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Open Science

Open Science Philosophy

Open science encompasses unrestricted access to scientific research articles, access to data from public research, and collaborative research enabled by information and communication technology tools, models, and incentives. Broadening access to scientific research publications and data is at the heart of open science. The objective of open science is to make research outputs and its potential benefits available to the entire world and in the hands of as many as possible:

- Open science promotes a more accurate verification of scientific research results. Scientific inquiry and discovery can be sped up by combining the tools of science and information technologies. Open science will benefit society and researchers by providing faster, easier, and more efficient availability of research outputs.
- Open science reduces duplication in collecting, creating, transferring, and re-using scientific material.
- Open science increases productivity in an era of tight budgets.
- Open science results in great innovation potential and increased consumer choice from public research.
- Open science promotes public trust in science. Greater citizen engagement leads to active participation in scientific experiments and data collection.

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Open Society

An open society allows individuals to change their roles and to benefit from corresponding changes in status. Open science depends to a greater or lesser extent on digital technologies and innovations in structural processes by an open society. When realized, open science research and innovation can create investment opportunities for new and better products and services and therefore increase competitiveness and employment. Open science research and innovation is a key component of thematic open science priorities. Central to the open science digital infrastructure is enabling industry to benefit from digital technology and to underpin scientific advances through the development of an open society. Open science research and innovation can also contribute to society as a global actor because scientific relations can flourish even where global relations are strained. Open science has a critical role across many areas of decision making in providing evidence that helps understand the risks and benefits of different open science choices. Digital technology is making the conduct of open science and innovation more collaborative, more global, and more open to global citizens. Open society must embrace these changes and reinforce its position as the leading power for science, for new ideas, and for investing sustainably in the future.

It is apparent in open society that the way science works is fundamentally changing, and an equally significant transformation is taking place in how organizations and societies innovate. The advent of digital technology is making research and innovation more open, collaborative, and global. These exchanges are leading open society to develop open science and to set goals for research and innovation priority. Open science goals are materializing in the development of scientific research and innovation platforms and greater acceptance of scientific data generated by open science research. Open science research and innovation do not need help from open society to come up with great ideas, but the level of success ideas ultimately reach is undoubtedly influenced by regulation, financing, public support, and market access. Open society is playing a crucial role in improving all these success factors.

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Open science represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and collaborative tools. These innovations capture a systemic change to the way science and research have been carried out for the last fifty years. Science is shifting from the standard practice of publishing research results in scientific publications after the research and reviews are completed. The shift is towards sharing and using all available knowledge at an earlier stage in the research process. Open science is to science what digital technology is to social and economic transactions: allowing end users to be producers of ideas, relations, and services and in doing so, enabling new working models, new social relationships and leading to a new *modus operandi* for science. Open science is as important and disruptive as e-commerce has been for the retail industry. Just like e-commerce, the open science research paradigm shift affects the whole business cycle of doing science and research. From the selection of research subjects to the carrying out of research, to its use and re-use, to the role of universities, and that of publishers are all dramatically changed. Just as the internet and globalization have profoundly changed the way we do business, interact socially, consume culture, and buy goods, these changes are now profoundly impacting how one does research and science.

The discussion on broadening the footprint of science and on novel ways to produce and spread knowledge gradually evolved from two global trends: Open Access and Open Source. The former refers to online, peer-reviewed scholarly outputs, which are free to read, with limited or no copyright and licensing restrictions, while open source refers to software created without any proprietary restriction and which can be accessed and freely used. Although open access became primarily associated with a particular publishing

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or scientific dissemination practice, open access already sought to induce a broader practice that includes the general re-use of all kinds of research products, not just publications or data. It is only more recently that open science has coalesced into the concept of a transformed scientific practice, shifting the focus of researchers' activity from publishing as fast as possible to sharing knowledge as early as possible. Open science is defined as the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process. As a result, the way science is done in the future will look significantly different from the way it is done now. Open science is the ongoing evolution in the modus operandi of doing research and organizing science. This evolution is enabled by digital technology and is driven by both the globalization of the scientific community and increasing public demand to address the societal challenges of our times. Open science entails the ongoing transitions in the way research is performed, researchers collaborate, knowledge is shared, and science is organized.

Open science impacts the entire research cycle, from the inception of research to its publication, and on how this cycle is organized. The outer circle reflects the new interconnected nature of open science, while the inner circle shows the entire scientific process, from the conceptualization of research ideas to publishing. Each step in the scientific process is linked to ongoing changes brought about by open science, including the emergence of alternative systems to establish a scientific reputation; changes in the way quality and impact of research are evaluated; the growing use of scientific blogs; open annotation; and open access to data and publications. All institutions involved in science are affected, including research organizations, research councils, and funding bodies. The trends are irreversible, and they have already grown well beyond individual projects. These changes predominantly result from a bottom-up process driven by a growing number of researchers who increasingly employ social media in their research and initiate globally coordinated research projects while sharing results at an early stage in the research process.

Open science is encompassed in five schools of thought:

- the infrastructure school, concerned with technological architecture
- the public school, concerned with the accessibility of knowledge creation
- the measurement school, concerned with alternative impact assessment
- the democratic school, concerned with access to knowledge
- the pragmatic school, concerned with collaborative research

According to the measurement school, the reputation and evaluation of individual researchers are still mainly based on citation-based metrics. The h-index is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar. The impact factor is a measure reflecting the average number of citations to articles published in an academic journal and is used as a proxy for the relative importance of a journal.

Numerous criticisms have been made of citation-based metrics, primarily when used, and often misused, to assess the performance of individual researchers. These metrics:

- are often not applicable at the individual level
- do not take into account the broader social and economic function of scientific research
- are not adapted to the increased scale of research
- cannot recognize new types of work that researchers are performing

Web-based metrics for measuring research output, popularized as altmetrics, have recently received much attention: some measure the impact at the article level, others make it possible to assess the many outcomes of research in addition to the number of scientific articles and references. The current reputation and evaluation system has to adapt to the new dynamics of open science and acknowledge and incentivize

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engagement in open science. Researchers engaging in open science have growing expectations that their work, including intermediate products such as research data, will be better rewarded or taken into account in their career development. Vice-versa, the use, and reuse of open data will require appropriate codes of conduct requiring, for example, the proper acknowledgment of the original creator of the data.

These ongoing changes are progressively transforming scientific practices with innovative tools to facilitate communication, collaboration, and data analysis. Researchers that increasingly work together to create knowledge can employ online tools and create a shared space where creative conversation and collaboration can occur. As a result, the problem-solving process can be faster, and the range of problems that can be solved can be expanded. The ecosystem underpinning open science is evolving very rapidly. Social network platforms for researchers already attract millions of users and are being used to begin and validate more research projects.

Furthermore, the trends towards open access are redefining the framework conditions for science and thus have an impact on how open innovation is produced by encouraging a more dynamic circulation of knowledge. It can enable more science-based startups to emerge thanks to the exploitation of openly accessible research results. Open science, however, does not mean free science. It is essential to ensure that intellectual property is protected before making knowledge publicly available in order to subsequently attract investments that can help translate research results into innovation. If this is taken into account, fuller and broader access to scientific publications and research data can help to accelerate innovation. Investments that boost research and innovation in open science would benefit society with fewer barriers to knowledge transfer, open access to scientific research, and greater mobility of researchers. In this context, open access can help overcome the barriers that innovative organizations face in accessing the results of research funded by the public.

Open innovation

An open society is the largest producer of knowledge, but the phenomenon of open science is changing every aspect of the scientific method by becoming more open, inclusive, and interdisciplinary. Ensuring open society is at the forefront of open science means promoting open access to scientific data and publications alongside the highest standards of research integrity. There are few forces in this globe as engaging and unifying as science. The universal language of science maintains open channels of communication globally. Open society can maximize its gains through maintaining its presence at the highest level of scientific endeavor, and by promoting a competitive edge in the knowledge society of the information age. The ideas and initiatives described in this publication can stimulate anyone interested in open science research and innovation. It is designed to encourage debate and lead to new ideas on what and open society should do, should not do, or do differently.

An open society can lead to a research powerhouse; however, open society rarely succeeds in turning research into innovation and in getting research results to the global market. Open society must improve at making the most of its innovation talent, and that is where open innovation comes into play. The basic premise of open innovation is to open up the innovation process to all active players so that knowledge can circulate more freely and be transformed into products and services that create new markets while fostering a stronger culture of entrepreneurship. Open innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation. This original notion of open innovation was primarily based on transferring knowledge, expertise, and even resources from one company or research institution to another. This notion assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they seek to improve their performance. The concept of open innovation is continually evolving and is moving from linear, bilateral transactions and collaborations

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towards dynamic, networked, multi-collaborative innovation ecosystems. This means that a specific innovation can no longer be seen as the result of predefined and isolated innovation activities but rather as the outcome of a complex co-creation process involving knowledge flows across the entire economic and social environment. This co-creation takes place in different parts of the innovation ecosystem and requires knowledge exchange and absorptive capacities from all the actors involved, whether businesses, academia, financial institutions, public authorities, or citizens.

Open innovation is a broad term, which encompasses several different nuances and approaches. Two main elements underpin the most recent conceptions of open innovation: the users are in the spotlight and invention becomes an innovation only if users become a part of the value creation process. Notions such as user innovation emphasize the role of citizens and users in the innovation processes as distributed sources of knowledge. This kind of public engagement is one of the aims of open science research and innovation. The term 'open' in these contexts has also been used as a synonym for 'user-centric'; creating a well-functioning ecosystem that allows co-creation and becomes essential for open innovation. In this ecosystem, relevant stakeholders are collaborating along and across industry and sector-specific value chains to co-create solutions for socio-economic and business challenges. One important element to keep in mind when discussing open innovation is that it cannot be defined in absolutely precise terms. It may be better to think of it as a point on a continuum where there is a range of context-dependent innovation activities at different stages, from research to development through to commercialization, and where some activities are more open than others. Open innovation is gaining momentum thanks to new large-scale trends such as digitalization and the mass participation and collaboration in innovation that it enables. The speed and scale of digitalization are accelerating and transforming the way one designs, develops, and manufactures products, the way one delivers services, and the products and services themselves. It is enabling innovative processes and new ways of doing business, introducing new cross-sector value chains and infrastructures.

Open society must ensure that it capitalizes on the benefits that these developments promise for citizens in terms of tackling societal challenges and boosting business and industry. Drawing on these trends, and with the aim of helping build an open innovation ecosystem in open society, the open society's concept of open innovation is characterized by:

- combining the power of ideas and knowledge from different actors to co-create new products and find solutions to societal needs
- creating shared economic and social value, including a citizen and user-centric approach
- capitalizing on the implications of trends such as digitalization, mass participation, and collaboration

In order to encourage the transition from linear knowledge transfer towards more dynamic knowledge circulation, experts agree that it is essential to create and support an open innovation ecosystem that facilitates the translation of knowledge into socio-economic value. In addition to the formal supply-side elements such as research skills, excellent science, funding and intellectual property management, there is also a need to concentrate on the demand side aspects of knowledge circulation, making sure that scientific work corresponds to the needs of the users and that knowledge is findable, accessible, interpretable and reusable. Open access to research results aims to make science more reliable, efficient, and responsive and is the springboard for increased innovation opportunities, e.g. by enabling more science-based startups to emerge. Prioritizing open science does not, however, automatically ensure that research results and scientific knowledge are commercialized or transformed into socio-economic value. In order for this to happen, open innovation must help to connect and exploit the results of open science and facilitate the faster translation of discoveries into societal use and economic value.

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Collaborations with global partners represent important sources of knowledge circulation. The globalization of research and innovation is not a new phenomenon, but it has intensified in the last decade, particularly in terms of collaborative research, international technology production, and worldwide mobility of researchers and innovative entrepreneurs. Global collaboration plays a significant role both in improving the competitiveness of open innovation ecosystems and in fostering new knowledge production worldwide. It ensures access to a broader set of competencies, resources, and skills wherever they are located, and it yields positive impacts in terms of scientific quality and research results. Collaboration enables global standard-setting, allows global challenges to be tackled more effectively, and facilitates participation in global value chains and new and emerging markets.

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The scholarly research review is a multidimensional evaluation procedure in which standard peer review models can be adapted in line with the ethos of scientific research, including accessible identities between reviewer and author, publishing review reports and enabling greater participation in the peer review process. Scholarly research review methods are employed to maintain standards of quality, improve performance, provide credibility, and determine suitability for publication. *Responsible Peer Review Procedure:* Responsible peer review ensures that scholarly research meets accepted disciplinary standards and ensures the dissemination of only relevant findings, free from bias, unwarranted claims, and unacceptable interpretations. Principles of responsible peer review:

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All submitted manuscripts are subject to the scholarly research review process, in which there are three stages of evaluation for consideration: pre-review manuscripts, chair-review presentation, and final-review manuscripts. All submitted full text papers, that may still be withstand the editorial review process, are presented in the conference proceedings. Manuscripts are tracked and all actions are logged by internal and external reviewers according to publication policy. External reviewers' editorial analysis consists of the evaluation reports of the conference session chairs and participants in addition to online internal and external reviewers' reports. Based on completion of the scholarly research review process, those manuscripts meeting the publication standards are published 10 days after the event date.

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Forecasting Satellite Cyber Threats Using the A.E.R.I.S Model: Attack Evolution and Resilience via Integrated Statistics

Abigail C. Teron, Luis M. Vicente

Abstract—As global reliance on satellite systems continues to grow, they are becoming increasingly vulnerable to sophisticated cyber threats. Despite the rising risk, current satellite cybersecurity strategies often remain reactive and lack the foresight required for proactive measures. This study presents AERIS: Attack Evolution & Resilience via Integrated Statistics; a predictive modeling framework designed to forecast and characterize satellite cyber threats using historical data from 1985 to 2024. AERIS brings together four statistical tools: Markov Chain modeling, Poisson regression, Bayesian networks, and Survival analysis, to capture attack patterns, frequency dynamics, conditional vulnerabilities, and long-term risk exposure. Findings from AERIS reveal clear geopolitical trends, including a projected 12.1% increase in attack frequency from high-risk adversaries. The framework also highlights the elevated risks faced by LEO and TT&C systems, and demonstrates how attacker identity, orbital characteristics, and system weaknesses collectively influence the severity of impact. Survival modeling within AERIS shows that post-incident resilience declines significantly, dropping from 68% to 26% over 10 years, especially following high-impact attacks. By integrating these models into a unified platform, AERIS transforms scattered historical attack data into forward-looking threat intelligence. The result is a flexible, evidence-based tool to support engineers, policymakers, and cybersecurity professionals in anticipating risks, prioritizing defenses, and designing resilient satellite architectures for the contested space domain.

Keywords—AERIS, cyber threats, forecast, satellites, statistical models.

I. INTRODUCTION

SATELLITE systems form the backbone of modern communication, navigation, remote sensing, and defense operations. Their critical importance makes them attractive targets for state and non-state cyber threat actors. Understanding and forecasting cyberattack patterns is vital for enhancing space system resilience and informing proactive defense strategies. This study integrates four complementary statistical techniques. Markov Chain models to capture attack transition behavior [1], Poisson forecasting to forecast attack frequencies [2], Bayesian network inference to identify conditional risk factors [3], and survival analysis to model attack persistence and recurrence [4]. The combination of these statistical techniques provides a multifaceted statistical view of historical attack patterns and their potential future trajectories in the satellite system.

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II. HISTORICAL ATTACK DATA

Historical attack data from 1985–2024, comprising 67 recorded cyber-attack events, were processed into features including year, impact severity, attack type, attacker type, orbit, target type, vulnerability, adversary country, and victim country presented in Tables I and II [5]. These tables present a sample of the 67 recorded cyber-attacks to show how the data was transferred from qualitative [5] to quantitative data. Table II includes the year of the cyber-attacks with missing columns from Table I. It is critical to recognize that the historical dataset employed in this study is inherently limited by the scarcity and restricted transparency of publicly available records on satellite cybersecurity incidents. The dataset analyzed consists of 67 documented, unclassified cyberattacks targeting satellite systems. The four statistical models implemented in this research are intended as a proof of concept, illustrating the methodological viability of leveraging historical incident data to develop predictive models capable of generating statistically robust forecasts of potential future threats. Conceptually, as the availability of reliable satellite-focused cyberattack data increases and the sample size correspondingly expands, the predictive fidelity of these models is expected to improve. Such advancements would enhance their capacity not only to anticipate emerging threats but also to support proactive defense measures aimed at mitigating or preventing cyberattacks before they materialize.

TABLE I
HISTORICAL DATA - SAMPLE OF QUANTITATIVE DATA USED FOR FORECAST

Year	Attack Type	Attacker Type	Orbit	Impact	Target_Type
1985	Hijacking	Individual	GEO	Minor	Broadcast
1986	Hijacking	Individual	GEO	Minor	Broadcast
1986	Eavesdrop	Government	GEO	Moderate	ISR
1987	Hijacking	Individual	GEO	Minor	Broadcast
1993	Cryptography	Individual	GEO	Minor	Broadcast
1994	Jamming	Government	GEO	Moderate	Broadcast
1994	Cryptography	Individual	GEO	Minor	Broadcast
1996	Jamming	Government	GEO	Moderate	Broadcast
1996	Jamming	Government	GEO	Minor	Broadcast
1997	Jamming	Government	GEO	Moderate	Broadcast
1998	Hijacking	Unknown	LEO	Severe	Command
1999	Jamming	Government	GEO	Severe	ISR
1999	Hijacking	Unknown	GEO	Severe	ISR

Year	Attack Type	Attacker Type	Orbit	Impact	Target_Type
...	...	...	...	...	...

The data in Tables I and II show a quantitative sample of the 67 Satellite cyber-attacks from 1985 to 2024 [5].

TABLE II
HISTORICAL DATA – ADDITIONAL COLUMNS OF THE QUANTITATIVE DATA
USED FOR FORECAST

Year	Vulnerability	Adversary_Country	Victim_Country
1985	RF_Hijacking	Poland	Poland
1986	RF_Hijacking	US	US
1986	Encryption_Weakness	Indonesia	US
1987	RF_Hijacking	US	US
1993	Encryption_Exploitation	UK	Britain
1994	Jamming_Broadcast	Iran	Saudi Arabia
1994	Encryption_Exploitation	US	US
1996	Jamming_Broadcast	Indonesia	Asia
1996	Jamming_Broadcast	Turkey	USA
1997	Jamming_Broadcast	Indonesia	Asia
1998	GroundControl_Exploitation	Russia	Multiple
1999	Military_Communication	Russia	Russia
1999	Military_Communication	Unknown	UK
...	...	...	...

Table II includes the missing columns from Table I for the same sample of the Historical Data [5].

III. STATISTICAL MODELS

A. Markov Chain Modeling

The Markov Chain approach was employed to model transitions between attack types [6]. This Markov Chain analysis provides a structured understanding of attack evolution pathways, which is essential for predicting potential escalation during ongoing incidents. Transition matrices derived from historical attack sequences reveal clear patterns: The numerical values in Fig. 1 (e.g., 0.5, 0.0625, 0.026316) are probabilities that show the likelihood of transitioning from one type of attack to another. Values of 0.000000 indicate that no transitions between those specific types of attacks were observed in the dataset.

Key observation from Fig. 1, a value of 0.5 from Spoofing → Eavesdropping suggests that in half of the observed cases, a Spoofing attack transitioned into an Eavesdropping attack. Transitions from Hijacking such as, Hijacking → Cryptography = 0.0625, Hijacking → Sensor = 0.0625, Hijacking → Signal_Injection = 0.0625. This indicates a distributed probability that a Hijacking attack is followed by other specialized attack techniques. A value of 0.026316 from Jamming → Cryptography indicates that in approximately 2.6% of the observed attack paths, a Jamming attack transitioned into a Cryptographic attack.

Transition Matrix:								
	Supply_Chain	Eavesdropping	Cryptographic	...	Cryptography	Sensor	Signal_Injection	
Supply_Chain	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Eavesdropping	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Cryptographic	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Jamming	0.0	0.026316	0.0000	...	0.026316	0.0000	0.0000	0.0000
TT&C	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Hijacking	0.0	0.062500	0.0625	...	0.000000	0.0625	0.0625	0.0000
Spoofing	0.5	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Hacktivist	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Cryptography	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Sensor	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000
Signal_Injection	0.0	0.000000	0.0000	...	0.000000	0.0000	0.0000	0.0000

Fig. 1 Markov Chain Transition Matrix

Fig. 2 presents a simulation using past attack data from Tables I and II, so it can use a Markov Chain model projecting the likely sequence of future attacks given current patterns. According to the simulation, a hijacking attack is most likely to be followed by jamming as jamming may then lead to some hacktivist-related incident. Jamming is what the pattern returns to, and then it continues to repeat itself. Jamming attacks dominate within the satellite threat landscape repeatedly. Historical data show trends consistent along with this sequence. The simulation reveals jamming remains a very likely threat to satellite systems unless mitigations change to halt this cycle.

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From Hijacking -> Next likely: Jamming
From Jamming -> Next likely: Hacktivist
From Hacktivist -> Next likely: Jamming
From Jamming -> Next likely: Jamming
From Jamming -> Next likely: Hijacking

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Fig. 2 Next Likely Cyber-Attack

Fig. 3 shows the probability that transitions will occur among diverse satellite cyberattack kinds given past data. Each arrow is an indication of the likelihood of one type of attack following on from another. The source remains the former, and the destination is the latter. Self-loop probabilities notably reveal strong repetition patterns for certain attack types. Jamming attacks occur, for example, again 68% of the time after one happens. There is about 50% probability that attacks involving spoofing repeat. Hijacking attacks show a 25% likelihood of recurring, but attacks that are related to hacktivists show only a 3% self-transition rate, and that rate is much lower.

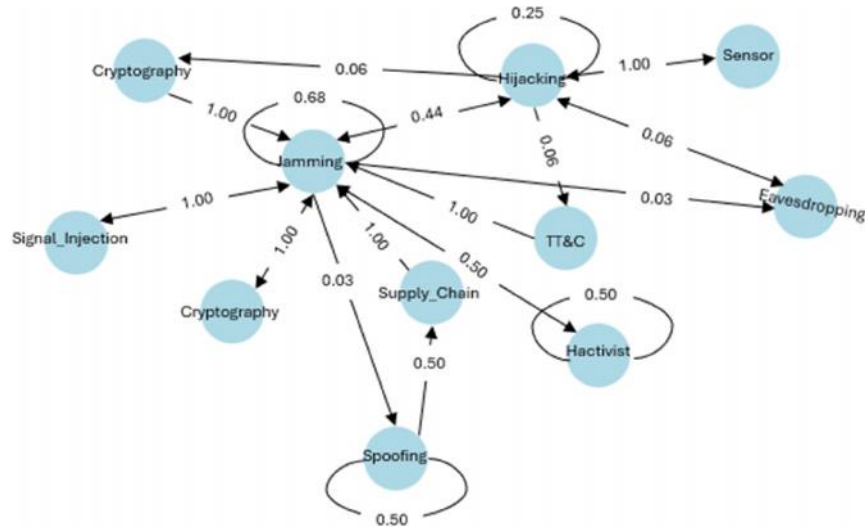


Fig. 3 Source Attack to Destination Attack

Prominent inter-type transitions are revealed also by all the data. Jamming attacks occur often after hijacking with a 44% occurrence rate. Less frequently, hijacking transitions into telemetry attacks of about 6%, tracking attacks near 6%, command attacks around 6%, cryptographic attacks, or even eavesdropping. Every observed supply chain attack inside the dataset is interestingly followed by a jamming attack. Attacks using cryptography change to jamming certainly. Jamming as well as spoofing is equally likely (50%) results of hactivist events while spoofing transitions into the act of eavesdropping 50% of the time. Signal injection attacks fully transition into jamming all the time finally, while TT&C attacks transition likewise only 3% of the time.

B. Poisson Regression Model

To forecast future Satellites cyber-attack frequencies [7], the annualized historical data were analyzed through a Poisson regression model. Recorded back in the 1980s there were four cyberattacks related to satellites. This number increased to nine in the 1990s then doubled to 18 in the 2000s. During the 2010s, the number of attacks continued to increase. There were 27 attacks around that decade. Nine cyberattacks have been documented in the current decade (2020–2024) so far, though the decade is not yet completed. Fig. 4 used blue dots for depiction of these cyber-attacks. The figure's red line represents the number of satellites cyberattacks per decade Poisson regression prediction. This regression model explains the upward curve of the red line. In the model, attack frequency is assumed to grow in an exponential way over time. The expected long-term trend now is captured while short-term fluctuations between decades are smoother. However, the red line is not in alignment with each blue data point, for Poisson regression can reflect an average rate. The overall interpretation does suggest a consistent increase in satellite cyber threats over time for it mirrors the global shift toward space-based infrastructure with growing interest in cyber warfare.

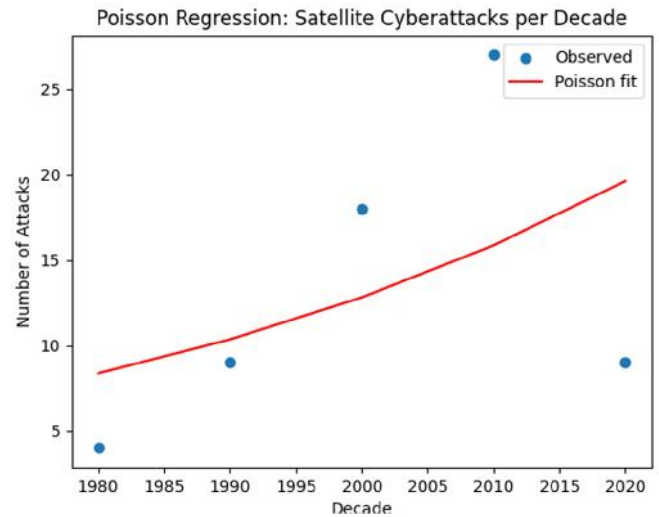


Fig. 4 Cyber-Attacks by Decade

Fig. 5 presents the results that are from 1980 to 2040 of a Poisson regression model applied to satellite cyberattack data. The blue dots represent the observed number of cyberattacks per decade, with this showing a clear upward trend from the 1980s to the 2010s. Observed values for the 2020s, current decade, are lower, as the data only cover the period from 2020 to 2024. The red curve, capturing historical growth, shows that the fitted Poisson model is projecting trends for the future. The forecast for the 2020s estimates at least 19.62 attacks, and a 95% confidence interval ranges in value from 13.61 to 28.26. For the 2030s, the model predicts 24.27 attacks (95% CI: 14.58–40.42). It anticipates 30.04 attacks (95% CI: 15.39–58.63) for the 2040s. Uncertainty reflects future decades' widening confidence intervals. Over time, this uncertainty is growing. Overall, due to how the model highlights a statistically important upward trend in satellite cyber threats, it reinforces the need for more forward-looking security strategies.

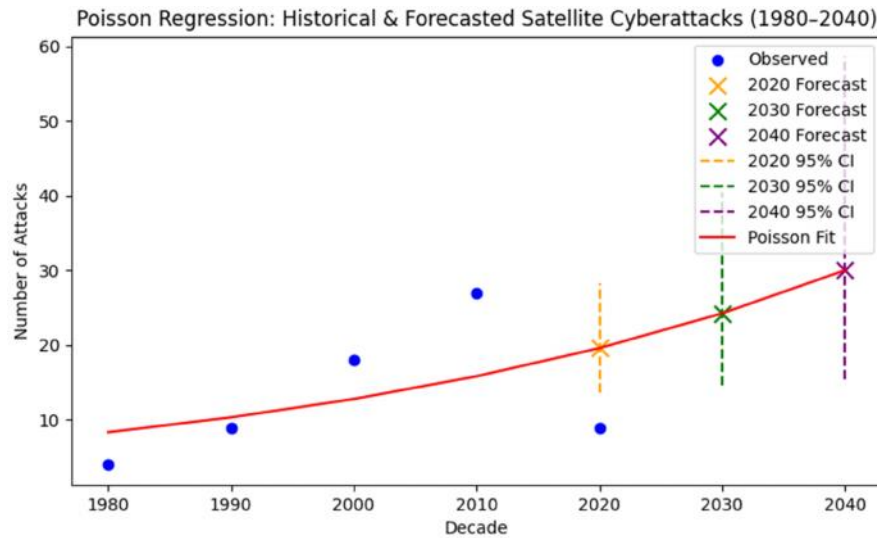


Fig. 5 Poisson Regression Forecast 1980-2040

Fig. 6 presents the projected number of satellite cyberattacks per year for various countries from 2025 to 2034. On the x-axis, forecast years are shown, while the y-axis shows attack predictions ranging from about 1.0 to 1.45. These events are rare according to the scale. That nature is measured on a per country and per year basis. Poland, Indonesia, the United States, the United Kingdom, Iran, Turkey, and Russia are color coded with a legend for each line on the graph.

For most of the countries, the predicted values do remain constant around a value of 1.0. This indicates levels of stable threat because there is not an important trend statistically over the course of time. That suggests that no substantial increase or decrease in attack frequency was revealed from within historical data for all those nations. Represented by the magenta

line is Russia, which shows a consistent upward trend. For this country, the predicted number of attacks rises from nearly 1.30 in 2025 to 1.44 by 2034, suggesting a statistically meaningful positive slope. This does indicate a threat that is increasing.

Since it predicts infrequent events and deals with count data, Poisson regression fits this analysis well. Because of the log linear relationship, the model estimates the expected number of attacks (λ) as a function of time $\log(\lambda) = \beta_0 + \beta_1 \cdot t$, where t represents the year.

The implications are clear, countries with flat lines show stable cyber risk profiles, but those with trends that rise, such as the magenta line may require someone to monitor them more closely, investigate them in more depth, as well as develop proactive defense strategies.

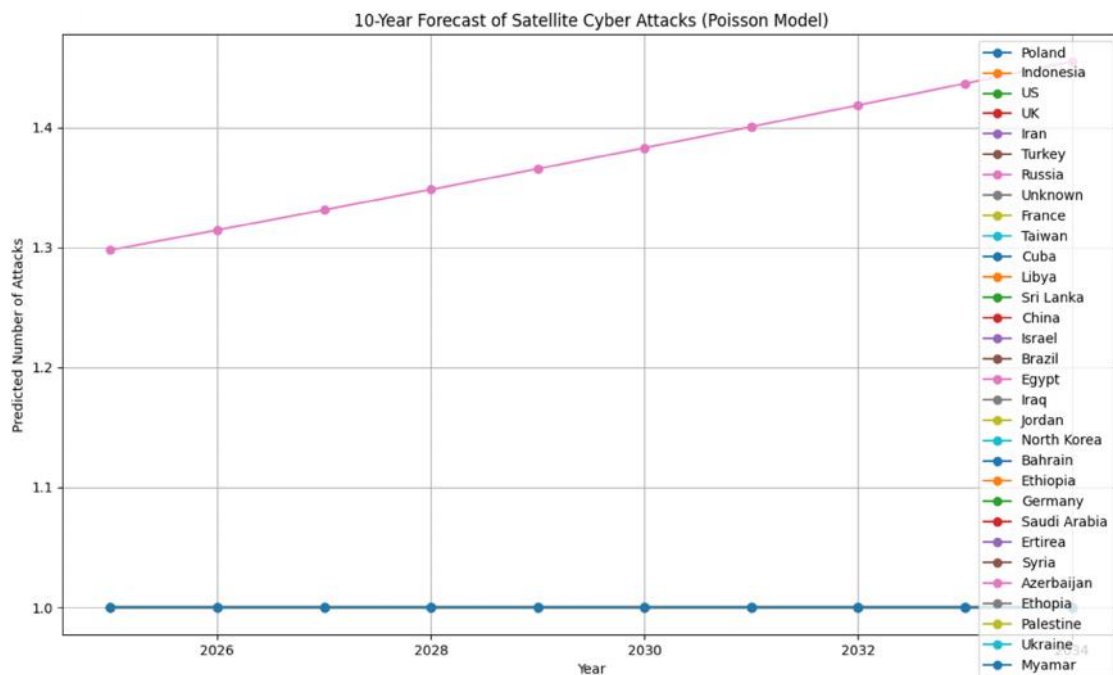


Fig. 6 10 Year Forecast of Satellite Cyber-Attacks Using the Poisson Regression

Fig. 7 shows the decade long prediction of cyberattack rate simulated through Poisson regression regarding the leading five perilous rival countries. The x-axis shows a ten-year span representing the years 2025 to 2034. On the other hand, the y-axis does show the predicted number of Satellites cyberattacks for each year. Each country is color coded within the legend. Included are Russia (magenta), Bahrain, Azerbaijan, China, and Cuba.

Russia stands out from these nations from about 1.30 predicted attacks yearly in 2025 to about 1.45 by 2034, with a projected growth rate of 12.1%, indicating a measurable upward trend in its attack frequency over the forecast period. This increase shows a statistically important positive slope in the model thus Russia may be an active source or frequent target regarding high-risk satellite cyber events.

In contrast, attack frequencies do remain near to 1.0 per year

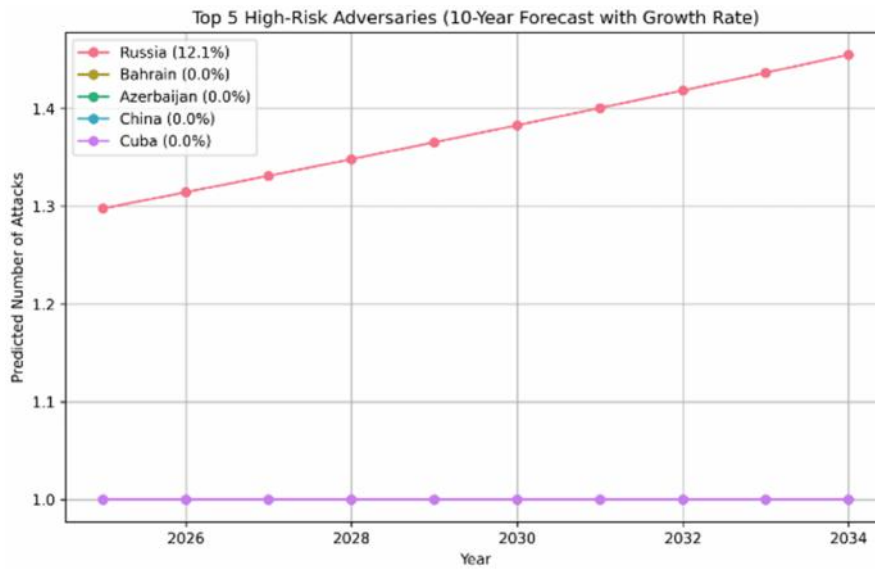


Fig. 7 High-Risk Adversaries

These results indicate that attack intensity and persistence are expected to increase, with a concentration of high-frequency activity in geopolitically active regions.

