention on the Rights of Persons with Disabilities (UNCRPD) and supports participatory development practices central to inclusive governance.

While empirical validation of the framework remains forthcoming, its development is anchored in comparative analysis, theoretical integration, and alignment with internationally recognized development targets (SDGs). Subsequent research will focus on implementing the framework in real-world pilot contexts to evaluate its practical usability and design effectiveness. By embedding user feedback loops, particularly from PWD organizations and advocacy groups, the framework enhances the legitimacy, contextuality, and usability of innovation outcomes. This is especially critical in design domains where top-down solutions have historically failed to account for the daily lived experiences of disabled populations (UNDESA, 2023).

5.1.4 Reframing the Role of Persons with Disabilities (PWDs)

The UDP-TRIZ framework provides a transferable model for multiple application domains, including:

- Policy design – supporting inclusive public infrastructure, accessible education policies, and disability-friendly innovation funding mechanisms.
- Product and system design – enabling the development of assistive technologies, inclusive work environments, and universal public services.
- Academic research – offering a transdisciplinary framework for investigating inclusive innovation that spans engineering, design, disability studies, and development policy.

These implications underscore the framework's flexibility and scalability, making it suitable not only for academic inquiry but also for implementation by governments, design firms, and civil society organizations.

5.2 Recommendations

The development of the UDP-TRIZ framework in this study offers a systematic model for disability-inclusive innovation aligned with the Sustainable Development Goals (SDGs). Building on the framework's theoretical underpinnings and operational mapping to the Quadruple Helix model, the following recommendations are proposed for stakeholders seeking to enhance inclusion, scalability, and cross-sector collaboration in innovation systems.

5.2.1 Policy Integration of Inclusive Innovation Frameworks

National governments and local authorities should formally integrate inclusive innovation frameworks such as UDP-TRIZ into their development planning, particularly for achieving SDG targets related to accessibility, education, employment, and infrastructure. This includes:

- Embedding inclusive design principles and structured problem-solving tools into national innovation strategies and urban development policies.
- Aligning accessibility laws with systematic design methodologies, not only with compliance checklists.
- Funding inclusive innovation programs through public-private partnerships guided by Quadruple Helix engagement models, ensuring direct involvement of PWDs in agenda-setting and evaluation.

These efforts align with the World Public Sector Report's (UNDESA, 2021) emphasis on inclusive governance mechanisms that support bottom-up, multi-actor innovation ecosystems.

5.2.2 Adoption of UDP-TRIZ in Design and Engineering Education

To scale the impact of the UDP-TRIZ framework, higher education institutions and technical training programs should incorporate it into design, engineering, and architecture curricula. Specifically:

- Courses on design thinking, product development, and innovation management should include modules on TRIZ, adapted for social inclusion.
- Universal Design training must move beyond ethical instruction and integrate TRIZ-based tools for resolving functional and social design contradictions.
- Interdisciplinary collaboration should be promoted through joint projects with industry, civil society, and government, using UDP-TRIZ as a shared problem-solving methodology.

Such educational reform supports the development of future designers and engineers capable of generating inclusive, scalable innovations aligned with global development needs.

5.2.3 Institutionalization of Multi-Stakeholder Co-Creation Platforms

Based on the application of the Quadruple Helix model (Table 1; Figure 2), institutions should establish permanent platforms for co-creation among academia, industry, government, and civil society. These platforms must:

- Be participatory and inclusive, ensuring the presence and decision-making power of marginalized groups, particularly persons with disabilities.

- Apply the UDP-TRIZ framework as a common operational language for resolving design challenges with diverse stakeholder input.
- Serve as hubs for testing, validating, and scaling UDP-TRIZ-based innovations across sectors.

Institutionalizing such platforms would enhance knowledge transfer and innovation diffusion, in line with SDG 17.17 on effective partnerships.

