

ISSN 3080-2555 (2025) Print
ISSN 3080-2563 (2025) Online
ISBN 978-969-487-024-3 (2024)

JOURNAL OF SCIENCE COMMUNICATION AND DIPLOMACY

BIANNUALLY

Special Issue

Volume 2	2025	Issue 2
Volume 3	2026	Issue 1

Science communication & science diplomacy can serve as a bridge between Islamic nations fostering collaborations in areas of mutual interest, enhancing diplomatic relations and promoting peace and stability.



Special Issue on Science Diplomacy

Celebrating Two Years of the Journal of Science Communication and Diplomacy



OIC Ministerial Standing Committee on
Scientific and Technological Cooperation

COMSTECH



Ministry of Foreign Affairs,
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MoFA

Special Issue on Science Diplomacy
Celebrating Two Years of the Journal of Science Communication and Diplomacy

Journal of Science Communication & Diplomacy

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Table of Contents

1. Message	iii
<i>Patron-in-Chief</i>	
2. Message	iv
<i>Editor-in-Chief</i>	
3. Personal Reflections on science Diplomacy: What it Entails and the Future.....	1
<i>Amna Baloch</i>	
4. Fifty Years of the Biological Weapons Convention and the unfulfilled promise of Article X	8
<i>Muhammad Adeel and Husham Ahmad, and Syed Javaid Khurshid</i>	
5. The Enduring Utility of the 1979 Moon Treaty: Preparing for a New Era of Lunar Governance	17
<i>Hasan Abbas</i>	
6. Regulating Military AI: Why IHL Sufficiency Fiction may not Sustain.....	27
<i>Umair Khalid</i>	
7. Science Diplomacy for Peacebuilding: Cognitive Neuroscience as a Tool for Conflict Prevention and Post-Conflict Reconciliation.....	32
<i>Dr. Shakaib Rafique</i>	
8. Designing a model of Innovation Districts as a Hub for Countries’ Development (Case Study: Iran International Innovation District (IIID)	43
<i>Mostafa Ghafari Asl and Ali Mamhoori</i>	
9. From Data to Dialogue: Science Communication and Diplomacy in Climate Negotiations for Vulnerable Developing Countries.....	54
<i>Muhammad Arif Goheer, and Syed Javaid Khurshid</i>	
10. Electronic Waste Management in Nigeria: Understanding Consumer Knowledge of Extended Producer Responsibility and Practices of Circular Economy.....	62
<i>Faluyi, Ibukun, and Nnorom Innocent C</i>	
11. The Bursting of The Bubble – A Review Of Psychosocial Chal- lenges In The Diplomatic Service	91
<i>Zahoor Ahmed</i>	
12. Landscape of National Capability in Emerging Technologies: A Case Study of Pakistan	96
<i>Saddam Shah and Mashaal Shahnawaz</i>	
13. Universities and Science Diplomacy: Lessons from a European University Alliance	121
<i>Eric Piaget</i>	

Message of Patron-in-Chief

Dear Scientists, Diplomats, Policymakers, Contributors, and Readers,

It gives us great pleasure to present Volume 2, Number 2 (2025) of the Journal of Science Communication & Diplomacy (JSC&D), a key initiative of OIC-COMSTECH and MoFA aimed at strengthening the links among science, policy, communication, and international cooperation.

In an increasingly interconnected and complex world, scientific knowledge plays a critical role not only in technological advancement and sustainable development but also in diplomacy, peacebuilding, and evidence-based policymaking. Contemporary global challenges—including climate change, emerging technologies, environmental sustainability, and regional security—require stronger collaboration between scientific communities, policymakers, and diplomatic institutions.

This Special Issue on science diplomacy reflects that vision through scholarly contributions that address important themes such as climate diplomacy, artificial intelligence, innovation ecosystems, technological sovereignty, peacebuilding, and strategic security challenges. These discussions highlight the growing importance of science diplomacy as a mechanism for dialogue, cooperation, and shared progress among nations.

It is particularly encouraging to see the increasing engagement of not only scientists and researchers, but also diplomats, policymakers, and strategic communities through this journal. This growing engagement supports effective diplomacy for science, innovation, and informed international collaboration.

The steady progress of JSC&D reflects the dedicated efforts of its editorial leadership and the continued support of OIC-COMSTECH and MoFA in promoting scientific cooperation and intellectual exchange across OIC member states and beyond. I sincerely congratulate the Editor-in-Chief and the Associate Editors for their commendable efforts in successfully compiling this special issue. I also congratulate the editorial board, authors, and reviewers for their valuable contributions in maintaining the academic quality and relevance of this publication.

I hope this journal will continue to inspire constructive dialogue, collaborative partnerships, and science-informed approaches for sustainable development and global cooperation.

Prof. Dr. M. Iqbal Choudhary

H.I., S.I., T.I., Mustafa (pbuh) Prize Laureate

Coordinator General, OIC-COMSTECH

Message of Editor-in-Chief

It is with great honor that I present the special issue on Science Diplomacy comprising of Volume 2, Number 2 (2025) and Volume 3, Issue 1, 2026 of the Journal of Science Communication & Diplomacy (JSC&D). This issue reaffirms our commitment to fostering a dynamic scholarly platform where science, communication, innovation, and diplomacy converge to address today's most pressing global challenges. In an era defined by technological transformation, environmental uncertainty, and shifting geopolitical realities, integrating scientific knowledge into policy and diplomacy has become more essential than ever.

This volume features a distinguished collection of contributions exploring critical themes, including cognitive neuroscience for peacebuilding, innovation ecosystems, climate diplomacy, electronic waste management, psychosocial dimensions of diplomacy, technological sovereignty, artificial intelligence in foreign policy, and the strategic implications of autonomous technologies. Together, these works underscore the expanding role of science diplomacy as both an academic discipline and a practical policy instrument.

The intellectual diversity of this issue—with contributions from scholars and practitioners across Pakistan, Iran, Nigeria, and beyond—reflects the growing significance of South–South cooperation and interdisciplinary engagement. These perspectives strengthen global discourse while highlighting the importance of scientific collaboration in advancing sustainable development, institutional resilience, and international partnership.

Particularly notable is the focus on emerging technologies, including artificial intelligence, data science, and autonomous systems, and their transformative impact on governance, diplomacy, and strategic policy. Equally vital are discussions on climate negotiations, circular economy frameworks, and innovation-driven development, all of which emphasize the critical role of science communication in promoting evidence-based policymaking.

By addressing both traditional and emerging dimensions of diplomacy, this issue broadens scholarly and policy discussions on international cooperation. Its interdisciplinary approaches to peacebuilding, governance, and strategic resilience demonstrate the evolving capacity of science diplomacy to contribute meaningfully to global stability and sustainable progress.

As Editor-in-Chief, I extend my sincere gratitude to our contributing authors for their scholarly excellence, to our reviewers for their rigorous evaluations, and to the editorial team for their unwavering dedication. Their collective efforts continue to strengthen JSC&D as a credible and impactful platform for scientific scholarship and diplomatic dialogue.

I also warmly invite researchers, policymakers, diplomats, and practitioners—particularly from OIC member states and the Global South—to continue contributing to this important platform. Through collaborative scholarship, informed dialogue, and strategic cooperation, we can further strengthen the science–policy–diplomacy nexus and advance innovative solutions to shared global challenges.

It is my sincere hope that this issue will serve not only as a valuable academic resource but also as a catalyst for policy innovation, international collaboration, and the advancement of science communication and diplomacy.

May the Journal of Science Communication & Diplomacy continue to serve as a trusted forum for promoting scientific excellence, diplomatic engagement, and sustainable global progress.

Prof. Dr. Syed Javaid Khurshid

Consultant, Science Communication & Diplomacy, OIC-COMSTECH
Coordinator, STI Policy Research & Training Center, OIC-COMSTECH

Personal Reflections on Science Diplomacy: What it Entails and the Future

Amna Baloch

Foreign Secretary, Ministry of Foreign Affairs, Pakistan

During the course of more than three decades in my career as a diplomat, I have seen firsthand how science, technology, and innovation have moved from the periphery to the center of diplomatic practice. Topics such as climate change, biotechnology, artificial intelligence, autonomous systems, and critical minerals, to name a few, are no longer optional extras but rather at the heart of bilateral and multilateral exchanges due to their impact on people and countries. Within this frame, science diplomacy has emerged as an important part of the diplomatic toolbox, with a distinct dimension to statecraft, and has the potential to contribute to socio-economic development while addressing global challenges. That said, no policy tool operates in a vacuum, and science diplomacy is similarly shaped by the broader geopolitical environment in which it is pursued. In this publication, I draw on my experiences at the interface of science diplomacy during two Ambassadorial assignments in Brussels and Kuala Lumpur to reflect on the opportunities, challenges, and evolving dynamics shaping science diplomacy in contemporary international relations.

1. Evaluating the Change

Building on the growing centrality of science and technology in international relations, the speed and the span with which technological issues have come to dominate diplomatic agendas have been remarkable and, at times, insufficiently appreciated. Furthermore, there has been a growing realization that the biggest challenges of our time, such as climate change, pandemics, and food security, sit at the intersection of science and technology (S&T) and politics, economics, and law. Science and policy, or, more broadly, the natural sciences and the humanities, have largely been treated as distinct domains within academia. In practice, they are increasingly inseparable as demonstrated by the mainstreaming of science diplomacy.

The diplomatic practice that I joined three decades ago has progressively expanded beyond its traditional remit. Within our traditional agendas, we are increasingly called upon to negotiate not only political and economic matters, but also the governance impact and implications of advances in frontier areas of science, such as biotechnology, quantum technologies, artificial intelligence, and space technologies.

A key consequence of this transformation is the erosion of the traditional divide between the “generalist diplomat” and the “technical specialist.” Contemporary diplomacy increasingly demands both substantive knowledge of specialized fields and the ability to mobilize, coordinate, and lead diverse communities of experts across institutional, disciplinary, and national boundaries. This leads to the realization that developing science diplomacy as an institutional capacity is no longer an option, but rather a necessity, if we are to navigate the technology-impacted challenges of our times.

2. What Science Diplomacy Entails?

There is a substantial body of literature that has emerged over the last 15 years or so on the typologies and definitions of science diplomacy. Rather than dwelling on these academic debates and conceptual nuances, it is important to focus on the practical realities of science diplomacy as I have observed and experienced this firsthand. From a practitioner's perspective, scientific governance now sits at a clear intersection with diplomacy, owing to its intrinsic and often profound impact on human life.

The politics and narratives surrounding how technologies are developed, commercialized, regulated, governed, and ultimately shared or withheld are having a profound impact on interstate dynamics. It also reflects enduring disparities between developed and developing countries in access to scientific knowledge, technological capabilities, and innovation ecosystems. In practice, the interlinkages of technology governance, access, and equity constitute one of the most prominent dimensions of the science diplomacy agenda.

2.1. View from Brussels and Kuala Lumpur

I write with the benefit of having served as an Ambassador in two geographically varied settings where science diplomacy was a working policy instrument, enabling the Mission to pursue synergies.

European Union – an institutional approach

During my time in Brussels, the EU was in the process of formalizing its science diplomacy strategy (which has now been finalized)¹ to leverage its scientific cooperation instruments, such as Horizon Europe and Erasmus+, to advance its objectives. Through a deliverable-minded approach, the EU has now been able to convert aspiration into institutions in science diplomacy. These instruments provided an opportunity to the Embassy in Brussels to develop an effective science diplomacy interface through joint activities such as engagement on Horizon Europe funding opportunities, participation in the Marie Skłodowska-Curie Actions, Erasmus+ programs, and broader knowledge exchanges on research collaboration, science popularization initiatives in Pakistan, and avenues for strengthening science-policy and science-diplomacy interfaces.²

The EU's institutional approach through the European Commission, as well as allied organizations such as Science Europe, gave an opportunity to mainstream Pakistan's intergovernmental scientific organization landscape, including the OIC Standing Committee on Scientific and Technological Cooperation (COM-STECH).

One of the most significant science diplomacy dividends arising from such engagement was the mobilization of the scientific diaspora and the development

1 https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/european-framework-science-diplomacy-2025-02-13_en

2 <https://mofa.gov.pk/press-releases/the-embassy-of-pakistan-in-brussels-hosted-a-science-diplomacy-networking-event>

of enduring talent partnerships. In this regard, the Erasmus Mundus program provides a compelling example: Pakistani students have been the largest recipients of these scholarships globally for five consecutive years. Similarly, under Horizon Europe, Pakistani universities and research institutions are participating in more than ten collaborative research projects with European partners.

Beyond their immediate educational and research benefits, these initiatives cultivate a generation of professionals with transnational experience, international networks, and the capacity to contribute to addressing complex global challenges. Importantly, they deepen people-to-people connections and strengthen links between scientific communities. Over time, this creates a valuable pool of talent and goodwill within Europe that can be mobilized to support broader Pakistan–Europe cooperation, generating positive spillovers across the bilateral relationship in areas extending well beyond science and technology.

Another key takeaway was the impactful linkage of science diplomacy with policy windows. For instance, in Brussels, during the annual European Public Health Week, the Embassy convened a session³ on bridging institutional silos to expand manufacturing capacity in developing countries. By bringing together a development organization (PATH), a university consortium (EUTOPIA), and the European Commission, a cross-sectoral coalition was facilitated. The key premise captured during the session was that the barriers to producing medicines and vaccines, especially in developing countries, are not solely scientific but also related to policy, financing, regulation, and inter-institutional silos.

The Malaysian model: development through science cooperation

During my time as High Commissioner in Malaysia, I gained a different but equally significant perspective on science diplomacy. Malaysia, being a fellow member state of the Organization of Islamic Cooperation, has, over the decades, harnessed science and technology as instruments of national development and of enduring partnerships with the Islamic world, an approach that also resonates with Pakistan.

In the case of Kuala Lumpur, science diplomacy was more about the steady cultivation of knowledge partnerships, research linkages, and technology cooperation than grand multilateral instruments. One precedent in this case was the establishment of the International Islamic University in Malaysia and Pakistan under the OIC Charter. Both institutions were founded to foster intellectual and cultural development in the Muslim world. Both were conceived as genuinely transnational institutions, committed by design to integrating contemporary scholarship with the intellectual traditions of Islam.

The takeaway in Kuala Lumpur was that the most consequential instruments

3 <https://mofa.gov.pk/press-releases/embassy-of-pakistan-brussels-in-collaboration-with-international-ngo-path-eu-and-eutopia-university-consortium-hosted-a-panel-discussion-and-networking-session-on-bridging-silos-to-increase-manufacturing-capacity-through-science-diplomacy-in-line-with-the-ongoing-european-public-health-week?mission=brussels>

Personal Reflections on Science Diplomacy

of science diplomacy are not the grand or dramatic outcomes, but rather the institutions and the human relationships that require patience, perseverance, and careful nurturing to mature over long horizons.

The country embarked on a trajectory of industrialization and development to become a knowledge-based powerhouse. A deliberate policy was adopted to develop an ecosystem of higher educational research institutions, open science initiatives, and robust commercialization to become a thriving economic force.

The Malaysian authorities' COVID-19 response⁴ further reinforced this lesson. It demonstrated how sustained investments in scientific capacity, strategic foresight, robust public health institutions, and international technology partnerships can translate into national resilience during periods of crisis. Malaysia combined domestic preparedness with international cooperation to secure access to vaccines and medical supplies, facilitate data sharing, and support collaborative research efforts. The broader lesson was that scientific capability and international scientific cooperation are not merely assets for development; they are strategic investments whose value becomes most apparent during times of disruption and uncertainty. The dividends of science diplomacy are often realized not in moments of stability, but when crises place the greatest demands on national resilience and international cooperation.

3. Future Casting Science Diplomacy

As mentioned earlier, science diplomacy and international scientific cooperation do not operate in a vacuum. It is shaped by the environment in which it operates. In this section, I will first identify how the evolving international order is impacting science diplomacy; second, the stumbling blocks; and lastly, deliberate on the future dimension.

3.1. Reordering of the International Architecture

There is no doubt that the international order has undergone a profound transformation over the past decade, marked by a succession of disruptive shocks and the experience of complex poly-crises. From the COVID-19 pandemic and climate-related emergencies to supply chain disruptions, economic uncertainty, and the intensification of geopolitical rivalries, these developments have exposed both the vulnerabilities and interdependencies of an increasingly globalized world. At the same time, assumptions underpinning globalization have come under growing strain, as states have reoriented towards resilience, strategic autonomy, technological sovereignty, and economic security. It is unfortunate that, at a time when greater international scientific collaboration is required to tackle global challenges, there is a reversal of this trend towards the securitization of knowledge and the weaponization of interdependence. In science diplomacy, this represents a shift from an idealistic to a more rigid framing.

4 https://www.who.int/docs/default-source/coronaviruse/country-case-studies/malaysia-c19-case-study-20-august.pdf?sfvrsn=a0f79358_2#:~:text=The%20first%20death%20from%20COVID,the%20number%20of%20available%20ventilators.

Science diplomacy, nonetheless, remains highly relevant within the current architecture of international relations. From the Paris Agreement and the pandemic treaty negotiations at the World Health Organization to the operationalization of the Biodiversity Beyond National Jurisdiction Agreement (BBNJ) Agreement, spectrum allocation negotiations within the International Telecommunication Union, and the emerging governance of artificial intelligence indicate that contemporary diplomacy is increasingly intertwined with scientific knowledge and technological change. These issues no longer merely inform diplomacy; they have become integral to the conduct of diplomacy itself, placing science diplomacy at the center of international negotiations.

Another reordering is the rising assertion of the Global South and the emergence of middle powers. For much of the post-World War II period, the architecture of technological governance was based across a small number of capitals, and the developing world was largely a recipient of these frameworks rather than the authors. Middle powers and developing countries are increasingly seeking to shape international debates by emphasizing the developmental dimensions of science and technology, often in contrast to the predominantly security-oriented narratives being advanced by major powers. However, a degree of realism is warranted. While these actors have become more visible and vocal, this momentum has not yet translated into a sustained agenda-setting power, and it would be premature to characterize this as a relationship of parity with the major technological powers. Rather than a fundamental redistribution of influence, we are witnessing the gradual emergence of a more plural, contested, and multipolar landscape in which a broader range of actors are seeking to shape the governance of science and technology.

3.2. Stumbling Blocks

With the above pretext, I would like to highlight the obstacles, barriers, and stumbling blocks that the field of science diplomacy must address in order to sustain itself as an effective policy instrument.

First is the future of open science. The international scientific order has been promoted on a rhetoric of openness, which is now under threat from export controls, restrictions on research mobility, de-risking, and de-coupling narratives.

Second is the reconciliation of geopolitics and political compulsion. Historically, Science diplomacy has been promoted as a neutral bridge that can bring together estranged parties and open channels of communication. Today, science and scientific prowess are being limited to confer strategic benefits linked to power dynamics.

Third, the prevailing asymmetry in scientific and technological capacity. The polycrisis environment and the rising retreat from multilateralism have led to a decline in funding and assistance for global instruments of international scientific cooperation. If this trend persists in the future, the divide will widen, resulting in inequitable partnerships.

Fourth, there is friction from divergent rules governing technology. As states and multilateral bodies adopt differing regulatory approaches to frontier technologies, ranging from artificial intelligence and biotechnology to data governance and digital infrastructure, the result is an increasingly fragmented governance environment. This not only raises the transaction costs of scientific collaboration and innovation but also risks splintering the global scientific order into competing regulatory and technological spheres.

3.3. Way Forward

On the sidelines of the United Nations General Assembly's Science Summit in September 2024, I had the opportunity to address an event⁵ convened by Science Europe on the theme of reciprocity in multilateral research collaboration. I took the liberty of adapting the following recommendations to the key arguments I made there, especially regarding the equitable nature of science diplomacy partnerships. The first step is recognizing that global challenges are interconnected and require coordinated action. To improve synergies, we must focus on four crucial strategies.

Firstly, we need inclusive collaboration frameworks. Global initiatives must be designed to bring all stakeholders to the table, especially those from the Global South. Far too often, their voices are underrepresented. We must ensure that scientists from developing countries are not just participants, but equal partners. This inclusivity is key to fostering innovation that addresses local and global needs. For instance, Pakistan's collaboration through intergovernmental organizations such as the OIC Standing Committee on Scientific and Technological Cooperation (COMSTECH), the Commission on Science and Technology for Sustainable Development in the South (COMSATS), and the ECO Science Foundation serves as a template for science diplomacy in the Global South.

Secondly, policy coordination and knowledge sharing are vital. We need to align national research policies with global objectives, such as the Sustainable Development Goals, and create mechanisms to synchronize efforts across programs. When policies are coherent and knowledge flows freely across borders, our solutions become more robust and effective. Pakistan's involvement in global health initiatives, such as the World Health Organization-led mRNA vaccine technology⁶ transfer during the pandemic, demonstrates how aligning national efforts with international health priorities can drive real progress.

Thirdly, we must promote interdisciplinary and cross-sector partnerships. The challenges we face are complex, and no single discipline can solve them alone. We need partnerships that bridge the gap between academia, industry, and government. Pakistan's active role in global scientific institutions such as CERN illustrates how multi-sector collaboration can foster synergies in infrastructure, research, and technology. Furthermore, capacity building for both diplomats and

⁵ <https://scienceeurope.org/media/qdyptl3t/20240917-programme-reciprocity-event-unga79.pdf>

⁶ [https://www.who.int/initiatives/mrna-technology-transfer-\(mrna-tt\)-programme](https://www.who.int/initiatives/mrna-technology-transfer-(mrna-tt)-programme)

scientists is essential for the effective governance of new and emerging technologies. Only by understanding each other's skill attributes and knowledge can science diplomacy play a practical role in bilateral and multilateral settings.

Lastly, there is a clear lag between technological progress and the regulatory framework. This gap has several negative implications and externalities for policymakers and innovators. A key challenge for science diplomacy is to promote regulatory frameworks that are proportionate to evidence-based risk while ensuring that they do not unnecessarily constrain innovation, technology diffusion, or development opportunities, particularly for developing countries. Addressing these challenges will require enhanced coordination across the multilateral architecture, including stronger linkages among treaty secretariats, better integration of international cooperation and scientific review processes, and institutionalized mechanisms that facilitate the regular transfer of knowledge and skills between scientists and diplomats. Such cross-fertilization will be critical for bridging the gap between technical expertise and policy decision-making.

4. Conclusion

Summing up, from my own personal journey as a diplomat, I am convinced that science diplomacy would be at the center stage of international relations and the conduct of foreign relations in the future. Global challenges have a visible scientific and technological component that would draw upon science diplomacy for policy action. The rules of the emerging technological and scientific order are still being written; we must work together to ensure they are written by the many and not the few.

Fifty Years of the Biological Weapons Convention and the unfulfilled promise of Article X

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Abstract

Fifty years after the entry into force of the Biological Weapons Convention (BWC), Article X remains central to the treaty's vision of promoting the peaceful exchange of biological science and technology. However, its implementation has long been constrained by differing interpretations among States Parties regarding the nature and scope of international cooperation. This policy review examines the evolution of Article X, the major debates surrounding its operationalization, and the prospects for progress ahead of the Tenth Review Conference in 2027. Drawing on official BWC documents, academic literature, and practical experience within BWC processes, the paper explores key challenges, including the tension between security and development objectives, technology-access concerns, export controls, and institutional limitations. It also highlights Pakistan's constructive role in advancing Article X through diplomatic engagement, national implementation measures, and proposals for an International Cooperation and Assistance (ICA) Mechanism.

The review argues that ongoing negotiations present a valuable opportunity to strengthen the Convention through a practical and sustainably funded cooperation framework. Coupled with a Science and Technology review mechanism, such reforms could enhance trust, capacity-building, and equitable access to the benefits of peaceful biotechnology. The paper concludes that science diplomacy, inclusive dialogue, and international partnership remain essential for realizing the original promise of Article X and ensuring the continued relevance of the BWC in a rapidly evolving scientific landscape.

Keywords: BWC, Article X, international cooperation, science diplomacy, biosecurity, biotechnology, Pakistan.

Introduction

The Biological Weapons Convention (BWC), at the time of its entry into force in March 1975, was the first treaty to prohibit an entire category of weapons. The treaty, now in its fifty years, remains institutionally fragile. Compared with other counterparts, such as the Chemical Weapons Convention (CWC), BWC still lacks a verification regime, a resource-starved Implementation Support Unit (ISU) rather than an implementing organization, and a dedicated cooperation program.

A key aspect of this fragility stems from the suboptimal operationalization of Article X, under which the State Parties have the right to share and an obligation to facilitate the peaceful exchange of biological science and technology. Over five decades have passed, and Member States still have foundational disagreements on what the “cooperation” entails. This policy review, with a quick historical overview, examines the key debates and future casts the probable outcomes leading towards the Tenth Review Conference of the BWC in 2027.

Approach and Sources

This analysis draws on personal engagement with the BWC community over the past several years, official BWC documents/working papers in the UN Official Document Library, as well as peer-reviewed literature on the BWC, especially on Article X.

Overview

The Table below summarizes the key historical developments/timeline related to the Article X deliberations.

1972–75	Treaty negotiated and entered into force; Article X cooperation language included from the outset.
1986–96	Second through Fourth Review Conferences expand Article X measures: information exchange, training, surveillance, and technology transfer.
1994–2001	The ad hoc group negotiates a verification protocol. International Cooperation Assistance (ICA) — and a proposed Cooperation Committee — are among the most contested issues. The draft protocol collapsed after the US rejection in 2001.
2003–11	Intersessional Programme sustains Article X discussion through expert-level engagement. The Seventh Review Conference in 2011 created the Article X database and biennial implementation reports.
2022	Ninth Review Conference establishes the Working Group and also decides to develop an ICA Mechanism.
2023–27	Working Group develops a hybrid ICA mechanism model; the Chair’s Rolling Text (August 2025) provides the first concrete negotiating text. The Tenth Review Conference (2027) may adopt an ICA mechanism — the treaty’s most significant institutional advance in decades.

Table 1. Historical timeline of the Article X-related developments

Deliberations on Article X continued during successive Review Conferences and crystallized during the failed Protocol negotiations during 1994-2001. The collapse of the negotiation was a consequential institutional milestone. It deepened the divide between donor and recipient states, as well as regional groups – an aspect which has shaped every Article X debate since. It has also been reported in the literature that proposed deliverables such as the database and Article X reports have underperformed.

Fifty Years of BWC and the Unfulfilled Promise of Article X

It was found that by 2024, only 39 Article X reports had been submitted (Shearer et al., 2026).

Core Debates

The fault lines around the operationalization of Article X revolve around the following key core debate, which contributes to competing visions. Enlisting these debates is important to understanding the modalities for any Article X or ICA mechanism.

Security v/s Development Dilemma

For the Non-Aligned Movement and much of the developing world, assured access to the equipment, materials, and scientific information of peaceful biology is the consideration at the heart of a grand bargain. States forwent the biological-weapons option in exchange for guaranteed participation in the benefits of the life sciences. On this reading, Article X is the Convention's developmental pillar and a positive, operational obligation, and its chronic under-implementation is a breach of the bargain itself. For many Western States, the Convention is first and foremost a disarmament instrument, and Article X functions principally as a safeguard clause; only an obligation not to obstruct legitimate peaceful activity rather than an affirmative duty to deliver assistance. Where these States do engage positively, they tend to frame assistance through the Convention's security purpose, i.e., concentrating on biosafety, biosecurity, disease surveillance, and preparedness against deliberate misuse, and resist a broad development mandate that would, in their view, duplicate the work of other bodies.

Compliance Standards

Without a common understanding of Article X and an implementing Protocol, compliance is self-assessed, resulting in underutilization. Shearer et al. (2026) have reported the mismatch between database offers (which are mostly regulatory/non-proliferation focused) and requests (which are mostly capacity and technology transfer focused), which explains the gap.

The discussions around export controls also complicate the debate. While there are nuances, most Member States, including the NAM Group, support export control and regard the Australia Group as a de facto standard if expectations are clarified (Revill & Garzon Maceda, 2022). The nuance within this debate is that there is no objection to the existence of the controls, but rather the aspect of denials without justification or an appeals mechanism. A proposal for a BWC-specific export regime has not found traction within the Western Group.

Scope of Cooperation

Another key debate is on the operating space within the BWC, while managing overlap with other bio-centric treaties/organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). The Western Group prefers a narrower cooperation focus, while NAM and developing countries favor a more expansive interpretation covering public health as well as biotechnology access.

Pakistan's Position in BWC Cooperation

Pakistan has played a proactive role in contributing to the discussions and debates within the BWC, as it is a developing country with a growing biotechnology sector and substantive public health needs. Pakistan has served as a technically engaged interlocutor that has consistently pursued structural reform of Article X while creating bridges between regional groups.

Pakistan's standing in the Convention's institutional development is anchored in a record of leadership at successive inflection points. Ambassador Masood Khan of Pakistan presided over the Sixth Review Conference in 2006 — the conference that decided to establish the Implementation Support Unit (ISU), the Convention's first standing institutional body — and is widely credited in Geneva circles with steering that outcome to consensus. He went on to chair the first Meeting of Experts of the ensuing intersessional programme in August 2007, which addressed national implementation, enforcement legislation and regional cooperation. Pakistan's facilitation role later reached the assistance pillar that sits closest to Article X: then-Counsellor Usman Iqbal Jadoon of Pakistan chaired the 2019 Meeting of Experts on Assistance, Response and Preparedness (MX4, 6–7 August 2019). Two decades after the ISU's creation, Pakistan has again been entrusted with an institution-building mandate, with Counsellor Husham Ahmed serving as one of the Friends of the Chair on organizational, institutional and financial matters within the Working Group on the Strengthening of the Convention (2023–present). It is the cross-cutting track on which the financial and organizational architecture of any future mechanism is being worked out. That States Parties have repeatedly placed Pakistan in chairing and facilitation roles is a reflection of Pakistan's cross-group credibility in the BWC community.

This engagement rests on a concrete material basis. As a developing country with a growing biotechnology sector and substantial public health needs, Pakistan is simultaneously a prospective recipient of advanced capabilities and a potential South–South provider of training and regulatory expertise to lower-capacity partners, giving it a direct stake in a functioning, non-discriminatory cooperation regime.

On the domestic front, Pakistan has also undertaken a major legislative milestone through the promulgation of the Biological and Toxin Weapons Convention (Implementation) Act.¹, 2026, which will now serve as the primary instrument for implementing Pakistan's obligations under the BWC. The Act gives the Central Authority a positive mandate not only to prevent misuse of biological agents and toxins, but also to facilitate legitimate biological research, disease prevention, peaceful biotechnology, and international scientific cooperation, a direct manifestation of Article X of the BWC. There are also provisions within the Act to respond to the cooperation requests from other Member States as well.

¹ https://www.na.gov.pk/uploads/documents/6965f27da3cb3_777.pdf

Pakistan's Proposal for a Cooperation and Assistance Mechanism under Article X

Pakistan's 2023 working paper submitted in the Working Group on Strengthening the BWC is its most substantive recent contribution to the operationalization of the ICA mechanism under Article X. It proposes a three-tier interconnected structure comprising ICA Program, ICA Committee, and ICA Fund. The biennial ICA Program is envisaged as the main vehicle to design, facilitate, and deliver projects pursuant to the cooperation and assistance framework envisioned in Article X. The ICA Program will be considered and approved by the ICA Committee, which will have 25 members elected on a regional basis. The ICA Fund will be used to finance the projects under Article X and will be financed through a hybrid option of voluntary assessed contributions.

Crucially, Pakistan favors a facilitative mandate rather than the adjudicative powers sought in more maximalist proposals, which makes it acceptable to Member States wary of sovereignty encroachment while credible to peers demanding reform.

This pragmatism reflects genuine national interest, not mere positioning. Pakistan participates in WHO biosafety programmes and BWC national workshops, has developed implementing legislation (the Pakistan Biological Safety and Security Rules, 2021), and increasingly functions as a potential South-South donor of training and regulatory expertise to lower-capacity neighbours. The National Institute for Biotechnology and Genetic Engineering (NIBGE) and the Centre for Applied Molecular Biology (CAMB) represent two domestic institutions that would benefit directly from improved access to dual-use equipment and international collaborative networks. A functioning mechanism that connects Pakistani institutions to global scientific networks and structures regional cooperation serves that interest directly.

Pakistan's working paper stimulated significant engagement in the Working Group, and the Chair's rolling text borrowed several elements from it. As a result, the ICA Mechanism, which is currently close to convergence, comprises the ICA Program and a limited membership body known as the ICA Steering Group (inspired by the ICA Committee). The ICA Mechanism proposed by the Chair will be funded through both voluntary and assessed contributions. While many elements proposed by the Chair enjoy consensus, there are still differences on key aspects that are currently being negotiated. e.g., election of Steering Group's members, unilateral coercive measures, etc.

Additional Aspects

About the progress of any ICA mechanism related to Article X, the following challenges and additional aspects are noteworthy:

Institutional and Resource Constraints

The limited capacity of the ISU and the absence of sustained programmatic funding are major hindrances, especially when compared to the workings of the Organization for the Prevention of Chemical Weapons (OPCW) and the International Atomic Energy Agency (IAEA). The OPCW has an International Cooperation and Assistance

Division with an annual budget allocation under Article XI of the CWC. The IAEA's Technical Cooperation Fund is financed by voluntary assessed contributions. For an ICA mechanism to prevail, a similar structure is a necessity. While assessed contributions ensure that the fund is sustainable and universal, it is not supported by the Western States. At the same time, relying solely on voluntary contributions would compromise the sustainability, sufficiency, and predictability of the fund. For this, a hybrid model combining assessed contributions for core operations and voluntary pledges for specific activities can be a way forward.