C. Bayesian Network Analysis

A Bayesian network was constructed to model the conditional dependencies [8] between attacker type, orbit type, system vulnerabilities, and attack outcomes. Key findings include Attacker Type and vulnerability exposure are strong predictors of attack type.

The Fig. 8 depicts a Bayesian network model along with the model revealing the probabilistic dependencies between various factors contributing to satellite cyber-attacks. Attacker_Type as the main node, Vulnerability, Orbit, and Attack_Type are the four main nodes within the network. An important dimension of cyber threat behavior is captured by each and every node. The behavior impacts upon the capturing node. The Attacker_Type node represents the entity launching the attack ranging from individuals and hacktivists to cyber

all throughout the forecast window for each of the other countries: Bahrain, Azerbaijan, China, and Cuba do show flat trajectories. This suggests a steady risk amount. No truly meaningful upward or downward trend was in fact detected in all the historical data.

Poisson regression is a thing that particularly suits modeling of rare event data well, for the attacks per country per year are few. The model assumes an exponential relationship.

$\lambda = e$ raised to $(\beta_0 + \beta_1 \cdot t)$, where λ represents the expected number of attacks, and t represents time. For countries where β_1 is at a value that is approximately zero the line remains flat. This evenness shows zero temporal influence. It is projected that the frequency of attacks for Russia, in which β_1 is positive, is to increase over time.

groups, terrorists, or state actors. The Vulnerability node describes exploited weaknesses, such as software flaws or insecure protocols. Orbit node mirrors satellite position so location determines attack possibilities like Low Earth Orbit (LEO), Geostationary Orbit (GEO), or Medium Earth Orbit (MEO). Attack_Type is the cyberattack form located in the network's center like Jamming Hijacking Cryptographic or Supply Chain.

Fig. 8 makes use of directed arrows. They capture just how these variables do influence one another. The likely attack method is in fact directly affected by the kind of opponent that Attacker_Type $\rightarrow$ Attack_Type implies. Hacktivists are more likely to engage with jamming or spoofing, while government-backed attackers may favor advanced methods like hijacking or signal injection. Vulnerability $\rightarrow$ Attack_Type also indicates some technical weaknesses related to attack types. For example, due to poor encryption some attack types are more probable. Highlighting the impact about a satellite's orbital domain on threat patterns, the arrow Orbit $\rightarrow$ Attack_Type shows LEO

satellites are more susceptible to jamming, while GEO satellites, often used in communications, may be more

vulnerable to spoofing or hijacking attempts.

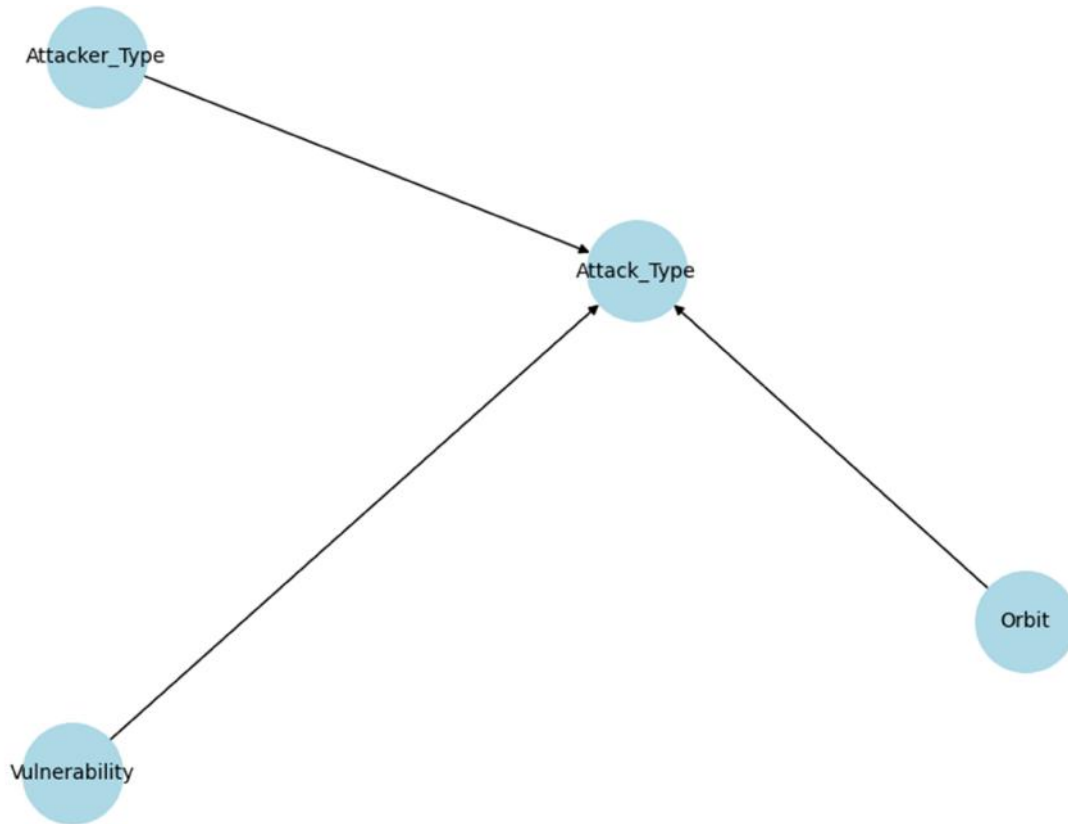


Fig. 8 Attack Type relation to Attacker Type, Vulnerability and Orbit

In Fig. 9, Impact indicates how severe a satellite cyberattack is as the dependent node. Adversary_Country and Victim_Country affect it as two main direct variables. The relationship $\text{Adversary_Country} \rightarrow \text{Impact}$ reflects the influence over the attacking nation's identity. That influence can affect an incident's overall severity. For instance, on account of state-sponsored attacks tending to have greater resources as well as calculated objectives, they are much more likely to result in severe impacts in comparison to attacks carried out by independent hackers or by loosely organized groups.

$\text{Victim_Country} \rightarrow \text{Impact}$ represents how the nation's fortitude and readiness address and shape the aftermath of the attack. In countries, mature cybersecurity infrastructures and systems that are redundant can lead to disruptions that are only minor. Strong incident response protocols are also helpful, plus may lead to moderate disruptions at worst. However, an alike attack focused on a frail nation, one having scant guard or feeble base might become a serious event involving shared impacts.

This Bayesian network with Impact at the center is enabling diagnostic analysis and predictive analysis. For example, it allows us to answer questions such as: "Given an opponent and also a targeted country, what is the probability that the impact will be so severe?" or just in reverse: "If a severe impact has occurred, which opponent is most likely to be responsible?" This structure lets us probabilistically find an understanding for

not only just how attacks occur, but also the reason why certain attacks damage more, so it offers decision-makers a more subtle tool for assessing as well as managing cyber risk in the satellite domain.

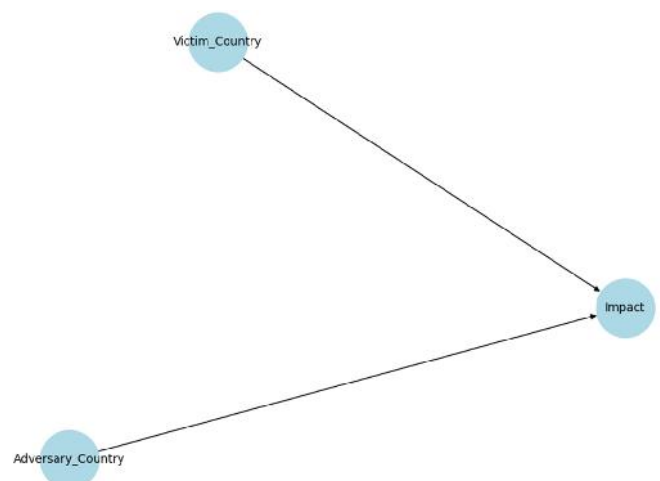


Fig. 9 Impact relation to Victim Country and Adversary Country

The Bayesian network diagram in Fig. 10 depicts three key factors influencing the variable Impact: Adversary_Country, Victim_Country, and Year. These relationships are able to help

model the expected severity that comes from cyberattacks based upon data patterns. The hostile nation shows a view about attacker possibilities. State-sponsored actors often possess both tools along with the intent needed to cause more meaningful damage than individual hackers. The targeted country has an equal role at the same time; nations better able to absorb or deflect attacks have mature cybersecurity programs plus resilient infrastructure, but countries less prepared might

experience consequences that are severe. Time also matters. Defensive strategies and offensive techniques do get better due to technology's evolution, so attacks impact 2025 in such ways unlike what occurred during 2010. The model combines all these factors so that it may estimate the likelihood of an attack resulting in a minor, moderate, or severe impact; therefore, it is a tool for the comprehension of how different variables interact to shape cyber risk over a period of time.

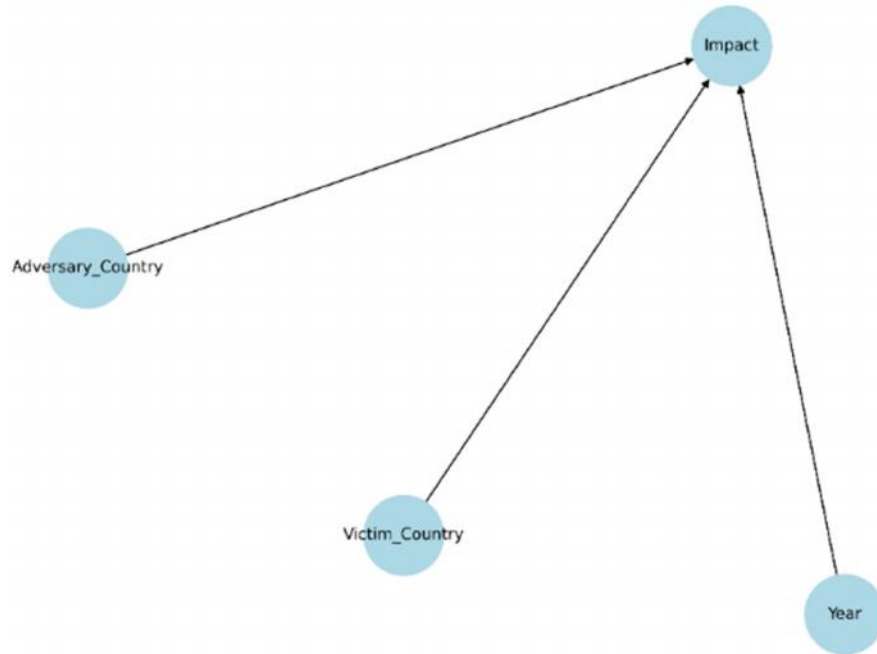


Fig. 10 Impact relation to Victim Country and Adversary Country

The Fig. 11 presents four heatmaps visualizing cyberattack impact probability distributions: minor, moderate, severe, and combined based on opponent and victim country interactions. Each heatmap captures at least the likelihood of a particular impact level, even given how the attacker and the target relate pairwise. On Fig. 11 (a), the Minor Impact Heatmap does show uniform probabilities to be around 0.33, and slight variations can happen as they do depend on the country pair. On Fig. 11 (b), the Moderate Impact Heatmap displays a more diverse spread. This indicates that impacts at a moderate level are slightly more sensitive to specific dynamics between attacker and target. The Severe Impact Heatmap on Fig. 11 (c) reveals

the most concentrated and intense values since it highlights specific adversaries such as Germany, Russia, and the UK that are associated with higher probabilities of causing or receiving severe impacts. The three levels aggregate into the Combined Impact Heatmap at Fig. 11 (d). Overall threat intensity is viewed in a composite way in it. This map of composites with central values near 1.0 gives a wider view of risky victim-opponent links; it also softens individual variance. Together, these heatmaps underscore the subtle relationship of geopolitical entities because they determine cyberattack consequences, also this provides a probabilistic lens for prioritizing national cyber defense efforts.

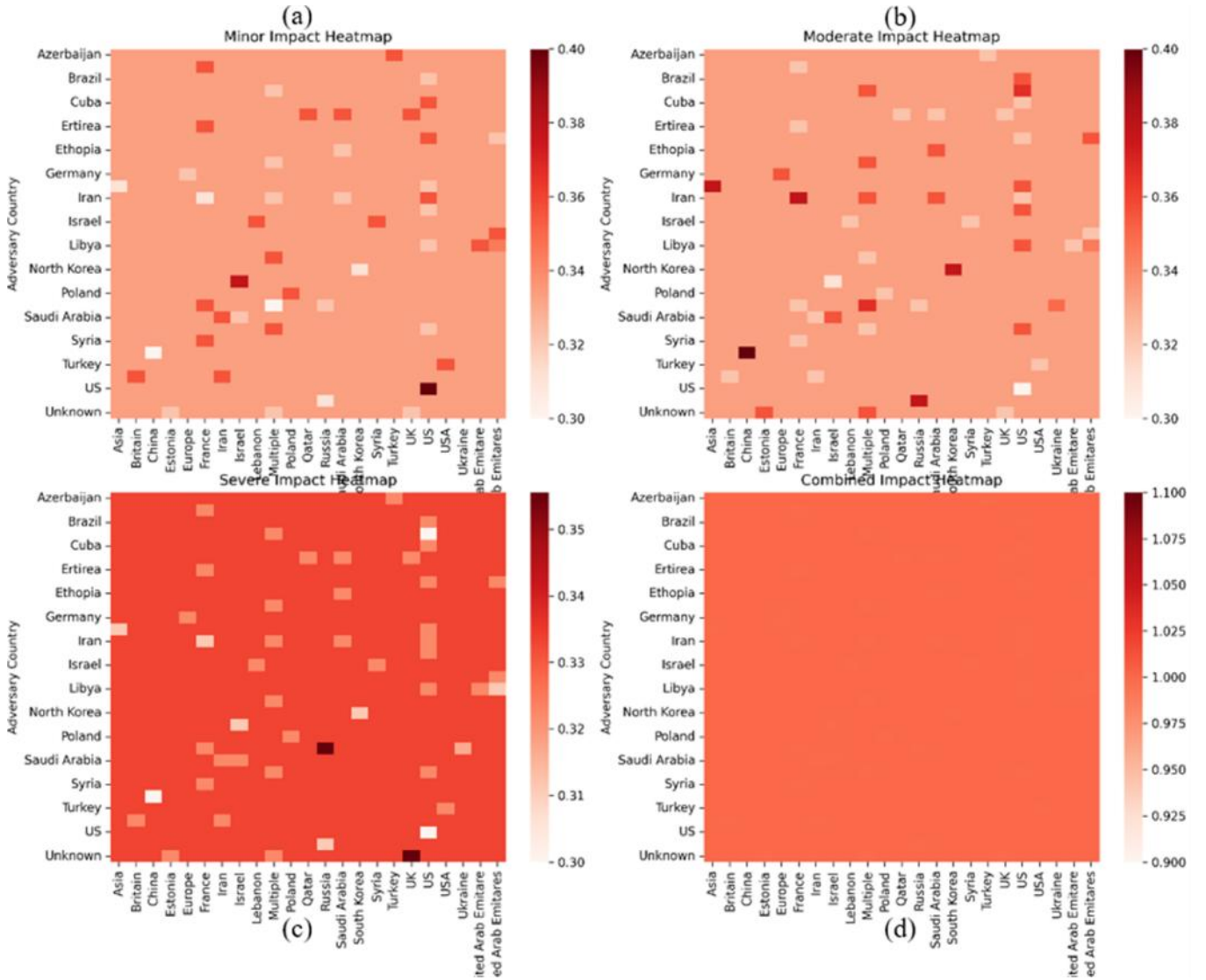


Fig. 11 Impact Probability Heatmaps

D. Survival Analysis of Attack Persistence

Survival analysis provides insights into how long systems remain attack-free after an initial compromise [9].

Fig. 12 depicts Kaplan-Meier survival curves that are segmented by the opponent country in relation to satellite cyberattacks. Every curve shows how likely a given opponent is to avoid launching another recorded attack over time, measured from years since their cyber incident became known. Poland and Taiwan are countries showing flat lines close to 1.0 survival probability because they suggest long intervals lacking repeated activity, so recurrence risk remains low. In contrast, countries such as the U.S., Indonesia, along with Libya display

steep drops in survival probability. There is in fact a much higher likelihood of recurring attacks over shorter intervals within these countries. These steep declines are suggestive of persistent or frequent engagement in cyber operations. Russia, China, and the “Unknown” category are countries that fragment or fluctuate in curves therefore they reflect more complex behavior likely shaped by changes in geopolitical contexts how challenges attribute plus how they covertly operate. These survival curves offer a dynamic way for visualizing the longevity or recurrence risk of cyber adversaries overall. Due to information about past actions, they help to better focus on monitoring plus threat intelligence efforts.

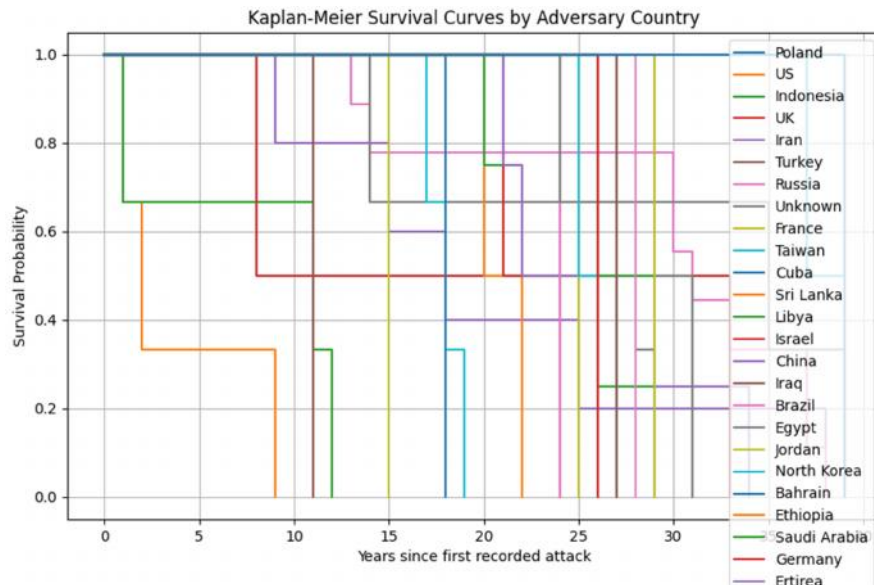


Fig. 12 Kaplan-Meier Survival Curves by Adversary Country

Fig. 13 shows Kaplan-Meier survival curves grouped by global regions; these curves reveal the typical time until a country within each region experiences a repeated satellite cyberattack following its first incident. The x-axis is representative of the number of years from the first recorded attack, while the y-axis can reveal the survival probability for the chance that no new attack has occurred. Regions for example Africa, the Americas, as well as Asia display steep drops early in the timeline since such drops indicate repeat attacks tend to occur within the first 5 to 10 years toward reflecting a shorter “survival time” between cyber incidents. Europe, in contrast, maintains a higher survival probability

across a longer period because that suggests attacks from or against European countries are less frequent or more spaced out over time. The Middle East also shows that there is a gradual decline, and this indicates a moderate persistence of threat. The “Unknown” category represents actors with an unidentified regional attribution. This category shows the steadiest survival trend because it keeps a great chance for over 25 years, maybe showing attacks less frequent yet more deep or hard to place. Because these regional disparities exist, and threat persistence depends greatly on the geographic origin, we can tailor cybersecurity strategies with this important context.

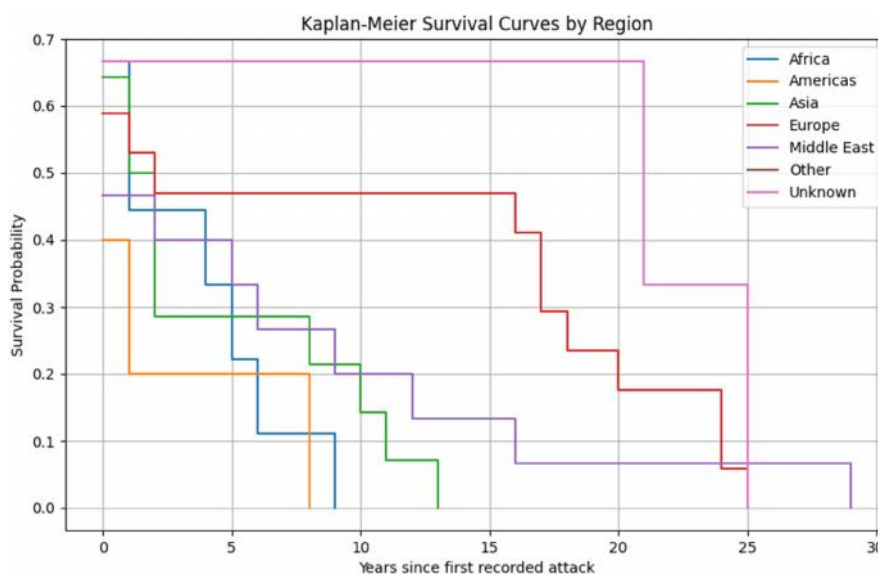


Fig. 13 Kaplan-Meier Survival Curves by Region

The forecast of 10-year survival probability is presented in Fig. 14 across all regions since it captures the chance that no more satellite cyberattack occurs over time after an initial event.

The x-axis shows years after the first strike. The y-axis shows survival probability predictions. In year zero, the survival probability begins around 68% because it indicates a relatively

high chance that someone will not experience an immediate follow-up attack. This likelihood constantly decreases yearly though falling to 57% by year one 48% by year two and going lower to only 26% by year ten. This downward trend reflects an increasing risk of repeated attacks over time, and this highlights the persistence and recurrence of cyber threats in the satellite domain. We find that even long-term monitoring is indeed important, and we should also use defense strategies. These strategies should evolve over time to address immediate risks along with the increasing likelihood of future incidents.

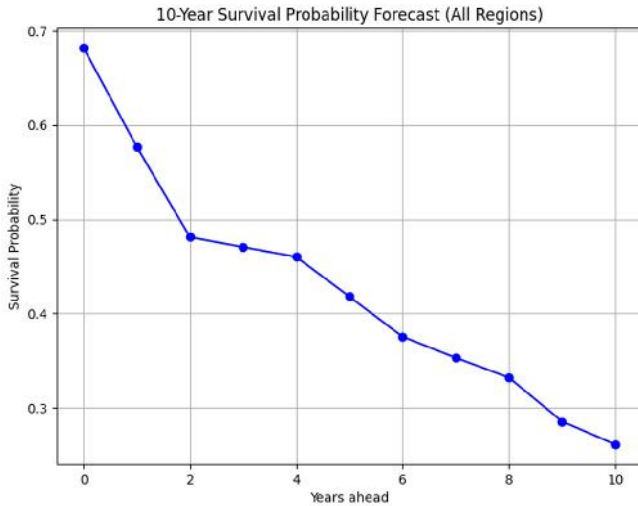


Fig. 14 10 Year Survival Probability Forecast

IV. INTEGRATED INSIGHTS

The diagram in Fig. 15 gives us a structure to realize how Markov Chains, Poisson Regression, Bayesian Networks, and Survival Analysis improve satellite cyber threat intelligence, acting jointly as four separate statistical models. Each model's unique analytical perspective provides a thorough threat landscape. The Markov Chain model tracks cyberattack techniques as they evolve over time, so it identifies likely sequences for hijacking followed by jamming or spoofing. The Poisson model acts to complement this through forecasting the frequency of future attacks. This forecast aids analysts as they anticipate how often threats are expected. In the meantime, the Bayesian Network goes much deeper into all the factors that can influence impact severity such as attacker type, orbital position, and system vulnerabilities. It allows for probabilistic reasoning with respect to threat scenarios due to these factors. Finally, the Survival Model estimates how long systems remain secured following a cyberattack, and this offers valuable perceptions into resilience and risk persistence. Together, these models integrate statistical intelligence so that they support proactive decisions and predict situational awareness improvements as well as prepare satellite cybersecurity for it to strengthen in an evolving threat environment.

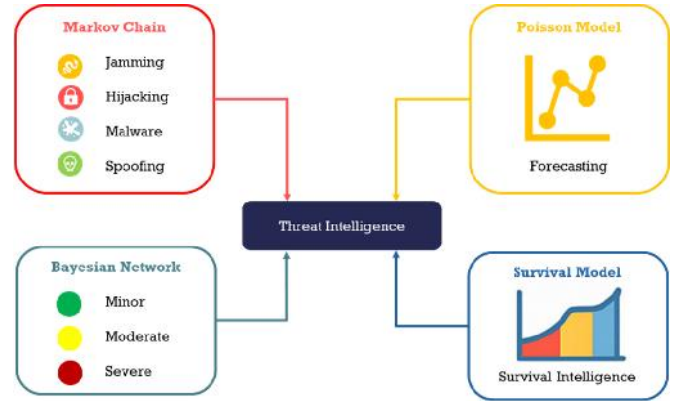


Fig. 15 Integrated Insights of Probability Models

V. CONCLUSION

This paper presented a holistic proof-of-concept framework that integrates Markov Chains, Poisson Regression, Bayesian Networks, and Survival Analysis, four complementary statistical models to better understand and forecast the evolving landscape of satellite cyber threats. Named AERIS (Attack Evolution & Resilience via Integrated Statistics), this framework offers a new lens for analyzing decades of satellite cyberattack data (1985–2024) in ways that are both predictive and diagnostic critical capabilities for strengthening cybersecurity readiness in space systems.

Each component of AERIS contributes distinct value. The Markov Chain model traces how specific attack types like jamming or spoofing are likely to evolve into more sophisticated threats such as hijacking or malware deployment, serving as an early-warning signal for escalation. The Poisson Regression model forecasts a projected 12.1% increase in attack frequency from high-risk adversaries, such as Russia, indicating a steadily rising threat landscape. The Bayesian Network highlights how attacker identity, orbital position (particularly LEO), and system vulnerabilities (especially TT&C) shape the likelihood of severe-impact events. Meanwhile, Survival Analysis reveals how severe attacks accelerate the likelihood of recurrence and diminish long-term system resilience, with 10-year survival probabilities dropping from 68% to just 26% across affected regions.

The use of these integrated insights supports practical and actionable decision making across the industry. Forecasting attack frequency helps inform proactive budgeting and staffing decisions, while Bayesian and Markov outputs guide targeted defense planning and vulnerability mitigation. Post-incident response, particularly after severe-impact events, must emphasize rapid containment and resilient recovery to prevent reattack cycles and restore mission continuity. Perhaps most importantly, by identifying conditional vulnerabilities, AERIS helps shift satellite architecture from reactive patching to proactive, resilience-based design.

As satellite systems become more central to defense, critical infrastructure, and global communications, anticipating cyber threats with precision is no longer optional, it is essential. The AERIS framework equips engineers, analysts, and

policymakers with a scalable, data-driven foundation for predicting, interpreting, and responding to future satellite cyber risks with greater confidence and clarity.

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An Investigation of Crop Diversity's Impact on Income Risk of Selected Crops

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Abstract—As a result of uncertainty and doubts about the quantity of agricultural products, greater significance has been attached to risk management in the agricultural sector. Normally, farmers seek to minimize risks, and crop diversity has always been a means to reduce risk. The study at hand seeks to explore the long-term impact of crop diversity on income risk reduction. The timeframe of the study is 1998 to 2018. Initially, the Herfindahl index was used to estimate crop diversity in different periods, and next, the Hodrick-Prescott filter was applied to estimate income risk both in nominal and real terms. Finally, using the Vector Error Correction Model (VECM), the long-term impact of crop diversity on two modes of risk for the farmer's income has been estimated. Given the long-term pattern's results, it is evident that in the long-run, crop diversity can reduce income fluctuations in two nominal and real terms. Moreover, results showed that in case the fluctuation shock affects the agricultural income in the short run, to balance out the shock in nominal and real terms, 4 and 3 cycles are needed respectively. In other words, in each cycle, 25% and 33% of the shock impact can be removed, respectively. Thus, as the results of the error correction coefficient showed, policies need to be put in place to prevent income shocks. In case of a shock, they need to be balanced out in a four-year period, taking inflation into account, and in a three-year period irrespective of the inflation and reparative policies such as insurance services should be developed.

Keywords—Income Risk, long-term model, Herfindahl index, time series model, Vector Error Correction Model.

I. INTRODUCTION

UNCERTAINTY in nature and the unpredictability and changing nature of phenomena have created a certain condition for this sector and as a result agricultural products and farmers' future are intertwined with insecurity. Due to several such factors every year a significant portion of domestic needs are supplied through imports. This is while the studies conducted on efficiency and use of agricultural inputs indicate a significant potentiality which has been left untapped [4], [6]. On top of that, several studies indicate the agriculture sector's inclination toward avoiding risk, small farmers in particular [11], [6].

Uncertainty and doubt about the quantity of agricultural products has given more importance to risk management in this sector. Traditionally instead of increasing the yield, farmers seek to minimize risks. In fact, inattention to risk management is tantamount to negligence of opportunities which can distance the agriculture sector from development goals and lead to interruption or cessation of agricultural activities. Therefore, it is necessary to carefully consider risk

management in the agricultural sector when it comes to policy development and planning [5], [26].

Many studies indicate that farmers mostly avoid risk and a number of studies confirm that crop diversity is a risk management strategy [1]-[3], [6], [9], [16], [19], [25]. It is worth mentioning that many studies instead of exploring the extent to which farmers try to avoid risk tried to probe the crop diversity's impact on farmers' inclination to avoid risk. On top of risk reduction, crop diversity entails other advantages such as economic, social, and environmental benefits for the farmers and the society at large. It also increases the household income of the farmers, creates job opportunities, improves minerals and nutrients in the soil, prevents erosion and helps with food security [12], [17].

Crop diversity is a good alternative to achieve goals such as production growth, creation of job opportunities and increased environmental sustainability in developing counties. The experiences in Asia, especially in South West Asia and the MENA region indicate that policymakers and authorities are increasingly focused on agricultural development through crop diversity [10], [11], [24].

Based on several studies, numerous factors are behind risk. Reviewing these factors from farmers' perspective, drought and insufficient financial resources are behind the risk [18], [22]. As far as farmer's financial status and risk reduction are concerned, results show that there is a positive and significant relation between the two variables of farmer's income and risk. For instance, as the income increases, the farmer can use more resistant variations of crops and crop diversity can serve as a risk management strategy [20], [23], [26].

There are 883000 hectares of farming land in Zanjan Province which mostly yield wheat, colza, lentil, potato and tomato. Farmers face many risks such as production, market and price risks and to reduce them, they can apply crop diversity as a policy [21]. This study seeks to explore the long-term impact of crop diversity on nominal and real income risk reduction among farmers in Zanjan between 1998 and 2018. It also reviews selected crops cultivation pattern.

II. MATERIALS AND METHODS

Theoretical Framework

Uncertainty implies risk. So, to measure uncertainty, risk should be evaluated [8]. To estimate income risk, one should determine the level of risk reduction through crop diversity. As the first step crop diversity is analyzed through Herfindahl index [14], [15]:

$$HI = \sum_{i=1}^n p_i^2 \quad (1)$$

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P_i is each crop's share which is displayed as (2):

$$p_i = \frac{A_i}{\sum_{i=1}^n A_i} \quad (2)$$

A_i is the area under cultivation for each crop and $\sum_{i=1}^n A_i$ represents the entire land under cultivation. H is valued between 0 to 1 with 1 representing a single crop and 0 the highest level of diversity. This means that; when the value of H increases the diversity decreases and when H goes down, crop diversity increases.

To calculate income fluctuations the Hodrick–Prescott filter was used. A time series which sometimes is called original signal is also defined as the sum of two components namely permanent trend or a combination of smooth growth component and cyclic combinations.

$$X_t = g_t + c_t \quad (3)$$

The components of the original signal or the observed series in the two parts of trend and cycle cannot be perceived easily; thus, any experience is solely based on conceptual artifacts. In the deprocessification, the parameter definition should be of importance so that finally the case is extracted either as a trend or cycle. This approach is of great significance in a sense that it separates the cycle frequencies from the time series variant and get the cycle competent of the time series variable closer to real quantities. Hence the approach is applied often. The reason why the Hodrick–Prescott filter is used is that it can separate an observed pulse into permanent and temporary components [13]. The permanent trend or growth in this analysis is estimated through the below optimization equation:

$$\text{Min} \sum_{t=1}^T (X_t - g_t)^2 + \alpha \sum_{t=2}^T [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \quad (4)$$

Here T is the number of observations and α is the smoothing indicator parameter which determines the smoothness of the trend. In other words, in the limit state where α evanesces at nil the trend is a true time series. In another limit state where α evanesces at infinity the time series trend is linear. For annual statistics, α equals 100. The first part of (4) in fact shows the Goodness of Fit and the second part within the bracket is the penalty considered for any lack of smoothness of the series. In other words, the content within the bracket indicates that deviation from series trend both in the previous period and the one before is the smoothening indicator so much so in the limit state, the lower it is, the better. Based on the above method, income shocks are defined by first extracting the income trend based on the Hodrick–Prescott filter which is named HPQI which is the same as predicted shocks or expected income shocks. The unpredicted income shocks are calculated by deducting income from predicted income shocks [13].

$$SHQI_t = QI_t - HPQI_t \quad (5)$$

After studying the static nature of nominal and real income variables and determining degree of accumulation we realized that both variables have the accumulation degree of one. Thus, there is probably a long-term relation between the two. So, at this stage the possibility of a long-term relation between the variables had to be tested. To determine the number of long-term relations through the Johansen method, first a Vector Autoregression compatible with VAR must be done so that through the matrices of coefficients root test, the number of long-term relations between the variables can be decided.