5.2.4 Development of Open-Access Knowledge and Toolkits

To encourage wider adoption, the UDP-TRIZ framework should be transformed into open-access resources, including:

- A toolkit combining TRIZ principles with UD guidance adapted for public sector, NGO, and private design teams.
- Case study repositories showcase successful applications of the framework in solving accessibility, mobility, and usability challenges.
- Monitoring and evaluation indicators to assess the contribution of UDP-TRIZ applications to specific SDG targets.

Such resources will support knowledge democratization and accelerate capacity-building, especially in low- and middle-income contexts.

5.2.5 Further Research and Pilot Testing

Finally, the framework should be tested in real-world pilot projects, especially in areas such as:

- Assistive educational technologies (SDG 4.a)
- Employment systems for PWDs (SDG 8.5)

Research institutions and innovation agencies should collaborate in documenting these pilots and assessing both technical outcomes and user-centred impacts. Additionally, further research is needed to explore how UDP-TRIZ can be integrated with digital technologies such as AI, IoT, or Smart Cities platforms to optimize accessibility in complex systems.

6. CONCLUSION

This study has introduced and conceptualized the UDP-TRIZ framework as an integrated theoretical model designed to address the persistent gap between inclusive design, systematic innovation, and the implementation of the Sustainable Development Goals (SDGs). It emerged from a recognized need to operationalize disability-inclusive development in a manner that is both methodologically rigorous and contextually scalable.

The research identified critical limitations in existing frameworks: Universal Design (UD), while ethically grounded, lacks procedural mechanisms for resolving complex design contradictions; TRIZ, though highly effective for inventive problem-solving, traditionally overlooks human diversity and social equity; and current SDG strategies, while aspirational, often fail to incorporate practical tools for inclusive innovation. In response, this paper proposed a hybrid solution that not only combines UD and TRIZ into a structured problem-solving approach but also embeds it within the Quadruple Helix innovation system to ensure multi-stakeholder engagement.

The conceptual and theoretical development of UDP-TRIZ offers several key contributions:

- A methodological bridge that translates inclusive design values into technical design solutions using TRIZ tools.
- A systemic platform for collaboration across academia, industry, government, and civil society, as modelled through the Quadruple Helix framework.
- A strategic alignment with multiple SDG targets, especially those related to education (SDG 4), work (SDG 8), innovation (SDG 9), inequality (SDG 10), urban access (SDG 11), and partnerships (SDG 17).

The framework repositions persons with disabilities (PWDs) from being passive recipients of development to becoming co-creators of inclusive solutions, reinforcing the participatory ideals of the UN Convention on the Rights of Persons with Disabilities (UNCRPD). The structure allows for iterative co-design, adaptability, and system-wide application, making it a replicable model for both developed and developing contexts.

While this paper is theoretical in scope, it lays the foundation for practical application and empirical testing. Future research should involve pilot implementation, toolkit development, and quantitative assessment of framework outcomes. This will not only validate the utility of UDP-TRIZ in real-world scenarios but also contribute to refining the model for broader scalability.

In conclusion, the UDP-TRIZ framework represents a novel contribution to the field of inclusive innovation. Aligning ethical design, inventive problem-solving, and multi-actor governance within the sustainable development agenda, it offers a pathway for achieving development that is not only innovative but truly inclusive. Future studies may explore the application of UDP-TRIZ in smart city development, accessible e-learning systems, or national disability action plans. Quantitative evaluations of design impact and stakeholder participation levels will further validate and refine the model.

ACKNOWLEDGEMENTS

The authors would like to express sincere appreciation to MyTRIZ Malaysia and Majlis Rekabentuk Malaysia for their valuable assistance throughout the data collection phase of this study, which was critical to the development of the UDP-TRIZ Framework. Their support in facilitating access to respondents and relevant resources substantially enhanced the robustness and applicability of the findings reported in this work.

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Conflict of interest statement: The authors declare no conflict of interest.

Author contributions statement: Conceptualization & Writing, Suhaimi Shahrin; Editing, K.A.A.A Rahman, R. C. Me & K. M. Kamarudin.