Defining the Scope

As shared earlier, the competing vision of the Article X related to development versus security will impede every scope, governing, and funding modalities related to a ICA mechanism. There is also a strong position by one or two States that unless the ICA Mechanism has in its scope the mandate to address denials/obstacles faced by them under Article X, they will not agree to the proposal. There is a need to come up with a negotiating language leading up to the 10th Review Conference, which can help bridge this ambiguity.

Science Diplomacy Opportunity

There are at least nine different conventions/protocols within the UN-based multilateral order regulating different aspects of biotechnologies. For instance, the Cartagena Protocol on Biosafety to the Convention on Biological Diversity regulates the environment-related impacts, whereas the International Plant Protection Convention, overseen by the Food and Agriculture Organization of the UN, deals with plant health and the spread of plant pests. These Conventions/Protocols are rich interfaces of science-policy interaction and feature science advice structures, but the impact remains to be optimized. One crucial missing link is a cross-treaty engagement platform to harmonize essential aspects, such as creating synergies between ICA mechanisms (Adeel, 2022).

It is also pertinent to note that ongoing activities such as laboratory twinning, regional workshops, scientific exchange, Youth for Biosecurity initiative.² Collaborative research and development platforms have already built a primordial platform, which can be scaled through a thorough ICA mechanism.

The ICA and Science and Technology (S&T) Mechanism in Tandem

Another avenue of synergy and a way forward is through the establishment of an ICA mechanism alongside an S&T review mechanism, leading up to the 10th Review Conference. From a science diplomacy perspective, such an approach would benefit from a feedback loop. The S&T mechanism can help identify areas of cooperation, including the technological landscape, while the ICA mechanism helps devise activities around capacity building. Revil and Garzon Maceda (2022) have also argued that cooperation and assessment mechanisms must be designed in concert rather than sequentially. Such a possibility may also result in the following three key positive implications:

2 <https://www.un-ilibrary.org/content/books/9789211071672>

Fifty Years of BWC and the Unfulfilled Promise of Article X

- A paired approach provides the structural scaffolding for both demand and supply sides of cooperation. It creates incentives for Member States to actively pursue deliberations in both mechanisms for effective operationalization.
- The mismatch between donor and recipient requirements would lessen. The ICA mechanism will help direct resources/capacity building opportunities towards a shared benchmark rather than a bilateral preference.
- More significantly, a pairing will help better operationalization of cooperation through effective strengthening of regional networks. A recipient member state can leverage the ICA mechanism to host regional capacity-building workshops, which are technically guided by the S&T mechanism.

Furthermore, an S&T review process that openly characterizes dual-use concerns establishes an evidence base against which both export-control decisions and allegations of non-compliance can be assessed.

Equally, a transparent S&T review process would begin to address the procedural opacity that Nasu (2013) identified as the core developing-country grievance regarding export controls: the absence of stated justifications, an appeals mechanism, and inclusive membership.

These prospects are nonetheless conditioned by genuine constraints, which a candid assessment must register. Negotiating two consensuses concurrently is more demanding than negotiating one, though it also enlarges the space for cross-issue compromise. Sustained participation in two technical bodies presupposes expert bandwidth that may strain smaller delegations themselves, an argument for investing in domestic science-diplomacy capacity in advance, a point that applies with particular force to the very developing countries the mechanisms are meant to serve.

At the same time, the decision to establish the two mechanisms was agreed as a package by the 9th Review Conference of the BWC in 2022. Therefore, their simultaneous establishment would be key to unlocking consensus on an issue, which has been on the agenda of the BWC community for decades.

Above all, the magnitude of these opportunities is contingent on scope: should the mechanisms be confined to deliberate-threat preparedness alone, much of the developmental promise sketched here would contract. The interest of states such as Pakistan therefore lies not merely in the establishment of the two mechanisms but in their being scoped broadly enough through an active Pillar 2 matchmaking function — to encompass the development dimension that Article X was, for many states parties, always intended to secure (Littlewood, 2005; Sims, 2001).

Conclusion

The BWC's fiftieth anniversary is a moment for honest reckoning rather than celebration. Article X, the article that promised science in the service of humanity, has become the arena in which the treaty's deepest tensions play out. Yet the gap between competing mechanism models has narrowed considerably over three years of Working

Group deliberation, and the Chair's Rolling Text gives negotiators concrete language to refine.

The viable path forward is now visible. It combines a narrowly scoped but sustainably funded ICA mechanism including assessed contributions for a core secretariat, voluntary contributions for project implementation, a facilitative rather than adjudicative mandate, and a reporting framework that binds both donors and recipients.

The prospect of pairing this mechanism with an S&T review body would amplify its effects by supplying an analytical foundation for genuine needs-based matchmaking and embedding the dual-use transparency that the treaty's most vulnerable members require. States like Pakistan, which bridge equity demands and sovereignty concerns through technically credible proposals, are essential to sustaining this zone of convergence.

If the Tenth Review Conference in 2027 adopts such an architecture, it will be the treaty's most significant institutional advance in decades. Fifty years on, the BWC's most important work may lie immediately ahead, and patient, technical science diplomacy will be its instrument.

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The Enduring Utility of the 1979 Moon Treaty: Preparing for a New Era of Lunar Governance

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Abstract

The renewed global interest in lunar exploration, driven by governmental space programs, commercial ventures, and emerging international partnerships, has revived debates on the governance of activities beyond Earth. Against this backdrop, the 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Treaty) remains one of the most debated yet least understood instruments of international space law. Despite its limited ratification and the absence of major spacefaring nations among its States Parties, the Treaty contains substantive provisions that address many of the governance challenges now arising from expanding lunar activities. This article re-examines the Moon Treaty from a contemporary legal and policy perspective, arguing that its relevance should be assessed not solely through the lens of political adherence but through the practical utility of its provisions. The study analyses key treaty elements relating to transparency, consultation, resource utilization, compliance mechanisms, peaceful use, operational safety, and international cooperation. It further situates these provisions within the evolving landscape of lunar governance, including the Artemis Accords, the International Lunar Research Station initiative, and the ongoing work of the Committee on the Peaceful Uses of Outer Space (COPUOS) Action Team on Lunar Activities Consultation (ATLAC). Adopting a balanced and forward-looking approach, the article contends that the Moon Treaty offers a valuable reservoir of pre-negotiated multilateral norms that can inform future governance arrangements. The paper concludes that constructive engagement with the Treaty's substantive provisions can strengthen international dialogue, promote responsible lunar activities, and contribute to an inclusive and cooperative framework for the peaceful exploration and sustainable use of lunar resources.

Keywords: Moon Treaty, lunar governance, space diplomacy, international space law, COPUOS, Artemis Accords, lunar resources, international cooperation.

1. Introduction

More than four decades after its adoption, the Moon Treaty Governing the Activities of States on the Moon and Other Celestial Bodies² (the Moon Treaty) occupies an

¹ The views expressed in this article are those of the author and do not necessarily reflect the official position of the Ministry of Foreign Affairs of the Islamic Republic of Pakistan.

² Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, opened for signature 18 December 1979, entered into force 11 July 1984, 1363 UNTS 3 (hereinafter "Moon Treaty").

The Enduring Utility of the 1979 Moon Treaty

unusual place in the corpus of international space law. It is in force, registered as international law, and was negotiated through the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) over nearly a decade of deliberations. Yet it counts only seventeen States Parties,³ none of which presently engages in self-launched human spaceflight, and it is frequently characterised, in both scholarly and policy writing, as a failed or marginal instrument. The conventional account treats the Moon Treaty as a closed chapter, of historical interest perhaps, but of limited relevance to the lunar activities now unfolding.

This article advances a different view, consonant with a growing strand of scholarship that has begun to revisit the Moon Treaty on its substantive merits rather than on the politics of adherence (Tronchetti, 2024; Hobe, 2019).^{4, 5} The conventional account, while accurate as to the politics of adherence, overlooks something more fundamental: that the Moon Treaty contains substantive treaty provisions, multilaterally negotiated and now part of international law, on precisely the questions that the international community is being forced to confront as lunar activity accelerates. The number of States Parties is a political fact; the content of the text is a legal and intellectual fact, and the two should not be conflated. Whatever shape future lunar governance arrangements take, the pre-negotiated text on questions the international community must answer should not be ignored.

The argument is developed across five sections. Part 2 sets out the present status and contested legacy of the Moon Treaty. Part 3, the analytical heart, identifies the provisions that bear directly on contemporary lunar governance questions, organised by the functional question they address rather than by article. Part 4 situates these provisions within the fragmented landscape of lunar governance, including the ongoing work of the COPUOS Action Team on Lunar Activities Consultation (ATLAC). Part 5 sets out implications, and Part 6 concludes with recommendations.

2. The Moon Treaty: Status, Origins and Contested Legacy

The Moon Treaty was adopted by the United Nations General Assembly on 5 December 1979 in resolution 34/68, which commended the Moon Treaty and expressed the General Assembly's hope for the widest possible adherence to it.⁶ The Moon Treaty was opened for signature on 18 December 1979 and entered into force on 11 July 1984, upon the deposit of the fifth instrument of ratification. It is the fifth and most ambitious of the United Nations space treaties, building upon and extending the

3 United Nations Office for Outer Space Affairs, "Moon Agreement", status of signatories and parties, available at <https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html>. Saudi Arabia gave notice of withdrawal in January 2023, with effect from January 2024, bringing the number of States Parties to seventeen.

4 Tronchetti, F. (2024) 'Moon Agreement: Key Provisions', in Bhat B., S., Ukey, D. and Variath, A. (eds.) *International Space Law in the New Space Era: Principles and Challenges*. Oxford: Oxford University Press, pp. 165–182, observing that despite limited ratification the Moon Treaty retains legal relevance, particularly in respect of the principles governing space resource utilisation.

5 Hobe, S. (2019) 'The Relevance of the Moon Agreement in the 21st Century', *ZLW – German Journal of Air and Space Law*, 68(3), pp. 437–454. See also Hobe, S. (2010) 'The Moon Agreement: Let's Use the Chance!', *ZLW*, 59(3).

6 UN General Assembly Resolution 34/68 of 5 December 1979, paragraph 3 (expressing the General Assembly's hope for the widest possible adherence to the Moon Treaty).

principles set out in the 1967 Outer Space Treaty as they apply to the Moon and other celestial bodies of the Solar System.

The Moon Treaty's legal status is unambiguous. It has been registered under Article 102 of the Charter of the United Nations and forms part of international law binding upon its States Parties. The same point was made authoritatively by States Parties themselves in a Joint Statement submitted to the forty-seventh session of the COPU-OS Legal Subcommittee in 2008, co-sponsored by Austria, Belgium, Chile, Mexico, the Netherlands, Pakistan, and the Philippines.⁷ That statement, while acknowledging the relatively poor rate of participation, set out in some detail the substantive provisions of the Moon Treaty that constitute its added value in relation to the 1967 Outer Space Treaty.⁸ It remains the most authoritative collective articulation of the Moon Treaty's contemporary relevance, and the analysis in Part 3 below draws extensively upon it.

There is no value in evading the politics of adherence. The major spacefaring States, the United States, the Russian Federation, China, and Japan, are not parties. Of the States that have reached the lunar surface, only India is a signatory (and not a State Party). Four States, namely France, Guatemala, India, and Romania, have signed but not ratified. In January 2023, Saudi Arabia notified the United Nations Secretary-General of its withdrawal from the Moon Treaty, the first such withdrawal from any of the United Nations space treaties (Listner and Newman, 2023);⁹ This took effect in January 2024. Adherence has thus contracted rather than expanded. The States Parties have, however, candidly acknowledged this reality and have done so without retreating from the proposition that the Moon Treaty's substantive provisions retain value.¹⁰

The principal source of political contestation has been Article 11, which describes the Moon and its natural resources as the common heritage of mankind and contemplates the future establishment of an international regime to govern the exploitation of those resources. The provision has been read, particularly in some capitals, as constraining commercial activity or as prescribing a particular distributive arrangement. Whether that reading is correct, a question to which we return in Part 3, the perception of constraint has shaped the politics of adherence. It has also informed the emergence, in parallel, of non-binding political instruments such as the Artemis Accords, which by February 2026 had sixty-one signatories and which articulate a particular vision of co-operative lunar exploration without engaging the Moon Treaty framework (Deplano,

7 Joint Statement on the benefits of adherence to the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies of 1979 by States Parties to that Agreement, submitted by Austria, Belgium, Chile, Mexico, the Netherlands, Pakistan and the Philippines, UN doc A/AC.105/C.2/2008/CRP.11 (2 April 2008) (hereinafter "2008 Joint Statement").

8 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, opened for signature 27 January 1967, entered into force 10 October 1967, 610 UNTS 205 (hereinafter "Outer Space Treaty").

9 Listner, M. and Newman, C. (2023) 'The Moon Agreement: Hanging by a Thread?', McGill Institute of Air and Space Law, 9 February, available at <https://www.mcgill.ca/iasl/article/moon-agreement-hanging-thread> (analysing the implications of the Saudi withdrawal for the future of the Moon Treaty).

10 2008 Joint Statement, supra n. 7, paragraph 4 (acknowledging the "relatively poor rate of participation" while affirming that the Moon Treaty, having been registered under Article 102 of the UN Charter and entered into force in 1984, is part of international law).

2021).^{11, 12} The compatibility of the Accords with the Moon Treaty has itself been the subject of significant scholarly analysis, particularly in respect of States parties to both instruments, such as Australia and Mexico (Nelson, 2020; Cocca y Esquivel, 2024).¹³

3. A Reservoir of Pre-Negotiated Provisions

The analytical case for the Moon Treaty's contemporary relevance does not rest on its political prospects. It rests on a more straightforward observation: that the Moon Treaty contains pre-negotiated multilateral text on a series of questions that lunar activities are now raising in practice, and that this text exists regardless of how many States have chosen to ratify the instrument (von der Dunk and Tronchetti, 2015).¹⁴ The following provisions illustrate the point. The list is not exhaustive; it is intended to demonstrate the breadth of substantive coverage that the Moon Treaty provides.

Notification and transparency of lunar activities: Article 5 of the Moon Treaty requires States Parties to inform the Secretary-General of the United Nations, as well as the public and the international scientific community, to the greatest extent feasible and practicable, of their activities concerned with the exploration and use of the Moon. The provision specifies the information to be provided, including the time, purposes, locations, orbital parameters, and duration of each mission, and contemplates periodic reporting for missions of longer duration.¹⁵ Article 9, in turn, addresses the establishment of stations on the Moon: it preserves the freedom of States Parties to establish stations, while subjecting that freedom to substantive and procedural conditions, including the requirement to inform the Secretary-General of the location and purpose of such stations and to ensure that other States Parties are not interfered with.¹⁶ Read together, these provisions amount to a treaty-grade transparency framework on questions that, at present, are addressed in a scattered and largely voluntary manner across various technical fora.

Resource exploitation and the contemplated international regime: Article 11 is the most discussed and most contested provision of the Moon Treaty. Three points merit emphasis. First, Article 11 is the only provision in any of the United Nations space

11 Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes (13 October 2020). As of February 2026, sixty-one States had signed the Accords; see United States National Statement, 63rd Session of the Scientific and Technical Subcommittee of COPUOS, 3 February 2026.

12 Deplano, R. (2021) 'The Artemis Accords: Evolution or Revolution in International Space Law?', *International and Comparative Law Quarterly*, 70(3), pp. 799–819, arguing that the Accords, while rooted in the Outer Space Treaty, introduce a significant innovation by replacing the anticipatory approach to the regulation of space resources.

13 On the compatibility question for States parties to both instruments, see Nelson, J.W. (2020) 'The Artemis Accords and the Future of International Space Law', *ASIL Insights*, 24(31); and Cocca y Esquivel, A.A.M. (2024) 'The Moon Agreement and the Artemis Accords: Is Latin America at a Crossroads?', in Froehlich, A. (ed.) *Space Fostering Latin American Societies*. Cham: Springer.

14 On the interpretation of the relevant provisions generally, see von der Dunk, F. and Tronchetti, F. (eds.) (2015) *Handbook of Space Law*. Cheltenham: Edward Elgar Publishing.

15 Moon Treaty, Article 5, paragraphs 1 to 3 (concerning the duty of States Parties to inform the Secretary-General, the public and the international scientific community of activities, missions and results).

16 Moon Treaty, Article 9 (concerning the establishment of stations on the Moon and the information to be furnished thereon to the Secretary-General). See also 2008 Joint Statement, *supra* n. 7, identifying Article 9 as one of the principal areas of added value of the Moon Treaty over and above the Outer Space Treaty.

treaties that explicitly anticipates the question of resource exploitation; it neither prohibits such exploitation nor pre-excludes any modality of it, whether public or private, and it does not forbid commercial treatment of lunar resources. Second, paragraph 5 contemplates the establishment of an international regime to govern such exploitation when it is about to become feasible; the Moon Treaty leaves the form, content, and timing of that regime to be determined by the States involved at the relevant time, including in light of technological developments. Third, paragraph 7 articulates four objectives that any such regime should serve, namely the orderly and safe development of lunar resources, the rational management of those resources, the expansion of opportunities in their use, and an equitable sharing by all States Parties in the benefits derived from those resources.¹⁷ These four objectives are not aspirational rhetoric. They identify the substantive policy questions that any framework for the exploitation of lunar resources will, at some point, have to answer, whether that framework is constructed within or outside the Moon Treaty. The 2008 Joint Statement made the same point in different terms when it observed that the Moon Treaty “does not pre-exclude any modality of exploitation, by public and/or by private entities, nor forbids commercial treatment, as long as such exploitation is compatible with the requirements of the Common Heritage of Mankind regime.”

Compliance and mutual assurance: Article 15 grants each State Party the right to assure itself that the activities of other States Parties are compatible with the Moon Treaty, and to this end provides that all space vehicles, equipment, facilities, stations and installations on the Moon shall be open to other States Parties, subject to reasonable advance notice and the avoidance of interference with normal operations.¹⁸ The 2008 Joint Statement compared the provision to the inspection regime of the 1959 Antarctic Treaty and observed that it accords with the principles of international cooperation that govern activities on the Moon and other celestial bodies. As the number of lunar missions multiplies, including missions in geographically proximate areas such as the lunar south polar region, the question of how States verify each other’s compliance with peaceful-use commitments will become operationally significant. Article 15 offers a pre-agreed framework for doing so.

Due regard and consultations: Articles 2, 4, and 5 elaborate the principle of due regard, which is itself drawn from Article IX of the 1967 Outer Space Treaty, in the specific context of lunar activities.¹⁹ They require States Parties to conduct their lunar activities with due regard to the corresponding interests of all other States Parties and contemplate consultations in cases where a State Party has reason to believe that another State Party is interfering with the rights of the former. The relevance of these

17 Moon Treaty, Article 11, paragraphs 5 and 7. The four objectives identified in paragraph 7 are: (a) the orderly and safe development of the natural resources of the Moon; (b) the rational management of those resources; (c) the expansion of opportunities in the use of those resources; and (d) an equitable sharing by all States Parties in the benefits derived from those resources.

18 Moon Treaty, Article 15, paragraph 1 (each State Party may assure itself that the activities of other States Parties in the exploration and use of the Moon are compatible with the provisions of the Moon Treaty; to this end, all space vehicles, equipment, facilities, stations and installations on the Moon shall be open to other States Parties).

19 Moon Treaty, Articles 2, 4 and 5; Outer Space Treaty, Article IX (concerning the principle of due regard to the corresponding interests of other States Parties).

The Enduring Utility of the 1979 Moon Treaty

provisions to the contemporary debate is direct: the lack of structured consultation arrangements is one of the principal gaps that the Action Team on Lunar Activities Consultation has been mandated to address.

Safety of personnel and equipment: Articles 10 and 12 extend the protections of the 1968 Rescue Agreement to personnel on the Moon and provide for the use, in cases of emergency, of the equipment, vehicles, installations, facilities and supplies of other States Parties.²⁰ These provisions speak to operational safety questions that will become increasingly salient as crewed lunar missions resume and as commercial actors enter the lunar environment.

Peaceful use and disarmament: Article 3 reiterates and extends the demilitarisation and peaceful-use principles of the 1967 Outer Space Treaty in the specific context of the Moon, prohibiting any threat or use of force or any other hostile act or threat of hostile act on the Moon.²¹ In a period in which the militarisation of outer space is a matter of growing international concern, the existence of treaty-level prohibitions on hostile activity on the Moon retains both legal and normative value.

Read collectively, these provisions describe a framework that addresses transparency, station establishment, resource exploitation, compliance, due regard, consultations, operational safety, and peaceful use. Each of these is a live question in 2026. None has been resolved comprehensively in any other treaty instrument. The provisions of the Moon Treaty do not, of themselves, constitute a complete governance framework for contemporary lunar activities, and they were not designed to do so. They do, however, constitute a pre-negotiated multilateral baseline on the substantive questions that any future framework will have to address.

4. The Contemporary Lunar Governance Landscape

The relevance of the Moon Treaty's substantive provisions is clarified, rather than obscured, by considering the landscape within which contemporary lunar governance is being addressed. That landscape is fragmented across three layers, and the fragmentation itself is part of the diagnostic case for engaging seriously with the Moon Treaty's text.

At the technical layer, a number of international mechanisms have active workstreams on lunar issues. There are, at the moment, six mechanisms: the International Telecommunication Union, the Space Frequencies Coordination Group, the International Committee on Global Navigation Satellite Systems, the Interagency Operations Advisory Group, the Consultative Committee for Space Data Systems, and the International Space Exploration Coordination Group. Three further mechanisms, the Inter-Agency Space Debris Coordination Committee, the International Asteroid Warning Network, and the Space Mission Planning Advisory Group, possess space-related expertise of

²⁰ Moon Treaty, Articles 10 and 12. See also Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, opened for signature 22 April 1968, entered into force 3 December 1968, 672 UNTS 119.

²¹ Moon Treaty, Article 3 (concerning the exclusively peaceful use of the Moon and the prohibition of any threat or use of force or other hostile act thereon).

high relevance to lunar issues. These mechanisms share three structural features: their mandates are technical, their participation is at the agency or operational level rather than at the State-to-State level, and, with the notable exception of the International Telecommunication Union, their outputs are voluntary and non-binding. None of them has a mandate to address legal or policy aspects of lunar activities, and none has a mandate to consider lunar issues holistically.

At the policy and political layer, the picture is similarly fragmented. Within the United Nations system, the principal forum currently considering the question of how the international community might better coordinate lunar activities is the Action Team on Lunar Activities Consultation, established by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) at its sixty-seventh session in 2024 and currently operating under a three-year workplan running from 2025 to 2027, with the possibility of continuation into 2028 (Lee, 2025).^{22, 23} The Action Team, co-chaired by Pakistan and Romania, is mandated to conduct focused, expert-level exchanges aimed at developing recommendations to improve consultations related to lunar activities, considering different options, including, for example, whether to recommend the establishment of an international mechanism. In 2026, it is in its elaboration phase, with finalisation of recommendations expected in 2027.²⁴

Outside the United Nations system, the Artemis Accords, opened for signature in October 2020, articulate a set of principles for cooperative lunar exploration and have attracted broad adherence; they are non-binding and do not engage the Moon Treaty framework. At the same time, in 2021, China and Russia announced the International Lunar Research Station (ILRS), which would carry out multi-objective and multi-disciplinary research activities (Su, 2023).²⁵ The Accords and the ILRS are now widely understood as parallel and, in some respects, competing architectural visions for lunar exploration (Wang, 2025).²⁶

Within this current landscape, there are five broad gaps that can be identified. There is no international mechanism specifically mandated to focus on lunar activities; there is no international mechanism considering lunar issues at the governmental level; there is no international mechanism considering lunar issues from the legal and policy angles; there is no international mechanism with independent legal status and decision-making competences, with the limited exception of the International Telecommunication Union within its specific mandate; and, there is no international mechanism addressing critical questions such as debris and disposal in the lunar environment, harmful

22 Lee, M. (2025) 'ATLAC and the Early Emergence of Lunar Governance', *The Space Review*, 17 March, available at <https://www.thespacereview.com/article/4953/1>.

23 Established by the Committee on the Peaceful Uses of Outer Space at its sixty-seventh session in 2024; see Report of the Committee on the Peaceful Uses of Outer Space on its sixty-seventh session, UN doc A/79/20, Annex IV. The mandate, terms of reference and methods of work of the Action Team on Lunar Activities Consultation were endorsed by the Committee at the same session.

24 Workplan of the Action Team on Lunar Activities Consultation (2025–2027/2028), endorsed by the Committee at its sixty-eighth session in 2025.

25 Su, J. (2023) 'The International Lunar Research Station: China's New Era of Space Cooperation and Its New Role in the Space Legal Order', *Space Policy*, 64, 101535.

26 Wang, G. (2025) 'Legal Measures to Preserve Lunar Security and Safety in the Context of China–US Competition to the Moon: An Appraisal from China's Perspective', *Leiden Journal of International Law*, 38(3) (observing that neither a US-centric nor a Sino-Russian-centric regime would benefit humanity, and that coordination between them is necessary).

The Enduring Utility of the 1979 Moon Treaty

interference between proximity operations, and scientific, cultural, ethical and environmental considerations associated with lunar activities (Wang, 2025).

At the moment, discussions within this ambit have revealed that any international mechanism can fulfil four significant functions, namely information sharing, consultation, coordination, and guidelines development. Each of these functions can correspond to provisions already present in the Moon Treaty. Information sharing maps onto Articles 5 and 9. Consultation maps onto Articles 2, 4, and 5. Coordination, in the operational sense, draws upon Articles 9 and 12. Guidelines development, in respect of resource activities, is anticipated by Article 11. The substantive coverage of the Moon Treaty's text is not a substitute for the institutional architecture towards which these discussions point, but neither is it irrelevant to that architecture. The Moon Treaty contains pre-negotiated multilateral language on questions that institutional design will have to confront. Whatever institutional form may eventually be formed, it would be analytically peculiar, and arguably wasteful, to construct that institutional design without reference to the existing treaty text on the same substantive questions.

5. Implications and Considerations

Three considerations follow from the foregoing analysis, each offered without overstatement.

First, the Moon Treaty should not be left out of contemporary lunar governance debates on the grounds of limited ratification alone. The argument that a treaty with seventeen States Parties is institutionally weak is sound; the argument that its provisions are therefore substantively irrelevant does not follow. The substantive questions the Moon Treaty addresses are present, real, and active. The text is not consulted as often as it might be, in part because its political reputation has overshadowed its analytical content. Bringing that content back into the conversation is a contribution that scholars, practitioners, and States can all make.

Second, States Parties have a particular interest, and arguably a particular responsibility, in articulating the Moon Treaty's continuing relevance. The 2008 Joint Statement remains the most authoritative collective articulation of the Moon Treaty's value, and it has aged well in substance. Nearly two decades on, however, the lunar context has changed materially: missions have multiplied, commercial actors have entered the field, technical mechanisms have proliferated, and the political landscape has been reshaped by the Artemis Accords and by the establishment of new forums such as the Action Team on Lunar Activities Consultation. A refreshed collective articulation, reflecting the substantive analysis offered above and updated to the realities of 2026, would be a natural next step.

Third, non-parties also have an interest in the Moon Treaty's substantive provisions, irrespective of any decision on ratification. The drafting history of the Moon Treaty reflects the broadest range of political and regional perspectives then available, and the resulting text speaks to questions any future framework will have to address. Engagement with the text need not entail acceptance of its institutional implications; it

does, however, allow for a more informed conversation about the substantive choices that lunar governance will require.

6. Recommendations

First, renewed scholarly and policy engagement with the Moon Treaty's substantive provisions: Academic institutions, think tanks, professional associations and bar bodies are well placed to engage with the Moon Treaty's text on its own analytical merits, independent of the politics of adherence. The corpus of scholarship on the Outer Space Treaty has grown considerably in the last decade; a comparable engagement with the Moon Treaty is overdue, though recent contributions have begun to revisit the instrument in light of contemporary realities (Hobe, 2019; Tronchetti, 2024).²⁷ The present article is offered as a modest contribution to that effort.

Second, informal coordination among existing States Parties: States Parties have not coordinated systematically on the Moon Treaty's contemporary relevance since the 2008 Joint Statement. Informal consultations among interested States Parties, building on the 2008 precedent and reflecting the developments of the intervening years, would be a natural next step. The objective of such consultations would not be to advance a campaign of further ratification, which is a separate question, but to identify the substantive elements of the Moon Treaty that bear on contemporary lunar governance questions and to give those elements clearer collective expression.

Third, a refreshed collective articulation: Should informal consultations yield common ground, a natural vehicle would be a refreshed Joint Statement submitted to a forthcoming session of the COPUOS Legal Subcommittee, building on the 2008 precedent.²⁸ Such a statement would update the substantive analysis to reflect the lunar realities of 2026, including the proliferation of technical mechanisms, the emergence of non-binding political instruments, and the establishment of ATLAC. It would not engage in the politics of adherence, which lies beyond its purpose; it would articulate, with renewed authority, the substantive contribution the Moon Treaty makes to the international community's thinking on lunar governance.

Fourth, engagement with the Action Team on Lunar Activities Consultation: ATLAC, established by COPUOS at its sixty-seventh session and now in its elaboration phase, provides a natural forum in which the Moon Treaty's substantive contributions can be brought to bear on the broader conversation about future consultation arrangements for lunar activities. The Action Team's mandate is consultative rather than legislative, and its workplan is structured precisely around the kinds of substantive questions on which the Moon Treaty contains pre-negotiated text. Member States, including in particular States Parties to the Moon Treaty, are well positioned to ensure that the substantive analysis offered above informs ATLAC's deliberations. The Action Team's co-leadership currently rests with Romania and Pakistan, and Pakistan's continued engagement in this and other space diplomacy efforts at COPUOS provides one of several constructive channels through which such substantive contributions can be made.

²⁷ Hobe (2019), *supra* n. 5; Tronchetti (2024), *supra* n. 4.

²⁸ 2008 Joint Statement, *supra* n. 7.

7. Conclusion

The 1979 Moon Treaty is neither the failed treaty of the conventional narrative nor a comprehensive answer to the lunar governance questions of 2026. It is a reservoir of substantive multilateral text on questions the international community is now confronting in practice, developed through nearly a decade of negotiations that reflected the broadest range of perspectives then available. Its limited ratification is a political fact and an important one. Its substantive content is a separate and more enduring fact, and that content has aged better than the politics of adherence has allowed many readers to recognise.

As lunar activities expand and as discussions about future governance arrangements mature, including within the Action Team on Lunar Activities Consultation, the provisions of the Moon Treaty deserve substantive engagement on their merits. The case for that engagement does not depend on persuading any State to ratify; it depends on the substance of the text and the durability of the questions it sought to address. For States Parties, including Pakistan, that engagement is also an opportunity to contribute to a conversation in which they have both standing and interest. For non-parties, it is an invitation to draw on a resource that exists and that addresses, in pre-negotiated form, questions that lunar governance will, in time, have to answer.

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Regulating Military AI: Why IHL sufficiency fiction may not sustain

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Abstract

The rapid integration of Artificial Intelligence (AI) into military operations has exposed significant gaps in the existing international legal framework governing armed conflict. This paper argues that the prevailing assumption that International Humanitarian Law (IHL), particularly Article 36 of Additional Protocol I to the Geneva Conventions, is sufficient to regulate Lethal Autonomous Weapons Systems (LAWS) is increasingly unsustainable. Drawing on recent developments in the Russia–Ukraine conflict and the Iran–US–Israel conflict, the paper demonstrates how AI-enabled weapons systems are evolving faster than existing regulatory institutions can respond. It highlights three major shortcomings of the current framework: the absence of a universally accepted definition of “meaningful human control,” the fragmented and privatised structure of the military AI industry, and the operational tempo of AI-assisted warfare that undermines genuine human oversight. The study further examines the growing accountability gap created by the involvement of private technology companies in the design and deployment of military AI systems. In response, the paper proposes a three-tiered policy approach consisting of a legally binding prohibition on fully autonomous weapons, investment in adaptive regulatory capacity through “radical optionality,” and greater coalition-building among middle powers such as Pakistan. The paper concludes that the challenges posed by military AI are no longer theoretical and require urgent international regulatory action to preserve accountability, strategic stability, and compliance with humanitarian law.

Keywords: Artificial Intelligence (AI), Lethal Autonomous Weapons Systems (LAWS); International Humanitarian Law (IHL), Meaningful Human Control; Military AI; Autonomous Warfare, Article 36, AI Governance; International Security, Pakistan Foreign Policy.

The rapid militarisation of Artificial Intelligence is outpacing the international community’s capacity to govern it. As AI-powered weapons systems are deployed across active conflict zones and the regulatory appetite of major powers declines, the risks of inadequate oversight are compounding. The argument that existing International Humanitarian Law (IHL) is adequate to govern the development and use of Lethal Autonomous Weapons Systems (LAWS) is insufficient. It is imperative to have new regulatory frameworks that combine a prohibition on fully autonomous systems with targeted capacity-building measures. For Pakistan, these developments carry specific strategic implications that require an engaged and proactive policy response.