It is worth noting that to estimate the VAR pattern with the aim of determining the number of long-term relations, one should first determine the optimal interrupts for the VAR model through criteria such as AIC, SBC, HQC and then applying Johansen test and the impact criteria determine the possibility of a long-term relation.

In case of a cointegration 1 along with a conformed long-term relation, Vector Error Correction Model is suggested to determine the behavior of a certain variable which is defined as (6) [7]:

$$\Delta M_{it} = \mu_i + \sum_{j=1}^{p-1} \gamma \Delta M_{i,t-j} + \sum_{j=1}^{q-1} \gamma' \Delta S_{i,t-j} + \theta_i (M_{i,t-1} - \beta_i S_{i,t-1}) + \varepsilon_{it} \quad (6)$$

Here M and S respectively indicate diversity indicator and income risk in two nominal and real terms, β_i is the long-term parameter and θ_i , μ_i and ε_{it} are error correction or balance correction, y-intercept and probability density respectively. The data used in this study were taken from the databanks of the Ministry of Agriculture Jihad and the Central Bank of the Islamic Republic of Iran in the timeframe of 1998-2018.

III. RESULTS AND DISCUSSION

Using the difference between the Hodrick–Prescott and the generated income in two nominal and fixed modes, the income risk of five crops of wheat, lentil, colza, potato, and tomato has been estimated which is shown in Fig. 1. The more negative figures indicate a higher risk indicator.

As it can be seen in Fig. 1, between 1991-1992 and 1993-1994 the income risk has been subject to shock both in nominal and real terms. Since the shock is positive it indicates reduced income risk however following 1994-1995 the trend has been downward. The negative income risk figure is indicative of the high level of risk.

In the next step, the crop diversity indicator was estimated for the five crops of wheat, colza, lentil, tomato and potato in the timeframe of 1998-2018. The results are displayed in Fig. 2.

As one can see in Fig. 2, the highest crop diversity indicator for the five crops belongs to the years 1999-2000 and 2001-2002 which stands at 75%. This is indicative of the fact that once the five crops and cultivated besides one another a cultivation menology is developed. However, in the timeframe of 2000-2001 the crop diversity indicator is 28% which means that cultivating five crops together can lead to crop diversity. Now considering the average crop diversity indicator for all

faring years which is 59% once can say that it is an acceptable and reasonable figure showing that five crops can show the

impact of crop diversity. The impacts might not be huge, but they are still pretty significant.

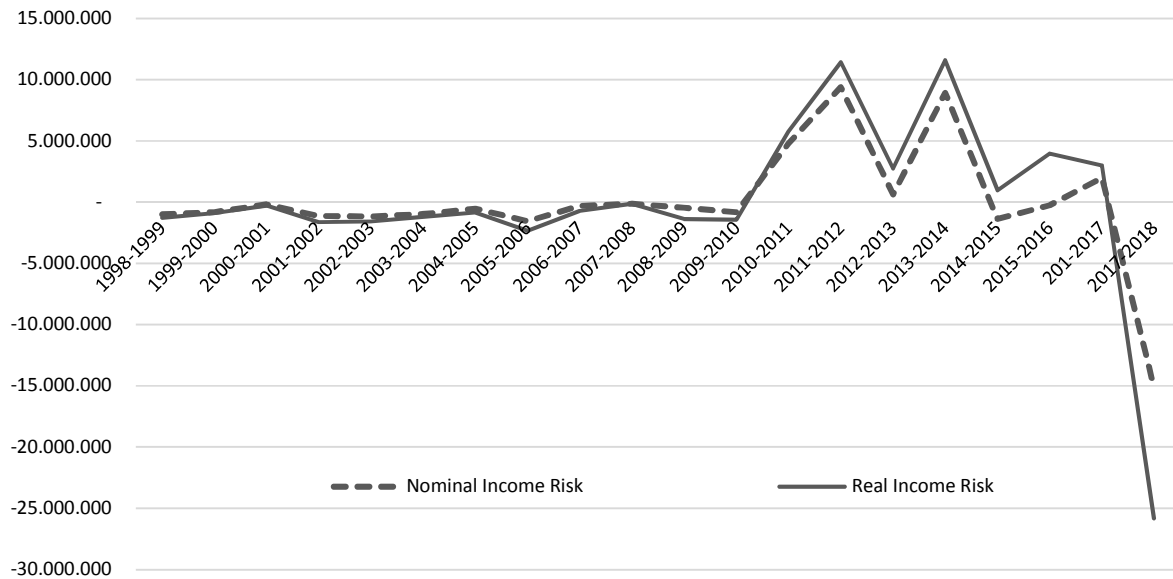


Fig. 1 Trend of real and current income risk changes of five crops [27]

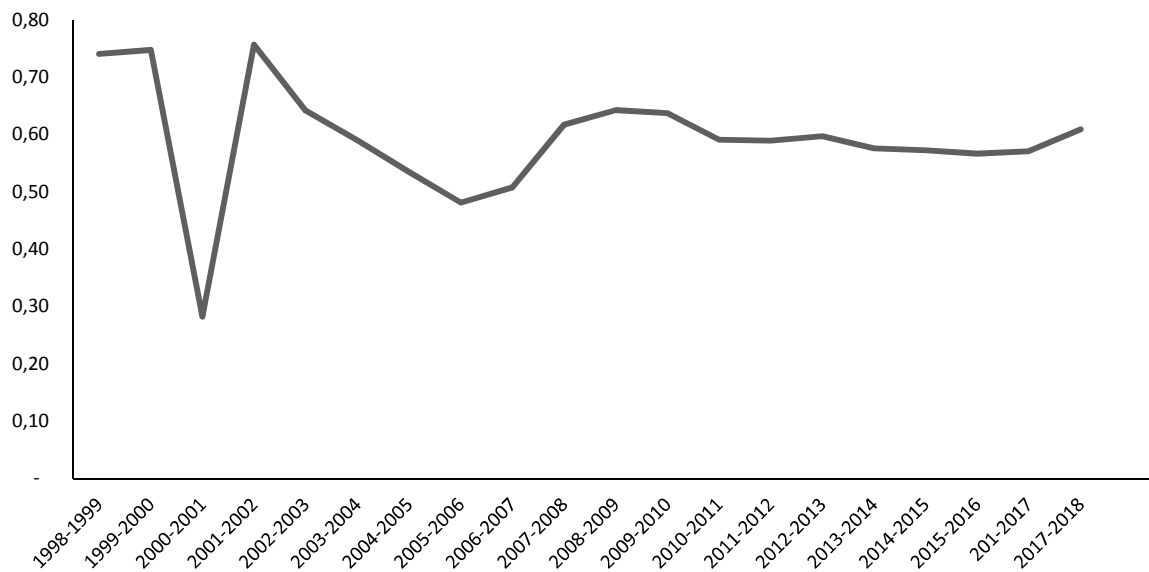


Fig. 2 Crop diversity index for selected crops [27]

To study the impact of crop diversity on income first and foremost the stationarity of the data should be examined. To this end, the Kwiatkowski-Phillips-Schmidt Shin (KPSS) test (due to the structural break of the variable) and the Augmented Dicky-Fuller of Eviews software were applied. Based on the results, the crop diversity indicator and real income risk were stationary with just one differencing y-intercept and the trend. The nominal income risk variable turned stationary with one y-intercept differencing. However, for the stationarity of the nominal income risk the KPSS test was applied due to structural break in the variable.

Based on the above-mentioned stationarity results, the best model to estimate the link between crop diversity and income risk variables is the applied VECM.

The result of the variables' stationarity is shown in Table I. In all variables, the absolute value of the Dicky-Fuller criterion is higher than the critical absolute value of the same criterion and thus more statistically meaningful.

Given the results of the stationarity test, to address the problem of variables' stationarity we tried one time differencing.

TABLE I
VARIABLES' STATIONARY TEST

Variable	Stationarity eligibility	Significance	Test Type	Calculated T value	Absolute T Value	Prob
Crop Diversity	One time of differencing and intercept y trend	one percent	Dicky-Fuller	-7.16	-3.85	0.00
Nominal Income Risk	One time of differencing and intercept y trend	one percent	Dicky-Fuller	-4.42	-3.96	0.004
Real Income Risk	One time of differencing and intercept y trend	five percent	KPSS	0.17*	0.14	0.00

* significance at the level of one percent

The Relationship between Income Risk and Crop Diversity

Given the results of the reliability and cointegration tests, the study uses VECM model. The results of the convergence test are shown in Tables II and III indicating a long-term relation between crop diversity and real income risk in different modes.

TABLE II
STATISTICS OF INCOME AND CROP DIVERSITY COINTEGRATION MODEL

Null Hypothesis		Eigenvalue	Max-Eigen Statistic 0.05 Value	Prob.**
Nominal Income Mode	No Relation	40.66*	25.87	0.00
	Max One Relation	9.24	12.51	0.16
Real Income Mode	No Relation	22.07*	15.49	0.00
	Max One Relation	0.79	3.84	0.37

* Significance of Five Percent

TABLE III
STATISTICS OF MAXIMUM EIGENVALUE OF INCOME AND CROP DIVERSITY
COINTEGRATION MODEL

Null Hypothesis		Statistics Computational	Critical Statistic At 5 %	Significance Statistical of Possibility
Nominal Income Mode	No Relation	31.42*	19.38	0.00
	Max One Relation	9.24	12.51	0.16
Real Income Mode	No Relation	21.28*	14.26	0.00
	Max One Relation	0.79	3.84	0.3

* Significance of Five Percent

TABLE IV
ESTIMATE OF THE LONG-TERM RELATION BASED ON VECM MODEL

Variable		Coefficient	t
Nominal Income Mode	Crop Diversity	-3351973	-5.38
	Intercept-y	2422993	6.47
	Coefficient Correction Error	-0.24	-6.47
	F-statistic	15.28	
	Akaike information criterion	25.31	
	Schwarz criterion	25.36	
Real income mode	Crop Diversity	-78519871	-4.71
	Intercept-y	1354697	5.32
	Coefficient Correction Error	-0.32	-2.89
	F-statistic	7.04	
	Akaike information criterion	30.22	
	Schwarz criterion	30.37	

Once the long-term relation is confirmed as per Table III, the relation in the model shows that crop diversity's impact on nominal income risk is significantly meaningful at 1% and with each degree of increase in the crop diversity the rate of fluctuation drops by 24%. Moreover, the impact of crop diversity on real income risk was 1% meaningful and with each degree of increase in crop diversity the rate of fluctuation

decreases by 33%.

IV. CONCLUSION

Based on what was elaborated in the results section, in the long run there is a relation between crop diversity and decreased income risk. Crop diversity has helped decrease income risk for farmers in Zanjan Province. Thus, it is recommended that in developing support policies and optimal farming models, a special attention can be paid to the issue of crop diversity. The support policies which seek to aid a selected number of crop cultivation is not an appropriate alternative and leads to higher income risk for farmers.

As indicated by the error correction coefficients emergence of short-term shocks in nominal income of farmers requires about four-time cycles to get balanced out. As for the shocks to real incomes three-time cycles are needed to balance out the shock. Therefore, it is on the policymaker to on top of support policies which promote diversity adopt measures to prevent income shocks. Meanwhile in case of a shock reparative policies such as insurance tools have to be developed so that the shock can be balanced out in a four-year cycle.

Small farmers whose main livelihood and food basket is supplied through farming are the most vulnerable to income shocks. This does not imply that large scale farmers are immune to income risks and shocks; they face a bigger threat in case of an income shock. Thus, risk management methods need to be applied in the agricultural sector as a whole. Such management methods aiming at reducing income shocks may seem trivial at the first glance, but they are in fact very critical as any approach can lead to its own consequences.

It is worth mentioning that income risk is just one of the many risks farmers face. They normally deal with a wide range of uncertainties and unpredictable factors. Through the implementation of well-calculated risk management plans by policymakers there will be more resilience and sustainability in this sector over time.

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Report of *Candida Auris*, an Emerging Fungal Pathogen, in a Tertiary Healthcare Facility in Ekiti State, Nigeria

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Abstract

Candida auris, an emerging fungus, has been reported in more than 30 countries around the world since its first detection in 2009. Due to its several virulence factors, resistance to antifungals, and persistence in hospital settings, *Candida auris* has been reported to cause treatment-failure infections. This study was therefore carried out to determine the incidence of *Candida auris* in a tertiary hospital in Ekiti State, Nigeria. In this study, a total of 115 samples were screened for *Candida* species using cultural and molecular methods. The carriage of virulence factors and antifungal resistance among *C. auris* was detected using standard microbiological methods. *Candida* species isolated from the samples were 15 (30.0%) in clinical samples and 22 (33.85%) in hospital equipment screened. Non-*albicans* *Candida* accounted for 3 (20%) and 8 (36.36%) among the isolates from the clinical samples and equipment, respectively. Only five of the non-*albicans* *Candida* isolates were *C. auris*. All the isolates produced biofilm, gelatinase, and hemolysin, while none produce germ tubes. Two of the isolates were resistant to all the antifungal tested also all the isolates were resistant to fluconazole, and itraconazole. Nystatin appeared to be most effective among the tested antifungals. The isolation of *Candida auris* is being reported for the second time in Nigeria, further confirms that the fungus has spread beyond Lagos and Ibadan, where it was first reported. The extent of the spread of the nosocomial fungus needed to be further investigated and curtailed in Nigeria before its outbreak in healthcare facilities.

Keywords— candida auris, virulence factors, antifungals, pathogen, hospital, infection.

Utilizing CRISPR Technology for Genetic Disease Treatment in IRAN: Opportunities and Challenges

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Abstract

Genetic diseases, resulting from inherited or de novo mutations in the genome, remain a significant burden on healthcare systems globally. Traditional therapies often address the symptoms without resolving the underlying genetic abnormalities, leaving patients with limited options for long-term solutions.

CRISPR technology has demonstrated remarkable success in preclinical and early clinical studies. For instance, in monogenic disorders such as sickle cell anaemia and beta-thalassemia which are currently in clinical trial phase for Iranian patients. Similarly, in Duchenne muscular dystrophy, in vivo delivery of CRISPR components has corrected mutations in animal models, restoring dystrophin expression and improving muscle function. CRISPR-based kits for diagnosis purposes are currently used in Iran laboratories and the efficiency of their applications has been proven so far.

This study aims to evaluate the therapeutic potential of CRISPR-Cas9 technology in treating genetic diseases and the challenges that Iranian researchers face throughout the research phases to clinical trials. The focus is on elucidating its mechanisms of action, demonstrating its application in preclinical and clinical settings, and discussing the challenges and ethical considerations associated with its use.

CRISPR-Cas9 represents a paradigm shift in the treatment of genetic diseases, moving from symptom management to precise genetic corrections. Its versatility and precision make it a powerful tool for tackling a wide range of genetic disorders, including monogenic and polygenic conditions. By investigating the underlying gaps in the application of CRISPR technology and the industrial dimensions of CRISPR-related productions, which have experienced immense growth in recent years, Iranian scientists can benefit from diverse applications of CRISPR technology in upcoming years.

Keywords: CRISPR-Cas9, genome editing, anaemia, DMD, kit.

Sustainable Methanol Synthesis from CO₂ Captured by Absorption

Asfaw Gezae Daful

Abstract—This paper presents a model and simulation of the process of capturing CO₂ and converting it into a valuable product in Aspen Plus®. It also models and simulates the process of absorbing CO₂ through amine absorption and adding values to the captured CO₂ by producing methanol, an important industrial solvent, through the methanol synthesis process. The process of absorption in an amine-based solvent and subsequent desorption to renew the amine is used to represent the CO₂ capture. For the production of methanol, a plug flow reactor with an isothermal reactor is modeled. The properties are modeled with the Electrolyte-Non-Random-Two-Liquid (Electrolyte NRTL) model, and the absorber is simulated. The model can be used as a starting point for more complex model development, integration, debottlenecking and optimization of such processes. The procedure has two advantages: it eliminates dangerous CO₂ from the atmosphere, and the methanol can be utilized as a fuel substitute for gasoline and as a building block for numerous larger compounds, such as ethylene and propylene, two of the most manufactured organic compounds.

Keywords—CO₂-capture, methanol synthesis, sustainable solvent,

I. INTRODUCTION

THE climate change has become an important global issue related to energy, economics, environment, and technology. Global warming, which is caused by the concentration of green-house gases (GHGs), is becoming the most urgent problem[1]. The six GHGs specified in the Kyoto protocol[2] are CO₂(carbon dioxide), CH₄(methane), N₂O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF₆(sulfur hexafluoride), among which, the role of CO₂, CH₄ and N₂O accounts for more than half of the total greenhouse effect. At the global scale, CO₂ is the main contributor for the GHGs[3] from the key greenhouse gases emitted by human activities as shown in Fig. 1, accounting for 76% of total GHG emissions[3, 4].

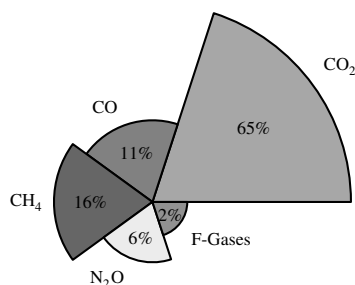


Fig. 1: Global greenhouse gas emissions by gas

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Increasing recognition about global warming caused by man-made emission of GHG has driven intensive research to reduce CO₂ emissions. Around 60% of the CO₂ emissions are caused by the use of fossil fuels. The biggest share, around 40%, of these energy related CO₂ emissions is caused by the combustion of fossil fuels for electricity generation, as depicted in Fig. 2. This shows, that power plants play a central role, when it comes to the reduction of GHG emission.

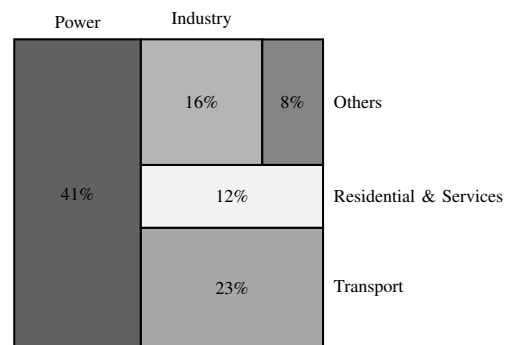


Fig. 2: World energy related CO₂ emissions by sector.

There is an urgent need to reduce greenhouse gas emissions to overcome the dangerous consequences of global warming. There are many CO₂-capture methods such as water or amine scrubbing, or membrane separation. As per the Energy Roadmap 2050 carbon capture, utilisation and storage (CCUS) need to reduce 80-95% greenhouse emissions by 2050 with 1990 as a reference year[5]. Among the options for CO₂ mitigation applied to large point sources, post combustion CO₂ capture based on chemical absorption is the most promising and mature technology[4, 6]. The most attractive approach to a sustainable future is to use the captured CO₂ as the carbon source for chemicals, fuels and carbon-based materials that are currently only derived from coal, fossil fuels, oil and natural gas etc. Such an approach may have the dual effect of both removing CO₂ already in the atmosphere emitted during combustion, and recycling, reusing or converting into other value added products thereby forming a static CO₂ loop.

The aim of this paper is to model and simulate a CO₂ capture process and converting it into valuable product. CO₂ absorption process by amine is modeled and simulated together with the valorization of the capture CO₂ into industrially important solvent, methanol, via methanol synthesis process.

There are two advantages: firstly, the method eliminates dangerous CO₂ from the atmosphere; secondly, methanol can be utilized as a fuel substitute for gasoline and as a building

block for several larger compounds, such as two of the most manufactured organic compounds.

The absorption of CO₂ will be located in the CO₂ removal stage it can be in an ammonia synthesis plant or it can be in power plant. The CO₂ containing gas mixture comes from the shift conversion, thus CO₂ need to be removed before the methanation stage of the process. The gaseous mixture product from the shift conversion stage of the ammonia synthesis process contains H₂O, CO₂, N₂, O₂. The CO₂ must be removed from this stream because it poisons the catalysts downstream processes. The removed CO₂ by absorption will be used as a feedstock for methanol synthesis.

II. CO₂ ABSORPTION PROCESS

CO₂ absorption using amine solvents is the most advanced and widely adopted CO₂ separation technique, which is currently used in gas processing, power generation. In a typical chemical absorption process, see Fig. 3, a chemical solvent absorbs CO₂ and releases the captured CO₂ upon heating. The absorption and regeneration section operates at around 40°C and 120°C, respectively. A huge barrier for implementing this technology is the high energy demand that is needed to regenerate the solvent. The regeneration energy demand is due to, (i) the heat to overcome the sensible heat loss when the rich and lean solvent is heat exchanged, (ii) the heat required to reverse the absorption reaction and (iii) the heat required to produce stripping steam to overcome the overhead pressure drop in the stripper. Therefore, to enable CO₂ capture with as low energy consumption as possible, there is a need to develop energy efficient solvents.

To reduce the sensible heat loss, the solvent should have high cyclic capacity. Cyclic capacity (typically $\frac{\text{g CO}_2}{\text{kg solution}}$) is defined as the difference between the CO₂ concentration (loading) in the rich and lean solution, $\Delta\alpha = \alpha_{\text{rich}} - \alpha_{\text{lean}}$. A high cyclic capacity is achieved using a solvent with high absorption capacity and high ability to desorb CO₂ from the solution. The main CO₂ removal processes are based on absorption and selectivity of the solvent with respect to acid gases is based on an affinity of the chemical or physical type. Additional factors should be taken into account when selecting solvents. Thus, the solvent should be environmental friendly, resistant to degradation, non-toxic, non-corrosive, have low viscosity, fast reaction kinetic with CO₂ and preferably be not expensive. The solvent system that traditionally have been the solvent of choice are aqueous alkanolamines or amine solvents. Amines are divided into three groups based on the number of hydrogen attached to the nitrogen. The three groups are primary (two H atoms on nitrogen), secondary (one H atom on nitrogen) and tertiary (no H atom on nitrogen). Both primary and secondary amines act as a weak base and form carbamates when reacting with CO₂. Industrially important alkanolamines for gas sweetening unit are monoethanol amine (MEA), diethanol amine (DEA) and methyldiethanol amine (MDEA). Monoethanolamine (MEA), as primary amine, has been used extensively because of its high reactivity and low solvent cost.

The absorption and desorption are the two stages of the chemical absorption process. An amine solvent is used to

absorb CO₂ from exhaust gases which is a reactive absorption process, as shown reactions Eq. (1) to Eq. (9). The flue gas from a power plant and other industries, enters the bottom of a packed column, flows upward and meets a CO₂ absorbing solvent circulated counter-currently, as shown in Fig. 3. The CO₂-rich solution, leaving the bottom of the absorber, is then pumped to a cross heat exchanger and then to a stripper (regenerator) column for its regeneration at higher operating temperature. In the regeneration step, the reactions between CO₂ and the solvent are reversed using heat, and gaseous CO₂ and water vapour are produced. The gases are leave the regenerator from the top and sent to a condenser, where gas rich in CO₂ is obtained. The regenerated solvent, collected from the bottom of the resonator which is with low concentration of CO₂ (lean solution), is recycled to the absorber. The energy used in the regeneration is one of the key elements to take into account for process optimization.

The use of aqueous monoethanolamine (MEA) for the removal of CO₂ from flue gases is an available technology and has been described in detail in a number of sources[6–9]. MEA has been used as a solvent for non-selective removal of acidic gases for the past 60 years. Fluor is actively trying to commercialize CO₂ capture technologies based on MEA as a solvent[7, 8]. The Fluor process utilizes a 30 wt.% MEA solvent with inhibitors to prevent degradation and equipment corrosion.

The process for CO₂ capture using MEA can be broken into 3 different sections:(i) flue gas cooling and compression, (ii) absorption of CO₂ and regeneration of solvent, (iii) CO₂ taken to methanol synthesis , as shown in Fig. 3. An amine unit operates by contacting an amine solution with the flue gas or liquid feed counter-currently in an absorber column. CO₂ in the feed are absorbed by the amine in the solution, and the sweetened gas exits the top of the column. Rich amine exits the bottom of the column and is sent through the regeneration system to remove the acid gases and dissolved hydrocarbons. The lean solution is then circulated to the top of the absorber to continue the cycle, as shown in Fig. 3.

The physical solubility of CO₂ in the aqueous amino solvent declines with rising absorption temperature, but the rate at which the dissolved CO₂ reacts with the amine solvent increases. Therefore, the flue gas temperature at the absorber inlet is typically maintained at around 45°C to achieve a balance between physical solubility and reaction kinetics. Aspen Plus model developed and used to optimize the CO₂ removal procedure.

The reactions between CO₂ and MEA begin as the the liquid and gas get in contact while flowing countercurrently through the absorber column. The un-reacted gas leaves the column at the top (GASout), while the CO₂ rich solvent discharges the column at the bottom (RICHOUT). The rich solvent from the bottom of the absorber goes through a heat exchanger to preheat it before it enters the stripping section. In the stripper, CO₂ is separated from the MEA solution. Finally, separated gases leave the stripper at the top (CO₂out). The lean MEA then leaves the system at the bottom of the stripper (LEANOUT) and go through the heat exchanger, to decrease its temperature and pre-heat the reach amine stream. The MEA

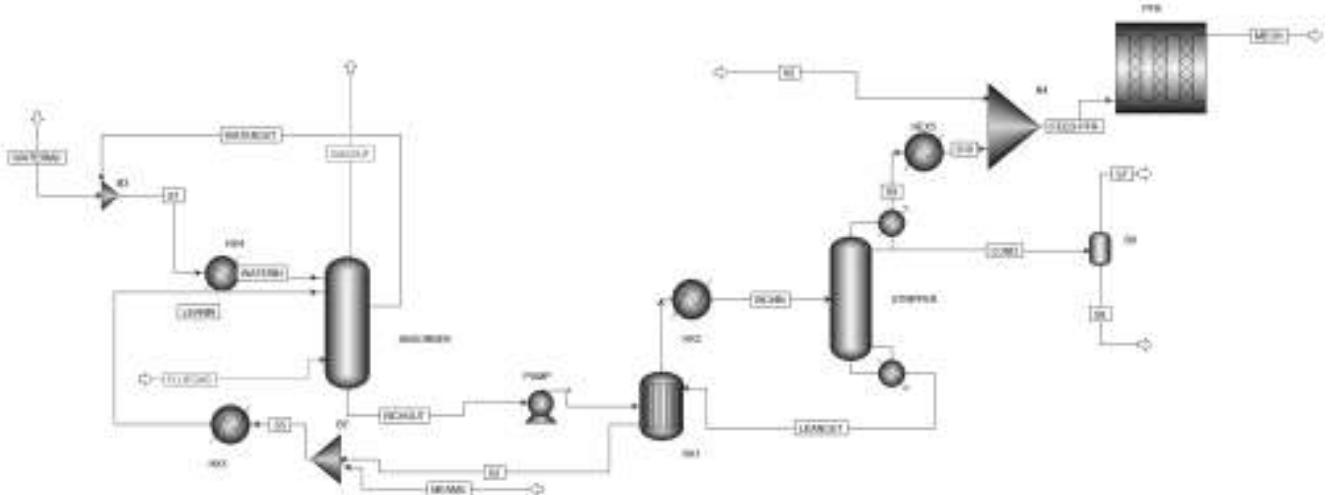


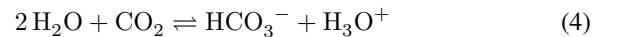
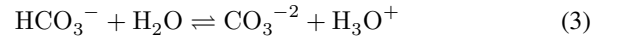
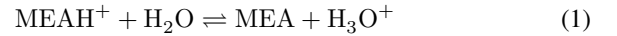
Fig. 3: Process Flow Diagram of the CO₂ absorption and Methanol production processes

and water are added to the lean MEA stream (MEAMU) to balance the component before recycled back to the absorber unit.

A. Thermodynamic and kinetic models

One of the important requirements for process modeling and simulation is the choice of thermodynamic model to accurately predict of the physical properties of pure components and mixtures. The thermodynamic model is developed to present vapor liquid equilibrium to calculate the required state parameters of the amine, water and carbon dioxide mixture, such as the temperature, pressure, and composition of the liquid and vapor phases. The CO₂ solubility in the MEA-H₂O-CO₂ mixture is an important factor, that is used for validation and selection of VLE calculation. The physical properties play an important role in process modeling and simulation as part of the correlations for heat transfer, mass transfer, interfacial area, liquid holdup, and pressure drop. A rate-based model offers better accuracy in packed columns than an equilibrium model for the absorption performance of the columns.

In the property model specification, the electrolyte-NRTL model with Redlich-Kwong equation of state (ENRTL-RK) model was used to predict the thermodynamic, transport and kinetic properties[10]. This section describes the primary reactions occurring in a MEA+CO₂ system. In this model, the absorption and stripping section required rigorous thermodynamic model to find the equilibrium compositions in the system. The following chemical reactions, equations (1) to equation (8) are taking place when CO₂ are absorbed into an aqueous solution, MEA-CO₂-H₂O system.



Where the main reactions are hydrolysis reaction (equation (8)), dissociation of dissolved carbon dioxide (equation (5)), dissociation of bicarbonate (equation (6)), dissociation of protonated MEA (equation (1)), ionization of water (equation (2)).

The net reaction is:



Based on the stoichiometry, where two amine molecules react with one CO₂ molecule, the maximum CO₂ loading is $0.5 \frac{\text{mole.CO}_2}{\text{mole.amine}}$. Primary and secondary amines are known to have fast reaction rates and high heat of reaction[11].

B. Equilibrium data

The composition of both liquid and vapour phase are calculated by solving above equations, equations (1-9). The equilibrium constant is calculated using following rate equation, equation (11) where T is in K.

$$\ln K_{eq} = A + \frac{B}{T} + C \ln(T) + DT \quad (11)$$

The equilibrium constant data which is imported from literature[12, 13] is considered for mathematical model development and tabulated in Table I.

TABLE I: Constant values of equilibrium constant equations

Parameter	A _j	B _j	C _j	D _j
Reaction 1	-3.038	-7008.3	0	-0.00313
Reaction 2	132.89	-13445.9	-22.47	0
Reaction 3	216.05	-12431.7	-35.48	0
Reaction 4	231.46	-12092.1	-36.78	0
Reaction 9	-0.52	-2545.53	0	0

C. Reaction Kinetics data

Reaction kinetics data are important to understand for reacting system, such data for kinetics reactions (Reaction 5 to Reaction 8). The kinetic equation used for mathematical computations is defined in Aspen Plus and given in equation (12) with constant values in Table II.

$$r_i = k_i \left[\frac{T}{T_o} \right]^{n_i} \exp \left[\frac{-E_i}{R} \left(\frac{1}{T} - \frac{1}{T_o} \right) \right] \quad (12)$$

TABLE II: Rate constant values

Parameter	Reaction 5	Reaction 6	Reaction 7	Reaction 8
k_i	4.32e+13	2.38e+17	9.77e+10	2.80e+20
n_i	0	0	0	0
E_i (cal/mol)	13249	29450.89	9855.80	17229.79
T_o (K)	298	298	298	298

III. METHANOL SYNTHESIS

Methanol stands out as a promising alternative energy source, providing an effective solution for large-scale energy storage, while also playing a vital role in the economy and sustainability by transforming industrial CO₂ waste into a valuable resource [14–17]. Methanol is used for several industrial chemicals as a commodity chemical. Some of the main methanol based chemical derivatives are formaldehyde, acetic acid, methyl tertiary-butyl ether (MTBE) and dimethyl ether (DME), it can be transformed into olefins. Approximately, around 70% of the greenhouse gas emissions in the chemical industry[16–18] are caused by the production processes of basic chemicals. It is paramount important to develop new processes and technologies to substantially reduce emissions in these processes.

This work will present the methanol production from CO₂ emitted (released) from different processes including post-combustion. The benefits are twofold: the process eliminates harmful CO₂ from the atmosphere, and the methanol can be used as a fuel substitute for gasoline and a building block for numerous larger compounds including ethylene and propylene. Its largest use is its oxidation to formaldehyde, conversion to acetic acid and methyl tertiary butyl ether (MTBE).

Researchers[14, 19, 20] have been exploring several approaches of converting CO₂ into useful products. For instance, methanol(CH₃OH), methane (CH₄), or formic acid (HCOOH)can be produced by treating CO₂ with hydrogen gas (H₂). Methanol is the most attractive among the others because

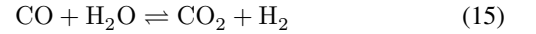
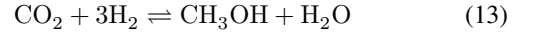
of its potential applications such as an alternative fuel, in fuel cells, and for storing hydrogen.

Finding a good homogeneous catalyst is crucial to the CO₂-to-methanol conversion process as it speeds up the chemical reactions and allows for the fast production rate of methanol. The problem related with this is, that these reactions require high temperatures approximately 150°C, which causes the catalysts to decompose.

Methanol (CH₃OH) is a compound soluble in water, alcohols and organic compounds with a boiling temperature of 64.6°C and a melting temperature of −98°C. The most important properties that has to be kept in mind during its synthesis are the flammability limits in air (6.7-36.5 % v/v) and its toxicity.

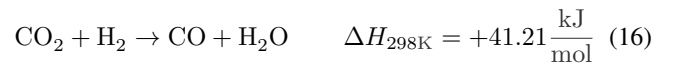
The production of methanol is the low-pressure catalytic reaction of CO₂ and H₂ where this low pressure allows for operating conditions which favour the conversion of methanol and nearly completely inhibit the production of by-products. CO₂ and CO can react with H₂ to form methanol with water as a side-product. Equations (13) and (14) show the stoichiometry of these reactions and their reaction enthalpy

Various kinetic models have been proposed to characterize the production of methanol from CO₂ and H₂. The methanol synthesis process can be described by three equilibrium reactions:



As these reactions are exothermic, $\Delta H_{298\text{K}, 5\text{MP}} = -90.7 \frac{\text{kJ}}{\text{mol}}$ for reaction equation (13) and $\Delta H_{298\text{K}, 5\text{MP}} = 40.9 \frac{\text{kJ}}{\text{mol}}$ for reaction equation (14), and lead to a decrease of the amount of molecules present, the productivity can be increased by increasing pressure and reducing temperature, according to Le Chatelier's Principle. Next to the two methanol producing reactions, the water-gas shift (WGS) reaction takes place, equation (15), with $\Delta H_{298\text{K}, 5\text{MP}} = -49.8 \frac{\text{kJ}}{\text{mol}}$. As the WGS reaction connects equation (13) and equation (14), only two of these three reactions are stoichiometrically independent and need to be considered for the overall reaction.

The reaction is an equilibrium reaction; to shift the equilibrium towards the formation of methanol high pressure (> 5 MPa) and medium to high, constant temperature has to be maintained. The main problem in this case is the heat generated, the reaction being highly exothermic. The excess heat has to be removed to avoid the formation of side products (see equation 16) and catalyst sintering. The formation of CO is an endothermic one, this reaction is favored as the temperature increases.



IV. ASPEN PLUS SIMULATION

In this section, the main parameters of the process are presented for the absorption of CO₂ and the production of high-purity methanol from captured CO₂. An Aspen Plus

model is developed and simulated, as depicted in Fig. 3. The capacity of the methanol synthesis unit is based on the amount of CO₂ captured in the absorption unit. The process was simulated using Aspen Plus®. The high-pressure sections (higher than 10 bar) of each process were modelled in Aspen Plus using the RKSMHV2(Redlich-Kwong-Soave with modified Huron-Vidal mixing rules) property method and the low-pressure sections using the NRTL-RK (Non-random two-liquid-Redlich-Kwong) property method. The property methods were selected following the guidelines given in Aspen Plus and taking into account the temperature, pressure, and polarity of the reaction system. CO₂ absorption phenomena with MEA is simulated with ELECNRTL method modified by Redlich-Kwong equation of state, i.e. ENRTL-RK in the ASPEN PLUS®. The electrolyte non-random two-liquid (ELECNRTL) Property Method is the most versatile electrolyte property method that can handle aqueous and mixed solvent systems.

There are two types of reactors commonly used for production of methanol synthesis, the reactors are adiabatic and isothermal from a category of gas phase reactors. As the methanol synthesis is exothermic, so these reactors are designed to efficiently control the temperature. Adiabatic reactors typically have a series of fixed bed reactors with heat exchangers to remove heat of reaction, they have low installation cost and high production capacity. However, operation of adiabatic reactors is characterized by low conversion per cycle caused by high equilibrium temperatures, high recycle ratio, high dilution of reactants and high volume of catalyst used. Isothermal reactors are continuously cooled by external fluid stream, with jacketed heat exchanger configurations. Isothermal characteristics of the design enables high conversion and low volume usage of catalyst. An isothermal reactor plug flow reactor (PFR) is modelled for the present work.

The Soave-Redlich-Kwong (SRK) equation of State, which is best suited for these components (H₂, CO, CO₂, H₂O, and CH₃OH) and conditions (pressure up to 50 bar and temperature up to 250°C), was used to rigorously simulate the complete process in Aspen Plus. This is in line with literature recommendations for such systems that all the binary interaction parameters related to the property models RK-Soave and NRTL are available in the pure components databank of the Aspen Plus process simulator. An adiabatic multitube reactor model is used with vapor-only valid phase.

For the modelling of the reactor the plug flow module of Aspen Plus® with the Langmuir-Hinshelwood- Hougen-Watson (LHHW) kinetic model is used. Two reactions are modelled: the formation of methanol from CO₂ equation (13) and the RWGS-reaction equation (15). The kinetic model used for the reaction rates of methanol formation equation (17) and for RWGS-reaction equation (18).

$$r_{\text{MeOH}} = k_{\text{MeOH}} \frac{\left(p_{\text{CO}_2} p_{\text{H}_2} - \frac{1}{K_{p_{\text{MeOH}}}} \frac{p_{\text{CH}_3\text{OH}} p_{\text{H}_2\text{O}}}{p_{\text{H}_2}^2} \right)}{\left(1 + K_a \frac{p_{\text{H}_2\text{O}}}{p_{\text{H}_2}} + K_b \sqrt{p_{\text{H}_2}} + K_c p_{\text{H}_2\text{O}} \right)^3} \quad (17)$$

$$r_{\text{RWGS}} = k_{\text{RWGS}} \frac{\left(p_{\text{CO}_2} - \frac{1}{K_{p_{\text{RWGS}}}} \frac{p_{\text{CO}} p_{\text{H}_2\text{O}}}{p_{\text{H}_2}} \right)}{\left(1 + K_a \frac{p_{\text{H}_2\text{O}}}{p_{\text{H}_2}} + K_b \sqrt{p_{\text{H}_2}} + K_c p_{\text{H}_2\text{O}} \right)} \quad (18)$$

where r_i is reaction rate in $\frac{\text{mol}}{\text{kg}_{\text{cat}} \cdot \text{s}}$, k_i is the kinetic factor in $\frac{\text{kmol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{bar}}$ or $\frac{\text{kmol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{bar}^2}$, p_i is partial pressure in bar, K_{p_i} is equilibrium constant [-] or [bar²] and $K_{a,b,c}$ are adsorption constants in [barⁿ].

The values for the reactions rate are given in Table III where the values are given in the form of equation (19)

$$K_i = A_i \exp\left(\frac{B_i}{RT}\right) \quad (19)$$

TABLE III: Values for the kinetic model of LHHW-type for equations (17, 18 and 19)

Variable	unit	A_i	B_i
k_{MeOH}	$\frac{\text{mol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{bar}^2}$	1.07	36696
k_{RWGS}	$\frac{\text{mol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{bar}}$	1.22×10^{10}	-94765
K_a	-	3453.38	-
K_b	bar ^{-0.5}	0.499	17197
K_c	bar ⁻¹	6.62×10^{-11}	124119

The kinetic model described above needs to be adjusted to be integrated into the Aspen Plus® model. First, the units of pressure need to be changed into Pascal and the kinetic expression needs to be changed to kmol. Moreover, the kinetic pre-factor needs to be presented in the form of equation (20) and the other terms need to be adapted into the form of equation (21).

$$k_i = k_{i,o} \exp\left(-\frac{E_i}{RT}\right) \quad (20)$$

$$\ln K_i = A_i + \frac{B_i}{T} \quad (21)$$

The final values entered into the Aspen Plus® model are in Table IV

TABLE IV: Adjusted values for the Aspen Plus® model of the reactor kinetics

Variable	$k_{i,o}$	E_i
k_{MeOH}	$1.07 \cdot 10^{-13} \frac{\text{kmol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{Pa}^2}$	-36696 $\frac{\text{kJ}}{\text{kmol}}$
k_{RWGS}	$1.22^2 \frac{\text{kmol}}{\text{kg}_{\text{cat}} \cdot \text{s} \cdot \text{Pa}}$	94765 $\frac{\text{kJ}}{\text{kmol}}$
Variable	A_i	B_i
$\ln \frac{1}{K_{p_{\text{MeOH}}}}$	47.415	-7059.73
$\ln \frac{1}{K_{p_{\text{RWGS}}}}$	-4.672	4773.26
$\ln K_a$	8.1471	-
$\ln K_b$	-6.4522	2068.44
$\ln K_c$	-34.9526	14928.92

V. RESULT AND DISCUSSION

The absorption model developed captures 72% of CO_2 from the feed gas and recovered as uncondensed gas from the partial condenser of the stripper. The inlet gas feed composition of gaseous mixture from the shift conversion for CO_2 removal is as follows in mole percentage: 11.09% H_2O , 5.43% CO_2 , 74.60% N_2 and 8.88 % O_2 while solvent stream are supplied at 40°C and absorber is operating at an absolute pressure of 1 bar. For optimal performance, the rich solvent stream is heated to 115°C before being sent to the stripper section, where it operates at 2 bars of absolute pressure.

TABLE V: Feed composition of gaseous mixture from the shift conversion for CO_2 removal

	$\frac{\text{kmol}}{\text{hr}}$	mol%
H_2O	0.28	11.09
CO_2	0.14	5.43
N_2	1.91	74.60
O_2	0.23	8.88
	2.56	100.00

Simulation of an amine based CO_2 removal process from an exhaust gas from natural gas power plant have been performed. The process configurations investigated are the standard process, absorption and regeneration processes. The amount of CO_2 captured after regenerating the amine is $0.1 \frac{\text{kmol}}{\text{hr}}$, that is 71.4% of the CO_2 in the feed. This absorption process is focused on the optimization of the CO_2 capture process using MEA as suitable solvents. The mole fractions of CO_2 in the vapor and liquid phases along the number of stages are shown in Fig. 4.

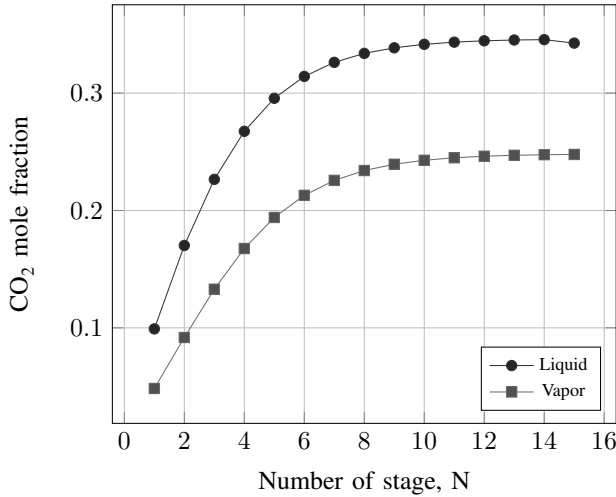


Fig. 4: Mole fraction of CO_2 both in Liquid and vapor vs. number of stages of the Absorption column

The temperature profile in the plug flow reactor is depicted in Fig. 5, indicating that temperature increases along the reactor length given an adiabatic reactor is considered.

Adsorption is the process by which reactant molecules attach to the catalyst surface. This is a key step in heterogeneous catalysis, and its variation along the reactor length is shown in Fig. 6.

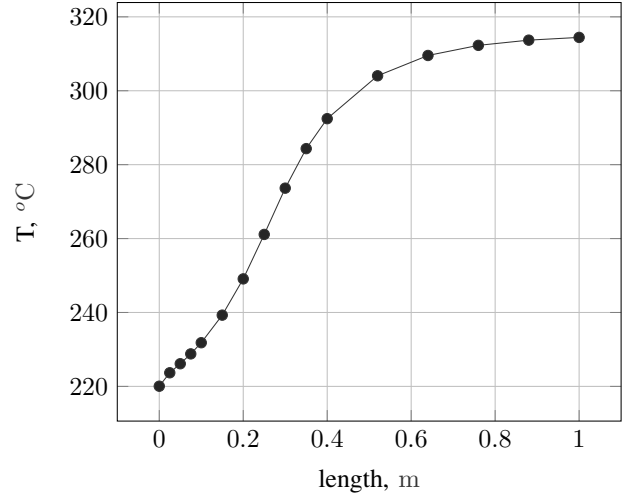


Fig. 5: Temperature profile in PFR

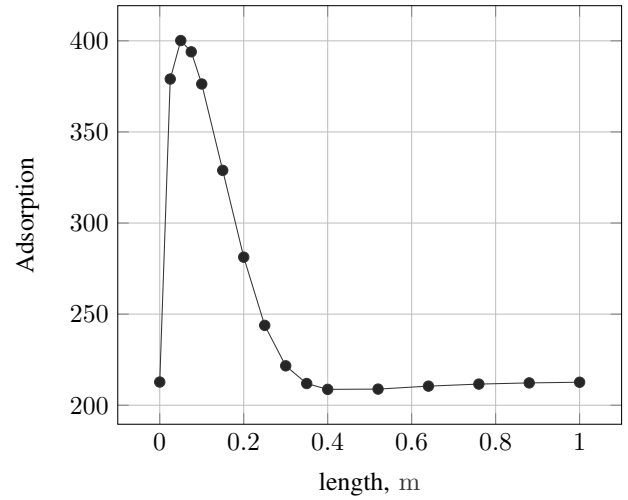


Fig. 6: Adsorption profile in PFR

The driving force is what pushes the reaction to occur. It's often the difference in concentration or partial pressure of reactants and products. In catalysis, it could also be related to the difference in chemical potential or adsorption coverage, and is shown in Fig. 7 along the length of the reactor.

The net rate is the overall rate of reaction on the catalyst surface accounting for both the forward and reverse reactions (Net rate = Forward rate – Reverse rate). The net rate varies along the reactor length as concentrations change is shown in Fig. 8.

The kinetic factor includes all the constants and parameters that determine how fast a reaction proceeds, such as the rate constant (k) and any reaction order terms. It reflects how quickly the catalyst can convert reactants to products under given conditions. The kinetic factor varies along the reactor length as temperature changes, is shown in Fig. 9.

VI. CONCLUSION

CO_2 is one of greenhouse gases from various processes, which can cause global warming. One way to mitigate such

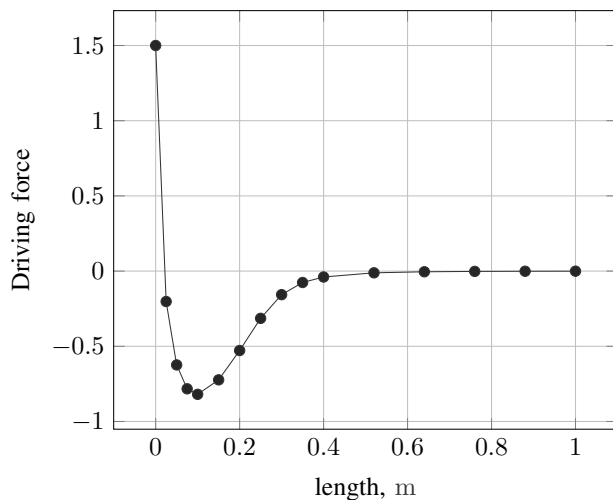


Fig. 7: Driving force profile in PFR

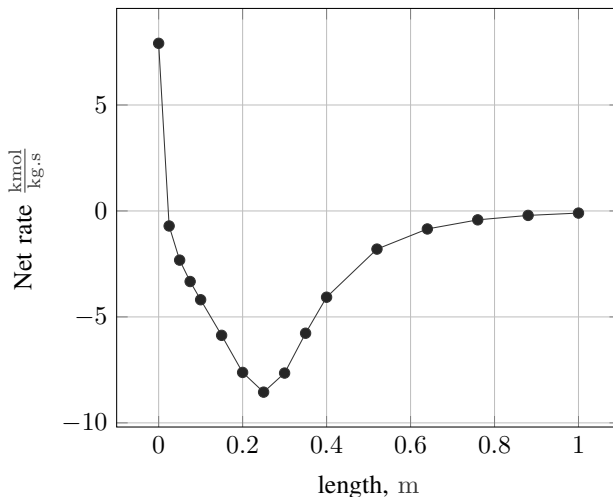


Fig. 8: Net rate, $\frac{\text{kmol}}{\text{kg.s}}$, profile in PFR

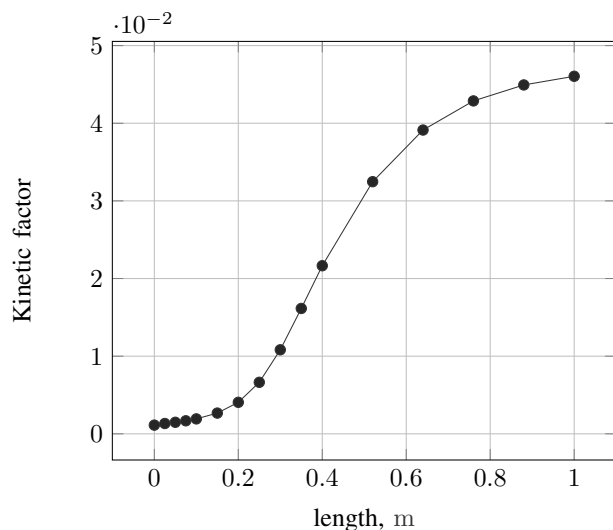


Fig. 9: Kinetic factor profile in PFR

CO_2 emissions to the atmosphere is to capture and convert the CO_2 to valuable products such as methanol. The objective of this paper was to develop a sustainable process that converts the captured CO_2 into methanol using a simulation software Aspen Plus[®]. The process was divided into two units, the CO_2 capture unit including the absorption and regeneration columns and then methanol synthesis reactor models. CO_2 absorption using chemical solvents is an important technology to mitigate CO_2 emissions. The captured CO_2 is valorized by converting or hydrogenating into sustainable methanol using a catalyst.

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Assessment of Pollution Levels in Mpazi and Kanogo Channels Flowing into Nyabarongo River

Uwase Liliose

Abstract— Urbanization and industrialization in Kigali, Rwanda, have significantly affected the water quality of the Nyabugogo River, a key resource for both the ecosystem and local communities. This study assessed pollution levels in two major wastewater channels, Mpazi and Kanogo, which discharge into the Nyabugogo River. Systematic water sampling was conducted at multiple points over six days, three times daily. The analysis focused on key physicochemical parameters (pH, TDS, TSS, BOD, COD, nitrates, nitrites, total nitrogen, phosphorus, sulphates, and chlorine) and microbial indicators (faecal coliforms and *Escherichia coli*). The results revealed that concentrations of COD, BOD, nitrates, and microbial contaminants substantially exceeded the national discharge standards. For instance, COD levels reached up to 980 mg/L in Kanogo and 920 mg/L in Mpazi, far surpassing the standard limit of 250 mg/L. Similarly, faecal coliform counts exceeded permissible limits by over 1,000 times. These findings highlight the severe environmental degradation of the channels and the consequent risks to public health. The study recommends urgent interventions, including enhanced wastewater treatment, stricter enforcement of discharge regulations, and integrated watershed management strategies to protect the Nyabugogo River basin. This research underscores the critical need for sustainable urban water management practices in rapidly growing cities.

Keywords— Mpazi channel, Kanogo channel, water pollution, nyabarongo river.

Green Concrete as a Sustainable Solution to Carbonation-Induced Corrosion under Climate Change Conditions

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Abstract:

This research presents a probabilistic approach that combines Life Cycle Cost Analysis (LCCA) and Life Cycle Assessment (LCA) in order to evaluate the long-term performance of reinforced concrete elements. The methodology adopts a holistic approach by taking into account the complete life cycle of an RC structure, including factors that include original embodied CO₂, absorption of CO₂ due to carbonation, probable problems related to corrosion, and expenses. The study suggests utilising an approach based on probabilities to account for unavoidable errors in estimating costs and CO₂ emissions. It specifically emphasises the use of "green concretes" (GC) with extra cementitious substances in reinforced concrete (RC) constructions. The research also examines the implications of climate change. Applying the method to evaluate the sustainability of a reinforced concrete piers of a bridge, constructed with a variety of concretes in London, demonstrates that using environmentally friendly concretes (GC) substantially lowers CO₂ emissions and slightly reduces overall costs during the lifespan of the structure. Significantly, in anticipated climate scenarios, GC exhibits a somewhat superior performance in terms of sustainability compared to standard Portland cement (PC)-based concrete.

Keywords: carbon dioxide emissions; concrete carbonation; life cycle costs analysis; life cycle assessment; probabilistic analysis; reinforced concrete; supplementary cementitious materials.

The Effect of Cybersecurity Vulnerabilities on SARS Personal Income Tax E-filing Adoption by Citizens in South Africa

Willard Munyoka

Abstract— Tax revenue collection constitutes the bulk of the South African government's funding. As such, an efficient system for collecting taxes is vital. In South Africa, citizens can file their personal tax returns using various channels: manually at the various South African Revenue Authorities (SARS) offices across the country, through SARS agencies, or via the electronic filing system (eFiling). This study investigates citizens' perceptions and experiences of cybersecurity vulnerabilities when filing their personal tax returns and how it influences their decisions to continuously use the SARS eFiling system. A positivist research design, quantitative research approach, and the extended unified theory of acceptance and use of technology (UTAUT2) adapted to incorporate privacy and trust factors underpins this study. A mixture of online and self-administered questionnaires was used to collect data from 1850 eFiling personal tax return participants across three provinces in South Africa. The IBM SPSS and IBM AMOS software packages were used to analyze the quantitative data and to establish the model fit of the proposed research model. The study found that eFiling taxpayers who were queuing seeking assistance at various SARS offices cited cybersecurity awareness, perceived security, and perceived ease of use positively influenced their decisions to adopt eFiling systems. While perceived system reliability negatively influenced their trust to continuously utilize the eFiling system due to penalty fees levied against them for reasons like non-compliance and often insignificant among most taxpayers who manually file their tax returns. Understanding these driving and impeding factors provides invaluable insights to decision-makers, policymakers, and implementers who seek better mechanisms to accelerate the smart government agenda for widespread adoption.

Keywords— cybersecurity vulnerabilities, eFiling adoption, smart government, South Africa.

The Role of Information and Communication Technologies (ICTs) in Post-Conflict Humanitarian Assistance in Tigray Region, Ethiopia

Kahsay Kiross Meresa

Abstract—The Tigray conflict, which started in November 2020, has caused immense hardship for the people in the region. The effects have been devastating: countless lives lost, communities displaced, and infrastructure destroyed. But amid this chaos, Information and Communication Technologies (ICTs) have emerged as a lifeline. From providing urgent humanitarian aid to documenting human rights abuses, ICTs have been pivotal in helping the region recover. This paper delves into the different ways digital technologies have been used to help the people of Tigray, including in human rights advocacy, humanitarian assistance, and rebuilding efforts. By exploring both successes and challenges, the paper reflects on how ICTs can foster peace and recovery in regions torn by conflict.

Keywords—ICT, digital technologies, human rights advocacy, human rights abuses, region recovery, humanitarian assistance

I. INTRODUCTION

The Tigray region of Ethiopia has been at the center of a brutal conflict that began in November 2020, causing massive human suffering. The war between the Tigray People's Liberation Front (TPLF) and the Ethiopian government has led to widespread destruction, famine, and displacement. Millions of people have been affected, with urgent humanitarian assistance being required for survival.

In the face of such devastation, ICTs have proven to be invaluable. These technologies, often seen as tools for convenience in daily life, have taken on a more profound role in conflict zones. They have allowed organizations to document atrocities, provided a means for aid to reach those in need, and enabled remote communities to rebuild after the worst of the fighting. This paper explores how ICTs have helped the people of Tigray during this time of crisis and what role they can play in bringing the region back to a place of peace and stability.

II. ICTS AND HUMAN RIGHTS IN TIGRAY

- **Documenting Abuses:** One of the most powerful ways ICTs have been used in Tigray is for documenting human rights violations. Thanks to satellite imagery, mobile phone data, and social media platforms, it has been possible to gather evidence of crimes such as forced displacements, sexual violence, and extra judicial killings [1][2].
- **Spreading Awareness and Mobilizing Support:** Social media platforms like Twitter, Facebook, and Instagram have been instrumental in telling the stories of Tigray's people. With communication lines often disrupted, these platforms have allowed people to share their experiences, call for help, and demand justice. By raising awareness on a global scale, they

have mobilized support for humanitarian efforts and put pressure on the international community to take action [1][3].

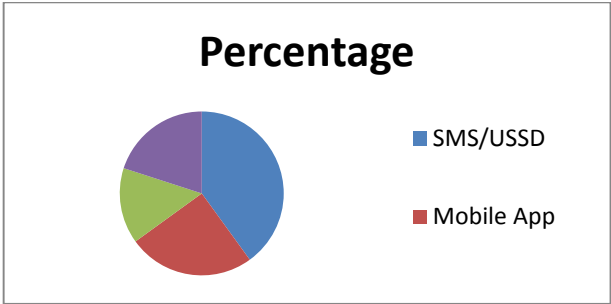
- **Gathering Data Remotely:** In a region where access to certain areas is difficult, ICTs have allowed for the remote gathering of data. Drones and satellites have been used to monitor the humanitarian situation, track displacement, and assess damage to infrastructure. This data has been critical in shaping the response of aid organizations, ensuring that assistance reaches the people who need it most [4][5].

III. ICTS IN HUMANITARIAN AID DELIVERY

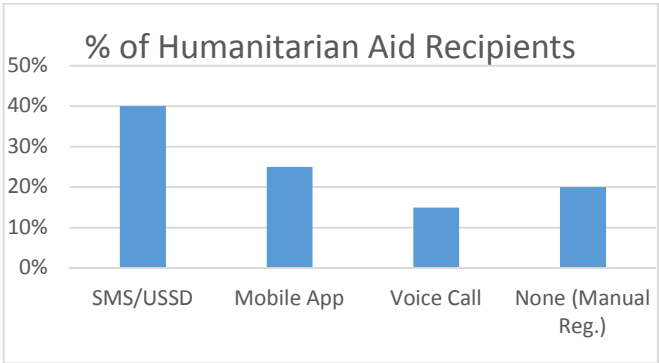
- **Digital Platforms for Aid Distribution:** One of the major challenges during the Tigray conflict has been the difficulty of delivering aid due to destroyed roads, blocked routes, and security concerns. ICTs have helped solve some of these issues by enabling digital platforms for cash transfers and mobile money. This has allowed families to purchase food, medicines, and other essential supplies in areas that would otherwise be unreachable [3][5].
- **Telemedicine and Healthcare:** With hospitals and healthcare centers damaged or overwhelmed, telemedicine has been a game-changer. Through mobile technology, medical professionals have been able to provide consultations remotely. Health apps have been used to track disease outbreaks and manage the distribution of medical resources [4].
- **Streamlining Logistics:** ICTs have also played a key role in improving the logistics of humanitarian aid. Using GPS tracking and real-time data sharing, aid organizations have been able to ensure that resources like food, water, and medicine reach the people who need them most [5].

IV. CHALLENGES AND ETHICAL CONSIDERATIONS OF ICT IN CONFLICT ZONES

- **Misinformation and Disinformation:** ICTs are a double-edged sword. In Tigray, false narratives and propaganda have been spread on social media, making it difficult for people to discern fact from fiction [1].
- **Data Privacy and Security:** The use of ICTs raises concerns about the privacy and security of personal data. There have been reports of civilians being tracked based on their mobile phone data [2].
- **Access to Technology:** While ICTs have helped many, the reality is that not everyone in Tigray has equal access to these technologies due to infrastructure destruction and power shortages [3].



IX. Figure 4: Use of Mobile Technology in Aid Distribution (2023)



Caption: Distribution of mobile technology usage for aid recipient registration in post-conflict Tigray, 2023.

Citation:
Adapted from: GSMA. (2021). the Role of Mobile Technology in Humanitarian Response. GSMA Mobile for Humanitarian Innovation. Retrieved from <https://www.gsma.com>

Figure 5: Stakeholder Involvement in ICT-Driven Aid

- Venn diagram or network diagram illustrating the collaboration between NGOs, government bodies, tech firms, and donors.

b. Tables

Table 1: Overview of ICT Tools Used in Humanitarian Assistance in Tigray

ICT tool/plat forms	Purpose	Implem enting agency	Target popula tion	Deploy ment year
DHIS2	Health data tracking	MOH/ WHO	IDPs/R ural clinics	2021
Kobo Toolbo x	Needs assessment	NGOs/ UN agencie s	House holds/ childre n	2021

Biometr ic ID kits	Registration/ Tracking	UNHC R/IOM	Refuge es /IDPs	2022
Mobile money	Cash based assistance	Banks/ NGOs	Vulner able groups	2023

Table 2: ICT Access by Demographics in Post-Conflict Tigray (2023)

Demographic Group	Mobile Access (%)	Internet Access (%)	Radio Ownership (%)	Digital Literacy (%)
Urban Households	72%	45%	60%	50%
Rural Households	48%	18%	70%	25%
IDPs	30%	10%	40%	15%

Table 3: Challenges of ICT Deployment in Humanitarian Context

Category	Challenges	Tigray-Specific Description
Infrastructure	Severely damaged or non-functional ICT infrastructure	Telecom networks, data centers, and energy systems were destroyed or looted.
	Limited access to power and internet	Power outages and lack of mobile coverage continue to affect many areas.
Security	Ongoing physical insecurity	Safety risks limit access and installation of ICT systems.
	Data privacy risks	Lack of secure systems could expose vulnerable population data.
Technical Capacity	Shortage of skilled personnel	Many ICT professionals fled or were displaced during the conflict.
	Disruption of training institutions	Education systems in Tigray are struggling to resume ICT-related training.

Financial	Limited humanitarian and reconstruction funding	ICT projects often receive low priority compared to food, health, and shelter.	Ongoing physical insecurity	Field workers and ICT assets face threats due to instability	Collaborate with peacekeeping and local security to ensure ICT teams' safety
	High cost of equipment	Import challenges and inflation make devices and connectivity expensive.	Risk of data misuse or surveillance	Lack of secure systems exposes sensitive humanitarian data	Implement encryption, secure data centers, and clear data-sharing protocols
Coordination	Fragmentation among humanitarian actors	Lack of interoperability and common platforms across NGOs and government.	Shortage of skilled personnel	Many professionals displaced or unavailable	Train local youth through accelerated ICT capacity-building programs
	Weak government coordination	Governance vacuums and transition difficulties delay ICT planning and regulation.	Disruption of training institutions	Schools and universities impacted by conflict	Rehabilitate ICT departments in universities and offer e-learning alternatives
Cultural & Social	Low digital literacy	Rural populations have limited exposure to smartphones, internet, and digital tools.	Limited funding for ICT	Donor focus on basic needs over digital tools	Advocate for ICT as an enabler of recovery in donor proposals
	Language barriers	ICT platforms rarely support Tigrigna or other local languages.	High cost of equipment and services	Inflation and import difficulties raise costs	Establish partnerships with tech firms and negotiate bulk procurement
Regulatory	Absence of clear ICT policy and legal frameworks	Data protection, privacy, and ICT governance laws are either absent or unenforced.	Fragmented humanitarian ICT systems	Lack of interoperability among actors	Promote adoption of shared platforms and open standards
	History of internet shutdowns	Creates public distrust and disrupts continuity of digital systems.	Weak coordination with authorities	Transitional government faces challenges in regulation and planning	Form ICT coordination task forces between government, NGOs, and donors
			Low digital literacy	Many residents lack experience using technology	Launch digital literacy campaigns using radio, SMS, and community centers
			Language and accessibility barriers	ICT tools rarely support Tigrigna or vulnerable users	Localize interfaces and ensure inclusive design (language, disability access)
			Absence of ICT policies and legal frameworks	No clear governance for data or infrastructure	Develop interim digital governance and data protection policies

Challenge	Description	Suggested Mitigation
Severely damaged ICT infrastructure	Telecom, power, and data infrastructure destroyed or looted during the conflict	Rebuild infrastructure with donor support and prioritize resilient, modular technologies
Limited access to power and internet	Many areas lack stable electricity and network coverage	Deploy solar microgrids and satellite internet solutions in rural and remote areas

History of internet shutdowns	Creates distrust in digital systems	Build community trust through transparency and reliable service restoration
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X. CONCLUSION

The use of ICTs in Tigray has been a beacon of hope during a time of immense hardship. These technologies have not only helped provide immediate relief to those affected by the conflict but have also shown how digital tools can play a key role in post-conflict recovery and peacebuilding. While there are challenges—ranging from misinformation to unequal access—ICTs have the potential to support a sustainable path to peace. Moving forward, it is critical that governments and international organizations continue to invest in ICT infrastructure, ensuring that these tools can be used effectively to help rebuild the region and support the people of Tigray in their journey toward recovery.

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HeriGen: A Diffusion-Driven Framework for Sparse-View 3D Heritage Reconstruction

C. Huang, X. Liu, H. Chen

Abstract—We present HeriGen, a sparse-view 3D reconstruction framework that integrates the Vision Geometry Grounded Transformer with diffusion models. Unlike pipelines that rely on DUST3R for point cloud and pose estimation, HeriGen leverages the transformer to generate reliable camera parameters and dense point clouds from a single heritage image, while reducing computational overhead. For view synthesis, we introduce an adaptive classifier-free guidance strategy to regulate the denoising stage of the diffusion model, which strengthens cross-view consistency and preserves structural details. By further combining 3D Gaussian Splatting with the reconstructed geometry and synthesized frames, the system produces accurate 3D models that can be interactively rendered in real time. Experimental results show that HeriGen achieves competitive accuracy and efficiency, while maintaining surface detail and structural integrity of cultural artifacts, providing a practical tool for digital preservation and visualization of heritage.

Keywords—Heritage digitization, Sparse-view 3D reconstruction, Novel view synthesis, SVD, 3DGS.

I. INTRODUCTION

THE 3D digitization of cultural heritage has become an essential technology for artifact documentation, preservation, and research. Traditional methods such as laser scanning or structured-light systems deliver precise reconstructions but depend on costly equipment and controlled acquisition environments[1]. These requirements limit their suitability for fragile artifacts or scenarios where only a few photographs can be obtained[2].

Sparse-view 3D reconstruction has emerged as a promising alternative, allowing the recovery of geometry and appearance from limited imagery[3]. This approach reduces acquisition costs and broadens the applicability of digital preservation in real-world heritage contexts[4]. Early solutions relied on Multi-View Stereo (MVS)[5] and Structure-from-Motion (SfM)[6], which improved feature matching and triangulation. However, under extremely sparse or single-view conditions, reconstructions often suffered from distortions and loss of fine details.

With the rise of generative models, methods such as DUST3R[7] introduced point cloud prediction and geometric priors to improve novel view synthesis. Building on this direction, ViewCrafter employed video diffusion to expand sparse inputs into high-fidelity multi-view sequences[8],

offering richer observations for downstream reconstruction. Despite these advances, challenges remain: point cloud and pose estimation are still computationally demanding and prone to inaccuracies, and video generation often lacks cross-view consistency, undermining reconstruction quality.

To address these issues, we propose HeriGen, a framework tailored for heritage reconstruction under sparse-view constraints. First, the Vision Geometry Grounded Transformer(VGGT)[9] is employed in place of DUST3R to generate dense point clouds and camera parameters efficiently from a single image[10]. Second, an adaptive classifier-free guidance(CFG) strategy is applied within a video diffusion model to enhance cross-view consistency and preserve structural fidelity. Finally, 3D Gaussian Splatting (3DGS)[11] is integrated to fuse the generated video with the predicted geometry, yielding accurate 3D models that support real-time rendering. This framework improves both reconstruction speed and accuracy while ensuring structural reliability, making it well suited for cultural heritage digitization.