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Regulating Military AI: Why IHL Sufficiency Fiction may not Sustain

The primary multilateral forum for addressing military AI is the Group of Governmental Experts on Lethal Autonomous Weapons Systems (GGE LAWS), convened under the Convention on Certain Conventional Weapons (CCW). The Seventh Review Conference of the High Contracting Parties, to be held in Geneva this year, will decide whether to commence negotiations of a legally binding instrument to prohibit LAWS that operate without meaningful human control, systems known sometimes by their dysphemism as “killer robots”. This forum matters because it brings the principal actors in the military AI industry to a common table.

The other significant venue for discussions on military applications of Artificial Intelligence has been the Summit on Responsible Artificial Intelligence in the Military Domain (REAIM). However, it is neither inclusive nor focused on the specific challenges associated with LAWS. At its first iteration in the Netherlands in 2023, sixty countries, including the US and China, though not Russia, participated and endorsed a “Call to Action”. By the third summit, held in Spain in February 2026, participation had declined sharply: only thirty-five of eighty-five attending countries signed the outcome document, “Pathways to Action”, and neither the US nor China participated (Horowitz, 2026). This trajectory reflects a broader erosion of political will among major powers to submit their military AI programmes to meaningful international scrutiny.

While regulatory momentum falters, military AI adoption is accelerating rapidly. The conflict between Russia and Ukraine as well as Iran-US-Israel conflict have become operational laboratories for these technologies. Ukraine has been testing autonomous drones and unmanned ground vehicles at scale and is reportedly approaching the capability threshold for fully autonomous systems capable of making real-time targeting decisions without human intervention (Adler, 2026). The United States has deployed AI-powered targeting platforms, notably tools developed by Palantir and Anthropic, capable of processing and selecting multiple targets simultaneously at a pace that fundamentally changes the character of warfare (Tara Copp, 2026).

These developments are not peripheral experiments. They represent a qualitative shift in how force is projected, and they are occurring faster than any regulatory framework has been designed to address. Many experts have characterised this as a new arms race, one in which AI-enabled weapons systems are emerging as a novel form of strategic deterrence, with some drawing explicit parallels to the logic of mutually assured destruction. Companies such as Anduril in the United States, ZALA in Russia, and AVIC in China are outpacing their competitors in the development of autonomous drone technologies, reshaping the competitive landscape of modern warfare (Satariano, 2026).

The parallel with nuclear weapons, however, has its limits: the consequences of nuclear conflict are well understood and have informed decades of arms control architecture. The risks of AI-enabled warfare remain far less legible, strategically, legally, and ethically. This uncertainty is compounded by the fact that the current arms race is being driven not only by state actors and traditional defence contractors, but increasingly by technology startups operating at a pace that existing regulatory structures are ill-equipped to match.

The standard response of states to concerns about military AI is that existing IHL, and specifically Article 36 of Additional Protocol I to the Geneva Conventions, provides an adequate regulatory framework. Article 36 requires High Contracting Parties to ensure compliance with international law in the “study, development, acquisition or adoption of a new weapon, means or method of warfare”. The argument is that as long as a human authorises the use of force, the technology in question is covered by these existing obligations (Pacholska, 2025). There are three major inadequacies associated with this argument.

First, the concept of “human control” which underpins the entire existing regulatory framework lacks any agreed legal definition. The United States defines it as allowing “commanders and operators to exercise appropriate levels of human judgment over the use of force” (Sayler, 2026). China, Russia, Germany, and others employ similarly open-ended formulations centred on “appropriate” or “reasonable” levels of human judgment. The absence of a common legal threshold means that every state self-certifies compliance, without any external mechanism for verification.

Second, the architecture of the military AI industry makes Article 36 compliance extremely difficult to ensure in practice. A recent SIPRI report, “Mapping the Military AI Industry” (Dr Alexander Blanchard, 2026), identifies three distinct layers of actors: the Hardware and Infrastructure Layer (chips, storage, data centres); the Foundational Software and Programming Layer (large language models and AI platforms); and the Application Layer (specific task-oriented tools deployed in the field). Within and across these layers, the report identifies four categories of actors: Defence Primes such as Lockheed Martin; Neoprimes building AI-specific products, such as Palantir; Big Tech companies including Microsoft and Google; and Foundational Model Providers such as OpenAI and Anthropic.

Article 36 is a state obligation, but the entities actually designing, training, and deploying these systems are predominantly private actors operating across multiple jurisdictions and layers of development. Ensuring consistent legal compliance across this distributed ecosystem and attributing responsibility when compliance breaks down goes well beyond what Article 36 was designed to do.

Third, even where human oversight nominally exists, the tempo of AI-assisted operations creates conditions in which that oversight is structurally inadequate. The United States reportedly conducted over 1,000 strikes against Iranian targets in the first twenty-four hours of its recent campaign (Tara Copp, 2026). One of those strikes hit a girls’ school, killing 175 people, an outcome attributed to an AI targeting system trained on outdated data (Baker, 2026). This incident illustrates a critical vulnerability: even when a human formally authorises each action, the cognitive and chronological conditions required for meaningful judgment are not present at that pace of operations. The fiction that a human “in the loop” guarantees compliance with IHL is increasingly difficult to sustain.

These failures in the existing framework converge on a deeper problem: the question of legal responsibility for harm caused by AI-enabled weapons systems is unre-

Regulating Military AI: Why IHL Sufficiency Fiction may not Sustain

solved. States generally maintain that a human chain of command lies behind every system, however autonomous, and that human responsibility therefore persists. Yet the diffusion of the development and deployment chain across multiple private actors, jurisdictions, and technical layers makes this claim increasingly hollow in practice. Palantir has explicitly disclaimed responsibility for errors committed by systems it has developed (Palantir, 2025). If neither the developer, the deployer, nor the state operator can be clearly held to account for a given harm, the deterrent function of IHL is fundamentally undermined. This accountability gap is not resolved by Article 36; it requires new legal mechanisms designed specifically for the distributed architecture of contemporary AI.

Given this analysis, three policy responses merit serious consideration, each operating at a different level.

Prohibition of LAWS

The most urgent is a binding prohibition on LAWS that operate without meaningful human control. The precedent exists: the Chemical Weapons Convention and the Biological Weapons Convention demonstrate that categorical prohibitions on specific classes of weapons are achievable within international law. Pakistan has already articulated support for this position in its working paper to the UN General Assembly and should advocate for it actively and specifically within the CCW process, pushing for a clear, legally defined threshold for human control rather than accepting formulations that allow each state to self-determine compliance (Pakistan, 2024).

Radical Optionality

Second, in parallel with prohibition efforts, states should invest in building regulatory capacity for semi-autonomous systems, an option termed as “radical optionality” by experts (Bullock, 2026). Since the trajectory of AI development cannot be predicted with precision, and since institutional preparation takes years, the priority is establishing governance infrastructure now. This would include mandatory transparency and reporting requirements for military AI development; robust whistleblower protections within defence industries; independent, third-party evaluation mechanisms for AI systems before deployment; and reforms to government hiring to bring technical expertise into regulatory bodies. These measures would also create a foundation for monitoring compliance with any future binding instrument.

Confidence-building measures

Third, Pakistan should also consider engaging in middle-power coalition-building or developing a platform of its own. As the REAIM process demonstrates, major powers are increasingly unwilling to constrain their own programmes through multilateral commitments. Middle powers, states with genuine stakes in the stability of the international order but without the asymmetric advantage that unregulated military AI confers on leading technology states, have both an interest in and a platform for articulating a distinct position (Horowitz, 2026). Pakistan’s diplomatic experience in

Geneva, its established engagement with the CCW process, and its regional strategic context, including proximity to nuclear-armed states also developing AI capabilities, all position it to play a substantive role in shaping this coalition.

The challenge of military AI regulation is not speculative. The systems under discussion are operational, the harms they can cause are documented, and the legal frameworks that ostensibly govern them are demonstrably inadequate to the institutional complexity and operational pace of contemporary AI-enabled warfare. The fact that major powers are retreating from regulatory commitments is an argument for more urgent and more precise engagement, not less. For Pakistan, whose security environment is directly shaped by the AI capabilities of its neighbours and the integrity of the international legal order, the stakes of inaction are concrete.

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Science Diplomacy for Peacebuilding: Cognitive Neuroscience as a Tool for Conflict Prevention and Post-Conflict Reconciliation

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Abstract

Conflict prevention and post-conflict reconciliation constitute the two important poles of the peacebuilding continuum. Normally, the conflict prevention or post-conflict reconciliation models include such elements as ranging from early warning to mediation; use of good offices; disarmament; and socio-economic development, to name a few. These essentially constitute structural, operational, and transnational components that are rooted in development, economic, and military tools. However, none of these components address the adversarial social construct of a particular nation or State towards the other, as the causal factor of any conflict between two States. This research paper presents the case for cognitive neuroscientific interventions as possible payloads in conflict prevention and post-conflict reconciliation by addressing the root causes of such adversarial social construct of two or more belligerent States towards each other. In doing so, this paper also presents the concept of neuro-cognitive diplomacy to integrate cognitive neuroscience-based models for preventing conflict and enabling post-conflict reconciliation with the field of international relations and diplomacy.

Keywords: Constructivist approach; Cognitive Neuroscience; Conflict prevention; Post-Conflict Reconciliation; Adversarial Social Construct; Neuro-cognitive diplomacy

Introduction

The modern-day interstate relations are quite complex in nature and range from peace and cooperation to being conflictual as well as competitive in nature (Testbook, n.d.). For managing the inter-state relations, the traditional diplomatic toolkit is still largely in vogue, which employs such modes and methods as mediation, good offices, development, and arms control, etc. (Kelly, 2022) to name a few, for managing inter-state conflicts or cooperative arrangements. The main focus of these modes and methods remains political and economic in connotation. It is for this reason that the above traditional diplomatic toolkit at times finds itself lacking in effectively managing inter-state relations, and most of the diplomatic endeavors therefore get wasted due to a lack of focus on addressing the root causes of conflicts or the avoidance of cooperation. With the evolution of the constructivist school of thought in international relations, a novel approach of understanding inter-state relations based on the social construct of the States towards each other has evolved (Theys, 2018). Accordingly, for the purposes of comprehending root causes of conflicts and cooperation between States, the so-

cio-psychological factors behind these root causes and the social construct of States towards each other have gained traction. A new scientific evidence-based approach is therefore needed for comprehending the socio-psychological factors, especially behind conflicts between states, as well as for deciphering the social construct of the States towards each other. It is essentially by addressing these aspects that cooperative possibilities between the States could also be evolved subsequently. This, indeed, is the aim of this research paper, which focuses on the peacebuilding linear and presents an alternative scientific evidence-based approach for conflict prevention and post-conflict reconciliation, anchored in cognitive neuroscientific interventions, as a payload of science diplomacy.

Contextualizing Conflict Prevention And Post-Conflict Reconciliation

Conflict Prevention and Post-Conflict Reconciliation form two important constituent elements of peacebuilding. (INCODIR, n.d.). Conflict prevention is meant to include the measures that are taken in order to halt or deter the tensions from escalating into armed violence, or even from reappearing after a peace settlement has been reached between the belligerent parties. The notion of conflict prevention involves both immediate interventions aimed at calming down the brewing disputes and long-term strategies that address such drivers of conflict that are structural in nature. (UNESCWA, n.d.). The different tools employed under conflict prevention include, among others, early warning, use of mediation or good offices, good governance, arms control and disarmament, socio-economic development, humanitarian and human rights law, as well as international justice. (Kelly, 2022). These tools are covered under the ambit of structural prevention, operational prevention, and systemic prevention models. (Melander & Pigache, n.d.). It is essentially the structural prevention model of conflict prevention that is relevant for the purposes of this paper. Structural prevention focuses on the root causes of violence. (Melander & Pigache, n.d.). However, a noticeable element in this regard is that the focus on the root causes thereof has remained restricted to the political, economic, and social features, rather than the broader socio-psychological aspects of the adversarial social construct of one State towards another State. Therefore, the reasons as to why a particular State develops animosity towards another State or draws fear or concern from an opponent State remain missing. Accordingly, it is essential to first understand why a State considers another State as the “adversary” to begin with. This paper focuses on the above elements and, therefore, considers the socio-psychological aspects as the root causes for any conflict, which need to be assessed and addressed in order to prevent a conflict from spilling over.

Post-conflict reconciliation is normally conceptualized as a goal and a process, at the same time. As a process, as per Bloomfield, Barnes, & Huyse, this notion is deemed to be quite expansive in nature and encompasses justice, healing, and reparation, so that movement towards a common future could be enabled (Bloomfield, Barnes, & Huyse, 2003). If one examines the components or tools in the post-conflict reconciliation, it would be observed that these are pivoted on different perspectives (Whitehouse, n.d.). Taking lead from the above observation of Whitehouse, it implies that the States hold

different perspectives regarding their rival 'others', which could be influenced by their particular social construct towards their rival State(s). Therefore, it is important to address the root causes related to an adversarial social construct of two or more States involved in a conflict with each other, during the post-conflict reconciliation process as well. This includes attempting to address the particular fears and biases that lead to the constitution of an adversarial social construct of one State towards the other. This paper would also address the above aspect by presenting the case for cognitive neuroscientific interventions.

Revisiting the Notion Of Social Construct Through a Constructivist Theoretical Lens

It would be pertinent to reflect on the concept of the social construct of States towards each other, in order to contextualize the discussion ahead. For this purpose, the constructivist theoretical framework of international politics is employed. As per the constructivist school of thought, the world and any understanding about it is socially constructed. (Theys, 2018). Furthermore, States tend to constitute certain identities regarding themselves as well as towards other States, which are all socially constructed. (Theys, 2018). This implies that States perceive other States based on ideas, norms, identities, (Theys, 2018) or perceptions that they hold towards 'other' States (Agius, 2022). It is essentially based on these perceptions and ideas that the States either perceive the 'other' States as friends or opponents. (Theys, 2018). It is this social construct of one State towards another that identifies the type of relations that such State would have towards the 'other' State(s) (Theys, 2018) (Agius, 2022). This social construct is evolved by a nation or State, based on its own peculiar perceptions of history, fears and concerns, or biases towards the 'other' State. This idea could be further advanced to extrapolate that it is on the basis of the above-mentioned fears, concerns, or biases that one State gets involved in a conflict against the adversary's other State. (Agius, 2022). This concept pervades the economic and development-related aspects and enters the realm of socio-psychological aspects of a nation's life. The social construct of a State towards another State(s) also hinges upon the very role or identity that a State views for itself in terms of global relations. (Theys, 2018). We could deduce from the above that a State also assumes for itself a certain role or identity, and therefore, based on that, pursues relations with other countries. (Theys, 2018). A theoretical premise for our discussion ahead could therefore be advanced on the above spectrum. Accordingly, if the decision makers of a State 'X' could hypothetically assume the role, biases, or concerns of the other State 'Y', they could better understand the likely causal factors of the concerns, biases, or fears of that competitor State 'Y'. In this manner, a State could not only contour its own foreign policy but also try to address the causal factors for concerns of fears of the adversary State in a better way.

Cognitive Neuroscience and Its Toolkit

In order to decipher the above-mentioned socio-psychological factors behind a certain bias of one State towards another or the social construct of States, this paper suggests employing the cognitive neuroscience-based models. This paper postulates that the

cognitive-neuroscience model is better placed for enabling a State to better comprehend the causal factors for the social construct of ‘self’ and the enemy State, with a view to preventing conflict or initiating post-conflict reconciliation.

A small word on cognitive neuroscience and some of its relevant techniques would be in order at this stage. Cognitive neuroscience essentially studies how the brain contours our behaviors, thoughts, and emotions (Anderson, 2024). By assessing the biological processes underlying our decision-making, learning, and thinking, cognitive neuroscience assists us in explaining how humans interact with the rest of the world (Anderson, 2024). Cognitive neuroscience, therefore, studies how our brain activity supports or assists our cerebral processes like perception, recollection, and problem-solving (Anderson, 2024). It examines the manner in which the structure of the brain creates the way we think and perform actions. This makes the field of cognitive neuroscience quite unique in nature (Anderson, 2024).

The field of cognitive neuroscience is mainly a combination of psychology, neuroscience, biology, and computer science. While psychologists study human behaviors, neuroscientists are involved in studying the brain, biologists examine body functions, and computer scientists construct models of the activity of the brain; cognitive neuroscience, through a combination of all the above factors, assists in creating a broader canvas of how the mind actually works. (Anderson, 2024).

The field of cognitive neuroscience has been quite beneficial in the domains of mental health as well as education. For instance, it assists the teachers and educators in designing improved learning techniques through a better comprehension of how memory works. In a similar manner, through cognitive neuroscience, therapists and doctors can employ the brain-related research for improving treatments for mental health conditions such as anxiety or depression. (Anderson, 2024).

In the domain of cognitive neuroscience, there are different techniques in use by scientists for studying brain activity nowadays. For instance, one imaging technique is called functional magnetic resonance imaging (fMRI). This technique was first developed during the 1990s. fMRI, essentially a non-invasive brain imaging technique, tracks changes in blood oxygen levels to study brain activity (Glover, 2011). As an example, when a part of the brain is activated, it consumes more oxygen, which alters the balance between oxygenated and deoxygenated blood. This produces a measurable signal called Blood Oxygen Level Dependent (BOLD) contrast. (Glover, 2011). Overall, this makes fMRI a very powerful tool for exploring how the brain supports thinking, memory, and decision-making. (Glover, 2011). Nowadays, researchers apply advanced statistical methods and machine learning to fMRI data for predicting the different states of the brain, developing biomarkers for diseases, and even training people to regulate their own brain activity. (Glover, 2011).

Positron Emission Tomography (PET) is another advanced imaging technique. It employs radioactive tracers for measuring the metabolic activity in our body and brain. PET is therefore very useful in cancer diagnosis, neurology, cardiology, and psychia-

Science Diplomacy for Peacebuilding

try (Kapoor, Heston, & Kasi., 2025). PET also assists in depicting the active regions of the brain under peculiar circumstances, such as stress, fear, memory recall, or decision-making (Kapoor, Heston, & Kasi., 2025).

There are certain electrophysiological techniques for studying human brain behaviors as well. For instance, an electroencephalogram (EEG) is a test that records our brain's electrical activity for detecting abnormalities in the brain waves. (John Hopkins Medicine, n.d.). EEGs are employed for evaluating such health conditions as epilepsy and brain lesions, to name a few. It also assesses certain psychiatric disorders, including trauma. (John Hopkins Medicine, n.d.). EEG techniques could therefore also be theoretically adapted in experimental settings, with a view to studying responses of individuals or groups to specific stimuli. This could reflect different cognitive or emotional patterns that are associated with decision-making, stress, or risk perception.

Magnetoencephalography (MEG) is another non-invasive method for measuring brain activity with millisecond precision. It therefore reveals both where and when the neurons are active (Institute for Learning and Brain Sciences, n.d.). MEG measures the neuronal activity directly, rather than through blood oxygenation (Institute for Learning and Brain Sciences, n.d.). MEG can be employed for studying how individuals respond to stimulated risk, stress, and even ethical dilemmas.

Interlacing Cognitive Neuroscience With Conflict Prevention and Post-Conflict Reconciliation

Before any conflict between two States or divided communities, there are indications of increasing polarization, prevalence of dehumanizing rhetoric, or mutual mistrust between them. The situation in the Balkans just before the breakup of the former Yugoslavia is a case in point. These aspects are essentially driven by such psychological factors as fear, trauma from perceived historical grievances, or in-group biases. Similarly, following the conflicts, the belligerent States face such gargantuan socio-psychological challenges as entrenched mistrust, collective trauma, and cycles of retribution. In such instances, traditional diplomacy remains handicapped in effectively addressing these deep-rooted psychological barriers. It is because the traditional diplomacy's toolkit takes on the issues from where they are placed and not from their points of origin. Diplomatic techniques and models such as mediation, truth and reconciliation, disarmament or arms control, and even international justice, tend to accept the situation on the ground as a starting point and do not factor in the psychological dilemmas referred to above, as the trigger points for the conflicts between two or more belligerent States or communities.

It is with the intention to address the above psychological dilemmas and the social constructs of States and societies towards each other that the role of cognitive neuroscience comes into play.

Through different cognitive neuroscientific tools on a "representative sample group" of any nation or State, the reasons for prejudices, empathy, and trauma modulate groups or States' dynamics could be established. Therefore, by addressing these psycholog-

ical traumas, the group or State leadership behaviors could be better understood, and overall State behaviors contoured through appropriate foreign policy approaches. For instance, by comprehending the prejudices based on amygdala-driven fear responses, empathy based on the study of mirror neuron activation, and trauma based on altered hippocampal function, the dynamics of the group of States could become more comprehensible.

In a pre-conflict situation, cognitive neuroscience could be employed for identifying and targeting early triggers of a conflict that are psychological in nature (For instance, dehumanization via out-group bias). By examining cross-community cognitive neuroscientific studies on “representative sample groups”, better comprehension of psychological trigger nodes could be made and, thereafter, appropriate policy options employed to address them. Similarly, in post-conflict situations, cognitive neuroscience could guide trauma-informed interventions.

In the following lines, we examine how, on a theoretical basis, different tools of cognitive neuroscience could be employed for better understanding the social construct of one State towards another State and policy options identified accordingly.

To begin with, Functional Magnetic Resonance Imaging (fMRI) could be used, for instance, to examine the blood flow to show which brain regions are activated when a sample group from a State ‘X’ is exposed to certain stimuli (e.g., the flag, speeches, or imagery of an opponent State). A heightened activity in the ‘amygdala’ may indicate fears or threats of the “representative sample groups,” e.g. memory of any invasion or colonization, while ‘prefrontal cortex’ activation may suggest rational evaluation or strategic thinking that could assist in understanding the manner of rational suppression of biases by the “representative sample groups”. Similarly, an fMRI done for the hippocampus could assist in assessing the historical recollection. On the basis of such studies, it could be better assessed in generalized terms as to what particular symbols, historical episodes, or professed values of an enemy ‘other’ State trigger fear or distrust in the target/focus State ‘X’ in general. These results could accordingly be employed in devising different foreign policy options for the purposes of conflict prevention or post-conflict reconciliation between two belligerent States.

Positron Emission Tomography (PET) could be employed on a “representative sample group” of the target/focus State ‘X’ to study their deep-seated biases or persistent perceptions about the enemy ‘other’ State. PET could be used to detect chronic patterns of metabolic activity, showing how deeply ingrained certain historical associations of the target/focus State ‘X’ are towards the enemy ‘other’ State (For instance, persistent suspicion of a State ‘X’ towards a former colonial power). PET could therefore reveal patterns of perception, bias, or emotional responses of the target/focus State ‘X’. In the context of international politics, the controlled PET studies on “representative sample groups” could help uncover deep-seated historical biases, security fears, or trust deficits between States by identifying how their brains react when exposed to symbols, narratives, or scenarios involving rival States or nations. Such insights could then be employed in conflict prevention and post-conflict reconciliation, as policy-

Science Diplomacy for Peacebuilding

makers would have a scientific lens to assess the subconscious drivers of hostility, mistrust, or cooperation among the belligerent States. This could also enable targeted dialogue and confidence-building strategies among such belligerent States.

Electroencephalography (EEG) could be used for detecting immediate emotional responses to different policy options, speeches, or symbolic actions by other States. For example, a rise in certain brain wave patterns might indicate heightened stress or openness.

Magnetoencephalography (MEG) could enable examination of exactly where and when the brains of “representative sample groups” react to another State’s actions, such as peace offers, sanctions, or threats. By exposing “representative sample groups” from a target/focus State ‘X’ to stimuli linked to historical events such as images of wars, alliances, treaties, flags, national symbols, or speeches from rival States, and/or maps highlighting disputed territories, the brain responses of the “representative sample groups” could reveal their emotional valence (fear, anger, trust, pride) linked to specific historical events.

MEG could also be used to study how “representative sample groups” respond to simulated stress, risk, or ethical dilemmas by capturing real-time neural activity. Exposing such “representative sample groups” to scenario-based simulations, while recording EEG responses, could reveal tendencies toward aggression, caution, or cooperation, which may also indirectly indicate historical biases, risk tolerance, or conflict-prone attitudes. Over time, such aggregated EEG data from multiple “representative sample groups” could provide deeper insights into a State’s collective decision-making style or predispositions in international relations. Accordingly, by analyzing such patterns, researchers could infer cognitive tendencies, decision-making strategies, and risk perceptions of the belligerent States in general, providing useful insights for conflict prevention, negotiation, and/or post-conflict reconciliation.

As mentioned earlier, EEG or MEG could be used to understand as to how fast a “representative sample group” reacts to historically sensitive triggers. In this context, a rapid and automatic negative response would suggest unconscious, long-standing bias. On the other end, a delayed and more controlled reaction by the “representative sample group” could indicate that group’s awareness of its bias but also hint at its attempt to rationally manage that bias. This understanding could be extremely helpful in gauging the willingness or otherwise of that “representative sample group” towards compromise, alongside its limits. These readings could be used for devising appropriate foreign policy options.

From the above discourse, we may infer that the above tools of cognitive neuroscience could be employed to undertake studies of “representative sample group” behaviors and then generalize these conclusions for mapping a State’s likely responses in different conflict or post-conflict situations. These tests could also guide us as to how the State’s leadership or diplomats would likely respond during any high-stakes talks. This would enable an assessment of that State’s level of trust in the rival State or even the mediators involved in facilitating the pre-conflict or post-conflict negotiations, as well as their willingness to compromise. These insights could be useful for belligerent

States as well, in better comprehending the expectations and redlines of an adversarial ‘other’ State while helping in contouring their foreign policies accordingly. For the long-term, such evaluations could assist in effectively addressing the other States’ fears, concerns, and biases. If broader ranges of representative social groups were studied, patterns could emerge showing the collective neural imprints of history on a State, in general. This would amount to mapping the cognitive neuroscience of collective memory, thus turning historical grievances or affinities into measurable brain activity, for appropriate foreign policy interventions, based on scientific evidence.

In the strategic context, the above studies or analyses could assist us in better explaining as to what psychological factors, fears, concerns and biases override rational agreements, thus explaining failure of agreements or treaties among States. This could also allow mediators to design bias-mitigating interventions, such as appropriate re-framing narratives or introducing such cooperative experiences that weaken negative neural responses.

From the above discussion, one would observe that the toolkit of cognitive neuroscience could be used in early detection of hostile historical biases and other elements of unconscious hostility much before these erupt into open conflict. This could assist in designing neural de-biasing dialogues including tailored confidence-building measures. As an instance, if a “representative sample group” reacts negatively to certain symbols, mediators could avoid triggering such manifestations during talks.

The above tools could also assist in understanding as to whether a State appears genuinely open to compromise, or its representatives are merely performing diplomacy. For instance, quick hostile responses from “representative sample groups” could suggest a fragile peace that might collapse. On the contrary, controlled, rational responses could be interpreted to depict readiness for pragmatic solutions. For Conflict Prevention, therefore, cognitive neuroscience tools act as early warning systems, unveiling hidden grievances before they explode into an open conflict.

In the post-conflict situations as well, cognitive neuroscience could help in diagnosing collective trauma in post-war societies. fMRI for instance, could show persistent threat responses to rival imagery, while EEG could be employed to reveal hypervigilance or distrust even during peace talks. The above studies could therefore be employed by mediators to design joint cultural, educational, or scientific projects that would create positive neural associations between belligerent States. For Post-Conflict Reconciliation, the cognitive neuroscience tools could enable scientific monitoring of peace processes, thus exhibiting as to whether reconciliation is truly taking root in the minds of the people of belligerent States or otherwise.

The main advantage of employing cognitive neuroscience interventions during conflict prevention and post-conflict reconciliation phases is that it relies on scientific evidence rather than self-reported trust surveys. It therefore graduates diplomacy to scientific-evidence based endeavor, rather than a trial-and-error exercise.

While presenting the case for cognitive neuroscience as a payload for science diplo-

Science Diplomacy for Peacebuilding

macy in preventing conflicts as well as during post-conflict reconciliation, one would need to consider different cultural and ethical sensitivities. For instance, any cognitive neuroscientific interventions in respect of “representative sample groups” should align with local beliefs and perspectives concerning mental health. In pre-conflict settings, the target communities in a State may actually resist such interventions as foreign; while in post-conflict settings, these interventions may be stigmatized. Similarly, the above interventions may also risk being perceived as manipulative and aiming at altering group perceptions or engineer propaganda tailored to exploit neural vulnerabilities. However, it may be noted that the suggested use of cognitive neuroscience here is only for analysis purposes and not desired to be manipulative in nature. Therefore, it is envisioned as a tool to better understand causal factors of a peculiar social construct of States towards other State(s), with a view to designing appropriate conflict prevention and post-conflict reconciliation strategies. It may also be added that the constitution of “representative sample groups” is only to be done on the basis of voluntary participation and not under duress, so that the representative insights from these sample groups could be gained.

In order to address the above concerns, diplomatic protocols that duly take into account and respect the ethical or cultural sensitivities at the global level would be required. For this purpose, a global framework for employing cognitive neuroscience for peacebuilding, especially conflict prevention and post conflict reconciliation would therefore be needed. In the domain of science diplomacy, international cognitive neuroscientific research hubs [for instance, research hubs modeled on the pattern of the European Organization for Nuclear Research (CERN)] could be established, gathering scientists from across the world, especially conflict-prone or post-conflict regions. Such research hubs could study bias assessment and suggested reduction in pre-conflict situation as well as trauma recovery during post-conflict milieus. The purpose of such research is self-explanatory. For instance, a shared study on fear responses in belligerent States could shift narratives from blame to shared humanity, thus preventing violence. In post-conflict milieu, collaborative research on trauma recovery could enable reconciliation, while creating empathetic linkages. Once institutionalized under the global framework with well-defined protocols, the diplomatic community could then embed such cognitive neuroscientific insights into pre-conflict prevention strategies such as community dialogue programs as well as post-conflict peace arrangements (for instance truth-and-reconciliation commissions), thus ensuring that the policies and approaches reflect psychological realities.

Cognitive Neurodiplomacy

Based on the above discussion pertaining to the employment of cognitive neuroscience in international relations, we enter into a new realm of diplomacy that may be termed “Cognitive Neurodiplomacy”. In its elementary form, this type of diplomacy could be conceptualized as an interdisciplinary field, where cognitive neuroscientific interventions and insights, involving shared inquiry into brain functions and processes, are employed for understanding and addressing the socio-psychological prejudices

and biases as well as the peculiar social construct of groups, communities or States towards each other, with a view to managing and improving inter-State relations. This type of diplomacy is one step ahead of cultural heritage-focused neurodiplomacy, which, if evaluated based on Forte's conceptualization, essentially remains pivoted on understanding people's emotional responses towards cultural heritage sites or artifacts and the manner in which this could affect perceptions about other cultures and assist cross-cultural interactions. (Forte, n.d.). Cognitive Neurodiplomacy is also, in a way, a niche high in terms of its scope as it encompasses the analyses of socio-psychological factors and social constructs of States by using cognitive neuroscientific interventions and employing the insights therefrom for managing inter-state relations.

Conclusion

From the above discussion, we may conclude that the current traditional methods and modes of diplomatic interventions for the purposes of conflict prevention and post-conflict reconciliation are getting archaic and need reorientation based on scientific evidence-based realities. This is necessitated because the above traditional diplomatic toolkit remains oblivious to the socio-psychological factors that form the bedrock for an adversarial social construct of one State towards another State(s). Without comprehending and addressing the above socio-psychological and social constructs, neither any conflict prevention could be enabled nor any post-conflict reconciliation foreseen. For this reason, this paper proffers the case for cognitive neuroscientific interventions as the payload for scientific diplomacy for the purposes of conflict prevention and post-conflict reconciliation in the peacebuilding continuum. The toolkit of cognitive neuroscience could enable us to better understand the brain activity and responses of "representative sample groups" (instituted on the basis of voluntary participation) towards the perceived enemy States, which then could be used for designing appropriate mitigation approaches. Through such approaches, the conflict prevention and post-conflict reconciliation could be ensured on a more durable basis. For doing so, a global framework would be required that takes into account all cultural and ethical concerns and inhibitions related to the employment of the cognitive neuroscientific tools for conflict prevention and post-conflict reconciliation. Under this framework, scientific research hubs may also need to be instituted to provide the scientific reports on bias assessment and suggested reduction in pre-conflict situations and trauma recovery during post-conflict settings. These studies could be utilized by the diplomatic community for pre-conflict prevention strategies and post-conflict peace arrangements. This approach would ensure that the policies and approaches for conflict prevention and post-conflict reconciliation reflect psychological realities. The above stratum of cognitive neuroscience being used in international relations opens vistas for a new domain of "Cognitive Neurodiplomacy" linking cognitive neuroscience with diplomatic practice.

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Designing a Model of Innovation Districts as a Hub for Countries' Development (Case Study: Iran International Innovation District (IIID))

*Mostafa Ghafari Asl and **Ali Mamhoori

Abstract

Innovation districts are expanding and evolving. Today, these areas are not only centers of innovation, business, research, and education, but also serve as hubs for recreational, cultural and social activities. However, various dimensions of innovation districts remain underexplored and ambiguous. In the contemporary world, such districts play a key role as engines of economic, scientific and technological growth for countries. This study aims to design a comprehensive model for the development of innovation districts—one that can serve as both a conceptual and practical framework to guide their growth and transformation. The research begins by examining the fundamental concepts and characteristics of innovation districts, followed by an analysis of their key success indicators. A proposed model is then presented, which outlines the main actors, structural features, assets, capabilities and core characteristics of these districts. Finally, the study offers practical recommendations for the effective implementation of this model at various levels.