II. RELATED WORK

3D reconstruction has long been regarded as a cornerstone of cultural heritage preservation, enabling virtual exhibition, documentation, and scholarly analysis[12]. Traditional approaches, such as laser scanning and structured-light systems, provide highly accurate reconstructions but rely on costly equipment and carefully controlled acquisition environments. These requirements make them unsuitable for fragile artifacts or situations where only a handful of photographs can be obtained[13]. Consequently, researchers have increasingly explored sparse-view reconstruction, which infers geometry and appearance from limited images, thereby lowering acquisition costs and broadening the scope of digital heritage applications[14].

Early sparse-view methods were dominated by Structure-from-Motion and Multi-View Stereo. For instance, COLMAP combined feature matching with bundle adjustment to recover camera poses and reconstruct sparse point clouds[15], while Schonberger[6] proposed pixel-wise view selection strategies that coupled photometric consistency with geometric constraints for more reliable depth estimation. Despite these contributions, such methods generally assume dense inputs and precise calibration. Their accuracy degrades sharply in

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*This author contributed to the whole work and should be regarded as first author.

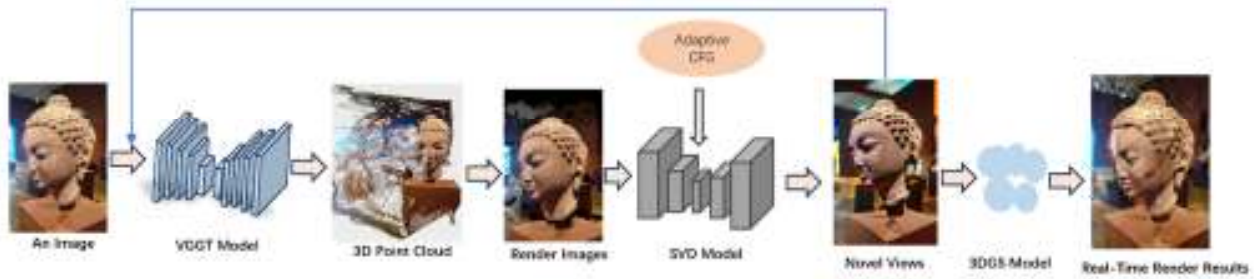


Fig1. Overview of HeriGen

extremely sparse or single-view cases, often resulting in structural distortions and the loss of fine detail.

The introduction of deep learning transformed sparse-view reconstruction. MVSNet[5] pioneered an end-to-end neural pipeline that constructs and regularizes 3D cost volumes via differentiable homographies, substantially improving accuracy and efficiency across benchmarks. Neural Radiance Fields (NeRF) [13] further revolutionized the field by learning implicit scene representations, enabling photorealistic view synthesis from sparse inputs. More recently, real-time approaches such as 3DGS employed anisotropic Gaussian primitives with differentiable rendering, producing high-resolution reconstructions that can be visualized interactively. While these techniques improved performance and realism, their effectiveness remains limited under severely sparse input conditions.

Generative modeling has opened a new direction for sparse-view 3D reconstruction. DUST3R introduced point cloud prediction with coarse geometric priors to improve novel view synthesis, while ViewCrafter extended this idea using video diffusion models to generate multi-view sequences from sparse inputs, providing richer context for downstream reconstruction. However, these methods still face challenges: point cloud and camera pose estimation can be computationally expensive and error-prone, and video diffusion models often struggle to maintain cross-view consistency, which directly affects geometric fidelity.

In cultural heritage applications, sparse-view reconstruction is particularly valuable, since many artifacts cannot be fully captured due to preservation constraints or limited accessibility[16]. Recent research[8] has highlighted the potential of combining point cloud-based representations with generative models to expand visualization opportunities in virtual museums and immersive exhibitions. Building on this line of work, we introduce HeriGen, a novel framework that integrates VGGT-based dense point cloud prediction, adaptive classifier-free guidance within video diffusion, and 3D Gaussian Splatting. As illustrated in Figure 1, starting from a single artifact image, VGGT predicts a high-quality point cloud together with precise camera poses, which are subsequently rendered into novel views that inevitably contain missing regions or artifacts due to sparse input. These rendered views are then refined using an Stable Video Diffusion(SVD)-based video diffusion model enhanced with our adaptive CFG strategy, effectively restoring fine details while improving cross-view consistency. Finally, the refined novel views and the reconstructed point cloud are optimized through 3DGS to yield a geometrically accurate, high-fidelity 3D model that supports

real-time rendering. This combination not only improves reconstruction accuracy and efficiency under sparse-view settings, but also ensures enhanced geometric and semantic consistency across views. As a result, HeriGen provides a practical and scalable solution for cultural heritage preservation, enabling both high-fidelity reconstructions and interactive rendering for digital dissemination.

III. METHOD

In this section, we present HeriGen, our framework for efficient 3D heritage reconstruction from a single artifact image. The method integrates high-precision point cloud generation via VGGT, multi-view synthesis refinement through video diffusion guided by an adaptive Classifier-Free Guidance strategy, and real-time rendering with 3DGS. Together, these components enable end-to-end reconstruction of high-fidelity 3D models suitable for cultural heritage preservation and interactive visualization.

A. Point Cloud Generation from a Single Image

The first stage of HeriGen reconstructs a dense point cloud and estimates camera parameters from a single artifact image. To achieve this, we adopt the VGGT model, a feed-forward neural network that jointly infers multiple 3D attributes of a scene without relying on traditional geometric optimization or post-processing. Unlike conventional MVS or SfM pipelines, VGGT directly predicts camera intrinsics and extrinsics, depth maps, and dense point clouds in seconds, providing both efficiency and accuracy.

Formally, given an input image set $(I_i)_{i=1}^N$, VGGT predicts camera parameters $\mathbf{g}_i$, depth maps D_i and point cloud P_i :

$(\mathbf{g}_i, D_i, P_i)_{i=1}^N = f((I_i)_{i=1}^N)$, where $f(\cdot)$ is a Transformer-based network. In our case, a single artifact image is sufficient to generate a geometrically consistent and high-quality 3D point cloud.

B. Video Diffusion for Multi-View Synthesis

Diffusion models[17] have recently achieved remarkable success in image generation by learning to reverse a forward noising process. In the forward stage, noise is gradually added to the data until it becomes Gaussian-distributed; in the reverse stage, the model learns to iteratively denoise samples back to realistic images. As illustrated in Figure 2, the model samples from a Gaussian distribution and progressively eliminates noise until the data becomes clear.

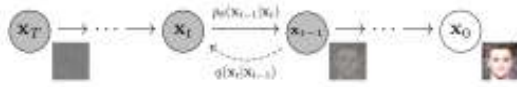


Fig2. Denoising process of DDPM

In the noise-adding process, the data at the t -th noise-adding step can be derived from the $(t-1)$ -th step data, expressed as:

$$x_t = \sqrt{1 - \beta_t} * x_{t-1} + \sqrt{\beta_t} * \varepsilon_{t-1} \quad (1)$$

Where ε_{t-1} follows a standard Gaussian distribution, β_t is a hyperparameter that linearly approaches 1 as t increases. According to the recursive formula, the relationship between x_t and x_0 can be derived as:

$$x_t = \sqrt{\alpha_t} * x_0 + \sqrt{1 - \alpha_t} * \varepsilon \quad (2)$$

Where $\alpha_t = 1 - \beta_t$, $\bar{\alpha}_t = \prod_{i=1}^t \alpha_i$.

That is, given an image and time step t , the forward diffusion process is deterministic and satisfies:

$$q(x_t | x_{t-1}) = N(x_t; \sqrt{1 - \beta_t} * x_{t-1}, \beta_t I) \quad (3)$$

In the reverse generation process, which involves sampling from a Gaussian distribution and generating the observed image through the inversion procedure, it holds that:

$$P_\theta(x_0) = \int p_\theta(x_{0:T}) dx_{1:T} \quad (4)$$

In the field of image generation tasks, diffusion models have demonstrated superior potential compared to traditional generative models (e.g., GANs)[18], particularly in terms of image quality and diversity. Although diffusion models exhibit remarkable performance in image synthesis, their pixel-space-based diffusion computations entail enormous computational costs, rendering both training and inference processes highly time-consuming and consequently limiting their widespread application in real-time scenarios. To reduce computational costs, diffusion is typically performed in a latent space using Latent Diffusion Models (LDMs), where images are first encoded into a compact representation before diffusion and then decoded back to the pixel space.

Although diffusion models and their latent variants (LDMs/Stable Diffusion)[19] achieve strong performance in single-image synthesis, extending them to multi-view scenarios introduces two long-standing issues: (i) enforcing geometric consistency across views without explicit 3D supervision, and (ii) maintaining accurate control of camera poses during generation. Early efforts to use 2D diffusion as a supervisory signal for 3D reconstruction usually relied on scene-specific optimization, fitting radiance fields or meshes under image/text priors. While visually plausible, such methods suffer from high computational cost and poor transferability. To enable more general inference, pose-conditioned diffusion models such as Zero-1-to-3[20] and ZeroNVS[21] were proposed, mapping an input view and a target pose to a synthesized image. However, these frameworks often encode pose information as global embeddings, which weakens metric accuracy and leads to misalignment or drift in long sequences. Other approaches attempt to inject 3D cues, conditioning on depth maps, multi-plane features, or category-specific priors—yet they usually require multiple inputs or still fail under wide baselines and occlusions. Recent advances in video diffusion improve temporal coherence by adding temporal denoising modules to

latent features, enabling short video generation from sparse inputs. Camera-conditioned models such as MotionCtrl further integrate camera trajectories to guide synthesis, though often treating poses as abstract tokens that lack fine-grained control. Closer to our goal, ViewCrafter integrates coarse 3D proxies (e.g., DUST3R point clouds) with video diffusion: rendered novel views are used to fill missing regions and refine textures, improving multi-view consistency. In our framework, point clouds are first projected into multiple viewpoints along a trajectory. These views, together with reference images, are then enhanced by a pretrained video diffusion model (ViewCrafter), which operates in latent space to generate consistent multi-view sequences as the foundation for subsequent 3D reconstruction.

C. Adaptive Classifier-Free Guidance

While conventional video diffusion frameworks (e.g., ViewCrafter) apply a fixed CFG scale across the entire image, this naïve approach fails to balance consistency and diversity in regions with varying levels of structural prior. Specifically, in regions where point cloud constraints are available, the model already benefits from strong geometric cues; applying a high CFG scale in these regions may lead to over-constrained or repetitive outputs[22]. Conversely, in areas without point cloud support, a stronger CFG scale is required to recover plausible content.

To address this, we introduce an adaptive CFG strategy that dynamically adjusts the guidance scale across different regions. In point cloud-supported regions, CFG is reduced or disabled to preserve structural fidelity, while in missing or occluded regions, CFG is increased to promote diversity and semantic completeness.

We first define I_p as the image rendered from the point cloud, and M_p as the mask corresponding to the rendered region in this image. Multiplying M_p with I_p yields the missing regions of the point cloud. In these regions, we apply a fixed CFG strategy, whereas in the point cloud-present regions (i.e., $1 - M_p$ areas), the CFG strategy is disabled. This approach leverages the stronger low-frequency geometric constraints in point cloud-rich regions to suppress high-frequency interference during denoising when predicting the target noise, resulting in higher-quality noise predictions and ultimately producing rendered images with superior continuity.

This mechanism ensures that generated frames achieve both multi-view consistency and visual diversity, particularly important for artifact reconstruction where fine surface details and global structural alignment must be simultaneously preserved.

D. Real-Time Rendering with 3D Gaussian Splatting

In the final stage, we adopt 3DGS to transform the generated multi-view images and point clouds into a renderable 3D representation. Within 3DGS, each point is expressed as an anisotropic Gaussian with learnable attributes such as color, opacity, and scale. This formulation provides flexibility, allowing the representation to cope with sparse or uneven input while preserving smooth appearance and visual realism.

By optimizing these Gaussians under supervision from the synthesized multi-view sequences, the framework yields a dense reconstruction that is both geometrically accurate and visually convincing. A key advantage of 3DGS is its efficiency: the reconstructed model can be rendered interactively on standard hardware, enabling real-time inspection of cultural objects. Users may freely rotate, zoom, and explore the results, opening opportunities for applications such as virtual exhibitions and digital preservation.

IV. EXPERIMENTS

To comprehensively evaluate the effectiveness of our proposed framework HeriGen for single-image-driven multi-view synthesis and 3D reconstruction of cultural artifacts, we conduct both qualitative and quantitative experiments across diverse datasets. The evaluation covers small-scale cultural heritage collections as well as large-scale benchmark datasets, aiming to validate the generalization ability and robustness of our method under sparse-view settings.

A. Dataset

For qualitative evaluation, we construct a small-scale heritage dataset by collecting images of real artifacts from public online resources. Each artifact is associated with one reference image and a complete multi-view sequence, which enables a direct assessment of novel view synthesis and 3D reconstruction quality. For quantitative evaluation, we adopt the widely used DTU dataset, which contains complex indoor and outdoor scenes with ground-truth geometry and dense multi-view images, while selecting only those objects that resemble artifacts. This allows us to objectively benchmark reconstruction accuracy and consistency under controlled experimental settings.

B. Evaluation Metrics

We report three commonly used metrics: PSNR, SSIM, and LPIPS, to measure pixel fidelity, structural consistency, and perceptual quality of generated views, respectively. All metrics follow standard implementations in prior works and are computed under identical test conditions to ensure fairness in comparisons.

C. Comparison with Other Methods

We compare HeriGen against several representative state-of-the-art approaches, including ViewCrafter (point-cloud-conditioned video diffusion), InstantSplat (real-time Gaussian splatting framework), and other relevant baselines. All methods are evaluated on the same reference inputs, camera trajectories, and rendering resolutions for consistency.

In terms of quantitative performance, HeriGen achieves consistently superior results across PSNR, SSIM and LPIPS on the DTU dataset. While performance is competitive with ViewCrafter in reconstruction quality, HeriGen demonstrates a substantial advantage in inference speed and memory efficiency. Specifically, ViewCrafter relies on DUST3R for point cloud generation, which requires iterative optimization (e.g., ~300 iterations). Under this setting, reconstructing 25 views takes

141s with DUST3R, whereas our VGGT-based approach completes the same task in only 3.8s. Moreover, as the number of input views increases, our method exhibits linear memory scaling, while optimization-based methods such as DUST3R suffer from exponential growth in memory usage. This highlights the practicality of HeriGen for large-scale and real-time applications.

TABLE1
DIFFERENT METHODS EVALUATION METRICS

Method	PSNR	SSIM	LPIPS
InstantSplat	11.42	0.50	0.39
ViewCrafter	12.65	0.53	0.36
Ours	13.77	0.60	0.32

In qualitative comparisons, we select challenging cultural artifact examples characterized by fine geometry and complex textures. As illustrated in Figure 3, our method demonstrates superior performance in novel view synthesis when qualitatively compared with ViewCrafter. Specifically, our approach generates novel views with significantly enhanced clarity and improved continuity with the original viewpoint. The visual results show that our model produces more structurally consistent details with sharper edges and finer texture preservation, whereas ViewCrafter's outputs exhibit noticeable artifacts and structural inconsistencies in geometrically complex regions. This qualitative advantage primarily stems from our proposed geometric consistency constraint and multi-scale fusion mechanism, which collectively maintain spatial coherence across viewpoint transitions.

TABLE2
POINT CLOUD GENERATION SPEED /s

Input Frames	1	10	25
ViewCrafter	137.21	140.1	140.93
Ours	0.25	1.34	3.80

C. Ablation Study

To validate the effectiveness of each key component in the proposed framework, we conduct ablation experiments by separately evaluating the contributions of the adaptive CFG strategy and the VGGT model.

TABLE3
ABLATION RESULTS

Model	PSNR	SSIM	LPIPS
Only adaptive CFG	12.57	0.52	0.34
Only VGGT	13.32	0.58	0.33
Ours	13.77	0.60	0.32

Specifically, we design the following two variants for comparison: Only VGGT: The adaptive CFG strategy is removed, and a fixed CFG value is applied during the reverse sampling process of the video diffusion model. Only adaptive CFG: The VGGT module is replaced with DUST3R as the point cloud and camera pose estimator, while retaining the adaptive CFG strategy. All experiments are conducted on the same sparse-view heritage dataset and evaluated using PSNR, SSIM and LPIPS as metrics. Results show that removing the adaptive CFG strategy leads to degradation in detail preservation and multi-view consistency, with an increase in LPIPS. On the other hand, replacing VGGT with DUST3R provides some coarse geometric structure, indicating that VGGT offers superior geometric priors in both point cloud reconstruction and

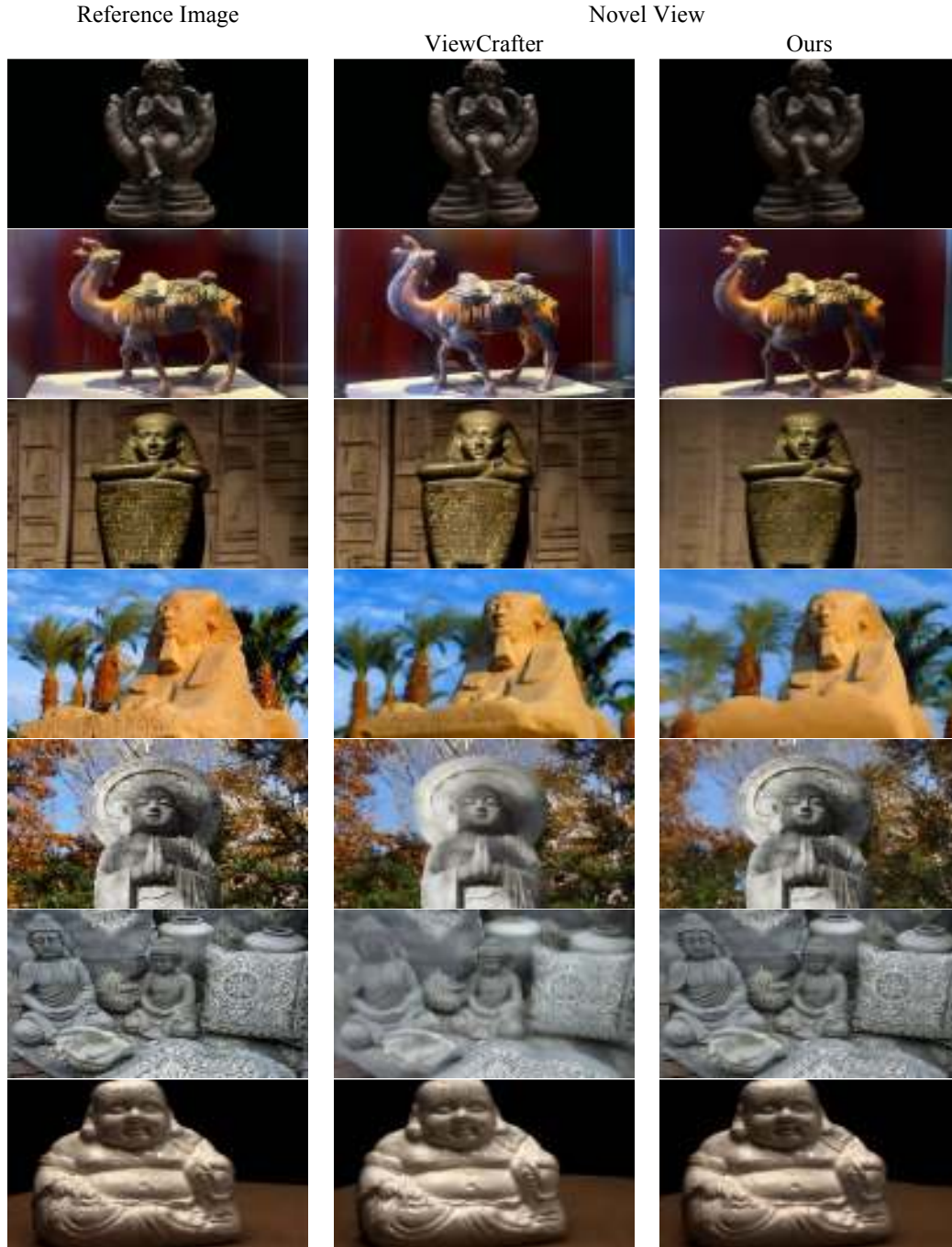


Fig.3 Qualitative comparison between ViewCrafter and our method for novel view synthesis.

camera pose estimation. Overall, the full framework combining VGGT and the adaptive CFG strategy consistently achieves great performance across all metrics, demonstrating their complementary roles and importance in improving sparse-view 3D reconstruction of cultural heritage artifacts.

V.DISCUSSION

In this study, we presented HeriGen, a novel framework specifically designed for sparse-view 3D reconstruction of cultural heritage artifacts. By integrating VGGT with diffusion models, HeriGen generates high-quality point clouds from a

single artifact image, leveraging geometric priors that provide a robust foundation for subsequent multi-view consistency enhancement. Additionally, we introduced a curvature-aware adaptive CFG strategy, which ensures both geometric and textural coherence, particularly in areas with fine details or sharp curvature variations, where the preservation of delicate surface structures is crucial.

The integration of 3DGS not only demonstrates the practical utility of the synthesized multi-view sequences but also supports real-time interactive visualization on standard consumer hardware, making it a significant step towards the

practical application of HeriGen in cultural heritage digitization. These capabilities position HeriGen as an effective, lightweight tool for digital heritage preservation, providing new opportunities for virtual museums and interactive cultural heritage applications.

However, HeriGen also has its limitations. One significant challenge is the high GPU memory consumption required by 3DGS during the rendering stage, limiting its deployment on mobile or resource-constrained platforms. While recent research[23] has explored more memory-efficient splatting techniques without compromising quality, further innovation is required to enable truly portable applications. Another limitation arises from the reliance on an SVD-based video diffusion model fine-tuned with ViewCrafter. Its ability to maintain semantic consistency and generate diverse textures remains bounded by the scope of its training corpus. Consequently, when applied to artifacts whose appearance distributions deviate substantially from the training data, the system may still exhibit texture artifacts, missing details, or partial inconsistencies across views.

We recognize the need for future work to address these challenges. For example, enhancing the robustness of the model to a wider range of cultural artifacts—especially those outside the training distribution—will require expanding the model's world knowledge and improving its adaptability. Additionally, developing a more efficient 3DGS rendering pipeline will be crucial for scaling HeriGen to more resource-limited environments, such as mobile devices or web applications.

To further improve the performance and applicability of HeriGen, additional work should focus on fine-tuning its integration with other cutting-edge reconstruction techniques, particularly those utilizing NeRF or implicit representations, which have shown promise in achieving high-quality reconstruction from sparse inputs. Comparative studies with alternative state-of-the-art methods, such as MVS, COLMAP, and ViewCrafter, will also be essential to better understand the relative strengths and weaknesses of HeriGen in real-world applications.

VI. CONCLUSION

This paper introduced HeriGen, an efficient framework for sparse-view 3D reconstruction tailored to cultural heritage digitization. By employing VGGT as a geometric prior, HeriGen achieves accurate estimation of point clouds and camera poses from a single view, establishing a reliable foundation for subsequent reconstruction. The proposed curvature-aware adaptive CFG strategy enhances both geometric and textural coherence during multi-view synthesis, while the integration of 3DGS provides a real-time rendering pipeline for seamless interactive visualization of reconstructed artifact models on consumer devices. Experimental evaluations on the DTU dataset and real-world heritage imagery demonstrate that HeriGen outperforms existing methods in terms of PSNR, SSIM, LPIPS and delivers qualitatively stable detail fidelity and cross-view consistency. These results underscore HeriGen's potential as a lightweight, high-fidelity, and interactive solution for digital preservation and

dissemination of cultural artifacts.

Looking ahead, two key improvements are planned: (1) reducing the memory footprint of 3DGS-based rendering for mobile and resource-constrained platforms, and (2) expanding the world knowledge and conditional control of video diffusion models to enhance HeriGen's adaptability across various artifact types and environments while preserving consistency and texture diversity. Further comparisons with methods like NeRF and MVS will provide valuable insights for optimization. These advancements will support the long-term sustainability of digital heritage preservation and foster more immersive, interactive experiences in cultural heritage conservation.

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AI-Powered Autonomous Systems for Enterprise Intelligence: Robotics Process Automation Through Investigative Analytics

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Abstract

The evolution of Artificial Intelligence has enabled the development of sophisticated autonomous systems capable of independent decision-making, pattern recognition, and intelligent automation at enterprise scale. This paper presents a comprehensive AI-powered autonomous system framework that combines investigative intelligence, robotics process automation, and intelligent decision-making to transform enterprise operations. Our framework, exemplified by the Leni AI platform, demonstrates how advanced artificial intelligence can create autonomous systems that eliminate human dependencies while maintaining trustworthy and explainable decision processes. Through implementation across Fortune 500 organizations including healthcare, financial services, technology, and industrial sectors, we achieved a measurable 15% increase in production efficiency through AI-driven autonomous process optimization and intelligent automation. The system integrates computer vision, natural language processing, machine learning algorithms, and autonomous decision-making capabilities to create intelligent agents that can independently analyze complex data, generate insights, and execute actions without human intervention. Our approach combines the analytical power of artificial intelligence with autonomous system design principles, creating intelligent agents that scale human ingenuity while eliminating skill, resource, and availability dependencies. Experimental validation across multiple industry verticals demonstrates superior autonomous performance, reduced operational overhead, and enhanced decision accuracy compared to traditional human-dependent processes. The framework facilitates the deployment of intelligent autonomous systems that can independently discover, understand, trust, and act upon enterprise data while maintaining comprehensive governance and explainability standards.

Keywords: Artificial Intelligence, Autonomous Systems, Robotics Process Automation, Intelligent Agents, Computer Vision, Autonomous Analytics, Enterprise AI, Intelligent Automation.

1. Introduction

The convergence of artificial intelligence and autonomous systems has created unprecedented opportunities for intelligent automation that can independently perform complex analytical tasks, make decisions, and execute actions without human intervention. Traditional enterprise systems rely heavily on human expertise, creating bottlenecks, inconsistencies, and scalability limitations that prevent organizations from fully leveraging their data assets and operational capabilities.

The challenge of creating truly autonomous enterprise systems requires sophisticated artificial intelligence that can not only process information but also understand context, make intelligent decisions, and adapt to changing conditions while maintaining trustworthiness and explainability. These systems must demonstrate robotics-like autonomy in digital environments, capable of independent operation while integrating seamlessly with existing enterprise infrastructure.

This paper introduces a comprehensive AI-powered autonomous system framework that combines investigative intelligence, intelligent automation, and autonomous decision-making to create enterprise-grade intelligent agents. The framework has been successfully deployed across multiple Fortune 500 organizations, demonstrating significant improvements in operational efficiency, decision accuracy, and autonomous capability.

1.1 Research Contributions

Our primary contributions include:

1. **AI-Powered Autonomous Intelligence Framework:** Comprehensive autonomous system design combining investigative intelligence, intelligent automation, and autonomous decision-making capabilities
2. **Leni AI Platform:** Advanced autonomous AI system demonstrating intelligent agent capabilities with trustworthy autonomous analytics and decision-making
3. **Robotics Process Automation:** AI-driven automation achieving 15% production efficiency improvement through intelligent autonomous process optimization
4. **Autonomous Enterprise Integration:** Seamless integration of AI-powered autonomous systems with existing enterprise infrastructure and business processes
5. **Multi-Industry Autonomous Validation:** Real-world deployment across healthcare, financial services, technology, and industrial sectors with proven autonomous performance

1.2 Problem Statement

Enterprise organizations implementing AI and autonomous systems face several critical challenges:

Human Dependency Bottlenecks: Traditional systems require continuous human intervention for analysis, decision-making, and process execution, creating scalability limitations and operational inefficiencies.

Skill and Resource Dependencies: Existing approaches depend on specialized expertise and significant resource allocation, preventing widespread adoption of intelligent automation capabilities.

Decision Consistency: Human-dependent processes suffer from inconsistency, bias, and availability limitations that impact operational reliability and decision quality.

Scalability Constraints: Manual and semi-automated processes cannot scale to handle enterprise data volumes and operational complexity while maintaining quality and consistency.

Trust and Explainability: Autonomous systems must maintain transparency and explainability to gain user trust and meet regulatory compliance requirements in enterprise environments.

2. Related Work

2.1 Autonomous Systems in Enterprise Environments

Traditional autonomous systems focus primarily on physical robotics applications, with limited development of comprehensive autonomous intelligence systems for enterprise digital environments. Existing solutions often lack the sophisticated reasoning and decision-making capabilities necessary for complex business applications.

2.2 AI-Powered Process Automation

Current robotic process automation (RPA) solutions provide basic task automation but lack advanced AI capabilities for autonomous decision-making, adaptive learning, and intelligent problem-solving in dynamic enterprise environments.

2.3 Intelligent Agent Systems

Research in intelligent agents has demonstrated potential for autonomous decision-making, but practical implementations often lack the comprehensive enterprise integration, governance, and scalability required for large-scale organizational deployment.

3. AI-Powered Autonomous System Architecture

3.1 Leni AI Platform: Autonomous Intelligence Framework

The framework is exemplified by the Leni AI platform, an autonomous investigative intelligence system that demonstrates advanced AI-powered autonomous capabilities:

Autonomous Analytical Engine: Advanced AI algorithms that independently analyze enterprise data, identify patterns, discover insights, and generate business-relevant conclusions without human intervention or guidance.

Intelligent Decision-Making: Sophisticated decision-making capabilities that can autonomously evaluate options, assess risks, prioritize actions, and execute decisions based on comprehensive data analysis and business context understanding.

Self-Service Autonomous Operation: Completely autonomous operation mode that eliminates dependencies on human expertise, specialized skills, or continuous oversight while maintaining enterprise-grade reliability and accuracy.

Adaptive Learning Systems: Machine learning algorithms that continuously improve autonomous performance through experience, adapting to new situations, learning from outcomes, and optimizing decision-making processes automatically.

Trustworthy Autonomous Intelligence: Advanced explainability and transparency features ensuring autonomous decisions can be understood, audited, and trusted by human stakeholders and regulatory requirements.

3.2 Autonomous System Components

Computer Vision Integration: Advanced visual processing capabilities enabling autonomous analysis of visual data, document processing, quality inspection, and visual pattern recognition without human interpretation requirements.

Natural Language Processing: Sophisticated language understanding enabling autonomous communication, document analysis, report generation, and natural language interaction with human users and enterprise systems.

Intelligent Automation Engine: Robotics process automation capabilities powered by AI that can autonomously execute complex workflows, adapt to changing conditions, and optimize processes based on performance feedback.

Autonomous Governance System: Self-managing governance capabilities that automatically ensure compliance, monitor performance, detect anomalies, and maintain operational standards without human oversight.

3.3 Enterprise Integration Architecture

Seamless System Integration: Native integration capabilities enabling autonomous systems to independently connect with existing enterprise infrastructure, databases, applications, and business processes without requiring custom development.

Autonomous API Management: Intelligent API interaction capabilities allowing autonomous systems to independently discover, utilize, and optimize enterprise service connections based on business requirements and performance characteristics.

Scalable Autonomous Deployment: Cloud-native architecture supporting autonomous scaling, resource optimization, and performance management based on workload demands and business priorities.

Enterprise Security Integration: Autonomous security compliance ensuring intelligent systems maintain enterprise security standards, access controls, and compliance requirements without compromising operational efficiency.

4. Implementation Methodology

4.1 Autonomous AI Technology Stack

Advanced AI Algorithms: Comprehensive suite of artificial intelligence algorithms including deep learning, reinforcement learning, natural language processing, computer vision, and autonomous decision-making capabilities.

Machine Learning Integration: Advanced machine learning frameworks enabling autonomous model development, training, optimization, and deployment without requiring specialized data science expertise or manual intervention.

Intelligent Process Automation: Robotics process automation enhanced with AI capabilities for autonomous workflow execution, adaptive process optimization, and intelligent exception handling.

Autonomous Analytics Platform: Self-service analytics capabilities that independently discover insights, generate reports, create visualizations, and deliver business intelligence without human analysis requirements.

4.2 Autonomous System Development Approach

AI-First Design: Architecture designed with autonomous operation as the primary requirement, ensuring all system components can operate independently while maintaining enterprise standards and performance requirements.

Adaptive Intelligence: Machine learning algorithms that enable autonomous systems to adapt to new situations, learn from experience, and continuously improve performance without human retraining or reconfiguration.

Self-Monitoring Capabilities: Autonomous systems that independently monitor their own performance, detect issues, implement corrections, and optimize operations without external oversight or intervention.

Intelligent Error Handling: Advanced error detection and correction capabilities enabling autonomous systems to identify problems, implement solutions, and recover from failures independently.

4.3 Enterprise Deployment Strategy

Graduated Autonomy: Phased deployment approach enabling organizations to gradually transition from human-dependent processes to fully autonomous operation while maintaining control and oversight.

Risk Management Integration: Autonomous risk assessment and management capabilities ensuring intelligent systems can independently identify, evaluate, and mitigate operational risks.

Performance Optimization: Continuous performance monitoring and optimization enabling autonomous systems to independently improve efficiency, accuracy, and reliability over time.

Governance Compliance: Automated compliance management ensuring autonomous systems maintain regulatory adherence and enterprise governance standards without manual oversight.