Keywords: Innovation districts, integrated development model, regional innovation hubs, innovation-driven policy.

1. Introduction

Over the past 50 years, the landscape of innovation has been dominated by remote peripheral areas that paid little attention to quality of life, housing, and leisure, and were often difficult to access, usually requiring private vehicles [1]. These environments were rather austere, where work and income were the sole priorities. However, in the past two decades, policies and programs have increasingly shifted toward the creation of creative and innovative spaces to foster competitiveness in the knowledge-based economy and to achieve sustainable socio-economic growth. Peripheral challenges—such as the need to strengthen local economies, create new opportunities driven by technological advancements, address adverse climatic conditions, and tackle unemployment and socio-economic inequalities—have pushed many cities to adopt innovation-led economic models. These cities have embraced new strategies and structural changes under the paradigm of knowledge-based urban development [2]. Through this paradigm, cities implement strategies to improve their infrastructure, enhance quality of life, and create attractive environments for talent and investment.

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Designing a model of Innovation Districts

Innovation is a key driver of economic growth and competitiveness, and innovation clusters host a substantial share of productive innovations in both creative industries and high-tech sectors. This evolution has led to a reconceptualization of the traditional “science and technology park” model into the more dynamic “innovation district” model. Innovation districts address some of the major shortcomings of the science and technology park concept: they are no longer mono-functional, isolated, inaccessible, or lacking a vibrant and attractive environment. Innovation districts appear to be more aligned with the preferences of today’s younger, highly educated generation. Moreover, companies increasingly seek locations where they can attract and retain talented individuals [3]. Theoretical Foundations of the Research Innovation districts are a combination of research centers, knowledge-based companies, universities, and government institutions that work together to promote technology development and the commercialization of innovations. A review of the literature reveals that various models for the development of these districts have been proposed, but a comprehensive model that can cover all dimensions of development is still in need of further investigation.

Since the late 1980s, there has been a growing inclination among policymakers to relocate industries outside of urban areas. Consequently, new industries began to emerge in the form of science parks and industrial towns around major cities in the early 21st century [1]. The financial crisis of 2008 prompted approaches such as diversifying national and organizational service offerings, focusing on creating new businesses and investing to attract elite individuals to become key strategies of urban management. Thus, the shift from an industry-based economy to an innovation-based economy gained prominence and there was an increasing tendency to utilize urban areas as a suitable source of workforce and facilities. Indeed, during the same period, countries’ competition for a higher position in the global economy led to increased attention to the role of cities in shaping high value-added industries. Consequently, the concept of innovation districts gradually emerged. This concept has become so pervasive that researchers believe the 19th century was the century of empires, the 20th century was the century of dominant states, but the 21st century will be the century of pioneering cities [1].



Figure 1 illustrates the evolution of economic regions and the transition from industrial parks to innovation districts [2]

With the expanding efforts of countries to shape and establish innovation ecosystems, the concept of innovation cities and regions has emerged. An Innovation district is a concentrated area of ecosystem elements, from the initial stages of idea formation to

the production and expansion of businesses, which provides suitable conditions for better communication and synergy among the elements [2].

Until the 1980s, science and technology parks were primarily established based on an infrastructure-oriented approach, with their main goal often being the provision of physical infrastructure. This approach faced significant criticism in the early 1990s, primarily due to its theoretical background, which considered technological development and progress as a linear process. Now, with the limited diversity of parks in the country's innovation ecosystem, there is a need to upgrade the quality of science and technology parks [3]. Innovation districts have various common characteristics that can facilitate their development and progress. Some of these common and fundamental features include:

1. Access to Talents and Research outputs from one or more leading universities.
2. Good connectivity of transportation and people flow around the region; for example, the presence of a metro station located in the area.
3. Flexible living, working and recreational residency.
4. Sufficient population density and proximity.
5. Access to legal, financial, accounting and marketing services.

However, there is a difference between what makes an innovation district practical and what leads to long-term success. What matters is understanding that these factors go beyond physical development and property expansion. Here, we are dealing with the creation and management of a complete ecosystem and of course, the existence of physical structures is equally important. But failing to grasp this danger can result in the area having little value for tenants and merely turning into a mixed-use development. An innovation district is comprised of various assets and components that, together, create the meaning of an innovation district [4]. Each of these assets has its own meaning and concept, which are briefly addressed here:

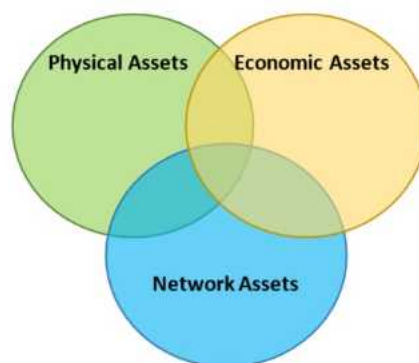


Figure 2 Assets of an Innovation District (Adapted from: (Katz & Wagner, The rise of Innovations Districts: A New Geography of Innovation in America, 2014))

Physical Assets

include buildings, streets, parks, open spaces and other infrastructures created by the private or public sector to stimulate collaboration, synergies and innovation. Physical assets are divided into three categories Public Spaces (like as Parks, trees, squares and lively, pleasant streets fall into this category), Private Spaces (like as Buildings and privately-owned spaces that innovate in new and creative ways, New types of offices, spaces and shared services, affordable housing, etc.) and Infrastructural Assets (Communication routes connecting the district internally as well as to surrounding areas. They include infrastructures for intra-city communications such as pedestrian paths, suitable streets and bike lanes, absence of walls and barriers between institutions and entities within the district, as well as infrastructures like metro lines, highways, etc., for easier connection to the main metropolis). Small housing units are another example of new physical assets [5].

Economic Assets

Economic assets refer to resources that hold value and can contribute to wealth generation within an individual, organization, or country. These assets can be both tangible (like physical property, machinery, or land) and intangible (such as intellectual property, human capital, and financial investments). Economic assets are crucial for driving economic development, sustainability, and long-term growth. They play a vital role in the functioning of economies by facilitating trade, supporting innovation, creating jobs, and fostering social stability [6].

The significance of economic assets extends beyond simple monetary value. For instance, human capital—skills, knowledge, and health—can be considered a powerful economic asset, as it enhances productivity and fosters creativity. Similarly, financial assets like stocks, bonds, and savings contribute to economic stability and allow businesses and governments to finance projects that further drive prosperity [7]. In addition to these, natural resources (land, water and energy) are indispensable economic assets, especially for countries that rely heavily on agriculture or extraction industries. Proper management of these assets is critical to ensuring sustainable development and addressing global challenges like poverty, inequality, and climate change.

Network Assets

Network assets refer to the value derived from the relationships, connections, and networks an individual, organization, or business has within its environment. These assets are not tangible in the traditional sense, but they hold immense value in terms of opportunities, knowledge exchange, collaborations, and access to resources. Network assets include connections in professional networks, partnerships, social media followers, and collaborations with other organizations or stakeholders [8]. In the modern economy, network assets are a powerful driver of growth and innovation. These assets facilitate the exchange of information, the creation of partnerships, and the sharing of resources, all of which can lead to increased efficiency, improved problem-solving capabilities, and market expansion [9]. For businesses, strong network assets can pro-

vide access to new markets, partners, funding opportunities, and intellectual property. Social networks and professional relationships are especially significant in industries like technology, consulting, and entrepreneurship, where collaboration and information flow are key to success [10]. On a broader scale, network assets also play a crucial role in social capital—the collective value of social networks. These assets can foster trust, support community development, and enhance societal well-being. Well-maintained networks can help individuals and organizations adapt to changing conditions, navigate challenges, and seize new opportunities [11].

Governance Model

A governance model refers to the structure, processes, and mechanisms by which decisions are made, implemented, and monitored within an organization, institution, or society. It outlines how authority, responsibility, and accountability are distributed among different stakeholders and how the rules and policies governing the entity are enforced. Governance models are essential for ensuring that an organization operates efficiently, ethically, and in alignment with its objectives, values, and legal obligations [12]. In the context of organizations, governance models define the roles of the board of directors, executives, and other leadership figures, as well as the systems for communication and decision-making. These models can vary depending on the type of organization—corporate, governmental, non-profit, or international—and may include centralized, decentralized, or hybrid approaches to decision-making [13]. Corporate governance, for example, refers to the system of rules, practices, and processes by which companies are directed and controlled. The board of directors typically oversees the company's activities, ensuring that the interests of shareholders, employees, and other stakeholders are aligned. Good governance models foster transparency, accountability, and ethical behavior, which are critical to sustaining long-term business success and public trust [14]. In public governance, the model involves the structures through which governments engage with citizens, manage resources, and ensure policies are executed fairly and effectively. Different political systems, such as democratic, authoritarian, or hybrid, may adopt different governance models, each with distinct mechanisms of public participation, checks and balances, and accountability structures [15].

Types of Governance Models:

1. **Hierarchical Model:** Centralized control where decision-making authority is concentrated at the top levels of an organization.
2. **Network Model:** A decentralized model that promotes collaboration and information-sharing across various entities within the organization or sector.
3. **Market-based Model:** Governance through market mechanisms where competition, consumer choice, and market forces play a dominant role in decision-making.
4. **Hybrid Models:** A blend of centralized and decentralized approaches, often used in large, complex organizations or multi-sector governance.



Figure 3 Quadruple Helix Model and Interactions between Components

2. Research Background

In this section and in Table 1 important researches carried out in innovation district conceptError! Reference source not found. are summarized and then the most important achievements of each research are mentioned.

Table 1 important researches carried out in innovation district concept

1	
Author	Maryana Scoralick De Almeida Tavares, Cláudia Fabiana Gohr, Sandra Morioka, Thereza Rakel da Cunha
Year	2021
Research Topic	Systematic literature review on innovation capabilities in clusters
Results	The authors provide a descriptive analysis followed by a thematic synthesis, in which we present 05 enablers and 20 critical factors (CF) of IC in clusters. The proposed framework emphasizes what needs to be done or improved to increase IC in cluster-based companies. Based on this systematic review and the framework proposed, the authors identified opportunities for future research.

2	
Author	T. Theeranattapong, D. Pickernell, C. Simms
Year	2021
Research Topic	Systematic literature review paper: the regional innovation system-university-science park nexus
Results	This paper presents a systematic review identifying the key roles of each actor in relation to innovation. We link the dynamic roles performed by the university between science parks and the RIS. Our results enable us to identify how the key activities performed by the university change during its interrelations within the RIS and with the science park.

3	
Author	Amir Asgari, Ali Khorsandi Taskoh, Saeed Ghiasi
Year	2021
Research Topic	Defining the Concept and Providing A Model for The Implementation of Innovation Districts: A Meta-Synthesis Analysis Using Text-Mining
Results	This research helps us understand both the approach to creating an innovation district and the concept of its development on one hand and its implementation on the other.

4	
Author	Tan Yigitcanlar, Rosemary Adu-McVie, Isil Erol
Year	2020
Research Topic	How Can Contemporary Innovation Districts Be Classified? A Systematic Review of The Literature
Results	This article shapes our understanding of the paradigm shift from the model of science and technology parks to innovation districts. It also discusses various classifications of innovation districts in another section.

3. Research Methodology

Content analysis is a qualitative research method used to analyze and interpret textual, auditory, or visual data and content. This method is particularly applicable in social sciences, psychology, media studies, and humanities, helping researchers identify patterns, themes, and specific topics within various texts [16]. The primary goal of content analysis is to uncover and analyze the hidden or explicit meanings embedded in a text or a collection of texts. Content analysis can be conducted in both quantitative and qualitative forms [17].

1. **Qualitative Content Analysis:** In this type of analysis, the researcher identifies patterns, themes, and concepts within the text. The goal is to gain a deep understanding of the content and the underlying meaning within it.
2. **Quantitative Content Analysis:** In this type, the focus is more on counting and coding specific concepts and words in the text to determine the frequency and extent of their use.

The main steps in conducting content analysis are as follows [18]:

1. **Data Preparation:** Collecting data from various sources such as books, articles, interviews, films, and other media.
2. **Data Coding:** Identifying semantic units (words, sentences, or paragraphs) and assigning codes to each semantic unit.
3. **Theme and Pattern Analysis:** Identifying the key themes, patterns, or concepts that are prominent in the text.

Designing a model of Innovation Districts

4. Interpretation and Conclusion: Analyzing the meaning of the extracted themes and concepts, and drawing conclusions about the main content of the text.

The content analysis method is particularly useful in analyzing complex data, especially in social and cultural contexts, as it helps identify and deeply analyze themes and concepts in various texts, utilizing them to better understand hidden structures and patterns [18]. As previously mentioned, this method has been employed in the current study.

4. Findings

The Iran International Innovation District (IIID) is an advanced strategic initiative designed to foster and accelerate innovation and technological development, particularly in the domains of scientific research, industrial innovation, and advanced technology. The core of this District lies in promoting international collaboration, facilitating interactions with various global partners to exchange knowledge, cutting-edge technologies, and expertise. One of the primary objectives of the District is to enhance Iran's domestic capabilities through foreign investment attraction, technology transfer, and the promotion of collaborative innovation across various sectors [19].

The development of the Innovation District is anchored in the establishment of specialized infrastructure, such as dedicated research and development centers, alongside offering incentives to encourage the growth of startups and technology-driven industries. Additionally, a strong emphasis is placed on educational initiatives, fostering research, and the commercialization of technological products and services. These efforts aim to create a sustainable innovation ecosystem that strengthens the country's position in the global competitive landscape.

Strategically, the Iran International Innovation District (IIID) also plays a pivotal role in Iran's broader economic diversification goals. By focusing on knowledge-based industries and reducing reliance on fossil fuels, particularly oil, the District seeks to contribute to long-term economic resilience and stability. Moreover, the District is an essential component of Iran's strategy to integrate into global innovation networks, thus driving sustainable socio-economic growth and further positioning the country as a regional hub for technological advancement and innovation [20].

5. Conclusion

The establishment of innovation District within a structured and coherent framework can play a pivotal role in driving the economic development of nations. Such Districts, when designed with careful attention to local conditions and strategic priorities, can serve as powerful catalysts for fostering technological advancement, stimulating entrepreneurship, and facilitating economic diversification. These Districts are crucial in creating environments conducive to innovation, where research institutions, businesses, and government agencies can collaborate to drive progress in various sectors, especially in knowledge-based industries.

Given the dynamic nature of global economies and the increasing importance of in-

novation in the 21st century, it is essential for governments and policymakers to adapt these models to their specific socio-economic contexts. While the general principles of innovation Districts remain relevant across different regions, successful implementation requires tailored solutions that consider local infrastructure, talent pools, and investment opportunities. Policymakers must adopt a comprehensive approach, incorporating strategic frameworks that emphasize infrastructure development, regulatory support, and incentivizing private sector engagement, particularly for startups and high-tech enterprises.

Furthermore, a coordinated effort between national and local stakeholders is necessary to overcome challenges such as resource limitations and institutional barriers. By ensuring alignment between innovation policy and broader economic objectives, Innovation Districts can contribute not only to technological progress but also to broader social and economic resilience. Ultimately, the successful implementation of Innovation District can significantly enhance a country's global competitiveness, reduce reliance on traditional sectors, and foster long-term sustainable growth.

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From Data to Dialogue: Science Communication and Diplomacy in Climate Negotiations for Vulnerable Developing Countries

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Abstract

Scientific, institutional, and diplomatic barriers persist in international climate negotiations for developing countries that are highly vulnerable to climate change. While they account for the least contribution to global greenhouse gas emissions, they face some of the worst impacts in the form of floods, droughts, heatwaves, food insecurity, and economic losses. Translating scientific evidence into credible negotiation positions and effective diplomatic influence remains a major challenge. This paper reviews the role that science communication and diplomacy play in shaping climate negotiations of vulnerable developing countries, particularly Pakistan, from a critical perspective. Based on a review of successive COPs under the UNFCCC, it analyzes negotiation dynamics, persistent gaps in climate finance, and deep-seated structural inequities within the global climate regime. The paper argues that science communication, if conducted effectively with coalition-based diplomacy, narrative framing, and enhancement of institutional capacity, can emerge as a real game-changer in enhancing the negotiating power of vulnerable countries. It concludes with some policy-relevant recommendations for strengthening science–diplomacy integration to foster more equitable global climate governance.

Keywords: Science communication; climate diplomacy; vulnerable developing countries; Pakistan; UNFCCC; COPs; climate finance; climate justice

1. Introduction

Climate change, over time, has emerged as one of the major challenges of the twenty-first century. However, its effects are very unevenly distributed. The developing nations with their tropical regions in Asia and Africa, as well as island states, are suffering immensely from this phenomenon despite their lowest contribution to carbon emissions to this effect. In this case, Pakistan has been ranked among those nations despite contributing just less than a percent to carbon emissions across the whole world. In fact, Pakistan has been ranked among the top 10 countries at risk because of this issue.

The international climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement create a struc-

tured forum for addressing these differences via mitigation, adaptation, climate finance, technology transfer, and capacity building. From a theoretical viewpoint, the global climate regime is supposed to be based on equity and the principle of Common but Differentiated Responsibilities and respective Capabilities (CBDR-RC). From a practical point of view, this is a task that developing nations find extremely difficult to accomplish.

One major factor that has contributed to the insufficient progress in negotiations is limited science communication. Scientific data, risk analysis, and information on economic losses are at many times pieced together in a disjointed fashion that is very technical at a storytelling level. On the other hand, negotiations at the global level are conditioned upon power imbalance, agenda setting with dominance of developed nations, as well as an imbalance in competence.

This paper will contend that science communication is not a side aspect of climate diplomas, but rather an integral one. Successful communication of climate science can help developing countries legitimize claims, articulate the framework of the negotiations having to do with justice and equality, and thus build international support. In an examination of the role of science communication and diplomas in the negotiations related to climate change, this paper will examine the Pakistan scenario through the medium of an article.

2. The Climate Vulnerability and Development Dilemma

2.1 Understanding Climate Vulnerability

Climate vulnerability is commonly understood as a function of exposure to climate hazards, sensitivity of social and economic systems, and adaptive capacity. The developing nations are most vulnerable to climate change, either by geographical or country exposure, dependence on climate-sensitive sectors, or the country's capacity of the country. The South Asian region, which holds a population of one-fifth of the world's population, is projected to face extreme weather, irregular monsoons, flooding events, and glacier melting.

Just how sensitive national economies can be in this regard is evident in the case of Pakistan. In 2022, their floods left over 33 million people affected, resulting in damage to infrastructure, agricultural crops, and estimated economic damage totaling almost US\$30 billion. Such disasters, rather than being outliers, symbolize a series of disasters triggered by the effects of global warming.

2.2 Development Constraints and Climate Risk

Vulnerability to climate change in developing countries is largely interconnected with development challenges. The governments of many nations face constrained budgets, debt, or deficient governance structures that make it difficult for them to invest in ADA. The climate funding requirements for Pakistan from 2023 to 2030 are estimated at over US\$350 billion. Additionally, weak climate data systems contribute to the existing difficulties. The inefficiency in emissions, climate change, and adaptation im-

plementation, data leaves little chance for developing countries to put together plausible proposals for funding and evidence of implementation. Consequently, scientific facts, if in place, do not convey particular strength in negotiations and finances.

3. Climate Negotiations: Progress and Persistent Gaps

International climate negotiations, which take place in the UNFCCC, happen annually through a series of Conferences of the Parties (COPs) supported by subsidiary bodies. These international dialogue forums discuss issues such as mitigation outcomes, adaptation needs, finances, technology, capacity building, and information, which, despite being inclusive, present high levels of asymmetries in some annual meetings.

COP15 in Copenhagen in 2009 was a turning point where the need for climate finance was recognized, with the promise that the developed countries would mobilize a sum of US\$100 billion by 2020. But it was only in 2022 that the promise was kept, causing disillusionment among both the developing and the developed countries. COP26 in Glasgow in 2021 showed progress in the areas of enhancement in the transparency framework and cutting emissions. A significant breakthrough was achieved at COP27 in Sharm el-Sheikh (2022) with the agreement to create a Loss and Damage Fund, confirming that some effects of climate change are beyond what can be dealt with by their adaptive capacities. However, this was continued at the next COPs with financial commitments well short of requirements.

COP29 in Baku agreed to scale climate finance to at least US\$300 billion annually by 2035. Yet, this progress is still not enough against developing countries' estimates of over US\$1 trillion per year. These continuing shortfalls reflect the limitation of what can be achieved through negotiations if the scientific evidence cannot be effectively transformed into diplomatic leverage.

4. Barriers to Effective Negotiation for Developing Countries

Structural inequalities remain one of the cardinal hindrances to effective participation by developing countries in international climate negotiations. Developed countries typically deploy large and well-resourced delegations that include legal experts, climate scientists, economists, finance specialists, and professional negotiators. These groups are capable of attending multiple parallel negotiation tracks, coordinating positions in real time, and responding quickly to evolve text proposals.

In contrast, developing countries often participate with small teams that have to cover various concurrent negotiation streams, thus leaving unattended critical discussions and compromising their impact on complex and technical outcomes. The imbalance dims prospects of information access, weakens the strategic coordination framework, and reinforces current power asymmetries within the negotiation process. Moreover, these challenges of limited scientific data are exacerbated by a lack of mechanisms and channels to link the scientific results into clear and scientifically based storytelling. In cases where the evidence is dispersed and not very scientifically contextual but scientifically based and explained in a less appealing and less scientifically based

manner, this evidence lacks the ability to appeal to and convince the negotiators, investors, and decision-makers.

5. Science Communication: From Evidence to Influence

Science is the foundation of the international climate regime because science determines the normative architecture as well as implementation procedures in international climate politics. Starting with periodic assessment reports by the Intergovernmental Panel on Climate Change (IPCC) to national inventories of greenhouse gases, adaptation communications, and biennial transparency exercises under the Paris Agreement Regime, science defines the architecture of decision-making by drawing primarily on scientific assessments to define risk, establish mitigation actions, and track progress. The role of science in international climate negotiations is not immediate or assured. Science has a role to play in shaping international climate outcomes only to the extent that science is communicated in modes that are intelligible and credible to diplomatic action.

In the case of susceptible developing nations, the role of science communication in climate diplomacy has three significant functions. First, science communication legitimates national positions with scientific justification for mitigation options, adaptation strategies, and financial support. Quantifiable evaluations of the impacts and vulnerabilities of climate change improve the positions of nations in negotiations involving financial support, losses, and the transfer of technology. Second, science communication influences the way negotiations take place by converting global goals into a context according to nations. By linking temperature thresholds and emissions trajectories to concrete impacts on food security, water availability, health, and livelihoods, scientific evidence can reframe negotiations from technical burden-sharing debates to discussions of equity, responsibility, and justice. Third, effective science communication supports domestic legitimacy by helping policymakers, parliamentarians, media, and civil society understand international commitments and their implications for national development pathways.

Despite its importance, science communication capacity remains weak in many developing countries. Technical complexity, limited research funding, fragmented data systems, and weak coordination between scientific institutions and negotiating teams constrain the effective use of evidence. Scientific outputs are often highly technical, poorly timed, or disconnected from negotiation needs. In addition, limited engagement with media and civil society reduces the public visibility of scientific evidence, weakening domestic pressure for ambitious and consistent international positions.

To improve science communication, there is, therefore, a need for strategic institutional engagement and building of capacity. There can also exist the possibility of bridging the gap that exists between the scientists and the diplomats through the formation of units in the respective climate ministries and/or institutions of research that can assist in science communication. Scientists and diplomats can also benefit through specific training that is geared towards improving on policy framing, narrative, and

communication of uncertainty, and the three can come together in increasing the capacity of evidence to speak to the strategic interests of the diplomatic engagement in such a way that, through science communication, the negotiations on the subject of climate change can move from abstract goals to discussions centered on human effects and shared moral responsibility in the climate regime framework.

6. Diplomacy and Strategy: Leveraging Science

Coalition building remains one of the most viable diplomatic strategies available to developing countries in multilateral climate negotiations. Individually, many developing countries are significantly hamstrung by limited technical capacity, negotiating power, and political influence. Working through collective platforms—the G77+China, the Climate Vulnerable Forum, and the Like-Minded Developing Countries—members can pool expertise, share analytical resources, and coordinate negotiation positions. Coalitions enhance visibility, reduce informational asymmetries, and enable developing countries to cope with increasingly complex and fast-changing negotiation processes.

Coalitions go beyond technical coordination to play an important role in normative and political structuring in climate negotiations. Shared narratives of climate justice, equity, and common but differentiated responsibilities frame a uniting logic that ties diverse national circumstances into a common moral and legal framing. Articulated consistently across sites of negotiation, these framings challenge purely technocratic approaches and re-center negotiations on questions of historical responsibility, differential vulnerability, and development needs. Coalition-based framing also raises negotiating leverage through the signaling of political unity and reducing the scope for divide-and-rule tactics.

The efficacy of diplomacy through a coalition is also increased through the application of credible scientific evidence. The application of science to a diplomacy plan should aim to transcend generalized global trends to country-level evidence. National impact assessments, sectoral vulnerability analysis, and country-level quantified economic loss assessment enable parties to make a case of how global warming levels equate to real risks for food security, water, health sectors, and infrastructure.

In parallel, it is critical to translate technical results into policy language that speaks to negotiators, finance banks, and policymakers. The results of climate modeling, uncertainty margins, and probabilistic risk analysis need to be expressed through compelling stories of urgency, feasibility, and equity. By translating scientific results into language centered on avoided risks, co-benefits of sustainable development, and human interests, science becomes a source of strategy, not just appendices. This increases credibility, builds more effective negotiating power, and makes it possible for more equal negotiations between scientifically advanced coalitions of nations and groups of developing nations. In effect, science-based coalition diplomacy enables countries most at risk to not only be heard but to set the agenda on international climate change agreements.

7. Pakistan's Climate Diplomacy Experience

Pakistan has consistently framed its role in international climate negotiations as a country that has made very minimal historical contributions to global greenhouse gas emissions but bears a disproportionate exposure to climate impacts. This asymmetry has been a core part of Pakistan's diplomatic narrative, informing its advocacy for enhanced adaptation finance, recognition of loss and damage, and fair implementation of the Paris Agreement. Devastating floods in 2022, which impacted over 30 million individuals and caused economic losses surpassing US\$30 billion, fortified Pakistan's claims that climate impacts are already eroding development gains and overshooting national adaptive capacity. The subsequent series of extreme events, such as recurrent flooding and heatwaves in 2025, further supported its argument that climate vulnerability is growing faster than existing international support mechanisms can deal with.

Pakistan sought to leverage the loss and damage agenda through a visible and strategic role at COP27 in Sharm el-Sheikh, building on political leadership within the G77+China grouping and on moral authority derived from fresh climate disasters. Pakistan linked scientific evidence on climate-attributed extreme events with human and economic impacts and thus contributed to building momentum for the establishment of the Loss and Damage Fund. Into the next rounds of negotiations, Pakistan continued to insist on predictable, grant-based finance. The implication of loan-driven climate finance is debt vulnerability and undermines long-term resilience, so its arguments have gone. Meanwhile, its engagement on the NCQG was again scale, accessibility, and equity-focused and highlighted the mismatch between developing-country needs and existing financial commitments.

Yet, despite these few diplomatic gains, the sustained influence of Pakistan in climate negotiations is structurally and institutionally constrained. Fragmented climate data systems, outdated sectoral assessments, and limited coverage of agriculture, water, and disaster risk indicators make consistent quantification of losses, adaptation needs, and finance requirements difficult. Institutional discontinuity, or frequent changes in negotiating teams coupled with limited retention of technical expertise, undermines strategic coherence across COP cycles. Secondly, poor integration between scientific institutions and policy-making processes restricts the timely translation of national research into negotiation-ready evidence.

In order for Pakistani climate diplomacy to be strengthened, it is necessary that it be focused on building its own data infrastructure for climate change at home. It can further benefit from impact assessments, which would help it in proactive engagement at an international level regarding climate change, where it can become an agenda-setter rather than an advocate.

8. Policy Recommendations

Developing countries always present challenges in international climate change negotiations due to institutional discontinuity, poorly developed data systems, and disjointed science-policy interfaces. It is therefore important to establish climate change

From Data to Dialogue

negotiation and science advisory services in the foreign relations and climate change ministries. These services would help countries maintain institutional memory from previous negotiations, ensure that negotiators are technically backed in international climate change negotiations, and ensure that national agendas for development are in line with international climate change obligations. Developing countries can also be proactive in responding to changing climate negotiation agendas as opposed to being reactive.

Investment in national climate data infrastructure is also crucial for informed diplomacy. Access to sound greenhouse gas inventory data, the impacts of climate change, and the sensitivity of the sectors to the impacts of climate change helps in informing the negotiations and the funding proposals. Lack of proper data infrastructure makes it difficult for developing countries to estimate their adaptation requirements or their loss and damage associated with the impacts of climate change. Data integration tools may be useful in negotiations.

It will be important to reinforce the bridging role that dedicated science communication platforms can play between research and diplomacy. These platforms could translate complex scientific findings into negotiation-ready briefs, visual tools, and policy narratives targeted at negotiators, financiers, media, and civil society. Effective communication ensures that scientific evidence does not remain confined to technical reports but actively shapes the negotiation frames on human impacts, economic risk, and long-term resilience. The coalition-based diplomacy needs to be further strengthened with a view towards multiplier impact. The coordination of positions within blocs—the G77+China, the Climate Vulnerable Forum, and other South-South alliances—allows countries to combine expertise and negotiate issues jointly. Framing demands around climate justice and equity, underpinned by quantified evidence of vulnerability, costs, and historical responsibility, enhances moral legitimacy and political traction.

In this regard, climate finance advocacy needs to emphasize grant-based mechanisms over loans, which run the risk of increasing debt distress in vulnerable economies. Developing countries must also champion solidarity levies and other innovative financing instruments, including climate risk-sharing mechanisms, to expand the global finance base. Finally, public engagement is key: communicating science increasingly into domestic awareness builds societal support, strengthens mandate legitimacy, and reinforces national positions in global climate diplomacy.

9. Conclusion

Climate change talks are much more than mere technicalities; they are intricate negotiations that involve the juncture of scientific information, power politicization, and justice. Developing nations that are adversely affected by the consequences of climate change, despite their insignificant contribution to emissions in the past as well as present, stand in dire need of an effective combination of scientific information to influence the proceedings of the talks. The scenario in Pakistan is no exception regarding the mitigation and opportunity factors that come with strong scientific information

combined with joint diplomacy efforts, beset by the lack of administrative consistency in the conservation of climatic information in the country.

Scientific evidence can neither inform nor educationally enlighten; it can also informally oblige. This is because the dissemination of vulnerability analysis findings, economic impact analysis results, and sector-wise projections holds the key for LDCs on how they can formally ask for equitable funding for adaptations, funding for loss and damages, and funding for technology transfer. Moreover, poor data and poor integration between science and policies will only oblige the negotiators on the agenda set by the other side. To bridge this gap, starkly divided by science-based data, science communication outreach efforts, along with improved institutional capacity, are necessary. Climate negotiation teams in permanent bodies, national data systems, or science communication systems will address this issue. Position alignment within already established coalitions of states, such as the G77&China or Climate Vulnerable Forum membership, with equity-based negotiation themes will have strong persuasion power. International negotiations concerning equity, justice, and specific effects are morally convincing in their argument.

With such integrated strategies, it is possible for the vulnerable developing nations to progress from being passive participants in global climate change actions towards taking a proactive or leading role in determining global climate policies based on their own realities. The way towards climate justice does not only depend on favorable outcomes but is made possible with dedicated investments in strategies of climate-related research and alliance development for nations such as Pakistan.

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Electronic Waste Management in Nigeria: Understanding Consumer Knowledge of Extended Producer Responsibility and Practices of Circular Economy

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Abstract

Nigeria's e-waste sector is dominated by informal practices, causing pollution and health hazards. To address this, Nigeria established a legislative framework and extended producer responsibility (EPR) program, leading to the formation of the E-waste Producer Responsibility Organization of Nigeria (EPRON) to ensure producers meet their obligations. In 2023, EPRON examined consumer behavior in e-waste management in Nigeria. The study investigated knowledge of circular economy (CE), EPR, and e-waste regulations, as well as EEE purchase, repair, and disposal behaviors among 3715 consumers across six states, aiming to identify factors influencing behavior and opportunities for change. The study found low awareness of CE (27.6%), EPR (10.4%), and e-waste regulations (26%) among consumers. About 28% of consumers are aware of the ban on the importation of used CRT (TVs and monitors) while 36% are aware of the ban on the importation of e-waste. Although the respondents exhibited minimal knowledge of CE, they unknowingly apply CE principles such as repair and reuse practices that prevents waste generation and increase resource efficiency. About 13.4% of the respondents indicated that they give out dysfunctional products to family and friends, 12.4% sold, and 22.5% store such. Others (66.2%) repair and reuse to extend product lifetime. Despite consumers' willingness to repair and refurbish dysfunctional EEE, factors such as high repair costs and lack of trust in technicians hinder these practices. Environmentally sound management of e-waste in Nigeria require increased awareness and incentivising consumers, better collection infrastructure, and integration of formal and informal e-waste sectors.

Keywords: circular economy, producer responsibility, electronic waste, Nigeria, awareness

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1. Introduction

Electronic waste (e-waste) is a major concern around the world due to its high rate of generation globally (Baldé et al., 2024) and regionally (Iattoni et al., 2023; Wagner et al., 2022; Babayemi et al., 2025). The situation is worsened by cross-border shipping to developing countries, and the lack of basic e-waste collection, storage, and recycling facilities in those developing countries, including Nigeria (Osibanjo and Nnorom, 2007; Nnorom and Osibanjo, 2008a). Large quantities of used EEE (UEEE), which is popularly known as Tokunbo in the local phraseology, often mixed with e-waste, arrive in developing countries (e.g., Nigeria) (Odeyingbo et al., 2019; McMahon et al., 2021), and these worsen the e-waste situation. Cheshmeh et al. (2023) observed that if the transboundary movements of UEEE follow legal requirements, it is a step towards a circular economy (CE), with UEEE recognised as a valuable resource. Otherwise, it presents a threat to developing countries.

To guarantee that a proper basis for e-waste collection and ESM is set in Nigeria, EPRON recognised the necessity to carry out a study to determine consumer behaviour in relation to EEE. The aim of this study is to gain a better understanding of consumers' behaviour towards CE in the EEE sector as it relates to the purchase of EEE, repair, and disposal practices in Nigeria. This study also investigated e-waste generation patterns, existing management practices, motivations and barriers to proper e-waste disposal, and collection approaches that consumers prefer.

2. Literature Review

The CE concept can reduce e-waste generation as it improves resource efficiency by preserving the value of materials and products and keeping them in use for longer. It is seen as a way to address broader resource and sustainability issues. CE requires designing products to last longer, reusing and upgrading them, and encouraging stakeholders to repair them. While recycling and eco-design are important, extending the life of products is key to achieving a circular economy (Parajuly et al., 2017; André et al., 2019; Svensson-Hoglund et al., 2021). CE entails several Rs (reduce, reuse, repair, recycle, recovery, rethinking, redesign, and so on), which highlight and connect the social, environmental, economic, and governance aspects of e-waste (Srivastava and Pathak, 2020). European countries are at the forefront of implementing CE. The EU WEEE policy framework hinges on CE, especially in promoting practices that extend the lifetime of EEE, mainly based on repair and second-hand markets (Bovea et al., 2018). In the realm of consumer products, individual subsidies have been provided to support bicycle repairs. Similarly, the government and local municipalities have actively supported the development of repair facilities for various products. Additionally, a repair fund has been established to cover 10% of the repair costs for electronic appliances, furniture, and textiles, funded by Extended Producer Responsibility (EPR) mechanisms. These initiatives represent a positive step towards reducing waste and promoting a more circular economy (Jourdain and Lamah, 2024).

EPR in Nigeria is a private sector-led initiative, with the government regulating the activities of all the stakeholders. E-waste Producer Responsibility Organization of Nigeria (EPRON) was established in 2018 as the sole PRO for the EEE sector with

Electronic Waste Management in Nigeria

a mandate that includes the establishment of a Registry, which will determine market shares of producers, collection of the EPR levy and utilize the funds to support recyclers and collectors, raise awareness, conduct research, establish standards, and support its own administration. Producers of EEE established EPRON in order to meet their commitments and ensure ESM of e-waste in Nigeria. In Nigeria, the producer is referred to as the entity (which may include but is not limited to the brand owner, manufacturer, franchisee, assembler, distributor, retailer or first importer of the product) who sells, offers for sale or distributes the product. It also includes the local manufacturer or importer of new and used EEE to be put on the market (POM) at the first invoice by sale or donation. The EPR system plays an important role in facilitating an EEE circular economy.

To enshrine CE and EPR in the EEE sector, the Nigeria Government amended the National Environmental (Electrical/Electronic Sector) Regulation S.I No 23 of 2011 and published the National Environmental (Electrical/Electronics) Regulation S.I. No 79, (of 2022) (Federal Republic of Nigeria, 2022). In the same year, the National Environmental Standards and Regulations Enforcement Agency (NESREA), the Agency of the Federal Ministry of Environment, responsible for the enforcement of all environmental laws in Nigeria also published the Guidance Document for the Implementation of the Extended Producer Responsibility (EPR) Programme for the Electrical /Electronics Sector in line with Circular Economy (NESREA, 2022). The impact of the new E-waste Framework is yet to be studied. The adoption of incorrect e-waste management procedures in Nigeria and other developing countries, particularly by the informal sector, causes environmental degradation and human exposure to harmful chemicals (Osibanjo et al., 2011; 2016; Manhart et al., 2011; Andeobu et al., 2023). Unfortunately, the understanding of CE and in particular the e-waste concept is still very low in many African countries. For instance, convenience or lack of e-waste collection infrastructure influence disposal decisions. Consumer behaviour plays a crucial role in e-waste generation, and the behaviour is influenced by demographics, attitudes, knowledge, perceived benefits, and barriers (Nnorom et al., 2009; Ohakwe et al., 2011). Understanding these characteristics is critical to fostering sustainable e-waste management strategies. This is because in the CE, consumers can also serve as key suppliers of resources (waste and secondary materials) and seeing consumers as suppliers means looking at how they dispose of their products once they reach the end of their useful lives (Jourdain and Lamah, 2024).

As consumer behaviour is the main success factor for the promotion of CE, it is also interesting to identify the profile of those consumers who are more or less likely to adopt such behaviour. This can be useful for targeting future awareness campaigns towards suitable audiences with the aim of promoting practices, such as repairing of the dysfunctional devices and second-hand purchases, as strategies for extending the lifetime of electronic products. Improved consumer knowledge of CE and active participation in formal e-waste disposal is essential for achieving the UN Sustainable Development Goal (number 12) on sustainable consumption.

3. Methodology

3.1 Study Design and Stakeholder Participation

The research was carried out in 2023 across six states in Nigeria - Abia, Adamawa, Kano, Ogun, Lagos, and Rivers States, and the Federal Capital Territory. Three LGAs were selected from each of the states, and within each of the selected LGAs/municipal areas, four communities were selected (Faluyi and Nnorom, 2023). Consultations were made with key officials of the regulatory bodies with responsibility for environmental issues, waste management, the National Environmental Standard and Regulations Enforcement Agency (NESREA), the Ministry of Environment of Abia, Adamawa, Kano, Ogun and Rivers States as well as the Abuja Environmental Protection Board, Lagos State Environmental Protection Agency (LASEPA) and Lagos Waste Management Authority (LAWMA).

3.2 Study Tools and Data Collection Approach

Choosing the right survey tools is very critical to the outcome of any study. It simplifies and optimizes the data collection process. The data was collected with electronic data collection tools (Kobocollect). The questionnaire used was developed after an extensive desk study, which included a review of the questionnaire used by the International Telecommunication Union (ITU) to assess e-waste management practices in different countries ('Questionnaire of the Supplement on Best Practices on E-waste Management'). The draft questionnaire was presented to stakeholders (producers, consumers, regulatory bodies and government agencies) for inputs during a stakeholders meeting. Thereafter the questions were programmed in a mobile app. Field officers with research experience were recruited and adequately trained. Ten (10) field enumerators and one supervisor administered the survey tools in each of the participating states. The study was conducted through physical visits to households and communities to administer the questionnaires. Heads of communities were approached for approval to administer the questionnaires in their communities. The study also included field visit to EEE repair shops and collection centres to observe e-waste generation patterns, existing management practices, motivations disposal by repairers and barriers to proper e-waste disposal. The enable monitoring and documentation of e-waste management practices in the studied communities. The data collection exercise was conducted over a period of eight days across the selected study areas. The survey administration also provided an opportunity to create awareness on e-waste issues and CE among the respondents.

3.3 Study Limitations and Constraints

As it is the case with similar studies, the study is fraught with its own limitations. One of which was the unwillingness of some consumers to provide responses to some of the questions. Also, some respondents had the questions translated into their native language – such a translation process that was not standardized across the board has the potential to taint the survey with some personal bias. Some consumers declined participation in the study, while the field officers could not gain entrance into some

homes with gates and security, especially within the middle-and-high-income neighbourhoods. Therefore, majority of the participants may be assumed to fall between the middle and the low-income cadre. Therefore the findings of the study may not be so representative of the higher income class of Nigeria.

4. Results and Discussion

4.1 Demography of the Study Participants

A total of 3715 consumers took part in the survey. Lagos had the most respondents (708 respondents; 19.1%), followed by Kano (17.6%), Abia State (16.3%), Rivers State (14.6%), Abuja (12.6%), Ogun (10.1%), and Adamawa (9.7%). In terms of LGAs surveyed, Ikeja LGA in Lagos had the most (302 respondents; 8.1%), followed by Fagge in Kano State (6.7%). Abeokuta South (2.5%) and Yola North (2.4%) had less than 100 respondents (Supplementary Material: Figure S1).

The majority of survey respondents (70.7%; 2626 respondents) were self-employed. Others work in the private sector (17.2%; 637 respondents), government (10.4%; 386 respondents), non-governmental organisations (1.2%; 46 respondents), or international agencies (0.5%; 20 respondents). The majority of respondents (56.6%) were male. The average age of the respondents was 37.3 ± 11.0 (mean $\pm$ standard deviation). Eighty-five (85%) of the respondents were between the ages of 18 – 49; 37.3% were between the ages of 30-39; 25% were between 18-29; 22.9% were between the ages of 40-49, while the age of 10.4% of the respondents ranged between 50-59. Only about 4.5% of the respondents were older than 60 years. Sixty-five (65%) of the respondents were married; 30% were single; a small percentage were divorced (1%) or widowed (3%); and approximately 1% decided not to disclose their marital status.

The family size varied widely, with the majority lying between one and five (61.6%). Some respondents reported very large households. Families with six to ten members accounted for 31.8% of the consumers polled, while those with eleven or more members constituted 6.6%. The average family size in the studied population was 5.5 ± 3.7 (range 1- 53 family members).

About 44% of consumers make less than ₦30,000 per month (Exchange rate: 1\$= ₦758.78 as at 27 June, 2023; Central Bank of Nigeria | Exchange Rate (cbn.gov.ng), which is less than the national minimum wage; approximately 33% earn between ₦30,000 and ₦60,000 monthly; 10% earn between ₦60,000 and ₦90,000 monthly, and 5.7% between ₦90,000 and ₦120,000 monthly. Only around 8.2% make more than ₦120,000 per month. The average monthly income is ₦ 59,550 $\pm$ 118,875, with some respondents reporting earnings of as much as ₦5,000,000.

4.2 Awareness of Circular Economy

Consumer awareness of CE ranged somewhat across the survey states, with the vast majority of consumers (72.4%) unaware of the CE concept. Among the studied states, the CE awareness was 31.8% in Abia State, 29.1% in FCT, 21.1% in Adamawa, 26.3% in Kano, 27.8% in Lagos, 30.5% in Ogun State, and 25.6% in Rivers State, with an average awareness of 27.6%.

A subsequent question was used to assess the level of awareness of CE among the 10,027 respondents who initially indicated awareness of CE - the majority, 49.2% (505 respondents), indicated a moderate understanding of CE, while 36.7% (372 respondents) had limited knowledge, and 14.1% (150 respondents) demonstrated a strong awareness. Presented in Table 1 is the extent of awareness of CE among consumers in different states in Nigeria that participated in the study.

Table 1. Awareness of CE among Nigerian EEE consumers

State	Extent of awareness of circular economy (%)		
	Low	Medium	High
Abia	27.3	60.6	12.1
Abuja	30.5	45.5	24.0
Adamawa	38.1	52.2	9.7
Kano	32.5	48.4	19.1
Lagos	38.0	49.3	12.7
Ogun	44.1	41.6	14.3
Rivers	46.6	46.5	6.9
Total participants	372	505	150

The data in Table 1 suggest that targeted education and awareness programs are needed to increase the understanding of CE among consumers in Nigeria. The variation in awareness levels across different states may indicate regional differences in exposure to CE concepts, education, or initiatives.

No relationship was observed between income and understanding of CE. Awareness of CE varied slightly among the various income levels: 26.8% (433 respondents) of respondents earning less than ₦30,000; 27.8% (340 respondents) that earns between ₦30,001 and ₦60,000; 26.2% (94 respondents) that earns between ₦60,001 and ₦90,000; 36.2% (76 respondents) that earns between ₦90,001 and ₦120,000, and 27.5% (84 respondents) for those that earn above ₦120,000.

The respondents' level of understanding of the circular economy depends on their state of residence. Respondents were given four options (in 4 separate questions) to select a 'yes' or 'no' if a given option is synonymous with CE ('reduced waste generation'; 'recycling'; 'green economy' and 'high-quality electronics'). This was intended to assess their grasp of the CE concept. A little over 33 % of respondents were of the opinion that CE is synonymous with 'reduced waste generation'; while for the next option, 42.3% believed that CE is synonymous with 'recycling'. Additionally, 11.4% of the respondents associate CE with 'green economy', while 7.8% of respondents connected CE with 'high-quality electronics'. This also highlights the need for education and awareness programs to improve respondents' understanding of CE.

It was also intriguing to observe that consumer knowledge of the circular economy affects consumer attitude towards EEE purchase and e-waste dispos-

Electronic Waste Management in Nigeria

al. Some consumers indicated that their awareness of CE influences their EEE purchase and disposal decision (Figure 1). Overall, 1412 respondents (38.0%) indicated that their CE knowledge influences their EEE purchase decision, whereas 1665 respondents (44.8%) reported that knowledge of CE influences their e-waste disposal attitude (Figure 1). Jourdain and Lamah (2024) observed that consumer attitude that slows down e-waste disposal, when coupled with a reduction in the acquisition of new products, can contribute to a sustainable circular economy. About 59.3% (2204 of 3715 consumers) of consumers who were asked about their comprehension of ‘repair and reuse’ as a CE practice stated that doing so can conserve energy and lessen the production of electronic waste.

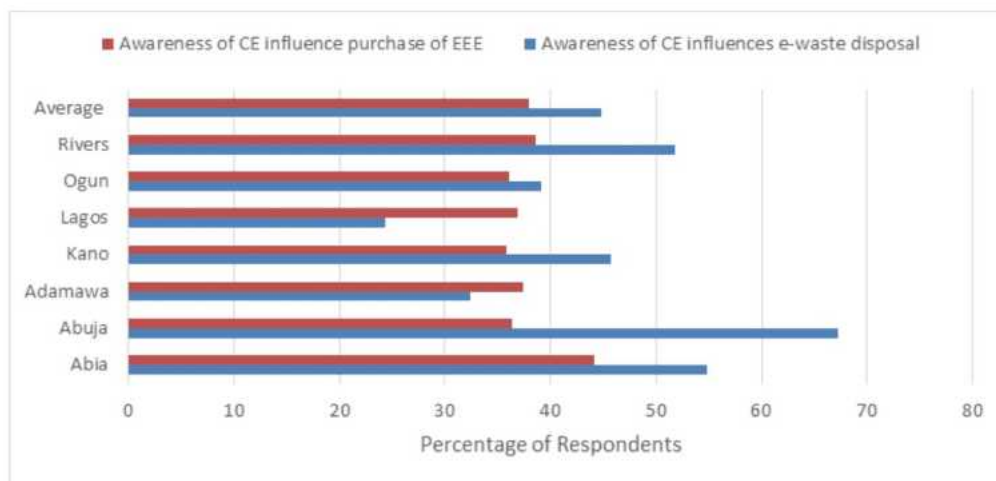


Figure 1. Influence of CE awareness on consumer EEE purchase and disposal decision

When consumers were asked about their source of CE awareness, only 1027 responded (99 in Abia, 121 in Abuja, 134 in Adamawa, 252 in Kano, 221 in Lagos, 84 in Ogun, and 116 in Rivers State). Presented in Figure 2 are the sources of CE awareness identified by respondents

Out of the states that participated in the study, it's only in Kano State that most of the respondents (58.7%) indicated that they became aware of CE through their friends and colleagues, this was distantly followed by workplace (17.9%), and then the media (16.7%). In Lagos, the respondents revealed that their awareness of CE is more from the workplace (35.8%), followed by from friends and colleagues (32.1%), with the number of respondents learning about CE from the media being the least at 20.8%. However, across all the States, consumers' awareness of CE is predominantly from the media (34.4%), followed by 'friends and colleagues' (31.7%) and then the workplace (20.3%). Only 13.6% of the participants indicated that they became aware of CE through educational institutions. There is therefore a need for integration of CE and the sustainability topic into educational curricula of both the secondary schools and higher education institutions.

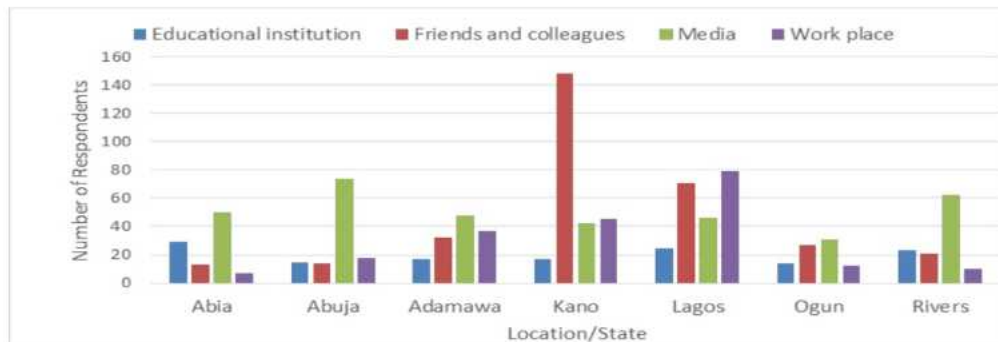


Figure 2. Sources of CE awareness among consumers

4.3 Awareness of the Nigerian National EE Framework and EPR

Figure 3 presents consumer awareness of the Nigerian E-waste Framework and EPR by location. Awareness of the E-waste Law is highest in Abuja (29.1%) which hosts the HQ of the Ministry of Environment and regulatory agency (NESREA) that enforces the Law. Meanwhile awareness of ban on importation of e-waste is more in Lagos (39.0%) which hosts the two main ports through which these items were imported. Awareness of the ban on CRT importation is highest in Ogun State (34.0%) followed by Lagos (31.5%). Ogun State shares boarder with Lagos State and has significant e-waste flows and management activities. On the average, 26.0% or 967 respondents are aware of the E-waste Law whereas more consumers are aware of the ban on importation of e-waste (35.5% or 1320 respondents). This could most likely be as a result of the media coverage of the ban compared to the Law.

Presented in Figure 3 is awareness of the E-waste Law, policy banning the importation of e-waste and CRT-containing devices. Only 1058 respondents (28.5%) are aware of the ban on importation of CRT-containing devices (TVs and monitors). Respondents who earned more (between ₦90,001- ₦120,000) were 1.5 times more likely to be aware of Nigeria's E-waste framework compared to those who earned less than ₦30,000.

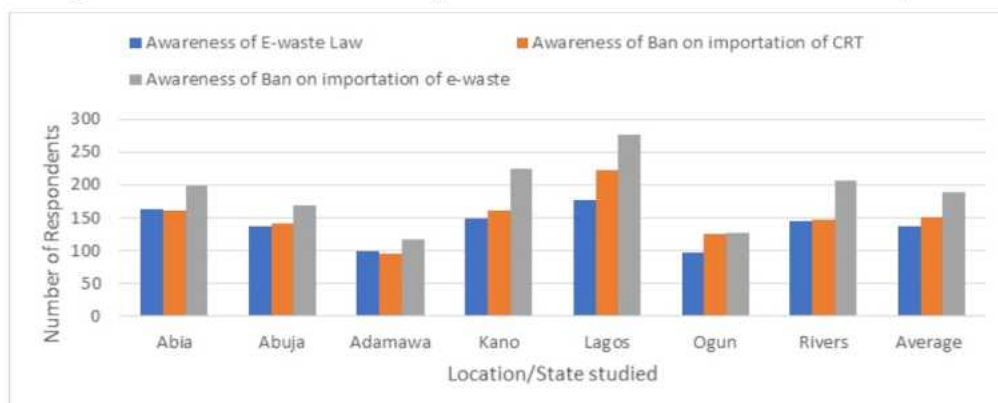


Figure 3. Consumer awareness of the Nigerian E-waste Framework

4.4 Consumer Awareness of EPR for EEE in Nigeria and EPRON

When asked if they had “heard of Extended Producer Responsibility (EPR)” before, only 388 of the 3715 participants responded ‘yes’, that is just 10.4% of the respondents. A follow-up question (‘what best explains EPR’) was used to gauge their understanding of EPR. Interestingly, 60.3% of these respondents (i.e., 234 of the 388 respondents indicated that they have heard of EPR before, and they believed that the ‘concept is based on the polluter pays principle’. Another 30.4% perceive EPR as a global strategy to produce electronics while 9.3% had no idea. Overall only 234 of the entire participants in the study (6.3%) have good knowledge of EPR. It is therefore not surprising that the majority of the respondents, about 90.6% (3366 respondents), indicated that they do not know that there is an EPR programme for the EEE sector in Nigeria. The level of awareness of EPR, was 12.2% in Abia State, 12.1% in FCT, 7.8% in Adamawa, 10.2% in Kano, 10.0% in Lagos, 7.0% in Ogun State and 12.0% in Rivers State. Only 388 respondent (10.4%) indicated that they were aware of EPR.

The percentage of respondents who have heard of EPRON, the organisation that implements EPR for EEE in Nigeria, is just 6.8% (252 respondents). Respondents from Lagos State (61 respondents or 8.6% of respondents in the State) had the highest level of awareness of EPRON activities compared to the other participating states. This is followed by Rivers State (56; 10.3% of respondents in the state), Kano (54 respondents; 8.3% of respondents in the state), Adamawa (36 respondents; 10% of respondents in the state), Abia and Abuja (19 respondents each; 3.1% in Abia of respondents in Abia state and 4.0% of respondents in Abuja) and then Ogun State (7 respondents; 1.9% of respondents in the state). The data show that respondents’ knowledge about EPRON depends on their state/location ($\alpha = 0.05$). Only around 4.3% (160 respondents) of the 3715 consumers are aware that EPRON coordinates the implementation of EPR for EEE in Nigeria.

4.5 EEE Purchasing Decisions for New and Used EEE

The 3715 respondents were asked how they mostly acquire EEE. About 76.9% of consumers (2856 of the respondents) indicated that they would rather buy new EEE; 12.5% (466 respondents) would rather purchase imported UEEE; 6.0% (221 respondents) purchase locally used second-hand EEE while another 2.3% have participated in business-to-business (B2B) transactions (transaction or business between two businesses rather than between a business and an individual consumer). Only 86 respondents (2.3% of the respondents) indicated that they would rather trade in their old devices for new ones.

Findings of this study compare well with the findings of an earlier survey of EEE consumption in Nigeria which reported that households (81.5%) prefer to purchase new EEE compared to imported UEEE (Ogunseye, 2019). Also, as more and more consumers discard devices because of the obsolescence of technology and not their functional obsolescence such devices are sold, upgraded/repaired and reused (Ogunseye, 2019; Moossa et al., 2023). Therefore, the demand for imported UEEE started

declining in recent times as its demand is now met by locally generated UEEE. Stakeholders in Nigeria, including the Nigerian Customs (Tin Can Island Port Lagos) and the Lagos State EPA (LASEPA, E-waste Unit), reported a substantial decline in the importation of UEEE from routine inspection and monitoring activities, though specific data to back this up is lacking. The decline UEEE/e-waste imports was attributed to better monitoring and enforcement of the E-waste Framework especially the ban of importation of CRTs and non-tested EEE. Also, there is a limit in the number of open displays of tested and non-tested EEE as a result of the ban. LASEPA also reported a decline in the number of e-waste disposed at dumpsites which it attributed to the benefits of increased sensitization of the citizens on the negative effect of indiscriminate dumping of e-waste and open burning of e-waste. Education on waste to wealth through circular economy in the e-waste sector has also increased in the past 5 years.

The respondents' experiences with buying new or used EEE and fixing it before use are shown in (Supplementary Material: Figure S2). Roughly 19.8% of the participants (734 respondents) stated that they had to repair a newly purchased EEE they had bought because they were defective. Another 750 respondents indicated that they have had to repair an acquired UEEE before use. This unexpected occurrence shows that the Nigerian EEE market contain appreciable quantities of inferior new EEE products. A sizeable number of the respondents (31% of the 3715 consumers; 1151 respondents) indicated that they have used 'old-for-new' deals to buy EEE (Supplementary Material: Figure S2).

4.6 Consumer Behaviour in EEE Acquisition (Quality and Country of Manufacture)

It's intriguing that some consumers equate the country of origin or manufacture of EEE with product quality and durability. When consumers (3715 respondents) were asked to select from four (4) different countries of EEE manufacture, as their preferred country of manufacture for EEE items, 1368 respondents (36.8%) chose Germany, followed by the United States (20.6%) and then China (20.5%). Just 10.3% of the respondents preferred to purchase EEE produced in Nigeria, while 11.9% had no preference.

Most consumers expressed willingness to pay more (premium) for higher-quality EEE products of known brands. Because they believe the items made in these countries and by certain brands are of higher quality, many consumers would be willing to pay an additional 10% for EEE made in specific countries. More of the respondents (36.7%) preferred products from Germany, followed by the United States (22.2%), and China (21.8%) (Figure 4). Boman et al., (2024) observed that consumers exhibit greater brand loyalty, possibly as a result of their prior usage of the brand being proven to be safe (and durable) by personal experience. The combined influence of emotions, strengthened by the contextual support of personal standards, determines how much people want sustainable products (Nascimento and Loureiro, 2024). Consumer feelings and desires also constitute fundamental elements in their decisions to purchase, repair, or dispose of products.

Electronic Waste Management in Nigeria

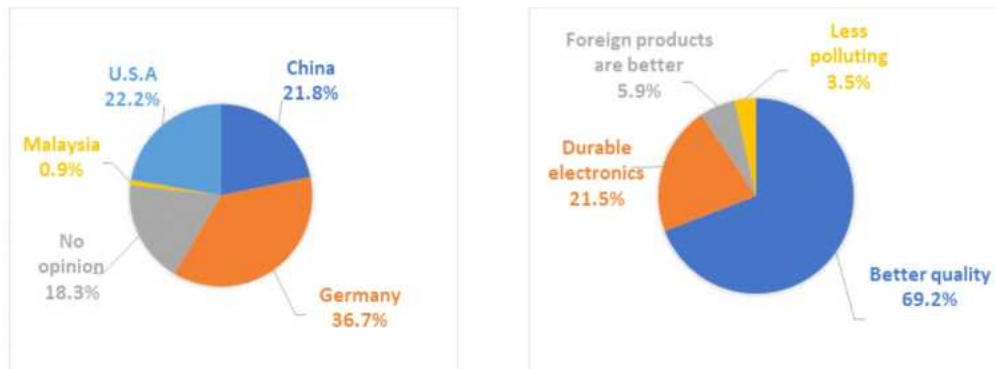


Figure 4 & 5: Willingness of consumers to pay 10% extra for devices made in selected countries

Subsequent probe to assess the potential motivations and drivers of consumers' willingness to pay an additional 10% for EEE manufactured in the above selected countries revealed that "quality" (69.6% of respondents) and "durability" (21.5%) of the EEE products were the main factors (Figure 5).

Respondents were also asked 'How much extra they were willing to pay for 'less polluting' EEE products. A sizable percentage of respondents (59.6%; 2213 participants) indicated willingness to pay extra (a premium) for EEE products that are 'less polluting'. Additionally, the 2213 respondents were asked how much extra they would be willing to pay.

Approximately 87.8% of consumers said they would be prepared to pay an additional 10% for 'less polluting' EEE items; 9.7% indicated they would be willing to pay extra 20% premium; 1.5% would be willing to pay extra 30% while about 1.0% said they would be willing to pay a 40% premium for 'less polluting' products.

The participants were asked the TV type/class they would like to buy, whether CRT TV or flat screen TV, should they desire to acquire a new TV. Majority of respondents (98.4%) favoured flat screen TVs (inclusive of plasma, LCD, and LED TV) over CRT TVs. This is more because flat screen TV is more fashionable now (flat screen technology is now the norm) and not because of environmental concern or because the government banned importation of CRT TVs (despite the fact that many participants are unaware of the policy that prohibited the importation of CRT TVs). Other studies have also shown that consumer willingness to pay for safer products is generally positive but low (Boman et al., 2024). In a much earlier study by Saphores et al., (2007) participants demonstrated a low willingness to pay for a premium for green electronics - most participants only expressed willingness to pay 1% premium for a 'green' mobile phone or desktop computer. Similar studies have pointed out that the low willingness to pay might be related to participants' lack of knowledge about toxicity of electronic waste (Saphores et al., 2007; Echegaray and Hansstein, 2017).

4.7 Consumer Attitude Towards Dysfunctional Devices

About 62% of the respondents reported that during the previous five years, one or more of their EEEs had malfunctioned. Presented in Table 2 is a summary of EEE possession and the number of products that respondents indicated became dysfunctional during the previous five years. More mobile phones than any other EE product became dysfunctional (over the past five years) about 32.1% of the respondents reported faulty mobile phones. This is followed by TVs (17.6%), freezers (9.3%), radios (10.3%), and pressing irons (14.3%) (Table 2). Participants did not mention 5 EEE product types among products that became dysfunctional in the past 5 years – these are medical equipment, automatic dispenser, toys, fan and sports equipment. In Nigeria, faulty or broken electronic gadgets are often fixed and repurposed instead of being thrown away. When asked ‘a short and direct question’ about repair of faulty EEE (Do you send your EEE for repair if they develop a fault?), 3058 of the 3715 respondents (82.1%) indicated ‘yes’; they repair faulty EEE products. However, when the same question was posed separately to participants with options that included (i) repairing, (ii) donating, (iii) selling, and (iv) storing faulty EEE, 3103 participants responded to each question independently from previous experiences (which may be for different devices). Details of consumers’ response to donating, selling (C2C) and storing faulty devices is presented in Table 2. It was observed that more consumers responded to handling options for faulty EEE.

Overall about 66.2% (2053 respondents) indicated that they repair and reuse faulty EEE. Out of 3103 responses, 414 respondents (or 13.3%) indicated that they donated, 385 respondents (12.4%) sold such devices, while 697 respondents (22.5%) said they stored such dysfunctional products at home (Supplementary Material: Figure S3).

Reasons proposed in literature for storing EEE especially small EEE items (such as mobile phones) include: (i) perceived economic and use value, (ii) protection of personal information stored in the device, (iii) emotional attachment/value, and (iv) the convenience of storing small items like mobile phone which takes up little space in closets (Zhang et al., 2021). The respondents’ decision to repair their faulty equipment depends on the equipment type ($\alpha = 0.05$). The difference in response to the two similar questions (almost 16% reduction) that assessed respondents’ attitude towards the repair of faulty EEE could be attributed to several factors including: (i) all the participants responded to the first question compared to the later, and (ii) some participants that repaired faulty EEE before selling or donating may have selected any of the options the other options (repair/donate/sell).

The success rate of repair of dysfunctional EEE was assessed by asking participants if ‘the repair of the faulty equipment was successful?’. Overall, respondents reported a very high success repair rate of 87% for dysfunctional EEE taken to a repairer’s shop. The finding of Pérez-Belis et al. (2017) showed that older consumers and females were more prone to repair small household EEE, while older males with medium family incomes tended to purchase second-hand small household EEE more. Several studies have shown that consumers often prefer to hoard/store/keep their last obsolete mobile phone at home (Yin et al., 2014; Wilson et al., 2017; Zhang et al., 2021).

Table 2: Disposal of faulty EEE types over previous 5 years period

EEE Type	Number of respondents that reported faulty EEE	Gave out faulty EEE		Sold faulty EEE		Faulty EEE stored	
		No	Yes	No	Yes	No	Yes
Desktop	31 (1.0%)*	29 (93.6%)**	2 (6.45%)	22 (70.97%)	9 (29.03%)	18 (58.06%)	13 (41.94%)
Freezer	287 (9.3%)	257 (89.55%)	30 (10.45%)	253 (88.15%)	34 (11.85%)	225 (78.40%)	62 (21.60%)
Laptop	139 (4.5%)	118 (84.89%)	21 (15.11%)	120 (86.33%)	19 (16.37%)	111 (79.86%)	28 (20.14%)
Microwave	74 (2.4%)	62 (83.78%)	12 (16.22%)	63 (85.14%)	11 (14.86%)	46 (62.16%)	28 (37.84%)
Mobile phone	995 (32.1%)	817 (82.11%)	178 (17.89%)	858 (86.23%)	137 (13.77%)	842 (84.62%)	153 (15.38%)
Photocopier	27 (0.9%)	25 (92.59%)	2 (7.41%)	23 (85.19%)	4 (14.81%)	20 (74.07%)	7 (25.93%)
Pressing iron	442 (14.3%)	390 (88.24%)	52 (11.76%)	391 (88.46%)	51 (11.54%)	320 (72.40%)	122 (27.60%)
Printer	33 (1.1%)	31 (93.94%)	2 (6.06%)	29 (87.88%)	4 (12.12%)	24 (72.73%)	9 (27.27%)
Radio	319 (10.3%)	288 (90.28%)	31 (9.72%)	279 (87.46%)	40 (12.54%)	221 (69.28%)	98 (30.72%)
Sewing machine	52 (1.7%)	51 (98.08%)	1 (1.92%)	50 (96.15%)	2 (3.85%)	39 (75.00%)	13 (25.00%)
Television	545 (17.6%)	490 (89.91%)	55 (10.09%)	494 (90.64%)	51 (9.36%)	414 (75.96%)	131 (24.04%)
Vacuum cleaner	11 (0.4%)	9 (81.82%)	2 (18.18%)	6 (54.55%)	5 (45.45%)	7 (63.64%)	4 (36.36%)
Video game	32 (1.0%)	24 (75.00%)	8 (25.00%)	27 (84.38%)	5 (15.63%)	22 (68.75%)	10 (31.25%)
Washing machine	115 (3.7%)	97 (84.35%)	18 (15.65%)	102 (88.70%)	13 (11.30%)	96 (83.48%)	19 (16.52%)
Total	2688 (86.7%)	414 (13.4%)	2717 (87.6%)	385 (12.4%)	2405 (77.5%)	697 (22.5%)	

* Percent of total respondents that reported faulty EEE irrespective of EEE type; **percent of participants that responded for a specific EEE

Mobile phones (74.3 percent of 995 respondents), electric sewing machines (73.1 percent of 52 respondents), freezers (69.7% of 287 respondents), washing machines (69.6% of 115 respondents), printers (66.7% of 33 respondents), TVs (65.1% of 545), laptops (64.0% of 139 respondents), photocopiers (63.0% of 27 respondents), pressing irons (61.5% of 442 respondents), and radios (58.3% of 319 respondents) are the EEEs that respondents repair most frequently (Supplementary Material: Figure S4). Microwaves (43.2% of 74 respondents), video games (37.5 percent of 32 respondents), desktop computers (25.6 percent of 31 respondents), and vacuum cleaners (18.2% of 11 respondents) are among the other gadgets that are frequently repaired and reused, thereby extending their lifetime. Extension of useful life as discussed by Vidal-Ayuso et al. (2023) could take three major forms: careful use of product; decisions to repair; and lastly decision to share underutilised assets.