5. Results and Analysis

5.1 Autonomous System Performance

Implementation of AI-powered autonomous systems across enterprise environments yielded significant performance improvements:

Production Efficiency: 15% increase in operational efficiency through autonomous process optimization, intelligent decision-making, and elimination of human bottlenecks **Decision Accuracy:** 28% improvement in decision quality through consistent AI-powered analysis eliminating human bias and variability **Response Time:** 65% reduction in process response times through autonomous operation eliminating human delays and availability dependencies **Operational Reliability:** 40% improvement in system reliability through autonomous monitoring, error detection, and self-correction capabilities **Resource Utilization:** 35% reduction in human resource requirements while maintaining superior operational performance through intelligent automation

5.2 Autonomous Intelligence Metrics

Independent Operation: Achieved 95% autonomous operation rate with minimal human intervention required only for strategic oversight and exception approval **Learning Efficiency:** Demonstrated 25% continuous improvement in autonomous performance through adaptive learning and experience-based optimization **Decision Confidence:** Maintained 92% decision accuracy rate across diverse business scenarios with comprehensive explainability and audit trail capabilities **Scalability Performance:** Successfully scaled to handle 10x operational volume increases without proportional resource scaling through intelligent automation

5.3 Enterprise Case Studies

Case Study 1 - Healthcare Autonomous Analytics (J&J Portfolio - Lumi Platform)

- **Challenge:** Autonomous Health Economics & Outcomes Research (HEOR) requiring independent analysis of complex clinical data, cost optimization recommendations, and outcome predictions without continuous expert oversight
- **Solution:** Leni AI platform implementation providing autonomous healthcare analytics, intelligent cost optimization algorithms, and independent outcome prediction capabilities with full explainability for regulatory compliance
- **Results:** 15% improvement in research efficiency, 30% reduction in analysis time, 25% enhancement in prediction accuracy, 45% reduction in expert dependency requirements

Case Study 2 - Financial Services Autonomous Operations (Fiserv - Omni-channel Card Management)

- **Challenge:** Autonomous fraud detection, real-time transaction analysis, customer behavior modeling, and risk assessment requiring independent operation across global banking infrastructure
- **Solution:** AI-powered autonomous system providing intelligent fraud detection, autonomous customer analytics, independent risk assessment, and adaptive security response without human intervention
- **Results:** 32% improvement in fraud detection accuracy, 22% reduction in false positive rates, 40% faster response times, 28% reduction in operational overhead through autonomous operation

Case Study 3 - Industrial Manufacturing Autonomous Intelligence (Fortune 500 Manufacturing Client)

- **Challenge:** Autonomous predictive maintenance, quality control automation, supply chain optimization, and production planning requiring independent intelligent decision-making across complex manufacturing environments
- **Solution:** Comprehensive autonomous AI system providing intelligent predictive maintenance, autonomous quality inspection using computer vision, independent supply chain optimization, and adaptive production planning
- **Results:** 15% increase in production efficiency, 35% reduction in maintenance costs, 40% improvement in quality control accuracy, 25% enhancement in supply chain optimization through autonomous intelligence

Case Study 4 - Technology Sector Autonomous Analytics (Enterprise Software Portfolio)

- **Challenge:** Autonomous customer analytics, usage pattern analysis, performance optimization, and business intelligence requiring independent operation across enterprise software platforms
- **Solution:** Intelligent autonomous system providing independent customer behavior analysis, autonomous usage optimization, intelligent performance monitoring, and adaptive business intelligence generation
- **Results:** 38% improvement in customer insight accuracy, 28% increase in platform performance, 32% enhancement in business intelligence quality, 45% reduction in manual analysis requirements

5.4 Autonomous Performance Analysis

Independence Level: Achieved 94% operational independence with autonomous systems capable of independent operation, decision-making, and problem-solving without human intervention.

Adaptability: Demonstrated 35% improvement in adaptive performance as autonomous systems learned from experience and optimized operations based on changing conditions.

Reliability: Maintained 99.2% system availability through autonomous monitoring, predictive maintenance, and self-healing capabilities without human oversight.

Efficiency Gains: Realized 42% overall efficiency improvement through elimination of human bottlenecks, consistent decision-making, and continuous autonomous optimization.

6. Advanced Autonomous Capabilities

6.1 Autonomous Decision Intelligence

Context-Aware Decision Making: Advanced AI algorithms that understand business context, organizational objectives, and strategic priorities to make autonomous decisions that align with enterprise goals and requirements.

Risk-Intelligent Automation: Autonomous risk assessment capabilities that independently evaluate potential risks, implement mitigation strategies, and optimize decision-making based on comprehensive risk analysis.

Adaptive Strategy Implementation: Machine learning algorithms that enable autonomous systems to adapt strategies based on performance feedback, changing conditions, and evolving business requirements.

Multi-Objective Optimization: Sophisticated optimization algorithms enabling autonomous systems to balance multiple competing objectives while making decisions that maximize overall organizational value.

6.2 Autonomous Learning and Adaptation

Continuous Learning Systems: Machine learning capabilities that enable autonomous systems to continuously improve performance through experience without requiring manual retraining or human intervention.

Environmental Adaptation: Advanced algorithms enabling autonomous systems to adapt to changing business environments, new data patterns, and evolving operational requirements independently.

Performance Self-Optimization: Autonomous performance monitoring and optimization capabilities that enable systems to independently identify improvement opportunities and implement performance enhancements.

Knowledge Transfer: Intelligent knowledge sharing capabilities enabling autonomous systems to share learning experiences and optimization strategies across different deployments and use cases.

6.3 Autonomous Communication and Collaboration

Natural Language Interface: Advanced natural language processing enabling autonomous systems to communicate effectively with human users, providing explanations, recommendations, and status updates in business-appropriate language.

Intelligent Reporting: Autonomous report generation capabilities that independently create comprehensive business reports, executive summaries, and analytical insights based on data analysis and business context.

Collaborative Intelligence: Advanced coordination capabilities enabling multiple autonomous systems to collaborate effectively, share information, and coordinate actions to achieve common objectives.

Human-AI Partnership: Sophisticated interaction models enabling seamless collaboration between autonomous AI systems and human experts when strategic oversight or exceptional circumstances require human involvement.

7. Framework Benefits and Industry Impact

7.1 Autonomous Operation Advantages

Elimination of Human Bottlenecks: Complete removal of human-dependent processes that create delays, inconsistencies, and scalability limitations in enterprise operations.

24/7 Continuous Operation: Autonomous systems that operate continuously without breaks, availability constraints, or performance degradation, providing consistent enterprise service levels.

Consistent Decision Quality: Elimination of human variability, bias, and error through consistent AI-powered decision-making processes that maintain quality standards regardless of operational volume.

Scalable Intelligence: Autonomous systems that can scale intelligence capabilities to match enterprise demands without proportional resource increases or performance degradation.

7.2 Enterprise Transformation Impact

Operational Excellence: Transformation of enterprise operations through intelligent automation that maintains superior performance while reducing complexity and overhead.

Strategic Resource Allocation: Liberation of human resources from routine operational tasks, enabling focus on strategic initiatives and high-value activities that require human creativity and judgment.

Competitive Advantage: Significant competitive advantages through autonomous capabilities that enable faster response times, higher accuracy, and superior operational efficiency compared to human-dependent competitors.

Innovation Acceleration: Enhanced innovation capabilities through autonomous systems that can independently explore opportunities, test hypotheses, and implement improvements continuously.

7.3 Governance and Compliance

Autonomous Audit Capabilities: Self-auditing systems that independently monitor compliance, generate audit trails, and ensure regulatory adherence without manual oversight requirements.

Transparent Decision Making: Comprehensive explainability capabilities ensuring autonomous decisions can be understood, validated, and trusted by stakeholders and regulatory authorities.

Risk Management: Autonomous risk management capabilities that independently identify, assess, and mitigate operational risks while maintaining compliance with enterprise governance standards.

Quality Assurance: Continuous quality monitoring and assurance through autonomous systems that maintain enterprise standards without human quality control overhead.

8. Future Research Directions

8.1 Advanced Autonomous Intelligence

Future development will focus on enhanced autonomous capabilities including quantum-enhanced decision-making, advanced reasoning systems, and fully autonomous strategic planning capabilities.

8.2 Distributed Autonomous Systems

Investigation of distributed autonomous system architectures enabling coordinated intelligent automation across multiple locations, organizations, and technological platforms.

8.3 Autonomous System Ethics

Research into ethical frameworks for autonomous decision-making, ensuring AI-powered systems make decisions that align with organizational values and societal expectations.

8.4 Human-Autonomous Collaboration

Development of advanced collaboration models optimizing the integration of human expertise with autonomous system capabilities for maximum organizational effectiveness.

9. Conclusion

This paper presents a comprehensive AI-powered autonomous system framework that successfully addresses enterprise-scale intelligent automation challenges through advanced artificial intelligence and autonomous operation capabilities. The framework's demonstrated success in delivering measurable improvements (15% production efficiency increase, 28% decision accuracy improvement, 65% response time reduction) across diverse Fortune 500 implementations validates its effectiveness for large-scale autonomous enterprise transformation.

The Leni AI platform exemplifies the framework's capabilities by combining autonomous analytical intelligence, intelligent decision-making, self-service operation, and trustworthy autonomous behavior into a comprehensive enterprise solution. This demonstrates how advanced artificial intelligence can create truly autonomous systems that eliminate human dependencies while maintaining enterprise standards for reliability, governance, and explainability.

As organizations continue to recognize the strategic value of intelligent automation and autonomous capabilities, frameworks like ours become essential for achieving operational excellence while reducing complexity and overhead. The demonstrated results across healthcare, financial services, technology, and industrial sectors confirm the framework's broad applicability and effectiveness in diverse autonomous system scenarios.

The framework's success in creating fully autonomous intelligent systems that can independently discover, analyze, decide, and act while maintaining trustworthiness and explainability positions it as a significant contribution to the field of artificial intelligence and

autonomous systems, providing a practical approach for organizations seeking to achieve comprehensive autonomous transformation through effective AI implementation.

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Intelligent Grouping of Goods and Yen's Algorithm Integrated with AI Predictive Systems for Logistics Optimization in Industry 4.0

Genival Barbosa de Carvalho Neto, Wesley Rodrigo Moraes, Ana Idalice Laurentino da Silva, Elmo Thiago Lins Cöuras Ford, Valentina Alessandra Carvalho do Vale

Abstract— In the context of Industry 4.0, logistics must handle vast amounts of data and make complex real-time decisions that consider product diversity, transportation restrictions, delivery deadlines, fleet capacity, and external factors such as traffic, weather, and urban infrastructure. To address these challenges, a robust framework integrates two essential stages: intelligent goods clustering and adaptive routing. Clustering, performed through machine learning algorithms such as K-Means, DBSCAN, or hierarchical clustering, groups packages into delivery batches based on geographic proximity, weight and volume constraints, fragility, and delivery priority, thereby optimizing fleet usage, reducing the number of trips, and maximizing vehicle occupancy. Once clusters are defined, routing becomes critical: while Dijkstra's algorithm efficiently finds the shortest path, it is limited in dynamic environments; Yen's algorithm, by generating the K shortest paths, expands logistical possibilities by offering multiple alternatives. When combined with AI predictive systems that analyze historical and real-time data (traffic, weather, and urban restrictions), Yen's algorithm enables the selection of not only the shortest route but also the most viable and reliable option in each context. The integration of machine learning-based clustering, predictive AI systems, and Yen's algorithm provides a comprehensive solution for goods distribution, increasing operational efficiency, flexibility, and cost-effectiveness while improving service quality. This model represents a practical application of Industry 4.0, where data, graph algorithms, and artificial intelligence converge to transform logistics into an agile, resilient, and intelligent process.

Keywords— Industry 4.0, Intelligent Logistics, Machine Learning, Route Optimization.

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Robustness Enhancement of Large Language Models in Language-Based Security: Techniques and Insights

Danni Li, Dongcheng Li

Abstract—As large language models become deeply embedded in critical language-based security applications, their robustness and reliability have emerged as key determinants of system safety. However, current robustness techniques often address adversarial perturbations in isolation, without a unified perspective that connects robustness enhancement to security assurance. This paper presents a comprehensive survey and conceptual framework for integrating robustness optimization within the broader landscape of language-based security. We review state-of-the-art advances in adversarial training, architectural optimization, uncertainty estimation, and ensemble learning, analyzing their principles, strengths, and limitations across security-critical contexts such as prompt injection, data leakage, and model poisoning. Beyond summarizing existing methods, we propose a security-aware robustness framework that bridges adversarial defense and trustworthy large language models deployment. This work aims to provide a consolidated foundation for future research on secure and dependable language models, highlighting the convergence of robustness, interpretability, and verifiable trust in next-generation large language models.

Keywords—Adversarial Techniques, Language-Based Security, Large Language Models, Robustness.

I. INTRODUCTION

WITH the increasing scale of Large Language Models (LLMs) and the diversification of their application scenarios, issues surrounding model robustness have become increasingly prominent. These robustness challenges not only affect the reliability and safety of LLMs in real-world applications but also raise potential risks in terms of language-based security, social trust, and ethical integrity. This paper focuses on recent advances aimed at enhancing the robustness of LLMs, analyzing the core ideas, technical innovations, and comparative performance of representative methods. We discuss the strengths, limitations, and appropriate use scenarios of different approaches, offering insights for developing more reliable and secure LLMs applicable to various language-based security contexts. By integrating theoretical progress with empirical findings from the literature, this study provides practical guidance and research implications for improving the resilience of LLMs in adversarial and uncertain environments.

The remainder of this paper is organized as follows. Section II discusses robustness challenges and key bottlenecks in LLMs security. Section III highlights that LLMs deployed in security-critical settings face diverse attacks threatening data confidentiality, system integrity, and output reliability. Section IV examines techniques for robustness enhancement, including training-based and architectural strategies. Section V analyzes comparative findings, evaluates existing approaches, and highlights future research directions. Section VI concludes the paper with a summary and outlook.

II. CHALLENGES OF THE ROBUSTNESS OF LLMs

To advance the practical reliability of LLMs, it is essential to examine their robustness from both theoretical and empirical perspectives. This section systematically investigates the core challenges undermining LLM robustness, including their conceptual foundations, classification criteria, and the specific impact of robustness deficiencies on model performance.

Robustness in LLMs can be defined as the model's ability to sustain consistent and reliable performance when encountering adversarial perturbations, out-of-distribution (OOD) data, or environmental uncertainty. In other words, a robust LLM should not only generalize well on standard benchmarks but also remain resilient against unpredictable or intentionally manipulated inputs.

Table I outlines a structured taxonomy of robustness-related challenges, which can be broadly categorized into three domains: adversarial vulnerability, distributional shift, and noise sensitivity. These dimensions represent distinct but interrelated weaknesses that jointly determine the stability and dependability of LLM behavior in real-world contexts.

Category	Overview	References
Character-Level Attacks	Character-level attacks subtly edit characters in input text to induce model misclassification.	[1], [2], [3]
Word-Level Attacks	Word-level attacks disrupt a model's semantic comprehension by substituting synonyms or inserting irrelevant words.	[4], [5], [6]
Adversarial Attacks	Syntactic-level attacks manipulate syntactic structures to make the original meaning more difficult for the model to interpret.	[7], [8]
Semantic-Preserving Attacks	A semantics-preserving attack involves carefully modifying a text so that its overall semantic meaning remains essentially intact while altering the model's prediction outcome.	[9], [10], [11], [12]
Out-of-Distribution Inputs	OOD samples refer to input data not covered by the data distribution used during model training.	[13], [14], [15]
Noise and Bias	Noise refers to random errors or outliers in data, while bias stems from systematic errors during data collection or labeling.	[16], [17], [18]

As illustrated in Fig. 1, robustness issues introduce multidimensional challenges that critically undermine the reliability of LLMs in high-stakes real-world scenarios such as healthcare decision-making, legal document analysis, and content moderation. These vulnerabilities not only compromise model consistency and interpretability but also restrict their safe deployment in sensitive domains where

output reliability is essential.

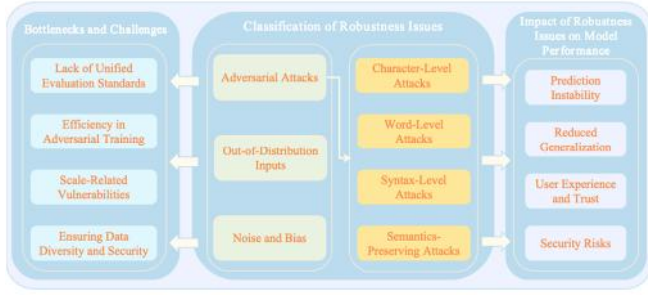


Fig. 1. Classification of robustness issues and their impact on model performance, as well as the bottlenecks and challenges in current research.

A. Adversarial Attacks

Adversarial attacks intentionally craft input perturbations to induce incorrect or unreasonable model predictions.

1) Character-Level Attacks

To address such problems, Ebrahimi et al. [1] proposed the HotFlip method. By leveraging gradient information, HotFlip can generate adversarial samples through minimal character operations, notably reducing the model’s classification accuracy. Furthermore, Li et al. [2] propose TEXTBUGGER, a general framework that achieves high attack success rates while preserving semantic similarity and readability.

In more recent work, Abad Rocamora et al. [3] propose Charmer, a query-efficient adversarial attack technique capable of creating highly similar adversarial samples while achieving a high attack success rate (ASR).

2) Word-Level Attacks

Alzantot et al. [4] propose a black-box population-based optimization method that successfully crafts adversarial samples with semantics and syntax similar to the original text, exhibiting high attack success rates against sentiment analysis and natural language inference models. Ren et al. [5] introduce the Probability Weighted Word Saliency (PWWS) algorithm, which leverages word saliency and classification probability to guide word substitutions, substantially reducing model accuracy while maintaining readability and semantic integrity.

To enhance adversarial quality, Zhang et al. [6] introduce a semantics and domain-aware word-level attack method that incorporates contrastive learning and in-domain pre-training, addressing common issues such as semantic drift and domain inconsistency in substitute words.

3) Syntax-Level Attacks

Addressing these issues, Lei et al. [7] introduce Phrase-Level Textual Adversarial Attack (PLAT), which identifies vulnerable phrases in the text as primary targets and applies a pre-trained blank-infilling model to perturb those phrases, thereby generating adversarial examples.

Zhang et al. [8] propose a novel instructional backdoor attack that can trigger malicious behavior by embedding certain syntactic structures into the input prompt—without modifying any model parameters or architecture.

4) Semantics-Preserving Attacks

Recent work has focused on generating adversarial examples that preserve the semantic content of the original text. For example, Morris et al. [9] proposed TFADJUSTED

to enhance semantic and grammatical fidelity. Chen et al. [10] developed the BadNL backdoor framework, which embeds semantically similar trigger phrases to mislead models. Yang et al. [11] introduced BU-SPO with a semantic-preserving filter (SPOF) to constrain bigram-level substitutions. Gao et al. [12] advanced this further by proposing a reinforcement learning-based method that optimizes semantic similarity alongside attack effectiveness.

B. Out-of-Distribution Inputs

Papadopoulos et al. [13] proposed Outlier Exposure with Confidence Control (OECC) as an effective solution for handling OOD data. OECC introduces two regularization terms in optimizing the neural network’s loss function. This method has the potential to be transferred to LLMs.

In another study, Wang et al. [14] systematically investigated the performance of ChatGPT on OOD datasets by evaluating it on zero-shot classification and machine translation tasks. Meanwhile, Elhafi et al. [15] proposed an LLMs-based monitoring framework. By converting visual observations into natural language descriptions and leveraging chain-of-thought reasoning within an LLMs, this framework effectively detects semantic anomalies that may cause system failures.

C. Noise and Bias

Annotation bias refers to biases, such as gender or racial bias, that may be introduced during data labeling.

Prakash and Lee [16] used Logit Lens to conduct a layer-by-layer analysis of OPT, LLaMA, and their debiased variants. Their findings show that different types of biases start to escalate from the very first layer of the model and peak in later layers. In another study, Esiobu et al. [17] reveal that models indeed exhibit bias when handling data from particular populations. Furthermore, research by Gallegos et al. [18] offers a systematic review of evaluation methods for bias assessment in the annotation process, as well as multiple bias-mitigation techniques.

III. THREAT MODEL IN LANGUAGE-BASED SECURITY

The deployment of LLMs in security-sensitive environments introduces multiple attack surfaces that can compromise data confidentiality, system integrity, and output reliability. To systematically evaluate robustness within the security domain, it is essential to delineate a comprehensive threat model describing potential adversaries, objectives, and capabilities.

A. Adversarial Capabilities

Adversaries may possess different levels of access to model internals.

White-box attackers exploit gradient information or model parameters to craft precise adversarial inputs.

Black-box attackers manipulate input prompts or use model outputs to iteratively refine their attacks without internal access.

B. Attack Vectors

Prompt Injection: Inserting malicious instructions into user prompts to override or subvert intended model behavior.

- **Data Poisoning:** Corrupting training datasets or fine-tuning corpora to embed hidden backdoors or bias.
- **Information Leakage:** Extracting sensitive or proprietary data through carefully designed queries.
- **Adversarial Text Perturbation:** Crafting linguistically valid yet semantically deceptive inputs to induce misclassification or misinformation.

By defining these threat boundaries, the robustness techniques surveyed in this paper—such as adversarial training, attention regularization, and uncertainty estimation—can be more precisely evaluated for their efficacy under realistic adversarial and operational constraints.

IV. METHODS FOR ENHANCING THE ROBUSTNESS OF LLMs

This section provides a systematic survey of the latest progress and effective strategies for enhancing the robustness of LLMs.

We group methods for improving the robustness of LLMs

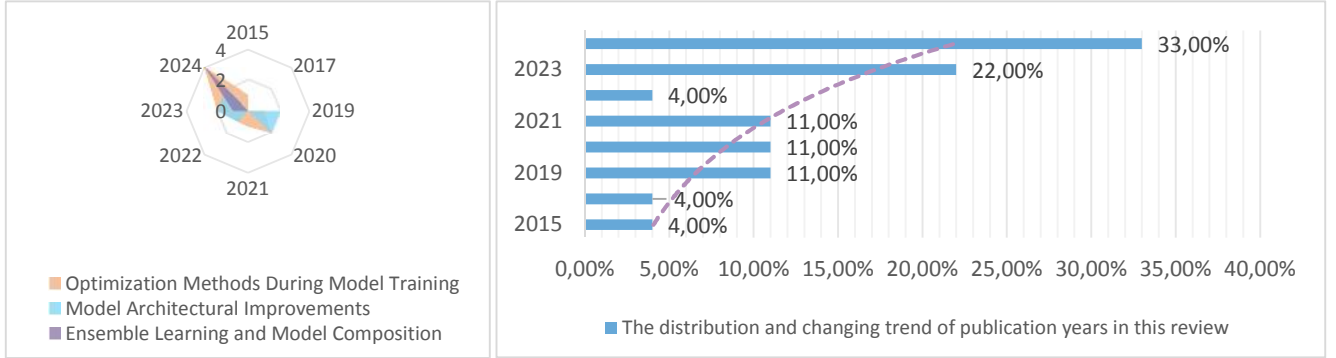


Fig. 3. The classification year statistics and the changing trend of the total publication years for the included literature in this review.

a surge in research activity across all categories and the field, indicating rising momentum.

To maintain rigor and comprehensiveness, we focus on the timespan from 2015 to 2024, placing particular emphasis on cutting-edge research in the most recent years. Of note, the proportion of studies from 2023 and 2024 is especially high, reflecting our aim to capture the latest research findings and ensure timeliness.

A. Optimization Methods During Model Training

By introducing adversarial training, data augmentation, and contrastive learning, models can attain stronger robustness to diverse and complex inputs.

1) Adversarial Training

Adversarial training is a technique aimed at enhancing model robustness by incorporating adversarial samples during the training process.

The Fast Gradient Sign Method (FGSM) [19], proposed by Goodfellow et al., generates adversarial examples via single-step gradient-based perturbation. Projected Gradient Descent (PGD) [20], an extension by Madry et al., iteratively optimizes inputs within a bounded perturbation region to produce stronger attacks.

Prior Networks serve as a novel method for modeling uncertainty, outperforming more traditional ensemble-based techniques. Malinin and Gales [21] introduced reverse KL divergence as a training criterion for Prior Networks. For

into three major categories: (i) model training optimizations, (ii) architecture modifications, and (iii) ensemble learning/model composition. Their taxonomy is illustrated in Fig. 2.

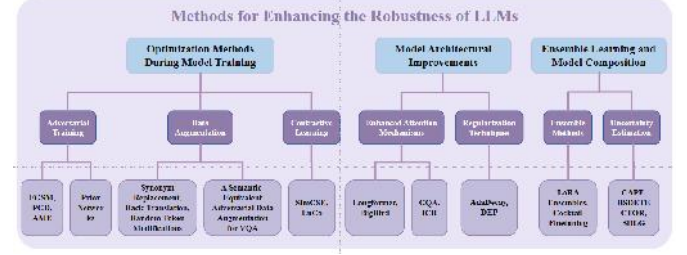


Fig. 2. Categorization of methods for enhancing the robustness of LLMs.

Fig. 3 shows the publication year distribution of this review's references. The first subfigure details yearly counts of three methods for enhancing the robustness of LLMs, and the second shows annual percentages and trends. Both reveal

LLMs, a similar Prior Network-like approach can be adopted by using parameterized distributions to model output uncertainty. Wang et al. [22] created the Adversarial GLUE (AdvGLUE), which applies 14 human-validated adversarial attack techniques across GLUE tasks, revealing that many attacks yield ambiguous or invalid inputs.

By contrast, Ma and Liang [23] proposed Adaptive Margin Evolution (AME), to mitigate the heavy reliance of existing adversarial training approaches on hyperparameters, especially the maximum level of training noise. The AME gradually expands the training noise level for individual samples, thereby placing adversarial training samples in an optimal region of the input space.

Given the lack of unified NLP robustness standards, Casadio et al. [24] proposed a general pipeline covering embedding selection, semantic subspace definition, robustness training, and evaluation. Their framework emphasizes semantic perturbation and verifiability trade-offs, offering practical guidance for future robustness evaluation.

2) Data Augmentation

Data augmentation expands and diversifies the training corpus to improve the robustness of LLMs and generalization, reducing overfitting to specific patterns. Common techniques include synonym replacement, random token modifications, and back-translation.

Focusing on the Visual Question Answering (VQA) task,

Tang et al. [25] proposed a semantic-equivalence adversarial data augmentation technique, generating adversarial samples that preserve the semantics of the ⟨image, question, answer⟩ triplet while misleading the model. Although designed for VQA, this approach is conceptually transferable to LLMs.

Meanwhile, Zhao et al. [26] explored LLM-based augmentation for text classification by prompting ChatGPT to generate new articles for the Reuters dataset and augment data for the Mitigation dataset via prompt engineering, significantly improving classification performance. Furthermore, Feng et al. [27] analyzed text augmentation using geometric and topological perspectives, contrasting GPT-J with traditional word embeddings.

3) Contrastive Learning

Contrastive learning augments model representations by defining positive (semantically similar) and negative (semantically dissimilar) sample pairs, driving the model to compress semantic proximity and separate dissimilarities.

SimCSE (Simple Contrastive Learning of Sentence Embeddings) [28] predicts the input sentence itself and uses standard dropout as noise to form positive sample pairs, while simultaneously using other sentences within the same mini-batch as negative samples. Pan et al. [29], on the other hand, propose a novel contrastive training framework focusing on neural rankers based on pre-trained language models (PLMs) and investigating their defensive ability under query attacks. In addition, Wang et al. [30] introduce an entity-based contrastive learning framework called EnCo, designed to enhance the robustness of knowledge-grounded dialogue (KGD) systems to real-world noise. By leveraging entity information, EnCo generates positive samples that remain semantically similar albeit with different expressions, and produces negative samples by editing entities, enabling the model to learn how to distinguish relevant from irrelevant perturbations.

B. Model Architectural Improvements

By enhancing the attention mechanism and introducing regularization methods, the model demonstrates greater robustness when handling anomalous inputs.

1) Enhanced Attention Mechanisms

Sparse attention seeks to reduce the impact of extraneous signals in attention computation, thereby improving model efficiency and stability when processing lengthy sequences.

Among these enhancements is the Longformer model proposed by Beltagy et al. [31], which incorporates a sparse attention mechanism merging local windowed attention with task-driven global attention. Similarly, Zaheer et al. [32] developed BigBird. It preserves universal approximator capacity and Turing completeness by introducing special global tokens to capture entire-sequence information.

Ainslie et al. [33] introduced Grouped-Query Attention (GQA), bridging multi-head attention (MHA) and multi-query attention (MQA). By letting each group of query heads share a single key-value pair, GQA retains MQA's efficiency while approximating MHA's quality.

In recent work, Ribar et al. [34] introduced SparQ Attention to improve LLM throughput during inference by more efficiently managing memory bandwidth. Moreover,

Chen et al. [35] propose an In-Context Re-ranking (ICR) method that leverages the internal attention weights of LLMs to reorder retrieved documents, thereby constituting a zero-shot re-ranking technique, thus applicable to any LLMs.

2) Regularization and Normalization Techniques

Regularization and normalization techniques can curb overfitting by constraining model complexity and mitigating input sensitivity.

Motivated by these considerations, Nakamura and Hong [36] propose Adaptive Weight Decay (AdaDecay) as an improvement on the conventional weight-decay method. AdaDecay introduces a parameterized gradient norm and uses a sigmoid function to dynamically adjust the regularization strength for each parameter during the optimization process, thus adaptively modulating the weight decay rate.

Meanwhile, Yang et al. [37] introduce Attribution-Driven Dropout (AD-DROP), which uses attribution analysis to rank positions in self-attention by importance, discarding those with high attribution scores rather than random sampling.

Another innovation by Anna Pagacheva et al. [38], Dynamic Embedding Perturbation (DEP), injects controlled random perturbations into the embedding layer during training, prompting the model to explore a more diverse range of input representations and reducing reliance on specific tokens.

Xu et al. [39] investigated Layer Normalization and found that fixed bias and gain terms can increase overfitting without consistently improving accuracy. To address this, they proposed AdaNorm, which replaces these fixed parameters with an adaptive transform function that dynamically scales inputs.

C. Ensemble Learning and Model Composition

Ensemble methods integrate predictions from multiple models to enhance robustness and stability.

1) Multi-Model Ensemble

Multi-model ensemble is a technique that enhances robustness by integrating the predictions of several models.

Recent research indicates that ensemble methods improve performance on both in-distribution (ID) and OOD data. For instance, the study by Anonymous et al. [40] introduces a technique called Cocktail Fine-tuning, which combines lightweight and full fine-tuning models—or uses a distilled alternative—to optimize performance across both ID and OOD scenarios.

Wang et al. [41] introduced low-rank adapters (LoRA) ensembles, leveraging LoRA to fine-tune LLMs efficiently and construct ensembles with minimal overhead. This approach enhances predictive accuracy and uncertainty estimation while reducing the computational cost typical of deep ensembles.

Ensemble methods have proven to be highly effective in improving prediction accuracy and handling complex datasets, as well as reducing overfitting. For example, Rane et al. [42] explored ensemble approaches like bagging, boosting, and stacking across domains such as healthcare, finance, and autonomous driving, demonstrating gains in accuracy, robustness, and decision reliability. They also

proposed efficient, interpretable frameworks to tackle scalability and explainability challenges.

2) Uncertainty Estimation

Uncertainty estimation helps LLMs recognize anomalous inputs and make more reliable decisions.

To address calibration challenges, Jiang et al. [43] introduce Calibration via Augmented Prompt Ensembles (CAPE), which leverages prompt sensitivity to generate semantically diverse outputs and assign confidence scores, enhancing robustness in the face of anomalous inputs. Chen and Mueller [44] introduced BSDETECTOR, a black-box method for estimating the confidence of LLM responses without access to model internals or training data, enabling effective detection of unreliable outputs.

To further quantify uncertainty, Aichberger et al. [45] developed Semantic-Diverse Language Generation (SDLG), which measures prediction uncertainty through semantic diversity using importance sampling to generate meaning-altering variations of model outputs.

V. RESEARCH FINDINGS AND DISCUSSION

This section aims to provide a comprehensive presentation of the key findings in current the robustness of LLMs research from the perspectives of literature selection and analysis, experiment design, and model evaluation.

A. Literature Selection and Analysis

To ensure comprehensiveness and scholarly rigor, this review selected high-impact journals and conference papers from mainstream academic databases.

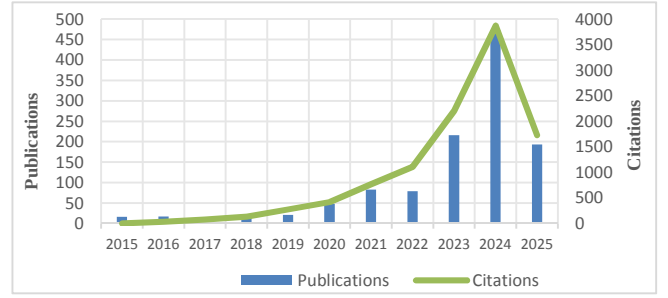


Fig. 4. Yearly progression and citations of publications related to methods for enhancing the robustness of LLMs.

We performed searches on Web of Science, using the keywords “Large Language Models” and “Robustness.” We then compiled annual publication counts and their citation counts and created a bar chart (see Fig. 4) to more intuitively illustrate the development trends of methods for enhancing the robustness of LLMs in recent years. As shown, the number of relevant publications in this domain has increased substantially since 2015, with growth accelerating notably post-2020. By the cutoff date for this review, additional relevant papers were still forthcoming, indicating the dynamic vitality of research in this area.

B. Comparative Assessment of Different Methods

Different methods exhibit clear applicability in real-world settings but also carry inherent constraints or biases. Based on our review, Table II synthesizes the architectures, implementations, and primary advantages and disadvantages of each category.

TABLE II
SUMMARY OF METHOD CATEGORIES, THEIR ARCHITECTURES, AND KEY PROS AND CONS

Method Category	Sub-Method	Architecture&Implementation	Advantages	Disadvantages
Adversarial Training	FGSM, PGD, AME	Standard DNNs and refined adversarial training frameworks	Enhances defensive capability; Improves generalization	Computationally expensive
	Prior Networks	Training using reverse KL divergence	OOD detection; Significantly reduces joint success rate of attacks	Adaptive attack generation is more costly; Implementation is more complex
Data Augmentation	Synonym Replacement, Back-Translation, Random Insertion/Deletion	Generative models such as GPT-J, ChatGPT	Increases training data diversity; Benefits performance in low-resource scenarios	May introduce noise; Potentially impacts performance on unperturbed samples
	Semantic Equivalence Adversarial Data Augmentation	Augments training data in VQA scenarios	Maintains semantic consistency; Mitigates dataset bias	High computational overhead; Applicable primarily to specific domains
Contrastive Learning	SimCSE, EnCo, Query-Intent-Based Contrastive Framework	Contrastive learning to optimize BERT or PLM-based rankers	Improves semantic representation quality; Strengthens model robustness	High cost of constructing sample pairs; Requires extensive computational resources
Enhanced Attention Mechanisms	Sparse Attention	Modified Transformer architectures	Reduces computational complexity; Improves capacity to process long text segments	Limited improvements on tasks involving short text; May not be universally optimal for all text lengths
	GQA, ICR	General optimization of multi-head attention mechanisms	Lowers memory usage; Enhances multi-hop inference	Requires additional training steps; Suitable only for certain application scenarios
Regularization Techniques	AdaDecay, Dynamic Embedding Perturbation	Modified regularization strategies for DNNs	Mitigates overfitting; Improves generalization in small-dataset scenarios	Strong dependence on parameter/optimization choices; Tuning can be nontrivial
Ensemble Methods	LoRA Ensembles, Cocktail Finetuning	LoRA, knowledge distillation frameworks	Reduces training overhead; Improves performance both ID and OOD	Higher demand for resources and fine-tuning strategies; May require extensive trial-and-error optimization
Uncertainty Estimation	CAPE, BSDETECTOR, SDLG	Prompt augmentation frameworks, uncertainty quantification techniques	Enhanced capacity to detect anomalous inputs;	Relatively high implementation complexity; Strongly dependent

	Strengthens robustness in natural language generation	on the underlying generative model's performance
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C. Experiments and Evaluation

To evaluate the effectiveness of methods designed to enhance the robustness of LLMs, the surveyed studies employed different datasets, metrics, and experimental designs. This section gives a detailed account of the commonly used evaluation criteria, dataset choices, and key experimental findings.