The importance of repair in transitioning to a CE have been highlighted in literature (Svensson-Hoglund et al., 2021). Both the EU and the US are implementing policies to promote repair and extend the lifespan of products. The EU has introduced changes to Eco-design regulations, while the US is considering Right to Repair legislation. These efforts aim to increase the number of repairs made and reduce waste (Svensson-Hoglund et al., 2021). The developing countries should also introduce initiatives to support the existing culture of repair-and-reuse with inputs from OEM and third party service companies. Presented in Table 2 is a summary of consumers' attitudes towards old/obsolete/dysfunctional EEE with respect to the three alternatives (i.e., to donate, to sell, or to store). In addition, when compared to other EEE types, mobile phones are the gadget that are handed out the most while TV, pressing iron, radio, and fridge come next. The fact that mobile phones are the most commonly owned EEE ($3227/3715 = 86.9\%$ possession rate) and that 32.1% of respondents reported having dysfunctional phones (Table 2) may help to explain why they are the gadgets that are passed down the most.

Bovea et al. (2018) analysed consumers habits and practices towards the store, repair and second-hand purchase of small EEE devices (ICT: MP3/MP4, video camera, photo camera, mobile phone, tablet, e-book, laptop, hard disk drive, navigator-GPS, radio/radio alarm clock) and reported that there is a tendency to store disused small ICT devices at home. On average for all the small ICT categories analysed, 73.91% of the respondents store disused small ICT devices at home. Related to the habits towards the repair and second-hand purchase of small ICT devices, 65.5% and 87.6% of the respondents have never taken such devices to repair and have never purchased them as second-hand, respectively (Bovea et al., 2018). Thus, the attitude of consumers is a key element in the repair and reuse of products, as they are directly responsible for the different decisions that affect the end of the useful life of such products (Gurauskienė, 2008; Bovea et al., 2018).

Results of this study shows that on the average, consumers donate (give out) 13.4% of EoL EEEs, 12.4% are sold, while 22.5% are stored (Table 2). The rest are repaired/re-furbished and reused to extend the product lifetime. The kind of equipment determines

whether consumers will repair/reuse, sell or give away such devices (at $\alpha = 0.05$). Mobile phones are stored more frequently followed by TV, pressing iron, radio and freezers. Surprisingly consumers continue to store dysfunctional or EoL EEE, despite reporting a very high success repair rate of 87% for faulty EEE taken to technicians for repairs. Literature shows that consumers sometimes find it difficult to give or sell used/EoL products, especially electronic devices. Ferraro et al. (2011) observed that the strong reactions consumers have to the loss of some items may seem difficult to understand and argued that consumers do not grieve for just any possessions; they grieve for possessions that are linked to self, a notion that is based on more than just the importance of the possession.

4.8 Challenges hindering EEE Repair and Reuse

Respondents in this study identified the high cost of fixing malfunctioning EEE (of certain categories) as one of the justifications for storing rather than repairing and reusing devices. King et al., (2006) also identified the cost of repair as the main challenge that prevent consumers from repairing their EEE more frequently, while other studies identified hygienic factors and the perception of poor quality as the reasons that discourage consumers from buying second-hand devices (Fisher et al., 2008; Lyndhurst, 2011).

Some of the consumers that indicated that they didn't repair faulty EEE were given the opportunity to select from seven (7) options that best describes their reasons for not bothering to repair dysfunctional EEE (only 1382 responded). About 24.9% (344 respondents) identified cost of repair as a major challenge. They indicated that they would prefer to save money and buy a new product if the cost of repair is rather high. Lack of funds for the repair (10.6% or 146 respondents), inadequate technician skills (8.6% or 119 respondents), and lack of confidence in the technician's ability to successfully repair the device based on past experience (24.6% or 340 respondents) are some additional reasons. Other respondents indicated that unavailability of technicians within reach (11.1%; 154 respondents) hindered repairs while the rest indicated that technicians' feedback (after assessment of the dysfunctional EEE) which suggested that the device is irreparable (20.2% or 279 respondents) stopped them from proceeding to repair faulty devices. Prolonging the lifetime of consumer electronics, particularly the duration of use, is essential for realizing a more circular economy and reducing e-waste (Yamamoto and Murakami, 2022).

The participants were further asked about the major challenges they face in repairing and reusing EEE. They listed the following as the main obstacles they encounter when attempting to repair malfunctioning EEE: a lack of OEM-certified or expert technicians for specific EEE products (28.6%; 1064 respondents); doubts about the devices' ability to be fixed adequately (22.8%; 846 respondents); absence of replacement parts (20%; 741 respondents); and product obsolescence brought on by the introduction of new technologies (15.2%; 566 respondents). Lastly, 13.4% of the participants (498 respondents) indicated that their likelihood of repairing and reusing a faulty device decreases when they can easily purchase a new one.

An additional question was posed to participants to understand why they chose to repair and reuse EEE. Most participants (2078 participants; 55.9%) indicated that they repair and reuse devices more when they have confidence that the product is of a good brand (good quality and durable). Others indicated that they repair faulty devices when they are unable to afford new equipment (38.1%; 1416 participants). However, only 6.0% (221 participants) repair and reuse because they are aware of the circular economy. About 43.3% of consumers indicated that they have one or more non-functional electronic devices stored at home. When asked if they would like to dispose of a device once it develops fault (without repair/reuse) and buy a new one, 1719 respondents (46.3%) responded 'yes'.

Storing old non-functional devices at home, a practice which is often described as hoarding, is not peculiar to Nigeria or developing countries. A recent UNITAR study on the update of WEEE collection rates, targets, flows, and hoarding in the EU-27, United Kingdom, Norway, Switzerland, and Iceland revealed that households possess an average of 74 EEE items (excluding luminaries and lamps). Nine (9) out of these items are functional but hoarded, while four (4) are dysfunctional but hoarded, and 61 items are in use (Baldé et al., 2022). Participants were asked how many times they have repaired any electronic device of their choice. Figure 6 shows that most consumers have repaired devices about 2 times. The average repair time (3715 respondents) is 2.1 ± 2.5 times.

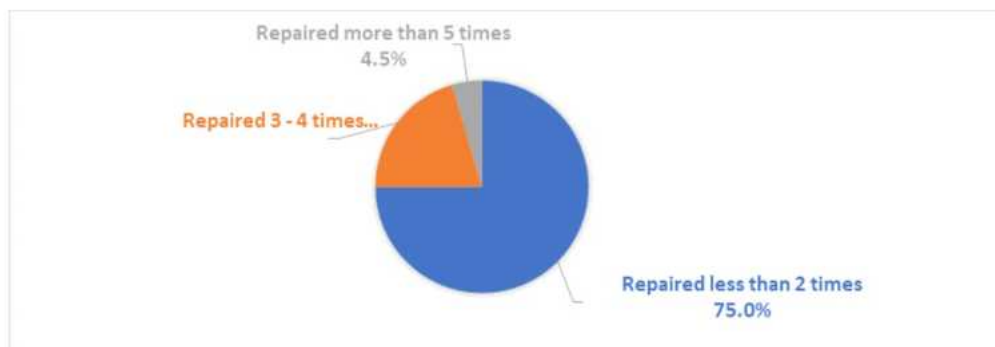


Figure 6: Number of times consumers repaired and reused EEE

4.9 Waste EEE Generation and Factors Influencing Disposal Attitude/Behaviour

Participants (3715) were asked about the condition of (most) EEEs when they stopped using them, with three options provided. The majority of respondents (2299; 61.9%) selected that they stopped using most EEE even when they were non-functional though not broken; 26% (966 respondents) indicated that they stopped using most devices because they were both damaged (broken) and nonfunctional, while the rest 12.1% (450 respondents) indicated that they stopped using most EEE even though they were still intact (not broken) and functional.

The observation that only 12% of respondents stopped using functional products may

Electronic Waste Management in Nigeria

be explained by the fact that the majority of respondents do not come from high-income families. It is evident that low-income earners would not routinely replace EEE products even when they are still functional. Researchers recommend awareness-raising campaigns to encourage and prioritize strategies for the reuse or repair of EEE versus other forms of recovery, such as recycling (in line with the Directive 2012/19/EU) (Bovea et al., 2018). Vidal-Ayuso et al. (2023) suggested that change will come when consumers increase their involvement and proactivity, by becoming active contributors to the CE, especially by extending the lifetime of EEE products and delaying the waste period.

Participants were asked ‘Which e-waste type/category have you disposed MOST in the past five years?’ Figure 7 shows the categories of e-waste that respondents have disposed of most frequently during the last five years. More often than not, consumers said they disposed of their mobile phones (1244 respondent or 33.5% of all respondents), then TVs (12.3%), press irons (9.8%), and freezers (5.2%). The percentage of consumers who said EEE shops encouraged them to return their EoL EEE for free was only approximately 17%. Moreover, just 7% of respondents said that recyclers had contacted them regarding returning their EoL EEE for ESM.

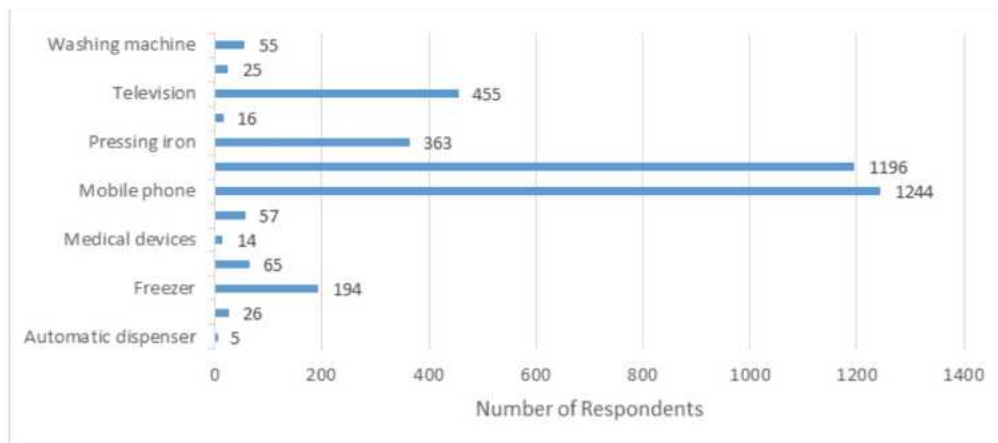


Figure 7: E-waste was mostly disposed of by respondents in the last five years.

Participants (3715 respondents) were once more asked what they did when they stopped using EEE (disposal strategies) with seven options provided. While 710 (19.1%) of the respondents said they disposed of e-waste with domestic trash, the majority of respondents (1785 respondents; 48.0%) indicated that they sold e-waste to door-to-door collectors. Another 17.2% (640 respondents) said they gifted such EEE to family and friends; 2.7% (100 respondents) disposed of e-waste at retail shops; 6.5% (240 respondents) used old-for-new schemes/programs; and 5.3% exchanged their EoL EEE for other products. Only a mere 1.2% (43 respondents) stated that they got rid of their e-waste at authorised e-waste collection centres.

This shows that although Nigeria has made gains in regulations, raising public awareness, and implementing externally sponsored projects that included the establishment

of collection centres, the informal sector still controls the majority of e-waste handling in the entire country. Researchers agree that the active involvement of consumers, especially in using formal e-waste disposal channels, is the most critical factor in achieving the much-desired success of sustainable e-waste recycling management (Nnorom et al., 2009; Borthakur and Govind, 2017; Islam et al., 2020; Nguyen, 2023).

Additionally, more questions were used to assess consumer attitude EEE. Participants were asked if they would be willing to exchange a broken device for a new one, and about 46% said 'yes'. Another question was used to gain insight into the number of times consumers have repaired dysfunctional EEE. About 75% of the respondents indicated that they have repaired some devices at least twice; with 20.5% reporting three or four repairs and 4.5% reporting more than five repairs. A sustainable CE can be facilitated by slowing down EEE disposal through repair and reuse of dysfunctional devices, which would obviously result in a decrease in the purchase of new goods (Jourdain and Lamah, 2024).

When asked about the best way to make them hand in your e-waste, the majority of respondents indicated that they would rather receive cash incentives (59.2%; 2198 respondents); followed by having collectors come to their doorstep (17.0%; 632 respondents); having collection centre located close by (17.0%; 632 respondents) or receiving a voucher (to be redeemed later) (4.0%; 147 respondents). The lesser preferred options are for consumers to make use of a company websites/a mobile app (1.3%; 47 respondents) or sending an email/text message (1.6%; 59 respondents) to notify collectors and recyclers of a collection. Even though they preferred financial incentives to hand over e-waste, when asked if environmental protection could be a motivation to hand in their e-waste to a registered collector, 31.5% (1169 respondents) responded 'yes'.

When asked which method of disposal they preferred, the majority of respondents—roughly 70% (69.7%; 2591 respondent)—selected door-to-door (household) collection Figure 7. This may not be unconnected with the financial advantages that door-to-door e-waste collectors provide. The participants (3715 consumers) were asked if EEE retailers have encouraged them to return e-waste free to their shops at no cost. Only 627 respondents (16.9%) indicated that retailers made such requests (Figure 8).

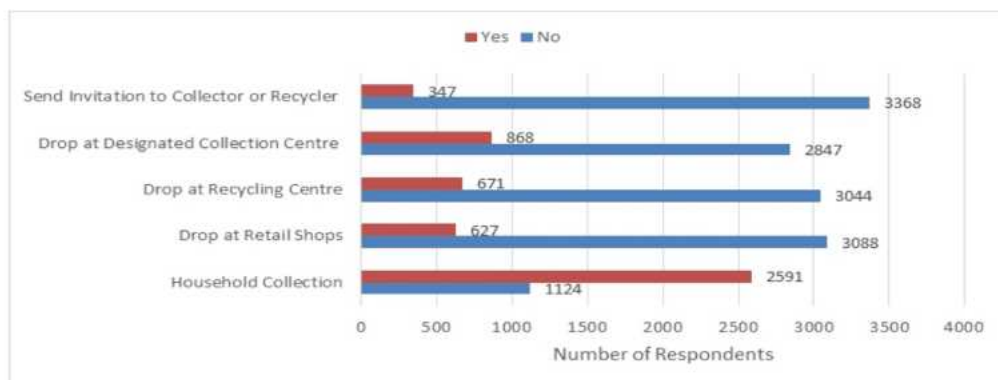


Figure 8: Consumer preferred e-waste collection approaches

Electronic Waste Management in Nigeria

This is also in line with the response that was received when consumers were offered the chance to dispose of their e-waste at recycling facilities: just 18.1% (671 respondents) chose to take part (Figure 7). Likewise, 23.4% of consumers (868 respondents) preferred to dispose of their e-waste at authorized e-waste collection/recycling facilities. Sending formal invites for e-waste collection to recyclers or collectors was favoured by just 9% of consumers (347 respondents) (Figure 7). When asked if recyclers had approached them physically or via email to hand in their e-waste for ESM, only 248 respondents (6.7%) responded 'yes'.

Our major findings corroborate those of Echegaray and Hansstein (2017), who reported that only a minority of respondents actually adopt adequate recycling practices connected to e-waste, a behaviour which is socially skewed among the higher income echelons of Brazilian society. Also, a study in China shows that 25% of respondents recycled their obsolete mobile phones through formal recycling channels, 19% give to others, 49% store is at home, 4% sell as second-hand, 1% discard as trash, while informal collectors hand 2% (Zhang et al., 2021).

Only about 32% of participants said that they are driven to recycle electronic waste due to their concern for the environment. When asked what encourages them to hand over their EoL devices for recycling, about 70% of the respondents (2599 respondents) said that the collection of financial incentives are what pushes them to recycle. When asked what the biggest obstacle is to proper disposal of EoL devices, the majority of respondents (74.5%) said they have trouble finding nearby collectors (or collection centres), while only 25.5% (948 respondents) said they had easy access to collectors.

Knowledge is an important determinant of willingness to participate in environmental protection activities. A study by Lakhan (2016) also observed that respondents' willingness to pay for environmental handling fees increased with a product's perceived environmental harm at the end of life. Lakhan (2016) observed that consumers did not consider electronic products as harmful and were averse to paying an environmental fee.

4.10 Consumer Awareness of E-waste Composition and Toxicity

Of the 3715 respondents, 2175 (58.5%) indicated they were aware that "repairing and reusing" faulty electronic devices reduces pollution and waste generation.

Respondents' awareness of the beneficial and harmful material contents of e-waste was also assessed. About 77.0% (2862 respondents) acknowledge the potential benefits of recycling e-waste, if done the right way (Supplementary Material: Figure S5). In a similar vein, around 41.5% (1541 respondents) are aware that some e-waste components contain valuable elements like silver and gold (Figure 15). However, 54.8% (2037 respondents) are aware that toxic elements such as lead and other harmful organic compounds can be found in e-waste. Most respondents (65.7%; 2440 respondents) are aware that disposing of e-waste into a surface water body used for domestic purposes (such as a stream) might affect the quality of the water supply. Overall, about 75.1% (2789 respondents) of consumers are aware that the adoption of inappropriate management of e-waste can pollute the environment.

A little over 61.4% (2281 respondents) of the respondents said they would be ready to pay a “recycling fee” in order to promote environmentally friendly recycling practices for e-waste. This demonstrates consumer awareness of ESM of e-waste. In a similar vein, 65.4% of respondents (2428 respondents) said they would be prepared to pay extra for a phone provided it could be produced in a way that does not immediately pollute the environment or does so in the future. Consumers were asked if they think Nigeria has the infrastructure to manage e-waste properly. More than half of the respondents (51.6%; 1916 respondents) said that there is not enough infrastructure in place in the entire country to efficiently collect and handle e-waste when questioned about the availability of e-waste collection and treatment facilities in their local areas.

E-waste poses significant risks to both health and the environment due to the toxic components it contains. The situation is worsened when improper disposal and recycling are adopted (Nnorom and Osibanjo 2008a; 2008b; Osibanjo et al., 2011; 2016; Püschel et al., 2024). Common e-waste components, such as lead, mercury, cadmium, and brominated flame retardants, can have severe detrimental effects on humans and the ecology at large. Lead, found in old CRT monitors and circuit boards, is a potent neurotoxin (Nnorom et al., 2011). The World Health Organisation (WHO) released its first in-depth report (Children and Digital Dumpsites: E-Waste Exposure and Child Health), on June 15, 2021 which chronicled the scope of the issue, the routes through which children are exposed, the health consequences connected to the various routes of exposure, and the steps that the health sector can take to address such issues (WHO, 2021).

5 Discussion

In addition to the requirement for suitable e-waste management regulations and legislation, consumer awareness of recycling is critical (Echegaray and Hansstein, 2017). The major findings of this study are similar to the observations of Echegaray and Hansstein (2017) in Brazil which observed that Brazilian EEE/EPR regulation, enacted in 2010, remain largely unfamiliar to consumers and are also poorly enforced among both manufacturers and local authorities. Consumer behaviour towards e-waste is influenced by many factors including attitudes, knowledge, perceived benefits, environmental concern, perceived risk, and barriers (such as shortage of infrastructure). The cost and affordability of inferior new devices and cheaper readily available imported used EEE, influence purchasing decisions of consumers and contribute to higher e-waste volumes. Studies have also shown that social influences, including peer pressure and prevailing social norms, shape consumer consumption patterns, further driving the cycle of e-waste generation (Sorkun, 2018; Thukral et al., 2023). It's obvious also that age, income, education, and occupation; as well as environmental concern, perceived risk, and a sense of responsibility impact consumer behaviour and disposal decision-making for EoL products. A comprehensive framework of circular consumption helps understanding how circular consumption practices are performed (Jourdain and Lamah, 2024). Qualitative findings reveal that formal schemes backed by EPR regulation engage consumer in circular fostering consumption. However, quantitative results highlight that circular consumption in second hand circulation also follow

Electronic Waste Management in Nigeria

informal paths, and can involve consumption slackening through repair and care for products (Jourdain and Lamah, 2024).

Findings of this study shows that consumer have non-functional electronic equipment, particularly mobile phones and would rather dispose such devices by gifting them to family or friends, selling them (C2C), or storing them. Only a small percentage of consumers use official/formal e-waste disposal facilities. Most consumers dispose e-waste through informal collectors that approach consumers using door-to-door approach and offer financial incentives. Most consumers are often unaware of the health risks associated with channelling e-waste into the informal sector.

Consumer understanding environmental and health impacts of adoption of informal e-waste management practices and proper disposal methods is crucial for a change in attitude. Factors like convenience, social status, consumer perceived benefits, such as cash incentives from collector's, influence e-waste disposal choices. Easy disposal options, such as door-to-door collection, often lead to irresponsible e-waste disposal practices. Economic considerations, such as incentives from informal collectors' routes e-waste towards the informal sector. Similarly, this study observed that a lack of access, infrastructure, and awareness can hinder sustainable e-waste disposal practices and treatment.

Informal recyclers play a significant role in e-waste collection and management in Nigeria, particularly in the absence of formal systems in most cities. Informal e-waste management provides livelihoods for many individuals, particularly in low-income communities. However, they operate outside regulatory frameworks, leading to social and environmental issues and exploitation, with the attendant negative impacts on the environmental and health of operators and residents. Many informal e-waste operators are unaware of e-waste issues and proper disposal methods. Common informal sector practices such as manual dismantling to recover valuable fractions and open burning of plastics and cables pose environmental and health risks. Informal recyclers are often motivated by economic factors and limited access to formal disposal options.

6. Recommendations

Consumer behaviour significantly contributes to e-waste generation and the management practices. This study has shown that an understanding of these patterns and the influencing factors is key to developing targeted interventions. By leveraging education, infrastructure, product design, economic incentives, social norms, and policy changes, Nigeria can promote responsible consumer behaviour and mitigate e-waste's environmental and health impacts (Dai et al., 2020). To promote e-waste recycling, we need to educate people about its importance, enforce EPR, improve infrastructure, design products for sustainability, offer incentives, encourage social norms, regulate effectively, and collaborate internationally. These actions are essential for creating a more sustainable and environmentally friendly e-waste management system. Many consumers are still uninformed of the environmental and health risks involved with incorrect e-waste disposal, exacerbating the problem. To improve e-waste management,

it is important to educate people about its composition, especially on the hazardous and likely environmental and health implications of adopting unapproved practices. This should go alongside creating awareness on CE and EPR. At the other end, recycling should be made convenient for consumers, while some form of economic incentives for responsible behaviour should be put in place to motivate consumers to route e-waste towards formal recycling. Strict implementation of the revised EE Regulation.

This study highlights the need for OEMs and their representatives to invest in training technicians to provide quality repair services. This shift from a sales-focused model to a repair-focused one can generate additional revenue and contribute to a more circular economy. The study also emphasizes the importance of consumer awareness and behaviour change. Encouraging consumers to repair and reuse electronic devices can significantly reduce e-waste. This can be achieved through initiatives like equipment leasing, sharing, and trade-in programs.

The government's role in promoting sustainable e-waste management is crucial. The National Environmental (Electrical/Electronics) Regulation and the Guidance Document provide a strong foundation for implementing circular economy principles. However, effective monitoring and enforcement are essential to ensure compliance and behavioural change.

It is imperative to allocate more resources towards awareness creation and the implementation of sound practices throughout the whole e-waste value chain. The intended level of pollution control cannot be attained in the absence of enforcement. Similarly, awareness among informal operators should especially focus on the provisions of the revised 2022 EE Regulations and other government policies on e-waste with emphasis on prohibited activities.

Since the EPR is entirely dependent on enforcement, it can only be effective if the compliance plan is shared with all relevant parties and carried out by the federal and state environmental regulatory agencies. Adequate monitoring is also necessary for enforcement. It is imperative to monitor the synergies that exist between environmental regulatory agencies at the federal and state levels. Regulatory agencies (EPRON and NESREA) should provide more information to the general public on the toxic substances contained in e-waste and their deleterious effects on health and the environment.

7. Conclusion

This study examined consumer behaviour in Nigeria regarding awareness of CE and EPR within the EEE sector. This is because consumer behaviour significantly contributes to e-waste generation and disposal in developed countries. Understanding these patterns and influencing factors would enable targeted interventions. Results of this study reveal critical insights about e-waste generation and disposal patterns. Key findings underscore the need for significant action from producers, consumers, and regulatory bodies. The study highlights a general lack of awareness about CE and EPR,

Electronic Waste Management in Nigeria

proper e-waste disposal, and the importance of ESM of e-waste. Similarly, awareness of the Nigerian EE Regulatory framework is low among consumers. The results of this study show that though most respondents have minimal knowledge of CE, they unknowingly apply CE principles through repair and reuse practices that prevent waste generation and increase resource efficiency.

However, barriers to repair and reuse persist, emphasizing the need for manufacturers to prioritize product reparability and EPR compliance. The majority of e-waste generated is from mobile phones, followed by TVs, pressing irons, radios, and freezers. Given that consumers are discouraged from repairing these frequently used EEE devices, due to the high cost of repairs and the scarcity of certified technicians who will readily repair these items, the dysfunctional products end up either in the hands of informal collectors as they are given up for cash incentives, or they will be given out to friends and families who may be able to give them a new lease on life, or they are simply stored away. Evidently, these items will need to be replaced, thus driving up the volume of e-waste generated. Also critical is the fact that formal collection centres are unavailable for consumers. These factors (repair barriers, absence of collection centres) do not bode well for the CE and the EPR system, and they keep EoL devices hoarded or in the hands of the informal sector.

This study observed that consumers often rely on informal collectors for disposal, driven by convenience and financial considerations. Many consumers are unaware of the environmental and health risks associated with improper e-waste disposal. The availability and accessibility of informal collectors often outweigh concerns about environmental impacts. Consumers are more likely to recycle e-waste when offered financial incentives. Consequently, most e-waste is handled by informal operators who offer cash incentives but use inappropriate disposal methods, worsening environmental pollution and health risks. Despite the willingness of a few consumers to use proper disposal channels, inadequate collection facilities hinder effective e-waste collection and management. Proper recycling and disposal practices are crucial to mitigating the risks posed by the adoption of low-end management options. Proper management of e-waste is crucial to mitigate these risks. This includes recycling through authorized facilities, reducing consumption of electronic devices, and promoting the repair and reuse of existing devices.

Effective implementation of EPR schemes can play a significant role in promoting sustainable e-waste management. EPR can provide financial resources for collection and recycling activities. Adopting a circular economy approach can reduce e-waste generation by promoting reuse, repair, and recycling. Government enforcement of regulations and implementation of an effective e-waste management system are essential. Stakeholders and NGOs should introduce programs to promote responsible consumer behaviour and encourage proper e-waste disposal and recycling. Given the large volume of e-waste in Nigeria, foreign investments in e-waste management could be highly beneficial, with potential tax incentives for investors. Raising awareness and fostering a culture of sustainability are crucial for long-term change. Educational

campaigns should address the environmental and health impacts of improper disposal and advocate for eco-friendly practices such as repairing, donating, and recycling. Implementing these recommendations aligns with Sustainable Development Goal 12 (responsible consumption and production), and contributes to achieving Goal 13 (climate action) and Goal 6 (clean water and sanitation).

Acknowledgement

The authors acknowledge the generous funding of HIS Towers, Nigeria. The views expressed in this publication are those of the authors and do not necessarily represent those of IHS Towers Nigeria Limited, nor does the citing of trade names, companies, schemes, or commercial processes constitute endorsement of any organization. The authors also appreciate the support of Mrs. Yewande Ajayi, Mr. Solomon C. Onuchukwu, Mr. Chukwuemeka G. Kalu, Mr. Chijioke Okorieh, Ms. Chinyere Onwusiribe, and Ms Amanda C. Chidi-Nnorom.

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The Bursting of The Bubble – A Review Of Psychosocial Challenges In The Diplomatic Service

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Keywords: Psycho-social challenge, diplomatic service, culture

Despite the general impression of diplomats having a fancy and luxurious lifestyle, the reality of diplomatic service is much more complex, which at times results in a high degree of stress and poses psychosocial challenges. Within the British bureaucracy, diplomats are referred to as the Ferraro Roche group, soft, well-rounded, chocolates wrapped in a gold foil -a symbol of luxury. But, diplomatic receptions, world traveling, and rubbing shoulders with the high and mighty are but a very small part of this career. On a day-in-day-out basis, it's a deeply hierarchical job with strict deadlines, multiple pressures, and a degree of social isolation which places severe restrictions on one's ability to control the course of one's life.

The lack of social support in the diplomatic bubble is glaring. When posted abroad, the exorbitant cost of international travel, especially for the younger officers who have their parents alive, makes them isolated. They cannot share their feelings with anyone in the office, most of the embassies being very small administrative units. They cannot do so with compatriots in the community, in this day and age of social media. There is a wide power distance with bosses in the embassy who, besides the usual control of a hierarchical structure, can also influence otherwise personal matters like the selection of accommodation, approval of certain allowances, selection of schools for the children and approval of medical facilities, etc. That leaves them with colleagues in the diplomatic community. Here also, there are many issues that are taboo, and by nature and training, diplomats hold their true feelings close to their hearts. The constant compulsion to say the right talking points to their foreign counterparts hinders the free flow of a relaxed conversation.

Not to mention, the need to adapt for a different culture and circumstances on each posting limits the possibility of a long-term social anchor apart from the nuclear family. At the same time, family members of diplomats are themselves impacted by the consequences of regular displacement; spouses having disruptive careers, children losing their long-held friendships and a stable educational environment and parents being deprived of the intimacy of their offsprings. The late sitting work culture leaves very little room for the extended family even when posted at headquarters.

Moreover, by their very nature, all Ministries of Foreign Affairs are under the close watch of the leadership as well as many stakeholders and the public. Being the custodian of sensitive information, not to be talked about, adds pressures of its own.

One way of understanding stress in the diplomatic service is to look at the Demand

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The Bursting of The Bubble

Control model which suggests that workplace stress is a factor of high workload as well as the degree of control over your work i.e “strain will be maximum in jobs where job demands are high but job control is very low” (Karasek.1990). International Labour Organisation (ILO) uses this model to define workplace stress as a “harmful physical and emotional response caused by an imbalance between the perceived demands and resources and abilities of individuals to cope with those demands” (Cox et al., 2000).

From this perspective, the foreign service is definitely a high stress job. Diplomacy is full of uncertainty. A diplomat is expected to be flexible in terms of culture and work style and be a spokesperson for policies he may not agree with. While there are opportunities for expressing a preference of the next place of posting, the compulsions and the structure of the career mean that getting a posting of one choice is rare. Even diplomats who invest in certain specialised roles or languages cannot be certain of having the opportunity of using these skills and further developing them.

Another model which looks at stress is the Life Events Approach which proposes a connection between significant life events, positive and negative, on individual well-being. These events include job relocation and becoming distant from old friends and family. The Social Readjustment Rating Scale (SRRS) is based on the premise that such events, regardless of whether they're positive or negative, might necessitate significant adjustment and, hence, induce stress. From this perspective also diplomacy is prone to a high level of stress.

This is not to say that the diplomatic career is not one of the most rewarding and exciting career choices that I know of. The nature of the job and the diversity of the work as well as the counterparts, culturally as well as intellectually is unmatched. On a personal note, this career allowed me the chance of living in six diverse countries of the world besides traveling widely and interacting with a wide cross section of the societies in these countries and develop some insight into their culture and peculiar behaviours.

In the course of my career, I became increasingly aware of the importance of sound mental health in one's life and career particularly in my line of work. I noticed that there were few studies on the impact of stress and behavioural issues on the performance of civil service and even fewer interventions to provide a safety net against them. Following my doctorate on wellbeing at workplace from the University of Liverpool UK, I have been engaged with various organizations and populations on this subject including researchers, civil servants, judges, business professionals and diplomats as well as training institutions, universities and thinktanks. The purpose is to normalise the connections on this issue and build up individual as well as institutional resources to deal with it.