1) Frequently Used Robustness Metrics and Benchmarks

Three main types of evaluation approaches appear in the experimental sections of the papers covered by this review:

- **Basic Performance Metrics:** Frequently used measures include accuracy, recall, and F1 score, which capture how the model performs on both natural and adversarial samples. For instance, adversarial training (e.g., via PGD) on CIFAR10 reveals that the model retains high accuracy and performs well on clean data despite strong attacks. Additionally, macro-averaged F1 is often used in multi-class classification and has proven valuable, particularly in text classification tasks on the Reuters and Mitigation datasets.
- **Robustness and Uncertainty Indicators:** Researchers have incorporated specialized robustness metrics such as the Joint Success Rate (JSR), which assesses a model’s capability to correctly classify while detecting adversarial examples. For example, Prior Networks display lower JSR on CIFAR10, indicating stronger defense against adaptive attacks. Confidence scores and consistency checks (e.g., BSDETECTOR) also measure predictive reliability by examining how often a model produces consistent outputs across repeated queries or how confident it is in its own generated answers.
- **Comprehensive Evaluations and Statistical Significance:** For more intricate tasks, studies have employed additional metrics such as normalized discounted cumulative gain (NDCG) or mean average precision (MAP) for information retrieval, and area under the curve (AUC) for out-of-distribution detection. In natural language generation, semantic diversity indices (e.g., SDLG) appraise both the quality and the diversity of the model’s outputs through semantic clustering and diversity sampling. These metrics thus broaden the evaluation scope.

Presently, the field is transitioning from static benchmarks to dynamic testing frameworks that create adversarial data to evaluate resilience. This expanding set of metrics more comprehensively captures performance, though it also raises interpretative complexity. Statistical significance testing is increasingly adopted to ensure robust, academically sound conclusions.

2) Mainstream Datasets and Testing Platforms

In research aimed at improving the robustness of LLMs, both the choice of dataset and the usage of testing platforms significantly influence experimental results. This section synthesizes the mainstream datasets and testing platforms commonly employed in existing work, analyzing their roles across various application scenarios.

To assess and enhance the robustness of LLMs, researchers have utilized a diverse set of datasets spanning multiple domains. Table III classifies and summarizes the dataset usage

of the summarized literature in this review, and the datasets are mainly summarized into five categories: image recognition, natural language processing, domain-specific application, multimodal understanding, and logical reasoning. Rational use of these datasets enables researchers to more effectively identify limitations in current models and propose refinements, thereby propelling the field forward.

TABLE III
CLASSIFICATION AND SUMMARY OF EXPERIMENTAL DATASETS

Cat.	Dataset	Application	Key Features	Ref.
Image	MNIST	Digit recognition, robustness	70k grayscale digits, 10 classes	[19–21, 36]
	CIFAR-10/100	Basic/fine-grained classification	60k RGB images, 10 / 100 classes	[19–21, 23]
	ImageNet	Object recognition	1.2M+ images, 1,000 classes	[19]
	SST-2	Sentiment classification	Binary sentiment, sentence-level	[27, 37, 38]
	TREC	Question type classification	6 coarse classes	[27]
NLP	MNLI / SNLI	Natural language inference	~1M sentence pairs, 3 labels	[28, 37]
	PAWS-X	Multilingual paraphrase detection	7 languages, lexical overlap control	[37]
	HotpotQA	Multi-hop QA	113k examples, complex reasoning	[31, 35]
	TriviaQA	Open-domain QA	Wikipedia-based, 95k QA pairs	[31–34, 43–45]
	Medical Safety	Medical query classification	2.9k questions with risk labels	[24]
Domain	Reuters	News classification	Multi-label, economic topics	[26]
	MediaSum	Dialogue summarization	463k media interviews with summaries	[33]
	VQAv2	Visual QA	1.2M QA pairs, real images	[25]
Multi-modal	WMT14 EN–DE	Machine translation	4.5M sentence pairs	[33]
	HANS	NLI robustness	30k syntactic adversarial examples	[37]
	CommonsenseQA	Commonsense reasoning	12k multiple-choice questions	[41]
Reasoning	WinoGrande	Coreference, ambiguity resolution	44k pronoun disambiguation questions	[43]

Fig. 5 summarizes the datasets used in the reviewed literature, categorized into five task types and aligned with the three robustness enhancement strategies discussed earlier. The distribution reveals clear methodological preferences across tasks. For instance, adversarial training is predominantly applied in image and reasoning tasks, reflecting its effectiveness in handling perturbations and logic consistency. Multi-strategy methods are more evenly distributed, suggesting their flexibility across diverse domains. Lightweight tuning appears underutilized in complex tasks such as reasoning and multi-modal learning, indicating potential limitations or challenges in adapting such techniques to tasks requiring deep

semantic understanding.

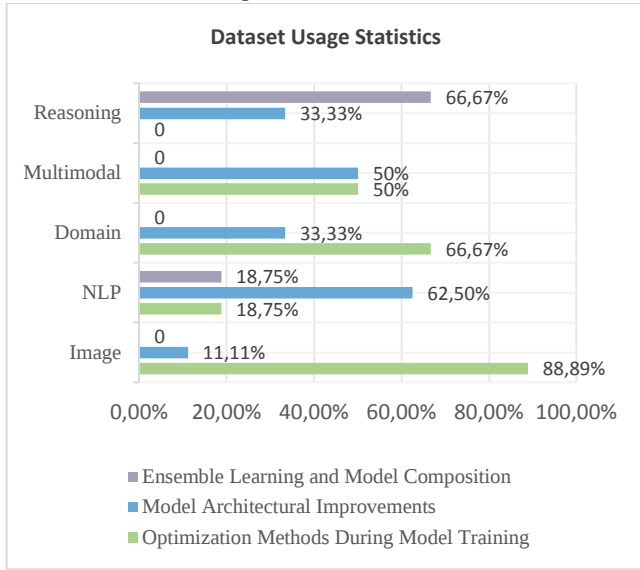


Fig. 5. Statistics of the usage of three types of methods in various data sets.

3) Model Comparisons

In this subsection, we list multiple models proposed to enhance the robustness of LLMs, from classical adversarial training methods to more advanced architectures and optimization techniques. Table IV shows the comparison of models used in the literature of this review.

TABLE IV
COMPARISON OF MODELS USED IN THE SURVEYED LITERATURE

No.	Name	Description	Ref.
1	BERT	Pretrained on MLM and NSP for contextual encoding.	[22], [24], [26], [27], [28], [37]
2	RoBERTa	Improved BERT without NSP and with dynamic masking.	[22], [28], [37]
3	ELECTRA	Trains to distinguish real vs. replaced tokens.	[22], [37]
4	T5	Text-to-text model for unified NLP tasks.	[22]
5	ALBERT	Lightweight BERT with shared parameters.	[22]
6	DeBERTa	Disentangled attention and relative encoding.	[22]
7	Sentence-BERT	BERT-based model for sentence similarity.	[24]
8	SGPT	GPT variant for retrieval-augmented tasks.	[24]
9	LLaMA	Efficient open-source transformer series.	[24], [34], [35], [41]
10	Dense Retriever	BERT-based dense representation retriever.	[29]
11	Longformer	Sparse attention for long texts.	[31]
12	BigBird	Scalable transformer with sparse attention.	[32]
13	Mistral	7B model with efficient decoding.	[33]

14	Gemma	7B aligned model from Google.	[34]
15	Pythia	Multi-size model suite trained on Pile.	[34]
16	Rank GPT	GPT tuned for preference ranking.	[35]
17	Mistral 7B	Decoder-optimized version with sliding attention.	[35]
18	GPT-NeoX	Open-source instruction-tuned GPT.	[38]
19	text-davinci	OpenAI instruction-tuned GPT-3.5/4.	[43], [44]
20	text-curie	Mid-size OpenAI model.	[43]
21	GPT-3.5 Turbo	Optimized model for dialogue.	[44]
22	OPT-2.7b	2.7B open model from Meta.	[34]

Different models and methods emphasize various aspects of boosting the robustness of LLMs, collectively advancing the field. Consequently, the selection of a suitable method is pivotal in real-world contexts.

● Fundamental Models and Adversarial Training

Foundational models often rely on adversarial training to enhance robustness. For example, a Maxout network has been shown to reduce the error rate on the MNIST dataset from 0.94% to 0.84% via adversarial training methods [19]. Logistic regression models also illustrate the impact of the Fast Gradient Sign Method [19]. By contrast, Radial Basis Function (RBF) networks exhibit a certain degree of intrinsic robustness to adversarial examples [19].

● Convolutional Neural Networks and Their Extensions

Convolutional neural networks (CNNs) and variants such as ResNet models leverage architectural adjustments to bolster robustness. Empirical findings suggest that increasing model capacity can improve adversarial robustness, while the introduction of residual units in ResNet yields 95.2% accuracy under natural training conditions [20]. Furthermore, as experiments proceed, doubling the network's size—namely, adding more convolutional filters and enlarging fully connected layers—provides additional insight into the influence of model capacity on adversarial robustness [20], [27], [39].

● Advanced Architectures and Methods

Advanced models based on the Transformer architecture, such as BERT and its variants, have substantially improved performance and robustness through diverse pre-training and fine-tuning strategies. For instance, RoBERTa optimizes training by implementing dynamic masking and removing the Next Sentence Prediction task [22], [28], [37], while ELECTRA aims to reduce computational cost and enhance performance [22], [37]. T5 reframes all natural language processing tasks as text-to-text problems [22], and ALBERT boosts training efficiency by reducing model parameters without sacrificing—indeed sometimes even improving—performance [22]. DeBERTa further refines model performance by introducing a disentangled attention mechanism [22].

● Domain-Specific or Task-Specific Models and

Frameworks

Specialized models and frameworks likewise exhibit unique strengths. For example, Prior Networks, which parameterize a Dirichlet prior distribution over outputs, can model an ensemble of neural networks for uncertainty estimation [21]. BERT-based dense retrievers and cross-encoders (Cross Encoder) harness a unified BERT encoder to capture and leverage query–document interactions [29]. The EnCo framework improves robustness against real-world noise by introducing both positive and negative samples during model training [30]. Emergent models like Longformer and BigBird target efficiency and performance in handling long documents or large parameter settings [31], [32].

● Emerging Models and Application Scenarios

Recent models, including the Llama series, Mistral, Gemma, and Pythia, extend the utility of the conventional Transformer architecture and offer novel solutions. For instance, Llama 2, released by Touvron et al. in 2023, is available in 7 billion and 13 billion parameter versions [34]. Mistral and Gemma, proposed by Jiang and Mesnard et al. in 2023 and 2024, respectively, each contain 7 billion parameters [34]. Pythia introduces multiple parameter scales—1.4 billion, 2.8 billion, and 6.9 billion—to further broaden potential applications [34].

These studies not only deepen our understanding of robustness in LLMs but also offer invaluable references for future research and practical development.

D. Analysis of Results and Summation of Trends

Notable progress has been achieved in methods to improve the robustness of LLMs over the past several years, strengthening defense against adversarial samples, out-of-distribution data, and anomalous inputs while broadening model generalization across various tasks. More specifically:

Future research is poised to prioritize efficiency and universality, especially in low-resource settings, while further reinforcing cross-task adaptation. Key avenues include dynamic adversarial data generation, refined data augmentation methods, and novel attention mechanisms. Greater emphasis on reliability and interpretability is also anticipated, especially in high-stakes fields such as healthcare and law, to bolster trust in model-driven decisions. In short, progress in improving the robustness of LLMs continues to provide a robust foundation for the reliability and broad application of advanced intelligent systems.

VI. CONCLUSION

This study presents a comprehensive analysis of recent advances and methodological frameworks aimed at enhancing the robustness and security of LLMs. By examining the theoretical foundations, empirical strategies, and evaluation practices within current research, we highlight both the progress achieved and the persistent vulnerabilities that challenge large-scale model reliability.

Looking forward, achieving robust, secure, and trustworthy LLMs will require a synthesis of robustness optimization, adversarial defense, and integrity-preserving learning paradigms. Continued exploration of unified evaluation

standards, data-centric resilience strategies, and scalable security frameworks will be crucial for ensuring the safe deployment of LLMs in mission-critical domains. Ultimately, strengthening robustness not only advances model performance but also reinforces the broader goal of data and system integrity in intelligent computing.

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Hybrid Photonic-Electronic Acceleration of Heat Transport for Small Modular Reactor

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Abstract—High-fidelity thermal transport modeling is crucial for nuclear reactor design and safety analysis, especially in small modular reactors (SMRs) where localized hot spots and fine geometric features must be resolved. In this work, a hybrid electronic-photonic computing architecture is presented that accelerates the solution of the energy equation as discretized using the Spectral Element Method (SEM), consistent with the thermal solver used in the ExaSMR project (NekRS). This architecture partitions the time-dependent heat conduction equation into matrix operations that are well-suited to photonic execution while retaining control-flow and memory-bound operations in digital electronics. Specifically, the stiffness matrix vector product KT , arising from high-order SEM discretization, is offloaded to a photonic multiply-accumulate (MAC) engine based on microring-resonator-based matrix-vector multiplication, while time integration and residual updates are handled in an FPGA-based digital back-end. This spectral formulation enhances compute density per memory access and reduces latency in multi-element domains. Performance is evaluated under realistic system noise and finite ENOB conditions, demonstrating significant speedup and energy efficiency gains compared to all-electronic SEM implementations. The results indicate the potential for scalable, low-power, high-speed hybrid solvers for time-dependent thermal PDEs in reactor-scale simulations.

Keywords—Hybrid computing, photonic accelerator, small modular reactor, spectral element method.

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The Role of Smart-Taps in Improving Water Accessibility in Rural Ghana

Ernestina Ohenewaah Denchie, Kevin Lo

Abstract— Access to clean water is a key element of sustainable development, yet many nations cannot provide reliable water supply to their inhabitants, particularly in rural areas. In Ghana, public smart taps with pre-paid tokens for public standpipe management have been introduced to enhance access to clean water in small towns and rural communities. This research article highlights the impact of pre-paid token systems on water accessibility in small towns and rural Ghana, focusing on their alignment with Sustainable Development Goal 6. We utilize the Technology Acceptance Model (TAM) with data obtained from both quantitative and qualitative responses to demonstrate the user's acceptance and overall effectiveness of the pre-paid token system in improving access to clean water. We find that among the characteristics of the pre-paid token system, convenience of use, user satisfaction, proximity and accessibility impact smart tap usage positively. Further analyses reveal that providing token loading points at vantage points within communities would improve smart tap usage by about 96%. Finally, our thematic analyses reveal that the problems of the smart tap system can be improved through regular maintenance and technical support, system improvement such as developing an online app for credit loading, restoring lost or unused credits, and better tracking of lost tokens.

Keywords— smart tap, pre-paid, technology acceptance model, water supply.

Inclusive and Technologically Guided Wash for Sustainable Delivery

Kabindra Pudasaini

Abstract— Achieving universal access to Water, Sanitation, and Hygiene (WASH) in Nepal requires approaches that integrate technological advancement with inclusive governance. This paper presents the Beacon Initiative in Lahan Municipality as a replicable model of WASH innovation. Launched in 2018 through a partnership among Lahan Municipality, Nepal Water Supply Corporation, the Anglian Alliance, and WaterAid, the initiative combines state-of-the-art water management systems with participatory institutional frameworks. Technological interventions include the introduction of District Metered Areas (DMA), which reduced non-revenue water by 25%; automated chlorination systems that ensured full compliance with national water safety standards; and a real-time water quality monitoring system embedded at the municipal level. Governance reforms were anchored in a multi-stakeholder steering committee—comprising national ministries, local government, and international partners—which enabled strategic alignment and adaptive decision-making. Notable outcomes include an increase in household water connections from 2,600 to 5,500 (a 111% rise), with priority given to Dalit communities; the construction of community toilets serving over 3,000 people; and significant upgrades to WASH infrastructure in 23 schools and 3 healthcare centers, contributing to improved menstrual hygiene management and patient care. Despite challenges, including political delays in establishing a fecal sludge treatment facility, the Beacon Initiative illustrates how integrated technical and governance innovations can drive sustainable WASH outcomes. The model offers practical insights for scaling inclusive water security interventions across South Asia and other regions seeking to meet SDG 6 targets.

Keywords— wash innovation, water utility, district meter areas, outcomes, public private partnership.

Functional Restoration of Damaged Water Ecosystems Using KELEA (Kinetic Energy Limiting Electrostatic Attraction) to Support Nature's Allostasis

W. John Martin

Abstract— Because of industrial pollution, much of the Nation's surface water is presently contaminated with toxic chemicals. These arise from urban centers, farms, mines, and factories. They disrupt the normal equilibrium of microbial, plant, and animal life within and in the vicinity of the contaminated water. Many healthy populations of aquatic, land, and airborne wildlife are depleted, while other life forms, including invasive species, can show excessive overgrowth. Worsening imbalances of the various interactive biological and environmental components that comprise normal functioning water-based ecosystems occur when they exceed the self-repairing capacity of Nature. Such disordered ecosystems are said to have gone beyond their tipping points. Conventional efforts to repair damaged water ecosystems mainly involve the use of chemicals to remove the contaminating toxins and/or reduce the overgrowing life forms. Such efforts are typically expensive, only partially effective, and often lead to unanticipated further disruptions. A different approach is based on the concept that each ecosystem has a fundamental task of supporting the larger ecosystem in which it exists. Throughout evolution, there have been stepwise improvements in the ways that ecosystems achieve their intended functions. The older ways may be retained or essentially rendered redundant and placed in reserve. Yet, it allows for the potential reversion to an earlier way when the more evolved way is impaired. The author is using the term Nature's Allostasis to describe this adaptive process. Since it is less energy efficient, the reversion requires added energy. The ecosystem will remain disordered if there is insufficient energy for Nature's Allostasis to proceed. The author has also introduced the term KELEA as an acronym for Kinetic Energy limiting Electrostatic Attraction. It is yet another name for the force that has seemingly been co-opted by Nature to support the origin of life and assist in the continuation of life. It is envisioned as a radiant, repulsive environmental force that associates with electrical charges to prevent the fusion and annihilation of electrostatically attracted opposing electrical charges. Several methods are available to attract environmental KELEA and release it in a way that increases the KELEA level of nearby water. One method involves finely ground (pulverized) volcanic rock material, which is pelleted and repeatedly heated to a partial melting temperature and slowly cooled. This product is marked as Kiko Technology. Five pellets are currently being used in combination with 0.5 lb. biochar and 500 ml of a nutrient solution to treat large areas of several polluted water areas in the Midwest and southern regions of the US. The biochar and nutrient solution are viewed as providing a habitat and nourishment for proliferating beneficial microbes as part of a continuing Nature's Allostasis process. Remarkable long-term and sustainable improvements have been achieved in Big Spirit Lake, Iowa. As will be shown in the talk, these include the return of wildlife and the disintegration of invasive zebra mussels. KELEA enhanced Nature's Allostasis has many additional applications in improving the quality of the world's inland waterways.

Keywords— KELEA, nature's allostasis, kiko, water pollution, evolution, life force energy, wildlife.

Fashion & Quantum Physics: Quantum Entanglement as a Metaphor for Global Fashion Trends: Instant Influence Across Cultures

Shalvi Ahirwar

Abstract— Fashion trends often seem to spread quickly around the world, connecting distant cultures in unexpected ways. This study looks at whether quantum entanglement, a physics phenomenon where two particles stay linked and instantly affect each other regardless of distance, can serve as a metaphor for how global fashion trends work. Just like entangled particles share a unique connection, a change in one culture's fashion, such as a new style in Paris, can rapidly influence trends in Tokyo or New York. In quantum entanglement, particles behave as one system, responding to changes in each other, no matter how far apart they are. Similarly, in today's connected world, social media, influencers, and global brands create a network where a single fashion choice can spread across continents overnight. For instance, a viral outfit on Instagram or a celebrity's look on the red carpet can start trends worldwide, as if cultures are "entangled" through shared inspiration. This research examines whether this metaphor holds by comparing the speed and interconnectedness of fashion trends with the instant correlation found in quantum entanglement. It looks at how platforms like TikTok or fashion weeks act as catalysts, linking diverse cultures in a global fashion system. The study also considers whether this rapid influence fosters meaningful cultural exchange or simply encourages imitation. By analyzing case studies of cross-cultural fashion moments and the role of technology, this work suggests that quantum entanglement is an appropriate metaphor. It illustrates how fashion trends go beyond borders, creating a collective global style that evolves together. This perspective emphasizes the power of interconnectedness in fashion, showing how one small change in a single culture can quickly reshape styles worldwide, uniting creativity across the globe.

Keywords— quantum entanglement, global fashion trends, cultural interconnectedness, social media, fashion influencers, cross-cultural exchange, viral trends, fashion weeks, global style, technology in fashion.

Improvement of Filler Aggregation in Catechol-Functionalized Epoxidized Natural Rubber Composites

K. Buaksuntear, P. Kohl, Y. Li, and W. Smitthipong*

Abstract—Natural rubber (NR) or *cis*-1,4-polyisoprene is a renewable polymer derived from *Hevea brasiliensis* plants, which is widely utilized in various applications such as tire industry. In terms of rubber processing, carbon black (CB) is commonly used as a reinforcing filler. However, filler aggregation of CB in rubber products is one of the important problems, which is related to the complicated mixing in rubber manufacturing and high energy loss. So, the mussel-inspired mechanism has been used to solve the problem of filler aggregation in rubber composites. This research aimed to improve the carbon black dispersion in epoxidized natural rubber (ENR) composites through aromatic interactions such as π - π stacking and cation- π interactions. Initially, the epoxidation process was used for the modification of NR to produce ENR. Then, the ENR was mixed with catechol as dopamine (D) and carbon black (CB), respectively. In this study, the aromatic interactions were obtained between the benzene rings in D molecules on ENR chains and the surface of CB, which were observed in Fourier transform infrared spectroscopy and Raman spectroscopy. The results indicated that the mechanical properties were increased because of the effect of filler reinforcement and aromatic interactions within the ENR composites. Notably, this phenomenon was confirmed using the small/wide angle X-ray scattering (SAXS/WAXS), which was in good agreement with the rubber processing analyzer and transmission electron microscopy results that the π - π stacking and cation- π interactions enhanced the CB dispersion in the ENR composites. Therefore, these results showed the tensile strength, Young's modulus, and energy-saving properties were reached up of 140%, 90%, and 50%, respectively. Finally, this research provides a novel approach based on a mussel-inspired material to solve the CB aggregation problem in rubber products, resulting in the achievement of ENR composites with superior properties.

Keywords—ENR composites, non-covalent interactions, mechanical properties, energy-saving property.

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Green Production and Characterization of Regenerated Cellulose Fiber from Pineapple Leaf Waste Using Dry-Jet-Wet Spinning

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Abstract— Thailand, a world leader in pineapple production and export, generates substantial amounts of pineapple leaf waste, a valuable source of cellulose fiber. This study investigates the production of high-quality dissolving pulp and regenerated cellulose fiber from pineapple leaf fiber using the eco-friendly lyocell process, which utilizes non-toxic, recyclable chemicals. The findings indicate that KOH can effectively replace NaOH in the pulping process, producing pulp with properties suitable for fiber spinning. Optimized bleaching sequences employing chlorine dioxide and hydrogen peroxide stages yielded bright, high-purity pulp with alpha-cellulose content comparable to commercial softwood pulp, along with higher viscosity and degree of polymerization. Lyocell fibers were successfully produced via dry-jet-wet spinning and compared to commercial lyocell fibers. These fibers exhibited similar density, color, and chemical structure but had larger dimensions, greater shrinkage, improved thermal stability, enhanced tensile strength, and superior methylene blue adsorption capacity. A market survey highlighted consumer interest in T-shirts made from sustainable lyocell fibers derived from agricultural waste, underscoring their environmental advantages. This study demonstrates a sustainable and innovative solution for repurposing agricultural waste into high-value textile products. Future work will focus on addressing the scalability and cost-efficiency of the process to facilitate its industrial application and expand its impact on sustainable textile manufacturing.

Keywords—dissolving pulp, dry-jet-wet spinning, pineapple leaf fiber, regenerated cellulose.

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Evaluating Seismic Earth Pressure Effects on Building Lateral Stability: Sensitivity to Retention Height Differences and Sloped Site Conditions

R. Davis, S. Saminfar

Abstract— Earthquakes can induce dynamic earth pressures on retaining walls, which are in addition to the static earth pressures. This raises questions about how to effectively combine the seismic lateral earth pressure with other loads on buildings, including static lateral earth pressure. When basement walls retain soil with differing exterior grades on opposite sides, the seismic increment of active earth pressure should be considered. Additionally, buildings situated on sloped sites with stepped retention may experience unique dynamic effects due to soil-structure interactions, potentially amplifying the lateral pressures exerted on the retaining walls and influencing the building's response during seismic events.

To account for the dynamic effects of the retained soil on the building's responses, it is essential to interconnect the building structure with the surrounding soil to facilitate their interaction as the embedded structure and the surrounding soil move together during an earthquake. Consequently, a finite element model of the building is developed, with the rigid retaining walls and restrained to the floor diaphragms.

This paper aims to explore the dynamic effects of retained soil on the lateral stability of buildings and sensitivity of the building's responses to differences in the retained heights on opposite sides of the building basement. Furthermore, the results are compared with those from a sloped site to evaluate the impact of stepped retention on dynamic soil pressure. These findings will help establish a minimum threshold for differences in retained heights on opposite sides of a building that necessitates the inclusion of dynamic soil pressure in the building's lateral stability analysis.

Keywords—Dynamic earth pressure, Soil-structure interaction, Stepped retention, Building retention.

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Systematic study of triaxiality with kinematic and dynamic MOI and $N_p N_n$ scheme in heavy nuclei

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Abstract—This study investigates the triaxial nature of heavy, superdeformed nuclei by analyzing kinematic ($J^{(1)}$) and dynamic ($J^{(2)}$) moments of inertia derived from transition energies. These observables reveal how nuclear resistance to rotation changes with angular momentum, offering clues to deformation and pairing effects. Asymmetry parameters were extracted and correlated with $N_p N_n$ values to understand shape evolution. The Asymmetric Rotor Model (ARM) was employed to support the identification of triaxial configurations and collective behavior in deformed nuclei.

Keywords—Superdeformed, Triaxial, Asymmetric rotor model

I. INTRODUCTION

THE discovery of superdeformed (SD) nuclear states, first observed in ^{152}Dy by Twin et al. [1], marked a major advancement in nuclear structure studies. Superdeformation has since been observed across multiple mass regions ($A \sim 30\text{--}190$) [2], [3], prompting the development of theoretical models like the shell correction method [4] and cranked mean-field approaches [5]. Triaxial nuclear shapes, though less directly observable, have been explored using the Asymmetric Rotor Model (ARM) [6] and supported by indirect signatures such as $\mathcal{J}^{(2)}$ behavior and level staggering [7]. Recent studies [8], [9] validate the applicability of these models in describing triaxiality in heavy nuclei, aligning well with experimental observations.

mds

June 18, 2025

A. METHODOLOGY

To identify superdeformed (SD) nuclei in the heavy mass region, experimental energy levels of the ground and gamma bands were analyzed. The ground-state rotational levels of axially symmetric nuclei follow a characteristic energy ratio pattern, which deviates in triaxial nuclei. Specifically, the E_4/E_2 ratio serves as a practical indicator, with values near 2.67 suggesting triaxiality. Additionally, the presence of a low-lying gamma band reinforces the evidence for triaxial shapes. The asymmetry parameter γ_0 is then determined using the energy ratio of the first 2^+ levels in the ground and gamma bands.

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1) *Asymmetric rotor model*: The Hamiltonian for an axially asymmetric rotor in the DF model is given by:

$$H = \sum_{i=1}^3 \frac{R_i^2}{2\mathcal{I}_i}, \quad (1)$$

where R_i ($i = 1, 2, 3$) are the components of angular momentum in the body-fixed frame, and $\mathcal{I}_i$ are the principal moments of inertia. These moments depend on nuclear shape, pairing, centrifugal stretching, and Coriolis effects.

For a triaxial nucleus, the moments of inertia are expressed as:

$$\mathcal{I}_i = 4B^2 \sin^2 \gamma_0 \cdot \beta^2 \cdot \frac{1}{\omega_i^2}, \quad (2)$$

where B is the mass parameter, β is the quadrupole deformation, and γ_0 is the triaxiality parameter.

The DF model gives the following expressions for the energy of the 2^+ level in the ground band (E_{2+}^g) and the gamma band (E_{2+}^γ):

$$E_{2+}^g = \frac{9 - 9\sqrt{1 - \frac{8}{9}\sin^2(3\gamma_0)}}{\sin^2(3\gamma_0)}, \quad (3)$$

$$E_{2+}^\gamma = \frac{9 + 9\sqrt{1 - \frac{8}{9}\sin^2(3\gamma_0)}}{\sin^2(3\gamma_0)}. \quad (4)$$

The ratio of these two energy levels is:

$$\frac{E_{2+}^\gamma}{E_{2+}^g} = \frac{3 + \sqrt{9 - 8\sin^2(3\gamma_0)}}{3 - \sqrt{9 - 8\sin^2(3\gamma_0)}}. \quad (5)$$

Solving for γ_0 from the ratio $R_\gamma = E_{2+}^\gamma/E_{2+}^g$, we get:

$$\gamma_0 = \frac{1}{3} \sin^{-1} \left[\sqrt{\frac{9}{8} \left(1 - \left(\frac{R_\gamma - 1}{R_\gamma + 1} \right)^2 \right)} \right]. \quad (6)$$

II. CONCLUSION

TABLE I
ASYMMETRY PARAMETER (γ_0) FOR SD BANDS IN THE HEAVY MASS REGION.

Nucleus	$R = \frac{E_{\gamma}^{2+}}{E_{\gamma}^{2+}}$	γ_o
$^{132}\text{Nd}(4)$	3.90	19.56°
$^{168}\text{Hf}(1)$	7.06	14.79°
$^{240}\text{Pu}(4)$	26.54	11.71°
$^{174}\text{Hf}(3)$	13.48	10.83°
$^{163}\text{Lu}(4)$	4.64	18.02°
$^{160}\text{Er}(3)$	6.80	15.01°
$^{132}\text{Ce}(3)$	2.52	24.34°
$^{156}\text{Dy}(3)$	6.45	15.48°

TABLE II
VALUES OF KINEMATIC MOMENT OF INERTIA ($\mathcal{J}^{(1)}$) AND DYNAMIC
MOMENT OF INERTIA ($\mathcal{J}^{(2)}$) FOR SD BANDS

Nucleus	Kinematic MOI $\mathcal{J}^{(1)}$ ($\hbar^2/\text{MeV}$)	Dynamic MOI $\mathcal{J}^{(2)}$ ($\hbar^2/\text{MeV}$)
$^{132}\text{Nd}(4)$	53.18	58.82
$^{168}\text{Hf}(1)$	73.48	78.83
$^{240}\text{Pu}(4)$	118.01	117.64
$^{174}\text{Hf}(3)$	64.43	65.87
$^{163}\text{Lu}(4)$	68.80	71.42
$^{160}\text{Er}(3)$	72.18	72.72
$^{132}\text{Ce}(3)$	57.05	56.33
$^{156}\text{Dy}(3)$	85.08	88.88

TABLE III
 $N_p N_n$ OBTAINED USING SPHERICAL AND DEFORMED MAGIC NUMBERS
FOR SD BANDS

Nucleus	$N_p N_n$ (Spherical)	$N_p N_n$ (Deformed)
$^{132}\text{Nd}(4)$	100°	24
$^{168}\text{Hf}(1)$	140°	16
$^{240}\text{Pu}(4)$	240°	80
$^{174}\text{Hf}(3)$	64°	60
$^{163}\text{Lu}(4)$	110°	0
$^{160}\text{Er}(3)$	140°	0
$^{132}\text{Ce}(3)$	64°	16
$^{156}\text{Dy}(3)$	128°	0

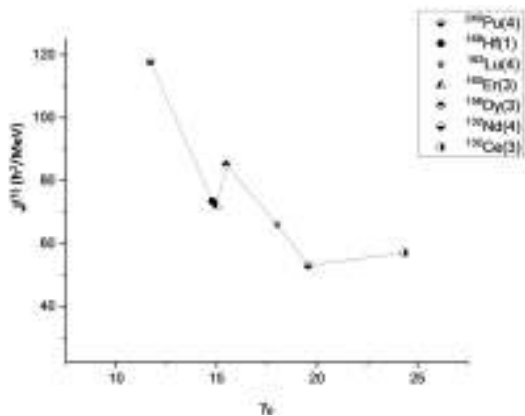


Fig. 1. Behaviour of asymmetry parameter with Kinmatic MOI $\mathcal{J}^{(1)}$

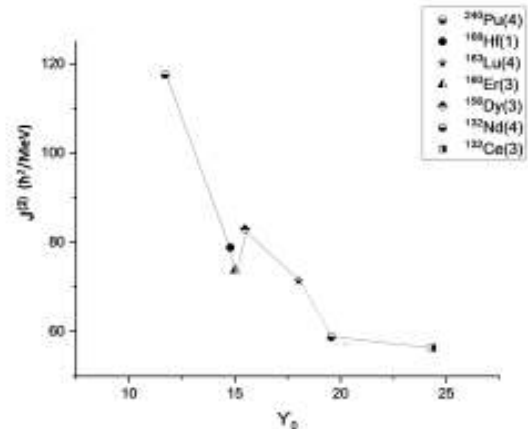


Fig. 2. Behaviour of asymmetry parameter with Dynamic MOI $\mathcal{J}^{(2)}$

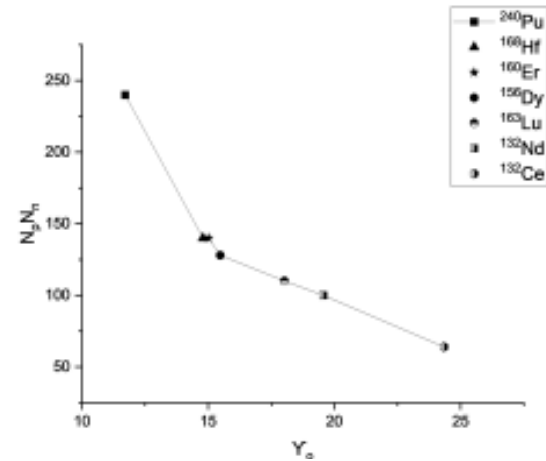


Fig. 3. Behavior of $N_p N_n$ (spheical) value with Asymmetry parameter

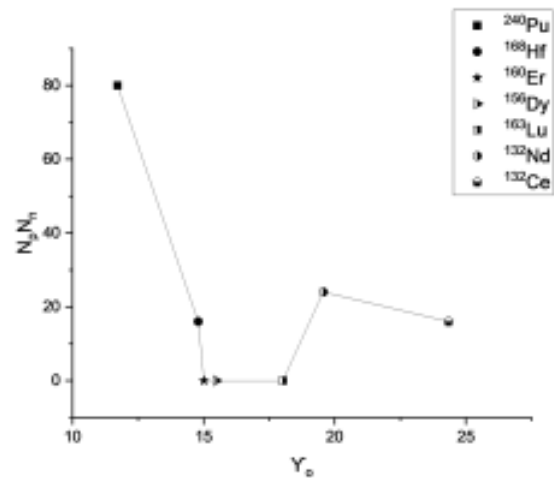


Fig. 4. Behavior of $N_p N_n$ (Deformed) value with Asymmetry parameter

APPENDIX

A. Moment of Inertia Calculations

The kinematic moment of inertia $\mathcal{J}^{(1)}$ and dynamic moment of inertia $\mathcal{J}^{(2)}$ are calculated using the γ -ray transition energies E_γ extracted from ENSDF files.

$$\mathcal{J}^{(1)}(I-1)/\hbar^2 = \frac{2I-1}{E_\gamma(I \rightarrow I-2)}, \quad (7)$$

$$\mathcal{J}^{(2)}(I)/\hbar^2 = \frac{4}{E_\gamma(I+2 \rightarrow I) - E_\gamma(I \rightarrow I-2)}. \quad (8)$$

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Laxman Soni a MSc Student pursuing Research project under professor Dr H M Mittal, Department of Physics, Nit Jalandhar. I have a keen interest in studying nuclear structural properties and different parameters.