My point is there should be no stigma to acknowledging the challenges of our profession and accommodating within reasonable limits those colleagues who are feeling the effects of these challenges. Stress in workplace is not unusual or unique to us. One survey showed that more than one third of the workers reported typically feeling tense or stressed out during their workday (Clark, 2012).

Covid has highlighted the significance of wellbeing at workplace even more, not only among psychologists and health professionals, but also management and businesses. The pandemic, exposed vulnerabilities in workplace, mental health infrastructure and highlighted mental health as a cornerstone of sustainable development and effective governance. Young people in particular are struggling, with a staggering 48% of Gen Z and 44% of Millennials reporting that they feel stressed most or all of the time. The 2023 Gallup Global Workplace Report estimates common mental disorders costing the global economy estimated at \$1.15 trillion annually by way of its impact on work performance, absenteeism turnover rates and health care costs.

These rising numbers, coupled with the costs associated with lost productivity, attracted the interest of business leaders for urgent action. In 2017, the annual World Mental Health Day adopted the theme of “Mental health in the workplace”. The Lancet-World Psychiatric Association Commission (2022) underscored that protecting mental health in the workplace has transitioned from optional to essential for national resilience. Wellbeing at work is directly linked to multiple Sustainable Development Goals including SDG 3 (Good Health and Well-being) and SDG 8 (Decent Work and Economic Growth).

Consistent distress can deplete psychological resources and influence the organisational roles of leaders and their relationships with their subordinates. It can affect their effective functioning in their role and make them engage in poor leadership practice. (Harms et al., 2017). This could result in transferring of negative emotions to employees also, a phenomenon which has been called “a crossover effect” or “affective crossover” (Ten Brummelhuis et al., 2014).

The stigma about this issue is not confined to us either. Despite growing awareness over the years in the developed world, mental health is still associated with stigma and discrimination. Although there is an increase in awareness on the effectiveness of treatments for mental health issues, the social acceptance of co-workers with mental health issues has not improved in the past 20 years (Schomerus et al., 2012). A survey in UK found that 44% of employers interviewed believed that employees suffering from stress could still perform their jobs effectively (Henderson, 2013). Another systematic review found that employers rank potential employees with mental health issues lower than employees with physical disabilities in terms of employability (Brohan et al., 2012) .

Workplace-related stress is widespread and usually not a problem if handled appropriately. The key is not to let stress turn into distress, which can harm the individual from a psychological, social, and health point of view, but also affect the productivity and performance of the organisation

Throughout my career in the civil service, I have seen brilliant people with apparently bright futures succumbing to psychosocial pressures. Civil servants in our part of the world, especially the central bureaucracy, are considered to be not only elite but immune and distant from the usual pressures of society, and sharing of such “weakness is

The Bursting of The Bubble

not encouraged. This goes back to the origins of our civil service in the colonial civil service, which by design was aloof, distant, and thriving in a bubble of its own. The colonial service symbolised the ideals of the WASP work ethic, which ignores the human aspects of work and emphasises the values of commitment, discipline, and hard work. We need to revisit the Islamic values of management, which display kindness, forgiveness, and humanistic understanding. Combined with our ritualistic and meditative traditions, these values can lead to a better workplace.

One example to consider is the US State Department's counselling and referral services resource WorkLife4You which is free and confidential for employees and their family members, 24/7, wherever they are.

While considering any intervention to stress-proof our workplace culture, we must not forget cultural and contextual adaptation. This can lead to a thoughtful integration of evidence-based psychological interventions with traditional wisdom, cultural values of Islamic meditation practices, and collectivist community support structures that are inherent in Pakistani society. There is a need to create awareness that all of us are human, and humans can have such issues. Strict maintenance of confidentiality and avoiding signaling out anybody could lessen stigmatization fears among government officials and discourage hiding and denying the existence of a ticking bomb. All this requires visible understanding and is demonstrated by institutional leaders.

Other implementable steps which can be taken to enhance the well-being of the diplomatic service include workshop style training and awareness programs for wellbeing at the entry level as well as throughout different stages of the career, a system of mentoring and an accountable mechanism for toxic senior officers who are known to negatively affect the well-being of their subordinates. While providing a confidential counselling service on the model of the US State Department should not be out of reach, creating a culture of respect and understanding is the key. In fact, anybody who has a serious problem might not want to approach a government-sponsored resource, considering the loopholes in the practice of therapist-patient confidentiality in our society.

While we should provide pathways where people who need help can comfortably and easily get help, those who might not be in need of help or not in their view at least, need to be aware of how to provide psychological first aid to those in distress and how to take care of themselves to build their resilience against possible future issues. I believe a primary approach addressing the issues before they appear and providing the employees with tools for looking after themselves can go a long way. Our training institutions need to integrate these approaches in their training courses.

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Landscape of National Capability in Emerging Technologies: A Case Study of Pakistan

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Abstract

Technological sovereignty has emerged as a defining strategic imperative, with emerging technologies — spanning artificial intelligence (AI), quantum, semiconductor, nanotechnology, cybersecurity, biotechnology, space systems, Internet of Things (IoT), and robotics — increasingly determining the economic competitiveness and national security of states. This paper examines Pakistan's capabilities in the above-mentioned emerging technologies, with a primary focus on the private sector's role in advancing both civilian and defense-relevant applications. The study assesses the national landscape across eight key technology domains, evaluating policy frameworks, institutional developments, and private sector capabilities. Through comparative analysis, it examines the national strategies of select countries, drawing contextually relevant lessons for Pakistan's institutional and resource realities. The study identifies systemic gaps and structural challenges that constrain the realization of Pakistan's emerging technology potential. Drawing on these findings, the paper proposes an integrated framework of context-specific policy reforms and strategic initiatives. The overarching aim is to foster technological sovereignty, accelerate private sector-led innovation, and align Pakistan's emerging technology ecosystem with its long-term national security and economic transformation objectives.

Keywords: Emerging Technologies, National Capability, Private Sector, Technological Sovereignty, Pakistan, Technology Diplomacy.

1. Introduction

Technological sovereignty has become absolutely essential in the twenty-first century — central to economic growth, national security, and global competitiveness. It denotes the ability of a state to possess technologies it deems critical for its welfare and strategic autonomy, and to develop or source them without one-sided structural dependency on external actors (Edler et al., 2020). This necessity has intensified as technological competition between major powers accelerates, supply chains for critical components are weaponized, and access to advanced technologies increasingly determines the balance of economic and military power.

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Central to this paradigm are emerging technologies — defined as those whose development, practical applications, or both are still largely unrealized, figuratively emerging into prominence from a background of non-existence or obscurity (IGI Global, n.d.). An emerging technology has five unique attributes (i) radical novelty; (ii) relatively fast growth; (iii) coherence; (iv) prominent impact; and (v) uncertainty and ambiguity (Rotolo et al., 2015). These features make emerging technologies simultaneously transformative and difficult to govern, demanding proactive rather than reactive national strategies.

A critical dimension of emerging technologies is their dual-use nature — the same innovations that power civilian industries also enable advanced defense capabilities. The concepts of spin-off (civilian technologies derived from defense research) and spin-on (defense systems incorporating civilian innovations) reflect this bidirectional reality. From AI-guided logistics to quantum cryptography and autonomous UAVs, the boundary between civilian and defense technology is increasingly indistinct — making private sector capability in emerging technologies a direct contributor to national security, not merely economic productivity.

For Pakistan, this convergence carries both strategic opportunity and immediate attention. The country's private sector has long demonstrated capability in Information and Communication Technologies (ICT) and IT-enabled services — evidenced by record IT exports of \$3.8 billion in FY2024–25 and a growing cohort of technology firms operating in global markets (Dawn, 2025). Yet Pakistan's technological footprint remains narrowly concentrated, leaving critical gaps in AI, quantum, semiconductors, nanotechnology, biotechnology, space technology, and cybersecurity — domains where sovereign capability increasingly determines a nation's ability to act independently on the world stage. Broadening private sector capabilities across these domains is therefore not only an economic objective; it is a strategic necessity for Pakistan's long-term technological sovereignty, national security, and competitive positioning in an increasingly technology-defined global order.

This study employs a qualitative, desk-based comparative research methodology, drawing on primary government documents, policy frameworks, institutional reports, and credible secondary sources to assess Pakistan's emerging technology ecosystem against select global models.

2. Policy and Institutional Framework

The development of private sector capabilities in emerging technologies is a slowly growing area of scholarly focus in Pakistan. The country's recent policy frameworks quantify and target development indicators in emerging technologies, laying out ambitious goals for capacity building, infrastructure, and innovation culture.

Artificial Intelligence (AI) is considered one of the most significant emerging technologies. The National Artificial Intelligence (AI) Policy 2025 articulates a six-pillar strategy aimed at transforming Pakistan into a knowledge-based economy powered by ethical AI innovation (MoITT, 2025). The policy allocates 30% of the Ignite-managed

Pakistan's Private Sector Capabilities in Emerging Technologies

R&D Fund to a National AI Fund (NAIF), targets training of one million AI professionals by 2030, envisions Centers of Excellence in AI across major cities, and aims to raise public AI awareness to 90% by 2026. In February 2026, the Prime Minister of Pakistan, while inaugurating Indus AI Week, announced a commitment to invest \$1 billion in AI by 2030, signaling renewed political will to accelerate execution of the said policy (Dawn, 2026).

Quantum computing represents another strategically significant emerging technology domain, currently in a pre-commercial stage globally. In 2025, the Government of Pakistan approved the establishment of a National Centre for Quantum Computing (NCQC), sponsored by the Higher Education Commission (HEC), with an allocated budget of approximately Rs. 3.318 billion (Qureca, 2026). The Uraan Pakistan National Economic Transformation Plan (2024–29) further envisions a Quantum Valley as a national innovation hub connecting academia, industry, and government, reflecting a strategic pivot toward sovereign capability in artificial intelligence and quantum technologies (Ministry of Planning, Development & Special Initiatives, 2025).

Semiconductors represent an equally critical emerging technology domain, whose strategic significance is underscored by contemporary technology geopolitics. Realizing the same, Pakistan's Ministry of Information Technology and Telecommunication (MoITT) drafted a Semiconductor Policy 2024, proposing a National Semiconductor Fund, soft loan rebates, tax incentives, and Special Technology Zone (STZ) benefits to build a domestic semiconductor value chain (MoITT, 2024). While the policy awaits formal notification, implementation has commenced through INSPIRE — Pakistan's first National Semiconductor Initiative — under the National Semiconductor Human Resource Development Programme (NSHRDP), with an approved budget of PKR 4.844 billion targeting 7,200 trained professionals over five years (MoITT, 2026).

Alongside AI, quantum, and semiconductors, cybersecurity has emerged as a foundational pillar of national technological sovereignty. The National Cyber Security Policy (NCSP) 2021 laid the foundational governance architecture for Pakistan's cybersecurity ecosystem, mandating 17 key policy deliverables addressing governance, human resource development, data privacy, protection frameworks, and public awareness (MoITT, 2021). Building on this, the Ministry of IT&T has drafted the National Cybersecurity Act 2026, which proposes a dedicated National Cybersecurity Authority (NCA) to lead nationwide incident response and threat intelligence, while expanding the mandate of the Pakistan Computer Emergency Response Team (PKCERT) (Dawn, 2025). Concurrently, the PTA introduced the Critical Telecom Data and Infrastructure Security Regulations 2025 (CTDISR-2025), a revised framework incorporating risk-based governance across expanded compliance domains including asset management, cloud security, insider threat detection, and data privacy (PTA, 2025). These cumulative reforms have contributed to Pakistan's rise to Tier-1 (Role-Modelling) status in the International Telecommunication Union (ITU) Global Cybersecurity Index 2024, placing it among the top 40 countries — a significant improvement from its previous 79th position (PTA, 2024).

Emerging technologies — from AI to quantum — highly depend on the digital ecosystem. In the case of Pakistan, digital infrastructure has expanded substantially, underpinned by the Digital Nation Pakistan Act 2025, which establishes the Pakistan Digital Authority, a National Digital Commission, and a National Digital Master Plan (MoITT, 2025). According to the Pakistan Telecommunication Authority (PTA) Annual Report 2024–25, Pakistan has surpassed 200 million telecom subscribers and 150 million broadband connections, with telecom coverage exceeding 92% and broadband penetration crossing 60%, while sectoral revenues exceeded PKR 1 trillion — a 12% year-on-year increase (Pakistan Telecommunication Authority [PTA], 2025). IT exports have recorded consistent 20% annual growth over the last three years, supported by spectrum reforms and an enabling policy environment (TechJuice, 2025).

Historically, industrial zones have helped industrial development. Likewise, dedicated technology zones — such as South Korea’s Daedeok Science Town, China’s Zhongguancun Science Park, and Turkey’s Technoparks — have demonstrated the value of clustering tech firms, universities, and research labs within incentivized environments. Pakistan’s Special Technology Zones Authority (STZA) — mandated to build a globally competitive knowledge and technology ecosystem — has notified 32 Special Technology Zones (STZs) across the country, covering approximately 5.8 million square feet of total area and housing over 300 tech firms so far (STZA, 2025). These zones offer decade-long fiscal incentives to tech enterprises, including full income tax exemptions, customs duty waivers on capital goods imports, foreign currency account facilitation, and capital gains relief — benefits secured until June 2035. In a recent regulatory development, STZA launched Phase Two of its Incentive Transition and Ecosystem Strengthening Programme, integrating its One Window Portal with the Federal Board of Revenue (FBR), the Securities and Exchange Commission of Pakistan (SECP), and customs systems to further streamline ease of doing business within these zones (STZA, 2026).

Pakistan’s technological sovereignty ambitions also rely on secure access to critical minerals and rare earth elements (REEs) — foundational inputs for semiconductors, quantum hardware, autonomous systems, nanotechnology, and space technologies. The Pakistan Mineral Investment Forum (PMIF) serves as the primary platform for international investor engagement, while the Special Investment Facilitation Council (SIFC) has designated minerals and energy among its five flagship investment priorities (SIFC, 2024). On energy, the Indicative Generation Capacity Expansion Plan (IGCEP 2024–2034) targets 60% renewable electricity by 2030, aimed at addressing the chronic industrial power deficits that directly constrain advanced technology manufacturing (NEPRA, 2024).

3. Research Gap

While limited literature addresses Pakistan’s emerging technology landscape, existing scholarship remains largely policy-descriptive — cataloguing initiatives such as the National AI Policy, Digital Pakistan, and Special Technology Zones — without offering systematic assessment of actual private sector capabilities, scalability, or

industrial depth across technology domains. Comparative analyses with global development models, including those of the United States, China, Türkiye, and India, remain fragmented and insufficiently grounded in Pakistan's specific institutional constraints, market structure, and regulatory environment. Cross-cutting structural challenges — including chronically low R&D investment, emigration of skilled human resources, regulatory fragmentation, and import dependence in critical technology inputs — are seldom examined in an integrated framework spanning multiple technology domains simultaneously. This study seeks to address these gaps by offering an integrated, comparative, evidence-based, and private-sector-focused analysis of Pakistan's emerging technology ecosystem, aimed at identifying actionable pathways toward technological self-reliance and strategic sovereignty.

4. Global Models of Private Sector Development in Emerging Technologies

Before analyzing Pakistan's private sector trajectory, it is essential to understand how other major countries have focused on emerging technology sectors, driving advancements through integrated civil-defence and public-private innovation frameworks.

a) United States: Civil-Military Synergy Fuels Broad Innovation

The U.S. exemplifies a mature emerging technologies ecosystem where innovations originally developed for defense, such as the Global Positioning System (GPS) and the internet, have become integral to civilian life. In 2024 alone, the approximate \$880 billion U.S. defense budget empowered agencies like the Defense Advanced Research Projects Agency (DARPA) and programs like the Small Business Innovation Research (SBIR) program to support startups working on artificial intelligence (AI), autonomous systems, and microelectronics (U.S. Senate Committee on Appropriations, 2023). In parallel, the Space Enterprise Consortium (SpEC) — established in 2017 by the U.S. Space Systems Command (SSC) — accelerated space technology development by connecting commercial innovators with defense priorities through Other Transaction Authority (OTA) agreements, spanning applications from defense surveillance to missile tracking (SpEC, 2026). This model streamlines acquisition by enabling rapid prototyping with reduced bureaucratic constraints, lowering barriers for startups and non-traditional vendors.

b) China: Military-Civil Fusion Driving Dual-Use Expansion

China's Military-Civil Fusion (MCF) strategy — formally codified as a national strategy in 2015 — seeks to integrate civilian technological innovation with the defense industrial base, with firms such as Huawei and Tencent identified by the U.S. Department of Defense (DoD) as MCF contributors (National Bureau of Asian Research [NBR], 2021; DoW, 2025). Between 2020 and 2024, China's arms imports declined by 64% compared to the preceding five-year period (2015–19), reflecting rapidly advancing domestic defense production and reduced reliance on foreign military technology (Stockholm International

Peace Research Institute [SIPRI], 2025). For the first time since 1990–94, China dropped out of the world's top ten arms importers, a shift attributed to its increasing ability to design and produce its own advanced military systems..

c) European Union: Collaborative Innovation and Commercial Ecosystems

The EU advances civilian-military technology integration through three complementary instruments. First is the European Defence Fund (EDF) (€7.3 billion, 2021–2027). Second is the Permanent Structured Cooperation (PESCO) — now entering its 2026–2030 phase with 75 active projects. The third one is the newly established European Defence Industry Programme (EDIP) (€1.5 billion, 2025–2027), which facilitates joint procurement and long-term armaments cooperation among member states (European Commission, 2025; Council of the EU, 2025). The EU Defence Innovation Scheme (EUDIS), embedded within the EDF, specifically supports startups and SMEs through civil-to-defense technology transfer, mobilizing approximately €2 billion by 2027 (EPRS, 2025). Combined EU member state defense expenditure reached €343 billion in 2024 — significant but still well below the United States' \$880 billion — reflecting Europe's accelerating yet still asymmetric defense investment trajectory (EDA, 2025; SIPRI, 2025).

d) Turkey: State-Led Growth in High-Tech Civilian and Defense Sectors

Turkey's defense export growth has been exceptional, reaching a record \$7.2 billion in 2024 — a 29% increase over 2023 — and representing a more than 250% rise from \$2.28 billion in 2020, driven by platforms including UAVs, smart munitions, and radar systems exported to over 180 countries (Presidency of Defense Industries [SSB], 2025). Private firm Baykar — one of the world's leading Unmanned Aerial Vehicle (UAV) manufacturers — generated 90% of its 2024 revenues from exports, notably without relying on state grants, financing all research and development from its own resources (Anadolu Agency, 2025). Turkey's broader policy framework emphasizes R&D tax incentives through Technology Development Zones (TDZs), local content requirements, and civil-military technology transfer — with defense-derived technologies progressively applied to civilian sectors including urban systems, electric rail, and health technologies (SSB, 2025; Atlantic Council, 2024).

e) India: Private Sector Empowerment in Dual-Use Innovation

India's Make in India and Atmanirbhar Bharat (Self-Reliant India) strategies, complemented by the Innovations for Defence Excellence (iDEX) programme, have encouraged private sector participation in aerospace, robotics, AI, and autonomous systems serving both defense and commercial sectors, including logistics, smart manufacturing, and energy (Ministry of Defence [MoD], 2025). Domestic defense production grew by 174% from FY2014–15 to FY2023–24,

Pakistan's Private Sector Capabilities in Emerging Technologies

reaching approximately \$15.2 billion, with FY2024–25 output rising further, crossing \$16 billion (MoD, 2025). Defence exports have surged 34-fold over the past decade, with goods exported to nearly 80 countries (MoD, 2025). As of February 2025, iDEX has engaged 619 startups and Micro, Small and Medium Enterprises (MSMEs) with 430 contracts signed, fostering a robust civil-military technology interplay in which large conglomerates and startups alike commercially deploy technologies initially developed for defense use (Press Information Bureau [PIB], 2025).

f) Indonesia: Incremental Dual-Use Capability Building

Indonesia pursues gradual defense industrialization anchored in the Law on the Defense Industry, which mandates offset clauses, technology transfer, and Domestic Component Level (TKDN) requirements in foreign defense contracts to promote local private sector involvement (Formosa Journal of Multidisciplinary Research, 2025). The state defense holding company DEFEND ID — consolidating major state-owned enterprises including PT PAL, PT Pindad, and PT Dirgantara Indonesia — serves as the primary vehicle for joint ventures with foreign counterparts.

5. Pakistan's Private Sector Capabilities in Emerging Technologies

Pakistan's private sector in emerging technologies reflects a developing ecosystem with notable strengths and considerable room for growth across key technology areas. The sector is backed by government policies, albeit inconsistent and fluctuating, and in an emerging entrepreneurial culture.

i. Artificial Intelligence (AI) and Autonomous Systems

Pakistan's AI ecosystem is gradually evolving, supported by dedicated institutional infrastructure. The National Centre for Artificial Intelligence (NCAI) at NUST has been established under the Higher Education Commission (HEC), focusing on developing AI technologies, while the Pakistan Air Force's Centre for Artificial Intelligence and Computing (CENTRIC) at NUST develops AI-powered systems for data fusion, smart surveillance, and autonomous decision-making (MoITT, 2025). On the defense front, Integrated Dynamics designs and exports autonomous surveillance Unmanned Aerial Vehicles (UAVs) with AI-enabled object recognition and navigation to markets including the United States, Australia, and South Korea (Tech-Juice, 2026). More recently, Woot Tech unveiled the HiMark-25, a jet-powered one-way attack drone integrating AI-guided precision strike capabilities, reflecting an emerging private sector interest in asymmetrical defense technologies (Quwa, 2026). Pakistan's inaugural Indus AI Week 2026 further demonstrated the dual-use nature of AI, with startups showcasing technologies spanning electronic warfare, autonomous navigation, and AI-enhanced drones for precision agriculture simultaneously — underscoring the deepening civil-military technology interplay.

ii. Nanotechnology

Nanotechnology in Pakistan is an emerging field with promising civilian applications and growing defense-relevant potential. The most significant institutional milestone is the government-backed National Centre for Nanoscience and Nanotechnology (NCNN), inaugurated in August 2023 with a total investment of PKR 3.3 billion and encompassing 14 affiliated laboratories across the country, aimed at advancing research in functional nanomaterials for energy storage, environmental monitoring, and biomedical applications (NUST, 2023). In the civilian sector, nano-coating applications are gaining traction in Pakistan's textile industry — the country's largest export sector — where antimicrobial and durability-enhancing nanomaterials offer competitive advantages, while water purification startups are exploring nanomaterial-based filtration to address critical public health challenges in urban and rural areas (Ahmed, 2022).

iii. Cybersecurity & Blockchain

Pakistan's private sector shows growing momentum in cybersecurity services, driven by rising digital adoption and escalating cyber threats. On the institutional side, the National Centre for Cyber Security (NCCS) — a joint initiative of the Higher Education Commission (HEC) and Planning Commission, headquartered at Air University, Islamabad — serves as a cybersecurity research and development hub, with affiliated R&D labs established across 11 universities specializing in domains including cybercrime forensics, smart devices and network security (NCCS, 2025). NCCS also organizes the annual Pak-Crypt International Symposium on Cybersecurity, providing a national and international knowledge-sharing platform. Firms such as Systems Limited provide network security and cyber threat intelligence to both domestic and global clients. Pakistan's improved cybersecurity posture is further reflected in its rise to Tier-1 (Role-Modelling) status in the ITU Global Cybersecurity Index 2024 — a significant leap from its previous 79th position (PTA, 2024).

Blockchain technology is similarly advancing, though slowly, with startups like Xord and BlockApex pioneering solutions in digital identity management, supply chain verification, and decentralized finance (GoodFirms, 2026).

iv. Quantum Computing & Cloud Infrastructure

Pakistan's quantum computing efforts remain at an emergent stage, driven primarily by academic research and institutional capacity-building. NUST's Quantum Computing Lab conducts active research in quantum key distribution (QKD), superconducting quantum processor design, and quantum cryptanalysis, while Lahore University of Management Sciences (LUMS) pursues complementary quantum computing research (NUST SINES, 2025). The National Centre for Physics (NCP), Islamabad, collaborating with CERN and ICTP, has emerged as a national venue for quantum capacity-building, hosting dedicated quantum technology workshops and co-organizing Pakistan's first National Quantum

Pakistan's Private Sector Capabilities in Emerging Technologies

Computing Hackathon in February 2026 (Business Recorder, 2026). Nevertheless, the pace of indigenous quantum research remains slow, and private sector involvement is limited (Express Tribune, 2025).

Cloud computing adoption is expanding rapidly, underpinned by both private and government-led infrastructure investment. Khazana Cloud collaborated with NASTP in 2024 to launch Pakistan's first hyperscale Tier-3 data centre powered by Huawei, ensuring data sovereignty and supporting AI and cloud workloads (NASTP, 2024). In February 2025, the government inaugurated the Astrolabes Data Centre — Pakistan's first prefabricated containerized data centre — at NED University, Karachi, and UET Lahore, through collaboration between the Higher Education Commission (HEC), Huawei, DWP Technologies, and the World Bank. It aims to offer cloud computing, AI, and high-performance computing services to universities and research institutions nationwide under the E-Pakistan strategy of the Uraan Pakistan programme (HEC, 2025).

v. Space Technologies

Pakistan's space sector has achieved several milestones over the past two years, gradually opening to academic and private-sector participation. Following Pakistan's Space Policy in 2023, key achievements include the launch of iCube-Qamar — Pakistan's first lunar nanosatellite — into lunar orbit in May 2024, the PakSAT-MM1 multi-mission communication satellite in May 2024, and the indigenously developed PRSC-EO1 electro-optical earth observation satellite in January 2025. iCube-Qamar was notably developed by the Institute of Space Technology (IST), Islamabad, in collaboration with SUPARCO and Shanghai Jiao Tong University — representing growing academic participation in space hardware development (CASS, 2024). Pakistan also launched its first hyperspectral satellite (HS-1) in October 2025 and the PRSC-EO3 earth observation satellite in April 2026, under the Space Vision 2047 long-term programme (SUPARCO, 2025). Private sector involvement remains nascent but is gaining policy support through STZA incentives and a government-approved venture capital fund supporting space-focused startups, as Pakistan's inaugural National Space Policy (2023) explicitly encourages commercial participation in satellite data analytics and remote sensing applications (The Friday Times, 2025).

vi. Biotechnology

Biotechnology represents a growing component of Pakistan's emerging technologies landscape, with focus concentrated in agricultural biotech, pharmaceuticals, diagnostics, and bioinformatics. On the institutional side, the National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad leads research in agricultural biotechnology and genomics, while the National Institute of Health (NIH), Islamabad, serves as the primary government body for vaccine manufacturing and biomedical research. The Centre of Excellence in Molecular Biology (CEMB) at Punjab University and the National Institute of Virology

(NIV) at the University of Karachi complement these efforts in molecular diagnostics and biosafety research, respectively. A landmark development came in June 2024, when Pakistan approved its first genetically modified (GM) crops for commercial cultivation — two GM sugarcane varieties (insect-resistant and herbicide-tolerant) developed at the Centre for Agricultural Biochemistry and Biotechnology (CABB), Faisalabad — marking Pakistan's first authorization of a GM food crop (CABB, 2024). The private sector is increasingly active in diagnostics, telemedicine, and health tech, leveraging partnerships with international institutions including the International Centre for Genetic Engineering and Biotechnology (ICGEB) to build domestic capacity.

vii. The Internet of Things (IoT)

Pakistan's private sector has shown some progress in the Internet of Things (IoT) domain as well. TPL Trakker offers vehicle tracking, fleet management, and location-based services across oil and gas, banking, and logistics sectors, and it has expanded operations to the Middle East and Africa. Urban IoT deployments led by firms such as LMKT improve utility management, traffic monitoring, and public safety in cities including Lahore and Islamabad. IoT-enabled agricultural applications — spanning smart irrigation, soil monitoring, and cold-chain management — are gaining traction among agri-tech startups, contributing to improved yields and sustainable farming. Government support through STZA incentives, the Digital Nation Pakistan Act 2025, and ongoing 5G spectrum rollout further accelerate IoT sector expansion.

viii. Robotics

Robotics represents a strategically important and growing field within Pakistan's private sector, with applications spanning education, manufacturing, agriculture, and defense-related domains. NEXERIN — an AI-powered drone manufacturer incubated at the National Incubation Center for Aerospace Technologies (NICAT), Rawalpindi — recently secured \$2 million in funding from a German corporation, signaling growing international confidence in Pakistan's robotics startups (TechJuice, 2026). Robotics competitions and training programs organized by NUST and FAST National University further nurture local talent in robotics design, programming, and electronics. LearnOBots provides robotics kits and STEM training programs nurturing technical skills among students, while AA Robotics focuses on autonomous systems for disaster response, defence and environmental applications, collectively reflecting a nascent but broadening private sector robotics ecosystem.

6. Gaps and Challenges in Pakistan's Emerging Technologies Ecosystem

While Pakistan's private sector capabilities in emerging technologies have advanced to some extent, the ecosystem faces deep, multifaceted structural challenges across all domains. Some of the major ones are discussed below:

Human Capital and Brain Drain

- Despite a reported workforce of over 600,000 IT professionals and expanding AI academic programs, Pakistan faces severe skilled talent shortages, with thousands of specialists migrating annually in search of better opportunities with career prospects and an improved standard of living abroad (Express Tribune, 2025).
- Shortages are acute in advanced domains including quantum computing, semiconductor design, aerospace engineering, and cloud-native development.

R&D and Financing

- R&D investment stands at approximately 0.16–0.3% of GDP — far below the global average of 2.3% — insufficient for sustained foundational research or cutting-edge hardware development (Express Tribune, 2025).
- Private venture capital remains nascent, and public funding is insufficient for long-term technology commercialization, particularly in capital-intensive domains such as semiconductors, quantum computing, and aerospace (Atta, 2025).
- Weak academia–startup–industry linkages limit the commercialization of research outputs across all technology domains.

Artificial Intelligence

- Data privacy and sovereignty concerns complicate domestic AI model training, with a very low number of firms hosting critical datasets locally.
- Implementation of the National AI Policy (2025) has largely stalled beyond its “Awareness and Readiness” pillar, with the AI Council’s reconstitution and provincial buy-in remaining unresolved more than six months after Cabinet approval (Dawn, 2026).
- Pakistan remains firmly in “adoption mode, not invention mode,” with startups facing bottlenecks including limited compute access and scarce proprietary datasets.

Semiconductors

- The semiconductor industry faces major capacity constraints — shortage of skilled chip design engineers, absence of ultra-clean fabrication facilities, and negligible venture capital for high-tech manufacturing (MoITT, 2024).
- The INSPIRE/NSHRDP programme addresses workforce development, but the broader semiconductor value chain remains entirely dependent on imported components and foreign technology, with the Draft Semiconductor Policy still awaiting formal gazette notification.

Nanotechnology

- Nanotechnology development is largely confined to academic research with minimal industry uptake; only a handful of institutions possess nanofabrication cleanrooms, and pilot-scale manufacturing remains absent.

- Scarcity of local production facilities drives dependency on imported raw materials and equipment, with customs delays and costs adding further barriers to commercialization.

Cybersecurity and Blockchain

- Pakistan's skilled and professionally trained cybersecurity workforce faces a visible deficit despite the initiation of relevant academic programs in many national institutes for higher education.
- Regulatory fragmentation undermines coordinated national responses; the draft Cybersecurity Act 2025 is still under process for full institutional operationalization of the National Cybersecurity Authority (NCA).
- Blockchain technology faces persistent legal ambiguities, particularly around cryptocurrency regulation, despite the establishment of the Pakistan Virtual Assets Regulatory Authority (PVARA) in 2024.

Quantum Computing and Cloud Infrastructure

- Quantum computing infrastructure and expertise remain embryonic; academic institutions, including NUST and NCP, lead research but lack funding and access to quantum hardware, with startups confined to small pilot projects without scale.
- Many government workloads still rely on foreign hyperscalers — AWS, Azure, and Google — compromising data sovereignty and exposing critical data to geopolitical risk, despite some recent initiatives to establish local data centers.
- Indigenous cloud providers have not yet achieved Tier-IV standards necessary for critical government environments; shortages of cloud-native engineers delay advanced capability deployments.

Space Capabilities

- Private space ventures remain niche and component-focused, primarily developing nanosatellite payloads and ground control equipment, with launch capability entirely dependent on foreign partners, limiting sovereign space access (The Friday Times, 2025).
- High capital intensity, absence of an aerospace-grade supply chain, and shortages of aerospace engineering and systems integration talent create significant bottlenecks for industrial-scale production.

Biotechnology

- Pakistan's biotech sector is hampered by fragmented R&D efforts, insufficient funding, and an immature regulatory regime — particularly concerning product approval, biosafety standards, and GMO commercialization pathways.
- Weak public-private partnerships limit the translation of academic research at institutions such as NIBGE and CEMB into commercially viable products.

IoT, Connectivity, and Robotics

- IoT growth is constrained by reliance on imported sensors, transceivers, and micro-controllers, exposing local companies to supply-chain risks and cost inefficiencies.
- Pakistan's 5G rollout — initiated following a \$507 million spectrum auction in March 2025 — remains incomplete, with only 5% of handsets currently 5G-capable and Apple's iPhone 5G support deferred to 2027 (Dawn, 2025). Rural and border areas remain particularly underserved.
- The telecom sector bears a tax burden of nearly 45% — among the highest globally — which industry leaders argue contradicts the Digital Pakistan vision by treating critical infrastructure as a revenue source rather than a developmental asset (Dawn, 2025).
- Pakistani robotics innovation is confined to a handful of startups producing small-batch outputs; indigenous development of critical subsystems — sensors, vision systems, and precision actuators — is negligible and import-dependent (Express Tribune, 2025).

Cross-Cutting Systemic Deficits

- Infrastructure constraints — intermittent grid power and patchy internet coverage — hamper digital transformation across all technology domains.
- Regulatory and policy frameworks remain fragmented and sometimes outdated, impeding innovation, technology transfer, and inbound foreign investment.
- Across all domains, the pattern of policy ambition outpacing execution capacity — visible in AI, semiconductors, quantum, and cloud — reflects the central institutional challenge for Pakistan's emerging technology ecosystem.

Addressing these challenges requires an integrated national strategy, emphasizing investment incentive reforms, advanced technology manufacturing incubation, STEM education and skills development, regulatory modernization, and strengthened public-private and international partnerships.

7. Recommendations to Enhance Pakistan's Private Sector Capabilities in Emerging Technologies

Pakistan stands at a pivotal juncture where deliberate, integrated, and institutionally grounded policy action can translate emerging technology ambitions into sovereign capability. The following recommendations draw on lessons from global models — the United States, China, Turkey, India, Indonesia, and Denmark — contextualized for Pakistan's institutional realities, resource constraints, and civil-defence imperatives.

Establish a High-Level National Emerging Technologies Council with Integrated Secretariat

- A National Emerging Technologies Council (NETC) — chaired at the highest level — should serve as the apex body for integrated strategy, inter-agency coordi-

nation, and performance monitoring across all emerging technology domains. Absent members, including the Chair, may be represented by designated alternates to ensure continuity of function.

- The Ministry of Science and Technology (MoST) — as the custodian of the National Science and Technology Policy (NSTP) 2022 — should be activated and empowered to serve as the permanent Secretariat of NETC.
- NETC should represent all federal stakeholders — MoITT, Ministry of Planning, HEC, STZA, strategic organizations, and relevant ministries — alongside provinces, Gilgit-Baltistan (GB), and Azad Jammu and Kashmir (AJK), ensuring nationwide coherence in the national emerging technology strategy.
- An Expert Advisory Group comprising private sector leaders, academic scientists, defense technologists, and international practitioners should provide evidence-based expert advice and conduct quarterly performance reviews.
- NETC must devise, implement, and review a National Emerging Technologies Policy and Strategy that integrates all currently fragmented instruments into a single coherent framework with synchronized implementation timelines and accountability mechanisms with respect to emerging technologies.

Integrated National Emerging Technologies Fund

- A National Emerging Technologies Fund (NETF) should be established by consolidating existing fragmented funding instruments — the National AI Fund (NAIF), National Semiconductor Fund, HEC R&D Fund, and Ignite Innovation Fund — into a single, professionally managed, ring-fenced fund with transparent governance.
- The Fund should target AI, quantum computing, nanotechnology, semiconductors, biotech, cloud infrastructure, and space technologies, with clearly defined commercialization milestones — not merely academic outputs — as conditions for disbursement.
- Venture capital facilitation mechanisms — including government co-investment, first-loss guarantees, and STZA-linked incubation — should crowd in private domestic and foreign risk capital, actively moving Pakistan's investment culture away from the less useful real estate sector toward very fruitful high-technology sectors.
- R&D spending should be raised from the current 0.16–0.3% of GDP to at least 1% by 2030, learning from South Korea's state-directed R&D acceleration model.

Regulatory Modernization and Governance

- Cybersecurity, data sovereignty, AI ethics, blockchain regulation, and export controls should be consolidated under a coherent National Emerging Technology Regulatory Framework, aligned with international best practices while reflecting Pakistan's developmental stage.

Pakistan's Private Sector Capabilities in Emerging Technologies

- Regulatory sandboxes for AI, fintech, blockchain, and biotech should provide controlled innovation environments, enabling private-sector solutions to be tested without premature regulatory risk.
- The Pakistan Digital Authority (PDA), PVARA, and expected NCA should be swiftly operationalized with adequate resources, technical expertise, and enforcement mandates to avoid the institutional inertia that has historically undermined policy implementation.
- Data localization policies should be carefully calibrated to balance national sovereignty with the cross-border collaboration requirements of an internationally competitive technology sector.

HEC Reform: Market-Linked Academia and Entrepreneurial Ecosystem

- The Higher Education Commission (HEC) must fundamentally realign its mandate from producing graduates to building a skilled, entrepreneurial workforce matched to emerging technology market needs.
- University curricula in AI, quantum sciences, cybersecurity, biotech, semiconductors, and robotics should be co-designed with industry partners, reviewed annually, and benchmarked against global standards.
- Technology Transfer Offices (TTOs) should be mandated at all Tier-1 universities to systematically convert research into licensable intellectual property and spin-off enterprises.
- Joint Applied Research Centers co-funded by industry and government — linking institutions like NUST, LUMS, GIKI, NED, UET, and COMSATS with private sector firms and STZs — should replace the current siloed academic research model.

Human Capital Development, Retention, and Diaspora Engagement

- A comprehensive talent retention strategy must go beyond financial incentives, creating an enabling ecosystem including: fast-tracked business registration within STZs; improved intellectual property protections; and performance-linked compensation for public sector researchers.
- A Pakistan Technology Diaspora Network (PTDN) should formally engage overseas Pakistani scientists, engineers, and entrepreneurs through returnee incentive packages including housing, tax relief, and startup grants; remote advisory and mentorship roles in universities and research institutions; and co-investment platforms enabling diaspora capital to fund domestic emerging-tech ventures.
- A hybrid ecosystem model should be institutionalized, recognizing that Pakistani professionals living abroad can meaningfully contribute through remote collaboration, knowledge transfer, virtual advisory boards, and diaspora-backed venture funds — without requiring physical return.

- Defense and civilian STEM scholarships should be expanded with mandatory return-of-service obligations to ensure public investment translates into national capability rather than mere remittances from international emigration.

Indigenous Manufacturing, Supply Chain Resilience, and Import Substitution

- Import dependency in critical technology components — microchips, sensors, nanomaterials, quantum hardware, precision actuators, and aerospace-grade materials — must be systematically addressed through import substitution industrialization programs, targeted subsidies, and public-private manufacturing partnerships.
- Industrial clusters for semiconductor design, advanced materials, and precision fabrication should be developed within STZs, co-locating firms, universities, and defense research labs.

Technology Diplomacy and International Partnerships

- Pakistan should develop a niche in emerging technology diplomacy — as Denmark pioneered in tech diplomacy by appointing dedicated Tech Ambassadors to Silicon Valley and other innovation hubs — establishing itself as a credible, proactive technology diplomacy actor rather than a passive technology importer.
- A dedicated Science and Technology Diplomacy Division should be re-organized within the Ministry of Foreign Affairs, staffed with science and technology-literate diplomats, to closely coordinate with national and international stakeholders.
- International Directorates within key institutions — MoST, MoITT, HEC, and others — should be activated with a sufficient number of experts to systematically monitor technological developments in priority countries, identify cooperation opportunities, and maintain active liaison with the Ministry of Foreign Affairs for international cooperation.
- Bilateral technology partnerships should be actively pursued with the United States, China, Türkiye, Japan, South Korea, Indonesia, Saudi Arabia, the UAE, Qatar, Germany, Italy, the UK, France, Denmark, the Netherlands, Egypt and Malaysia — structured around capacity building, technology transfer, joint ventures, and co-investment rather than one-sided commercial arrangements.
- International MoUs and agreements should specifically target access to quantum hardware and semiconductor fabrication know-how; AI research collaborations; cybersecurity information sharing; space technology cooperation; and other areas of cooperation with respect to emerging technologies.
- Pakistan should strategically leverage its memberships in regional and multilateral forums to advance its emerging technology agenda:
 - SCO (Shanghai Cooperation Organization): As Pakistan is set to chair the SCO from next year, it should propose the establishment of an SCO Emerging

Pakistan's Private Sector Capabilities in Emerging Technologies

Technologies Organization headquartered in Islamabad, positioning Pakistan as a regional technology governance hub.

- OIC / COMSTECH: The OIC Standing Committee on Scientific and Technological Cooperation (COMSTECH), headquartered in Islamabad, should be leveraged to spearhead an OIC Emerging Technologies Initiative — proposing joint R&D frameworks, harmonized cybersecurity standards, and pooled quantum and AI research investments among member states.
- ECO (Economic Cooperation Organization): The ECO Science Foundation should be engaged for regional science and technology cooperation spanning regional countries.
- COMSATS: The Commission on Science and Technology for Sustainable Development in the South (COMSATS), also headquartered in Islamabad, should be mobilized for South-South technology cooperation, particularly in AI, biotech, and clean energy.
- AU, ASEAN, GCC, and EU: Structured technology cooperation agreements with the African Union, ASEAN, Gulf Cooperation Council, and European Union should be pursued for knowledge exchange, joint research, and market access.
- It may additionally propose an Emerging Technologies Organisation of the Asia-Europe Foundation headquartered in Islamabad, reinforcing the country's positioning as a bridge between Asian and European technology ecosystems.

Civil-Military Technology Integration

- A dedicated Civil-Military Technology Integration Cell — a symbol of genuine civil-military partnership for a common national goal — should be institutionalized within NETC, coordinating between civilian R&D institutions and defense organizations to merge combined resources, eliminate duplication, and accelerate emerging technology development.
- A Pakistan Defence Innovation Accelerator should provide startups with milestone-based grants, access to defense test facilities, and fast-tracked procurement pathways, lowering entry barriers for non-traditional vendors.
- Combined civil-military resources should be pooled for shared critical infrastructure, including quantum labs, cybersecurity operations centers, AI compute clusters, and nanotechnology cleanrooms — maximizing national returns on investment.
- National Critical Minerals Strategy — Connecting REEs to Technology Sovereignty
- Pakistan must develop a National Critical Minerals Strategy (NCMS) that explicitly maps domestic REE and mineral deposits to the input requirements of its priority emerging technology domains, establishing a sovereign supply chain logic that prioritizes downstream processing over raw material export. The SIFC

should operationalize the NCMS by attracting joint venture investment in technology-grade mineral processing within STZs, with all bilateral agreements with processing partners structured to include mandatory technology transfer obligations rather than purely commercial extraction arrangements. The Reko Diq project should be developed as an anchor for a downstream critical minerals industrial cluster in Balochistan, producing technology-grade copper and associated REE byproducts linked directly to Pakistan's semiconductor and advanced manufacturing pipeline. Membership in various multilateral platforms should be leveraged to propose a Regional Critical Minerals Cooperation Framework — connecting Pakistan's mineral endowment with Central Asian REE deposits and East Asian processing expertise — reducing collective dependency, positioning Pakistan as a regional mineral security hub. A Critical Minerals Sovereign Fund, seeded by Reko Diq royalty revenues, should finance domestic processing infrastructure and equity participation in international REE joint ventures, institutionalizing the link between natural resource wealth and technology industrial development.

Dedicated Energy Infrastructure for Emerging Technology Zones

- Energy security must be formally designated as a precondition for technological sovereignty within the National Emerging Technologies Policy, with NEPRA and the Ministry of Energy represented within NETC. All 32 notified STZs should be designated as critical national infrastructure, ring-fenced from load-shedding schedules and guaranteed industrial-grade power quality. Each major STZ should develop an integrated renewable micro-grid — combining solar, wind, and battery storage — with the national grid serving as backup only, eliminating operational dependency on grid stability; NASTP, Islamabad Technology Park, and Lahore Knowledge Park should be prioritized as pilot sites. A dedicated Technology Zone Electricity Tariff (TZET) may be developed — a preferential, stable, and internationally competitive rate exclusively for STZ-resident technology firms — directly addressing one of the most frequently cited barriers to foreign technology investment. A Technology Zone Energy Security Fund — jointly financed by STZ resident firms, government, and international development partners including the World Bank and Asian Development Bank — should finance micro-grid installation costs, while data centres and AI compute facilities should be required to meet minimum renewable energy sourcing thresholds.

Building a Technology-Savvy Citizenry

- Technological sovereignty cannot rest on elite institutions alone — it requires a broadly literate, technology-savvy citizenry as its social foundation. Digital and technology literacy — covering AI, cybersecurity, data privacy, and IoT — should be formally embedded in the national curriculum from the primary level, drawing on Estonia's nationally integrated digital education model. TVET institutions should be upgraded to produce a skilled technical workforce in emerging technology operations and maintenance, addressing the mid-tier skills gap that constrains industrial adoption. Women's participation in STEM should be explicitly targeted

Pakistan's Private Sector Capabilities in Emerging Technologies

through dedicated scholarships and STZ-linked employment pathways, recognizing that Pakistan cannot achieve technology sovereignty while excluding half its potential talent pool. A National Technology Literacy Index should annually measure digital skills and awareness across provinces, providing accountability metrics for government programs.

Technology Governance: Ethical, Responsible, and Human-Controlled

- As Pakistan deploys emerging technologies across multiple domains, a coherent technology governance framework is essential to prevent algorithmic bias, surveillance overreach, and autonomous systems operating without meaningful human control. A National Technology Ethics and Governance Framework — developed under MoST in consultation with civil society, legal experts, and the private sector — should establish binding principles for ethical AI deployment, data protection, and oversight of autonomous systems. Meaningful human control over AI-enabled defense systems must be institutionalized as a standard consistent with international humanitarian law. Comprehensive data protection legislation should be urgently enacted, drawing on the EU GDPR as a reference framework, while AI ethics review boards within NCAI and NCCS should mandate independent impact assessments before deployment in law enforcement, healthcare, and military applications.

International Law, Technology Governance, and Pakistan's Normative Role

- Pakistan's position as a nuclear-armed state, SCO Chair, and prominent Global South voice creates both an opportunity and a responsibility to actively shape international norms governing emerging technologies in conflict and strategic competition. Pakistan should formally articulate a National Position on Emerging Technology and International Law, advocating for legally binding human control standards. Through its SCO Chairmanship, Pakistan should propose a regional Code of Conduct for Emerging Technologies in Security Contexts, deterring offensive AI deployment and autonomous weapons proliferation. Leveraging OIC, COMSTECH, and COMSATS platforms, Pakistan should build Global South solidarity around equitable technology access, mandatory technology transfer obligations, and IP reform — positioning itself as a bridge between major technology powers and the developing world, advocating for norms that prevent technology-driven warmongering and strategic instability across regions.

Conclusion

Pakistan's emerging technology ecosystem stands at a critical juncture. Meaningful foundations have been laid — a National AI Policy, an operational semiconductor training programme, record IT exports, a first lunar nanosatellite, 5G spectrum rollout, and a rising cohort of private sector innovators in UAVs, cybersecurity, and AI. Yet the central finding of this study remains unambiguous: policy ambition consistently outpaces execution capacity. Negligible R&D investment and fragmented institutional

frameworks continue to impede progress. Bridging this gap demands an integrated national architecture — a fully empowered National Emerging Technologies Council, a consolidated funding mechanism, genuine civil-defence technology convergence, and a regulatory ecosystem that rewards innovation. Equally, it requires a paradigm shift from technology consumption toward indigenous production, commercialization, and active technology diplomacy across multilateral and bilateral platforms. Global comparators demonstrate that technological sovereignty is achievable through sustained institutional commitment, not merely policy declaration. Pakistan's private sector has demonstrated both the appetite and capability to lead; what it requires is a state that matches that ambition with coordination, investment, and institutional consistency.

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Universities and Science Diplomacy: Lessons from a European University Alliance

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Conference Report on EUTOPIA Science Diplomacy Conference

Abstract

This piece examines the role of universities as science diplomacy actors in a geopolitical context increasingly marked by competition, closure, and strategic uses of knowledge. It argues that while science diplomacy has traditionally been understood through a state-centered lens, this framing leaves insufficient space for actors that defend the international character of science itself. Building on Van Langenhove and Burgelman's concept of "Diplomacy in Science" and Doulet's framework of science diplomacy regimes, the article positions universities as institutions with distinctive diplomatic capacities rooted in long-term cooperation, knowledge exchange, and public engagement. It uses the concept of university science diplomacy actorness to show how universities already contribute to science diplomacy through research partnerships, policy engagement, curricula, alumni networks, public outreach, and multistakeholder convening. Using the EUTOPIA European University Alliance as an illustrative case, the article shows how universities and university alliances can move from implicit to intentional science diplomacy by embedding science diplomacy across enabling, operational, and strategic tools. It concludes that while universities certainly cannot replace states or international organizations, they can help sustain scientific cooperation and support science as a global public good in a fragmented world. If diplomats increasingly use science to advance foreign policy objectives, science too needs diplomats capable of keeping knowledge open, collaborative, and genuinely international. Universities are key institutions for supporting that vision.

Science Diplomacy as Statecraft

When science diplomacy emerged as a distinct concept in the early twenty-first century, it was largely understood through the lens of formal diplomatic actors, particularly nation-states and international organizations. The landmark 2010 report by the British Royal Society and the American Association for the Advancement of Science (AAAS), *New Frontiers in Science Diplomacy*, introduced the now familiar tripartite framework of Science in Diplomacy, Science for Diplomacy, and Diplomacy for Science. While alternative definitions have since emerged, many retain a strong focus on the foreign policy objectives of states.

As Rasmus Bertelsen (2024) argues, in the term science diplomacy, the central noun

Universities and Science Diplomacy

remains diplomacy. Science diplomacy is therefore best understood as a subset of diplomacy rather than as a separate practice. In other words, to understand science diplomacy, one must first understand diplomacy itself. Traditionally, diplomacy has been concerned with representing states, protecting national interests, negotiating with foreign governments, gathering information, and promoting friendly relations between countries. As codified in the 1961 Vienna Convention on Diplomatic Relations, diplomacy is fundamentally a practice undertaken by states in pursuit of their interests and relationships with other states. Science diplomacy, in its classical conception, therefore largely refers to the use of scientific knowledge, scientific cooperation, and scientific actors in support of these broader diplomatic functions.

The Blind Spot: Who Speaks for Science?

Non-state actors, including universities, may enjoy significant operational autonomy on the world stage. Nevertheless, they operate within an international system structured by states and are therefore often shaped by broader foreign policy priorities. This dynamic becomes more visible during periods like the present, marked by geopolitical competition, when academic cooperation, research partnerships, and knowledge exchange become increasingly intertwined with national strategic interests.

This raises an important question. If science diplomacy is primarily understood as a tool of statecraft, who stands up for science itself? Who defends scientific cooperation when it fails to neatly align with national strategy? And who safeguards science as a global public good when scientific knowledge is increasingly mobilised for geopolitical purposes?

The Fourth Dimension: Diplomacy in Science

Returning to the tripartite conceptualisation of science diplomacy, Luk Van Langenhove and Jean-Claude Burgelman (2021) argued that it had become insufficient for understanding the challenges facing science in the twenty-first century. While the three dimensions explain how science can support diplomacy and how diplomacy can support science, they leave unanswered a fundamental question: who stands up for science itself when scientific cooperation becomes increasingly subordinated to geopolitical interests?

As competition between states intensifies, science becomes more and more viewed primarily through the lens of national advantage. Scientific knowledge is mobilised to advance foreign policy objectives, research collaborations are scrutinised through the prism of security concerns, and international partnerships become entangled in broader geopolitical rivalries. In such a context, who acts on behalf of science as a global public good?

To address this gap, Van Langenhove and Burgelman proposed a fourth dimension of science diplomacy: Diplomacy in Science. Unlike the traditional dimensions, which place states and their interests at the centre, diplomacy in science focuses on safeguarding the global commons of knowledge. Organisations such as UNESCO and the

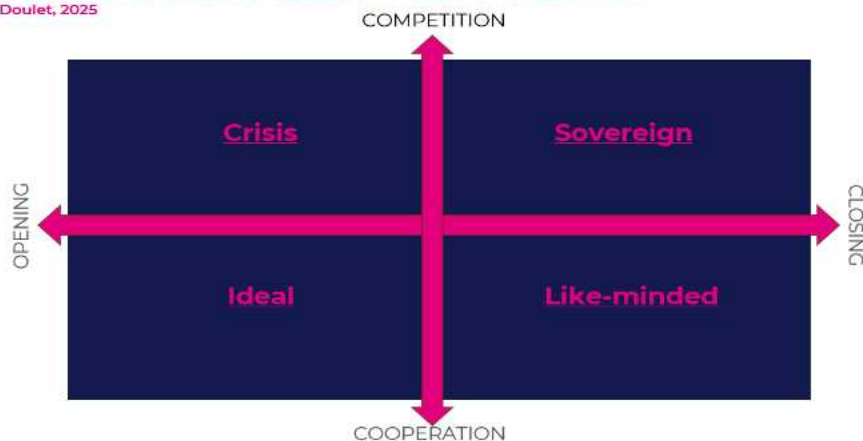
International Science Council already play an important role in advancing this vision, but they cannot bear this responsibility alone. For diplomacy in science to become a meaningful practice, it requires a wider ecosystem of actors. It envisions scientists, research institutions, and universities as actors that can advocate for scientific cooperation, defend academic freedom, bridge knowledge divides, and strengthen the role of evidence in public decision-making. If diplomats are increasingly using science to advance foreign policy objectives, then science too needs science diplomats (or diplomatic scientists): actors capable of ensuring that knowledge remains open, collaborative, and genuinely international.

Science Diplomacy in a Fragmented World

The significance of this fourth dimension becomes especially apparent in the current geopolitical environment. To make sense of the changing dynamics of science diplomacy, Jean-François Doulet (2025) proposes a useful framework based on two axes: cooperation versus competition and openness versus closure. Together, these dimensions generate four distinct “regimes of action” in science diplomacy.

The four regimes of action in science diplomacy

Doulet, 2025



The first is the Ideal regime, characterised by openness and cooperation. This reflects the vision of science as a global public good, where knowledge circulates freely across borders, and international collaboration is pursued for the collective benefit of humanity.

The second is the Like-minded regime, which remains cooperative but is more selective. Scientific collaboration continues, but increasingly takes place within trusted networks of partners that share similar political values, regulatory approaches, or strategic interests.

The third is the Crisis regime, where openness is maintained despite heightened competition. In this context, scientific cooperation may continue because pressing global challenges require engagement even among geopolitical rivals.

Universities and Science Diplomacy

Finally, the Sovereign regime combines competition with closure. Here, science and technology become instruments of strategic advantage, and concerns relating to research security, technological sovereignty, and national competitiveness lead states to restrict collaboration and knowledge flows.

Doulet's framework is particularly valuable because it illustrates that science diplomacy today does not operate within a single logic of international cooperation. Rather, it is increasingly shaped by tensions between openness and security, collaboration and competition. Different regimes can coexist simultaneously, depending on the scientific field, geopolitical context, or policy objective.

Universities as Science Diplomacy Actors

Against the backdrop of Doulet's four regimes, universities occupy a distinctive position: they operate within a world increasingly shaped by competition and closure, whilst their historical purpose has long depended on openness, circulation, and international connection. As arguably among the oldest international institutions, universities draw their vitality from the movement of people, ideas, texts, methods, and knowledge across borders. When they become disconnected from the wider world, they lose something key to their mission.

This raises an important question. If science diplomacy is increasingly being pulled into sovereign and like-minded regimes, the issue is no longer only how states use science, but how scientific and academic institutions can preserve the international character of knowledge.

Of course, universities are not detached from geopolitical realities. They depend on public funding. They operate within national regulatory systems. And they are often affected by the foreign policy priorities of the countries in which they are located. However, they also possess forms of agency that distinguish them from states. They build long-term partnerships that can outlast political cycles. They host international students and researchers. They produce knowledge across borders, participate in global networks, advise policymakers, and convene actors from science, diplomacy, civil society, industry, and international organisations.

In this sense, universities should be seen as institutions with their own diplomatic capacities. This can be understood through the concept of science diplomacy actorness: the capacity of an entity, such as a university or network of universities, to actively participate in and shape science diplomacy through its institutional structures, knowledge networks, partnerships, and public missions (Piaget & Radut-Gaghi, 2025). This does not mean that universities become diplomatic actors in the same way as states. Rather, it means that they can generate diplomatic effects through the ways they organise cooperation, sustain dialogue, mobilise expertise, and connect different communities across borders.

This point is important because much of what universities do already has diplomatic significance, even when it is not described as diplomacy. International research collaborations create channels of trust and exchange across borders. Partnerships with

embassies, ministries, international organisations, cities, and regional authorities connect academic expertise to diplomatic and policy processes. International students and researchers contribute to intercultural understanding and form lifelong transnational networks. Alumni can act as informal ambassadors, carrying institutional values into international organisations, governments, research centres, and civil society. Research funding sustains cross-border cooperation around shared challenges. Policy engagement allows universities to contribute evidence to decision-making. Curricula and training prepare future generations to navigate the interface between science, policy, and diplomacy. Public outreach helps defend the societal value of science and strengthens trust in knowledge.

Viewed together, these activities show that universities already practise science diplomacy, even when they do not call it by that name. The challenge is to move from implicit science diplomacy to intentional science diplomacy. In other words, universities need to recognise, organise, and strengthen the diplomatic dimensions of what they already do.

This also requires moving beyond a narrow understanding of diplomacy as something that takes place only through formal channels. Universities often operate through informal diplomacy: the patient building of relationships, trust, shared vocabularies, and long-term cooperation (Cino Pagliarello, 2024). Their influence is not always immediate or visible. It is often relational, cumulative, and embedded in networks. University alliances can therefore be understood as informal diplomatic infrastructures: spaces where scientific cooperation, academic exchange, policy dialogue, and trust-building come together in ways that broaden the terrain of diplomacy beyond traditional state-centred frameworks (Cino Pagliarello & Piaget, 2026).

This does not replace formal diplomacy; it complements it. States remain central actors in international relations, and universities cannot simply step outside the political environments in which they operate. But universities can help maintain forms of cooperation that states alone may struggle to preserve, especially in moments of geopolitical tension. They can keep channels of dialogue open, defend academic freedom, promote responsible internationalisation, and help ensure that science remains connected to broader public and global goods.

EUTOPIA: From Implicit to Intentional Science Diplomacy

The EUTOPIA European University Alliance offers one example of how this shift can take place in practice. Established in 2019 under the European Universities Initiative, EUTOPIA brings together ten European universities and six global partners.¹ Its structure is therefore not simply European, but transnational and globally connected.

1 EUTOPIA partners are: Vrije Universiteit Brussel (Belgium), Ca' Foscari University of Venice (Italy), CY Cergy Paris Université (France), NOVA University Lisbon (Portugal), Pompeu Fabra University (Spain), Technische Universität Dresden (Germany), University of Gothenburg (Sweden), University of Ljubljana (Slovenia), University of Warwick (United Kingdom), and Babeş-Bolyai University (Cluj-Napoca, Romania); and global partners are Arizona State University (USA), Kyungpook National University (South Korea), Monash University (Australia), Stellenbosch University (South Africa), Universidad de los Andes (Colombia), Université Internationale de Rabat (Morocco).

Universities and Science Diplomacy

It links universities across different national systems, disciplinary cultures, regional ecosystems, and global partnerships.

Like many university alliances, EUTOPIA was created to deepen cooperation across education, research, and societal impact. In that process, it has also become a platform for reflecting more explicitly on the diplomatic role of universities in a changing world order. It illustrates how an alliance can move from implicit contributions to science diplomacy toward a more intentional and strategic approach.

Through its science diplomacy seminars, conferences, workshops, and collaborative projects, EUTOPIA has brought together academics, diplomats, policymakers, students, regional actors, civil society, and international organisations. These activities have addressed issues such as evidence-informed policymaking, sub-national science diplomacy, responsible internationalisation, cultural heritage, academic freedom, and the future of scientific cooperation in a fragmented world. In addition to the exchange of ideas, these activities have also created spaces where different communities can meet, develop shared vocabularies, build trust, and reflect collectively on the role of science in international affairs.

This is one of the central contributions universities can make to science diplomacy. They provide spaces where science, policy, and society can encounter one another. In a world where many global challenges require cooperation across sectors and borders, this convening capacity is itself a diplomatic resource. Universities can act as bridges between local, regional, national, European, and global discussions. They can translate scientific expertise into policy-relevant dialogue while also bringing societal, ethical, and international questions back into research and education.

EUTOPIA's work also shows that science diplomacy should not be treated as a stand-alone activity. As the EUTOPIA Science Diplomacy Guidelines suggest, it can function as a transversal dimension of university strategy, connecting international cooperation, interdisciplinary engagement, societal impact, responsible internationalisation, and education (Piaget & Radut-Gaghi, 2026). This is particularly important because science diplomacy is not only about high-level policy declarations. It also requires skills, structures, and practices that allow universities and researchers to engage responsibly with complex international environments.

Here, the distinction between enabling, operational, and strategic tools is useful. This structure is borrowed from the EU's Framework for Science Diplomacy (2026) and Luk Van Langenhove's Tools for an EU Science Diplomacy (2017). Enabling tools refer to the capacities that make science diplomacy possible: education, training, and capacity building. Operational tools refer to the concrete mechanisms through which science diplomacy is practised: seminars, workshops, policy dialogues, partnerships, expert networks, and multistakeholder engagement. Strategic tools provide the long-term orientation: the institutional vision, priorities, and frameworks that allow science diplomacy to become part of how a university or alliance understands its role in the world.

EUTOPIA's experience suggests that university science diplomacy often develops from the bottom up. It begins with seminars, training activities, research collaborations, and informal networks. Over time, these activities can become more structured, more visible, and more strategic. This is important because universities should not wait for perfect institutional strategies before acting. They can begin by identifying where science diplomacy already exists within their institutions and then build from there.

This mapping exercise is crucial. In work developed by EUTOPIA, universities' science diplomacy actorness can be observed across several domains: international collaborations, diplomatic partnerships, international students and researchers, alumni engagement, research funding, science and policy influence, curricula development, and public outreach (Piaget & Radut-Gaghi, 2025). These domains provide a practical way to identify the many places where universities already contribute to international cooperation. They also help universities see where their capacities remain underdeveloped. For example, many universities have strong international research partnerships but weaker alumni strategies. Others engage in policy dialogue but have not yet developed curricula that train students and researchers to navigate the science-policy-diplomacy interface.

One role of European university alliances is to amplify these capacities. A single university may develop a course, host a policy dialogue, or maintain an international partnership. An alliance can connect these efforts across countries, disciplines, and institutional cultures. It can help turn isolated initiatives into shared platforms. It can also provide a laboratory for experimentation, where new forms of cooperation, training, and policy engagement can be tested before being scaled more broadly.

At the same time, EUTOPIA also illustrates the limits of university science diplomacy. University alliances remain dependent on external funding. They operate within national regulatory systems. Their member institutions may have different priorities, capacities, and political contexts. They also operate within academic cultures and reward systems that do not always recognise science diplomacy as part of core university work. Academic careers are still often assessed primarily through publications, citations, and competitive research funding, while activities such as policy engagement, public outreach, international bridge-building, trust-building, and contributions to societal resilience remain harder to measure and less consistently rewarded. This points to the need for a broader cultural shift within universities: if science diplomacy is to become more intentional, universities must also expand their understanding of academic excellence to include societal impact and contributions to the global public good (Van Langenhove & Burgelman, 2021). The science diplomacy actorness of universities is therefore bounded and negotiated rather than absolute. But this does not make it insignificant. On the contrary, it shows why university science diplomacy must be understood as a practical and evolving field.

The broader lesson is that universities can help carry forward the fourth dimension of science diplomacy. They can promote risk-aware openness and responsible inter-

nationalisation. They can support evidence-informed policymaking. They can help to keep scientific cooperation alive in difficult geopolitical conditions. And they can educate future researchers, policymakers, and citizens to understand that science does not exist outside politics, but neither should it be reduced to politics.

Conclusion: Science Needs Its Diplomats

If the twentieth-century story of science diplomacy was largely about how states used science in the service of diplomacy, the twenty-first-century challenge may be different. It is now about how science can remain open, trusted, and international in a world increasingly shaped by competition and closure.

Universities cannot carry this responsibility alone. Organisations such as UNESCO and the International Science Council remain essential. States, too, will continue to play a decisive role, as will the “tech titans” that are increasingly amassing influence on par with states (Royal Society, 2025). But universities bring something distinctive: long-term networks, educational missions, institutional continuity, interdisciplinary expertise, and the ability to connect people across borders even when political relations become strained.

This is why university science diplomacy matters. It gives practical form to the idea that knowledge is not only a national asset. It is also a global public good. It recognises that universities are not merely sites of teaching and research, but also spaces where international cooperation can be sustained, repaired, and reimaged.

If diplomats are increasingly using science to advance foreign policy objectives, then science too needs its diplomats: actors capable of ensuring that knowledge remains open, collaborative, and genuinely international. Universities have a leading role to play in supporting that vision.

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The journal will like to connect the scientists of OIC countries and across the world to the field of science Communication and Diplomacy to disseminate the results for the betterment of the nations. The journal will explore the concept of 'science diplomacy' which develops the scientific and foreign policy communities work together without compromising their different but complementary objectives. It will solidify the potential of science and diplomacy to complement each other to the mutual benefits.

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