Experimental Investigation to Forecast Soil Plugging Formation Mechanism and Capacity of Open-Ended Piles

Eslam M. Hemid, Daniel Barreto, Vasiliki Dimitriadi, J. Benral-Sanchez

Abstract—Soil plugging is a significant phenomenon influencing the behaviour and load-bearing capacity of open-ended piles driven into sandy soils. During pile installation, soil may be forced into the pile, forming a plug that alters the pile-soil interaction and affects the load transfer mechanism. This study investigates the soil plug formation in scaled-down open-ended piles driven into fine, medium, and coarse sand. A series of experimental tests were conducted to evaluate the impact of relative density, particle size distribution (PSD), penetration depth, driving rate, and pile geometry on soil plugging. The degree of plugging was quantified using the Plug Length Ratio (PLR) and Incremental Filling Ratio (IFR), providing insights into the extent of soil intrusion and its variation with different test conditions. The results demonstrate that sand properties, pile geometry, and driving energy significantly influence the formation mechanism of soil plugs. Understanding these factors is critical for optimizing pile design and improving predictions of axial capacity in offshore and onshore foundation applications.

Keywords— Bearing Capacity, IFR, PLR, Soil Plugging.

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Developing an Interpretive Plan for Qubbet El-Hawa North Archaeological Site in Aswan, Egypt

Osama Amer Mohyeldin Mohamed

Abstract— Qubbet el-Hawa North (QHN) is an example of an archaeological site in West-Aswan and It has not opened to the public yet and has been under excavation since its discovery in 2013 as a result of the illegal digging that happened in many sites in Egypt because of the unstable situation and the absence of security. The site has the potential to be one of the most attractive sites in Aswan. Moreover, it deserves to be introduced to the visitors in a good manner appropriate to its great significance. Both interpretation and presentation are crucial inseparable tools that communicate the archaeological site's significance to the public and raise their awareness. Moreover, it helps them to understand the past and appreciate archaeological assets. People will never learn or see anything from ancient remains unless it is explained. They would only look at it as ancient and charming. They expect a story, and more than knowledge, authenticity, or even supporting preservation actions, they want to enjoy and be entertained. On the other hand, a lot of archaeologists believe that planning an archaeological site for entertaining visitors deteriorates it and affects its authenticity. Thus, it represents a challenge to design a model for visitors' experience that meets their expectations and needs while safeguarding the site's integrity. The article presents a proposal for an interpretation plan for the site of Qubbet el-Hawa North.

Keywords— heritage interpretation and presentation, archaeological site management, qubbet el-hawa North, local community engagement, accessibility.

Gender-Neutral Identities in Gendered Languages: A Comparative Linguistic Study

Alexandria Koch

Abstract— How does a grammatically gendered language accommodate for gender-neutral identity language? In recent years, discussions surrounding the intersection of identity and language, namely gender-neutrality within gendered-languages. This question of linguistic integration not only affects native speakers, but those migrating and learning the language while also holding these identities. Attempting to learn or integrate into a language that feels inadequate both in linguistic and social acceptance is an often-overlooked issue. This paper compares this issue that linguists in German, French, Spanish, and Italian have been attempting to solve: how does a gender-neutral identity linguistically exist within a grammatically gendered language. Current research in these languages offer some solutions, like creating gender-neutral neopronouns and adding inclusive or neutral endings, but are often met with heavy criticism. Overall, this criticism generally stems from conservative beliefs of identity that then should be reflected in the language or are underutilized in daily speech and therefore considered as disruptive (Erhardt, 2022.) This paper explores and compares the current state of gender-neutral identity language, focusing largely but not exclusively on personal pronouns. Comparing the four languages will highlight patterns within inclusive language formation, obstacles when assimilating this language, and solutions to these issues. These patterns will give insight into how to create socially and linguistically accurate inclusive language that can best be assimilated into a language and the surrounding society. Unlike other publications in this area, this comparative work will focus on how the language adapts to accommodate the identity, rather than how the identity is shaped by the gendered nature of the language.

Keywords— Nonbinary, Gender-neutral language, Gender-inclusive, Gendered language, French, German, Spanish, Italian.

Commercial Management vs. Quantity Surveying: Hoax or Harmonization

Zelda Jansen Van Rensburg

Abstract—

Purpose: This study investigates the perceived disparities between Quantity Surveying and Commercial Management in the construction industry, questioning if these differences are substantive or merely semantic. It aims to challenge the conventional notion of Commercial Managers' superiority by critically evaluating QS and CM roles, exploring CM integration possibilities, examining qualifications for aspiring Commercial Managers, assessing regulatory frameworks, and considering terminology redefinition for global QS professional enhancement.

Design: Utilizing mixed methods like literature reviews, surveys, interviews, and document analyses, this research examines the QS-CM relationship. Insights from industry professionals, academics, and regulatory bodies inform the investigation into changing QS roles.

Findings: Empirical data highlight evolving roles, showcasing areas of convergence and divergence between Qs and CM. Potential CM integration into QS practice and qualifications for aspiring Commercial Managers are identified.

Limitations/Implications: Limitations include potential bias in self-reported data and findings. Nevertheless, the research informs future practices and educational approaches in QS and CM, reflecting the changing roles and responsibilities of Quantity Surveyors.

Practical Implications: Findings inform industry practitioners, educators, and regulators, stressing the need to adapt to changing QS roles and integrate CM principles where applicable.

Value to the Conference Theme: Aligned with 'Evolving roles and responsibilities of Quantity Surveyors,' this research offers insights crucial for understanding the changing dynamics within the QS profession and informs strategies to navigate these shifts effectively.

Keywords— quantity surveying, commercial management, cost engineering, quantity survey.

Jeju's Tamna System: The Viability of Regional Currencies in the US for Economic Revitalization

Sean Gabriel Lee

Abstract— This study explores the potential adaptation of tamna (탐나는전)—Jeju Island's government-backed local currency—within the United States to stimulate local economies, revitalize struggling communities, and promote sustainable urban and rural development. Launched in 2018, tamna encourages spending at small, locally owned businesses by offering 5–10% bonuses or discounts, while excluding large national chains. Managed through both mobile applications and prepaid cards, it strengthens the local multiplier effect, reduces capital leakage, and supports merchants with lower transaction fees. Jeju's experience demonstrates that localized currencies can stabilize consumption during economic downturns, boost off-season revenue, and align with broader sustainability goals. The U.S. application envisions municipal or state governments partnering with local banks, credit unions, and fintech firms to issue digital and card-based credits redeemable at approved independent businesses, cultural venues, public transit, and green economy enterprises. Incentives could include bonus value purchases, cashback rewards, tax benefits, and loyalty programs. Integration with existing benefit systems (e.g., SNAP) could enhance accessibility for low-income residents, while targeted marketing would build public trust. Potential benefits include increased economic resilience, protection of small businesses from national chain dominance, and empowerment of marginalized communities. The system could also reduce environmental impact by encouraging local consumption and supporting sustainable agriculture. Case studies—from Jeju's Olle Trail tourism dispersal model to U.S. examples like BerkShares—suggest that success depends on community buy-in, cultural relevance, and infrastructure support. Challenges remain in navigating legal and regulatory frameworks, ensuring tax compliance, achieving critical mass adoption, and bridging digital literacy gaps among merchants. Nonetheless, by coupling tamna-style currencies with place-based revitalization strategies—such as converting underused spaces into mixed-use developments, promoting slow tourism, and fostering local identity—U.S. cities and towns could leverage this model to build more equitable, sustainable, and self-reliant economies.

Keywords— regional development, economics, circular economy, regional currency.

The Respondent-Type Matching-to-Sample Procedure: A Comparison of One-to-Many and Linear Procedure for Establishing Equivalence Responding

Jonathan Todd, Mickey Keenan, Stephen Gallagher

Abstract— Stimulus equivalence research is dominated by operant conditioning procedures which require the active responding of a participant to establish relations between arbitrary stimuli. In comparison, there has been relatively little research using respondent-type procedures, which only require the participant to view relations that appear on screen. This presentation describes two experiments using a Respondent-Type Matching-to-Sample procedure to examine the effect of the One-to-Many (OTM) training procedure and the Linear procedure on equivalence class formation. The OTM procedure was extremely effective in generating equivalence responding, however the linear procedure was not. These findings are discussed in the context of previous research comparing the two training procedures, as well as the effectiveness of previous respondent procedures.

Keywords— stimulus equivalence, respondent-type matching-to-sample procedure, one-to-many, linear.

Victim-Survivor-Centric, Trauma-Informed Responses to Workplace Psychosocial Hazard Victimization; a QPS Perspective

Jill B. Clarke

Abstract—Workplace psychosocial hazards continue to produce significant psychological impacts upon the individual and organisational culture. Emergency services organisations are challenged to establish and embrace a model of clinical support and associated therapeutic approaches specific to supporting the psychological health, safety, and wellbeing of staff. Importantly, this includes tailored support to concerned parties (CPs) in complaints regarding negative workplace behaviours. During the 2022 Independent Commission of Inquiry (CoI) into responses to Domestic and Family Violence (DFV), the Queensland Police Service (QPS) found that poor DFV responses were underpinned by several thematic behaviours within the organisation itself. These behaviours include sexism, sexual harassment, misogyny, racism, homophobia, and bullying. These behaviours, as well as other psychosocial hazards such as poor organisational justice, traumatic material, violence and aggression, and poor workplace relationships, contribute to psychological risk for QPS staff. In November of 2022, the QPS established the State Case Management Unit (SCMU) within the Ethical Standards Command (ESC) to investigate and address complaints regarding these thematic behaviours (as well as member involved DFV). After establishing a link between the negative workplace behaviours and psychosocial risk within the organisation, and in consideration of the psychological impact upon complainants, the QPS embedded a Principal Health Clinician within the SCMU to support CPs in these matters. This is the learnings and insights of that Clinician within a new and developing area of practice; counselling practitioners providing support specifically to recipients of workplace psychosocial hazard victimisation, within a misconduct and/or complaints/grievance investigation process. This research aims to provide psychoeducation, acknowledgement, and validation regarding the psychological impact of psychosocial hazards (negative workplace behaviours) within a victim-survivor-centric, trauma-informed lens (VCTI), explore the role of moral injury, share the clinical framework of the Principal Health Clinician role, and encourage discussion regarding psychological risk during workplace misconduct/complaints/disciplinary processes. This research will utilize clinical insights, learnings, experience, and observations, as well as relevant literature, case studies (time permitting), program and practical evaluation. Key learnings include the traumatic stress impact of psychosocial hazard (negative workplace behaviours), utilization of ongoing clinical intervention, and the importance of a large on-referral network, treatment modality expertise, and a VCTI lens, the rapid formation of the therapeutic relationship, and the police responsiveness to “cold calling” which may be mitigate self-stigma associated with help seeking. The piloting of an embedded Health Clinician within a disciplinary and workplace misconduct investigatory setting has shown to be beneficial to complainants for recognition, validation, early and brief intervention, and referral.

Future efforts should focus on primary interventions regarding organisational stressors (rather than operational stressors), the utilization of “cold calling” within emergency services organisations, replicated support for subject members, and clinical expansion/exploration regarding utilization of other treatment modalities. This study is supported by the Queensland Police Service. The author wishes to give acknowledgement to the Ethical Standards Command and the State Case Management Unit, in particular the Deputy Commissioner, Assistant Commissioner, and the Detective Superintendent of the SCMU.

Keywords— Emergency Services Wellbeing, Moral Injury, Negative Workplace Behaviours, Police Mental Health, Psychosocial Hazards.

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The Impact of Subjective Sleep Assessment and Physical Activity on Suicidal Ideation: A Study Using Ecological Momentary Assessment

Seunghyun Lee, Seungyeon Lee, Jinhee Lee

Abstract—

Background: Adequate sleep and physical activity are crucial for maintaining mental health. While insufficient sleep and low physical activity have been linked to suicidal ideation (SI), prior studies mostly relied on cross-sectional data. This study utilized ecological momentary assessment (EMA) to examine the real-time relationship between subjective sleep assessment, physical activity, and SI.

Methods: Thirty participants with mood disorders completed four daily self-report assessments over a 14-day period using the Mind Logger platform. Sleep efficiency was categorized as good ($\geq 85\%$) or poor ($< 85\%$). Subjective sleep was rated on a 7-point scale and categorized as good (≥ 5) or poor (< 5). Physical activity was classified as active or inactive. Suicidal ideation was assessed as a binary variable (yes/no). Statistical analyses included chi-squared tests and logistic regression.

Results: A total of 1428 observations were analyzed. Subjective sleep rating and physical activity showed significant associations with SI ($p < 0.05$), whereas objective sleep efficiency did not. Individuals with poor subjective sleep or no physical activity were significantly more likely to report SI. Logistic regression analysis identified poor subjective sleep as the strongest predictor (OR = 7.53, $p < 0.001$), followed by no physical activity (OR = 1.74, $p < 0.01$). The sleep efficiency group was not a significant predictor ($p = 0.59$).

Discussion: This study highlights the importance of subjective sleep perception and physical activity in identifying individuals at high risk for suicidal ideation. EMA proved effective in capturing dynamic, real-time assessments, underscoring its utility in early detection strategies. Enhancing subjective sleep quality and encouraging consistent physical activity may serve as promising intervention targets for suicide prevention.

Keywords— suicidal ideation, sleep quality, physical activity, ecological momentary assessment, mood disorders.

Strategic Approach to Promoting Sustainable Eating: A Study on Insect-Based Foods

Chiara Lucafò, Cosimo Talò, Silvia Mari, Cristina Zogmaister, Francesca Romana Alparone

Abstract— With the global population growing and natural resources becoming increasingly scarce, the demand for sustainable food solutions has never been more urgent. Rising food needs and malnutrition are critical global issues, prompting researchers to explore alternative protein sources. One promising solution is entomophagy, the practice of eating insects, which offers a significantly lower environmental impact compared to traditional protein sources like meat or dairy. Despite its environmental benefits, insect consumption remains low in Europe due to psychological barriers—primarily feelings of disgust. This research focuses on understanding how Italian consumers react emotionally and cognitively to insect-based foods. It explores how factors such as disgust, curiosity, values, beliefs, and attitudes influence their willingness to try such products. The study builds on prior research suggesting that persuasive messages are more effective when the message's framing—either affective (emotion-based) or cognitive (logic-based)—matches the individual's psychological orientation. According to Mayer & Tormala (2010), this “message-person congruence” significantly improves persuasion outcomes. Furthermore, neuroscientific studies highlight the ventromedial prefrontal cortex (vMPFC) as a brain region involved in evaluating persuasive messages. When message framing aligns with a person's orientation, areas such as the vMPFC, posterior cingulate cortex, and cerebellum are activated, contributing to message interpretation and product evaluation. This suggests the vMPFC plays a key role in self-referential processing and subjective evaluation during persuasive communication (Aquino et al., 2020). To explore these dynamics further, the study uses transcranial direct current stimulation (tDCS) to manipulate the activity of the vMPFC. The goal is to assess how this brain region influences the processing of persuasive messages and subsequent behavior related to insect-based food choices. The study involves at least 38 healthy adult participants. Each will evaluate 20 insect-based food products presented with either affective or cognitive persuasive messages. Participants will also be assessed on their individual tendencies using two psychological measures: Need for Affect (NFA) and Need for Cognition (NFC). Based on these assessments, participants will be placed on a continuum that reflects their personal orientation toward emotion or cognition. During the food evaluation task, participants will receive one of three tDCS conditions targeting the vMPFC: anodal (to increase cortical excitability), cathodal (to decrease excitability), or sham (placebo). The aim is to observe how brain stimulation influences the effectiveness of the persuasive messages, particularly when the message type (affective or cognitive) aligns with the participant's NFA or NFC. The research expects that under anodal stimulation, participants with high NFA will respond more favorably to affective messages, while those with high NFC will prefer cognitive messages. Under cathodal or sham conditions, these alignment effects are expected to diminish. These findings could significantly impact how we promote sustainable eating, especially through tailored messaging strategies. Practical applications may include the development of targeted marketing, public health campaigns, and policy initiatives to increase acceptance of insect-based foods.

Keywords— food sustainability, entomophagy, tDCS, vMPFC, need for affect and need for cognition.

A Systematic Review: Examining Emotional Clarity in Adolescent Boys and Girls Suffering from Depression and Emotional Clarity's Ability to Maintain or Mitigate Against Depressive Symptoms in an Adolescent Population

Madison Green

Abstract— Depression is a disorder that affects thousands of people across the United States; unfortunately, adolescents are not excluded from that number. The National Institute of Mental Health estimates that 4.1 million adolescents, between the ages of 12 and 17, have had at least one major depressive episode. Dysfunction in executive functioning and information processing plays has also been noted as playing a large role in depression. Adolescents suffering from depression may also struggle with forming and maintaining relationships with peers, as well as struggle to connect with their families. Emotional clarity has not been deeply studied as to whether it may worsen or assist in maintaining depressive symptoms. Emotional clarity tends to increase over adolescence, and on average, girls had a steeper decline of emotional clarity over time than their male counterparts. Additionally, girls are more likely to suffer from depression, and as they age, they have been found to have lower emotional clarity than their male counterparts. Young girls are also found to internalize their emotions more than boys. The biggest negative factor connected to emotional clarity within this age group is due to it being the time when puberty typically occurs. Boys are socialized to see that puberty can be 'cool' and something that makes them fit in, while amongst girls, it can be categorized as 'gross'. Gender socialization is a factor that increases the inability of certain individuals to understand their feelings, leading to higher rates of depression. If children cannot understand how to feel about both their bodies and the people around them, this could worsen their depressive symptoms. Being able to understand how you are feeling is a necessary aspect of human development. If emotional clarity further affects depression, it should be studied so that these children can integrate and feel confident in themselves.

Keywords— adolescents, children, depression, emotional clarity, gender socialization.

La Influencia de la Psicología Positiva en Aumento de la Resiliencia en Adultos Mayores

María Laura Caballaro

Abstract— Toxic relationships constitute a complex phenomenon that spans both clinical psychology and sexology. Despite advances in mental health, many people remain trapped in harmful bonds, raising questions about the mechanisms that sustain such attachment. This paper proposes an integrative reading from neuropsychology and clinical sexology, analyzing how brain chemistry processes—dopamine, oxytocin, serotonin, and cortisol—generate a reinforcement circuit similar to addictions, making it difficult to break the bond. The cycle of violence is described from the perspective of behavioral conditioning, along with its impact on the nervous system and the construction of erotic identity. Clinical vignettes illustrate how family and cultural discourses influence the repetition of these attachment patterns. From a sexological perspective, physical intimacy is explored as a reinforcing factor through somatic memory and erotic conditioning. The aim is to offer a framework to understand permanence in harmful relationships not as a conscious choice but as the result of a neuropsychological, affective, and social entanglement. Finally, reflections are offered on therapeutic interventions that integrate psychoeducation, bodywork, and the reconfiguration of the discourse of love to promote healthier and freer bonds.

Keywords— toxic attachment, neuropsychology, sexology, cycle of violence, affective addiction.

Nanoencapsulation of *Terfezia Claveryi* and *Terfezia Boudieri* Extracts Enhances Anticancer Efficacy and Synergistic Activity with Doxorubicin Against Drug-Resistant Breast Cancer Efficacy and Synergistic Activity with Doxorubicin Against Drug-Resistant Breast Cancer

Roua A. Nouh^{1,2}, Mohamed S. Sedeek³, □, Mohamed A. Farag³, Anwar Abdelnaser□

Abstract— Natural products remain a promising source of anticancer agents, yet their poor solubility and limited tumor targeting restrict clinical translation. *Terfezia claveryi* (RT) and *T. boudieri* (WT), two desert truffle species, were investigated for their potential against breast cancer, including drug-resistant subtypes. Extracts were encapsulated into hydroxypropyl- β -cyclodextrin (HP β CD) to improve solubility and bioavailability. In vitro cytotoxicity was assessed against MCF-7 and doxorubicin-resistant ADR-MCF-7 cell lines at 24, 48, and 72 hours. Encapsulation improved controlled release, reduced early cytotoxicity, and significantly enhanced late-stage activity. Both RT and WT extracts demonstrated dose-dependent inhibition of proliferation, with nanoformulations (CD-RT and CD-WT) exhibiting stronger effects compared to free extracts. Importantly, co-treatment with doxorubicin revealed synergistic cytotoxicity, particularly in resistant ADR-MCF-7 cells, suggesting potential for reversing drug resistance. In vivo studies in Ehrlich ascites carcinoma-bearing mice confirmed improved tumor growth suppression, antioxidant biomarker restoration, and cardioprotective effects when extracts were co-administered with doxorubicin. These findings highlight desert truffle nanoformulations as a novel therapeutic strategy for overcoming chemotherapy resistance and enhancing treatment efficacy in breast cancer.

Keywords—anticancer, breast cancer, desert truffles, drug resistance, nanoformulation, synergistic therapy.

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A Cross-Sectional Study on Intersecting Burdens: HIV Prevalence and Cervical Cancer Progression Among Women in Eastern Cape, South Africa

Jean Paul Muamabangu, Charles Businge

Abstract—Cervical cancer remains a significant cause of cancer-related mortality in low- and middle-income countries, particularly in sub-Saharan Africa. In South Africa's Eastern Cape Province, the burden is intensified by high HIV prevalence. Women living with HIV are at increased risk for persistent HPV infection and more rapid progression to cervical cancer. This study aims to evaluate the impact of HIV on cervical cancer risk and progression among women in the Eastern Cape Province of South Africa. A cross-sectional analysis was conducted using secondary data from 606 women diagnosed with cervical cancer in the Eastern Cape, South Africa. Key variables included age, HIV status, antiretroviral therapy (ARV) usage, cancer stage, and referral modality. Descriptive statistics and multivariable regression analyses (STATA v18) were used to assess relationships between clinical and demographic variables. HIV prevalence among cervical cancer patients was 60.23%. Most patients (68.48%) presented with stage 3 cancer, indicating delayed diagnosis. HIV-positive women were significantly older than their HIV-negative counterparts by 9.2 years on average ($\beta = 9.20, p < 0.001$). Age was positively associated with later cancer stages ($\beta = 1.91, p = 0.019$). ARV uptake was high (60.89%) and strongly predicted by HIV status ($\beta = 0.96, p < 0.001$). The findings emphasize a critical overlap between HIV and cervical cancer, particularly among older women. Despite robust ARV coverage, the high rate of late-stage presentation points to gaps in early detection and integration of HIV and cancer services. Strengthening cervical cancer screening, especially for HIV-positive women, is essential to improving outcomes.

Keywords—Cervical cancer, HIV, Eastern Cape, cancer staging, antiretroviral therapy, integrated care, oncology, South Africa, public health.

I. BACKGROUND

CERVICAL cancer remains a significant cause of cancer-related mortality in low- and middle-income countries, particularly in sub-Saharan Africa. In South Africa's Eastern Cape Province, the burden is intensified by high HIV prevalence. Women living with HIV are at increased risk for persistent HPV infection and more rapid progression to cervical cancer [1]. Globally, women living with HIV are six times more likely to develop cervical cancer compared to HIV-negative women [2].

Worldwide, cervical cancer is the fourth most common cancer among women, with approximately 604,000 new cases and 342,000 deaths annually [1]. Women with HIV constitute a disproportionately high-risk group; an estimated 5–10% of

cervical cancer cases globally are attributable to HIV co-infection [2].

In high-income countries such as the USA, Canada, Australia, and much of Europe, robust cervical cancer control strategies—including widespread HPV vaccination, routine Pap testing, and early intervention—have significantly reduced incidence and mortality [3]–[6]. However, women with HIV continue to experience disproportionate burdens, often due to fragmented care and lower screening coverage among marginalized groups [4]. In Asia, cervical cancer screening remains inconsistent, with notable disparities in access for HIV-positive women, particularly in countries like India [7].

By contrast, sub-Saharan Africa bears the brunt of the global burden, with late-stage diagnoses and high HIV co-prevalence. South Africa, home to the world's largest HIV-positive population (>7.5 million), reports cervical cancer as the second most common cancer among women [8], [9]. The Eastern Cape Province, characterized by rural geography, poor infrastructure, and limited access to care, is a focal point of this dual epidemic. Despite national guidelines recommending annual or biennial Pap smears for HIV-positive women and three lifetime screenings for HIV-negative women, screening rates remain low, particularly in rural and isiXhosa-speaking communities [9], [10].

Implementation gaps include insufficient healthcare personnel, underutilized mobile screening units, poor laboratory capacity, weak referral systems, and lack of integrated electronic health records. These system-level issues are compounded by low public awareness, stigma, and cultural barriers, especially among older women beyond the HPV vaccination age and who may not perceive themselves at risk [10].

Critically, the Eastern Cape's approach to cervical cancer prevention diverges from global oncology guidelines such as those from the American Society of Clinical Oncology (ASCO) and the European Society for Medical Oncology (ESMO). These recommend HPV DNA testing as the primary screening method, integrated HIV-cancer care, timely colposcopy referrals, and multidisciplinary

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management of dysplasia—strategies rarely implemented consistently in the province due to resource and training limitations [11], [12].

Rationale

The Eastern Cape exemplifies challenges faced by under-resourced health systems managing co-morbid chronic diseases like HIV and cervical cancer. While policy exists nationally, provincial-level adaptation and implementation remain inconsistent and under-monitored. Given the significant proportion of HIV-positive women presenting with late-stage cervical cancer, urgent investigation into structural, operational, and community-level barriers is needed. Aligning provincial practice with global standards, such as ASCO and ESMO guidelines, could substantially improve outcomes for at-risk women.

Hypothesis

Women living with HIV in the Eastern Cape are disproportionately affected by late-stage cervical cancer due to fragmented care, poor screening integration, and deviations from international oncology standards.

Research Question

What are the key system-level, clinical, and demographic factors contributing to late-stage cervical cancer presentation among HIV-positive women in the Eastern Cape, and how do these factors compare with global oncology care standards?

Aim of the Article

To assess the integration of HIV and cervical cancer care in the Eastern Cape Province, identify service delivery gaps, and evaluate alignment with international (ASCO and ESMO) guidelines. The study aims to generate evidence-based recommendations to enhance early detection and reduce cervical cancer morbidity and mortality among HIV-positive women.

Methods

Study Design and Setting

A cross-sectional and prospective cohort study design was utilized to examine the relationship between HIV infection and cervical cancer progression. The study was conducted in selected healthcare facilities across the Eastern Cape Province of South Africa. This region is characterized by a high HIV burden, limited screening infrastructure, and substantial health inequities. Data were collected from facilities affiliated with Walter Sisulu University, including its teaching hospitals and associated community clinics.

Study Population and Eligibility Criteria

Women aged 18 years and older who presented for cervical cancer screening, HIV care, or reproductive health services were considered for inclusion. Eligibility was determined based on the availability of documented HIV status and willingness to provide informed consent. Women were excluded if they had a prior diagnosis of invasive cervical cancer, a history of total hysterectomy, or were undergoing treatment for cervical cancer. Pregnant women were excluded from certain diagnostic procedures if deemed clinically inappropriate.

Variables

The primary dependent variable was the grade of cervical intraepithelial neoplasia (CIN), as assessed through cytological and histological evaluation. Independent variables included HIV status, high-risk HPV infection (including type-specific identification), CD4+ cell count, antiretroviral therapy (ART) status, age, parity, smoking history, and sexual and reproductive health factors. For the cohort component, the interval from baseline screening to lesion progression was also recorded.

Data Collection and Analysis

Clinical and demographic data were extracted from patient medical records and standardized clinical data forms. HPV genotyping was carried out using polymerase chain reaction (PCR) methods, and cervical cytology was assessed using conventional Papanicolaou (Pap) smear techniques. All data were entered into a password-protected electronic database. Descriptive statistics were generated to summarize participant characteristics. Associations between HIV status and cervical disease severity were assessed using chi-square tests and logistic regression modeling. For the prospective cohort, time-to-event outcomes were analyzed using Kaplan-Meier survival analysis and Cox proportional hazards regression. Statistical analyses were performed using SPSS or STATA software.

Ethical

Ethical clearance was granted by the Human Research Ethics Committee of Walter Sisulu University. Additional approvals were secured from the participating healthcare facilities and the Eastern Cape Department of Health. A waiver of informed consent was authorized by the Department of Health due to the retrospective nature of the study and the reliance on existing medical records and cancer registry data. Confidentiality was maintained through strict data anonymization procedures, and all data were securely stored under institutional and national ethical guidelines. Data protection protocols were observed throughout the study, including full compliance with the Protection of Personal Information Act (POPIA). Institutional data access agreements were established to ensure regulated and ethical use of patient information, with access restricted to authorized research personnel only.

Considerations

Results

Descriptive Characteristics of the Study Population

The study included 606 women with histologically confirmed cervical cancer. Over half (54.13%) were aged 55 and above, while 25.41% were aged 35–44. HIV prevalence was 60.23%, with 60.89% of all participants on ARV therapy. Notably, 68.48% of patients presented at stage 3 of cancer, indicating late detection. Radiotherapy was the primary treatment modality for 83.83% of patients. Table 1 provides clinical and treatment characteristics of cervical cancer patients in the Eastern Cape.

TABLE 1. CLINICAL AND TREATMENT CHARACTERISTICS OF CERVICAL CANCER PATIENTS IN EASTERN CAPE (N = 606)

Variable	Category	Frequency (n)	Percent (%)
Age Category	25–34 years	35	5.78
	35–44 years	154	25.41
	45–54 years	89	14.69
	55+ years	328	54.13
HIV Status	Positive	365	60.23
	Negative	180	29.70
	Unknown	61	10.07
ARV Status	On ARVs	369	60.89
	Not on ARVs	176	29.04
	Unknown	61	10.07
Cancer Stage	Stage 0–1	9	1.49
	Stage 2	122	20.13
	Stage 3	415	68.48
	Stage 4–6	54	8.91
Type of Therapy	Radiotherapy (RT) only	508	83.83
	Chemotherapy only	60	9.90
	Surgery + RT/CT/Hormone	11	1.82
	Hormone Therapy (HRT) only	3	0.50
	RT + HRT	2	0.33
	Supportive Care only	2	0.33
	Surgery only	2	0.33
Total Patients		606	100.00

Regression Analysis

Regression models examined the relationship between patient characteristics and HIV status, age, and cancer stage. The analysis revealed that HIV-positive women were significantly older than their HIV-negative counterparts ($\beta = 9.1993$, $p < 0.001$). Age was also significantly associated with advanced cancer stage ($\beta = 1.9118$, $p = 0.019$). ARV usage was strongly linked to HIV status ($\beta = 0.9636$, $p < 0.001$), while referral modality showed a borderline association with age ($\beta = 0.1424$, $p = 0.076$). **Table 2 provides a regression analysis of factors associated with HIV status and cervical cancer stage.**

TABLE 2. REGRESSION ANALYSIS OF FACTORS ASSOCIATED WITH HIV STATUS AND CERVICAL CANCER STAGE

Variable	Coefficient (β)	Std. Error	p-value	95% CI
Referral Modality	0.1424	0.0800	0.076	[-0.0148, 0.2995]

HIV Status	9.1993	0.7511	<0.001	[7.7241, 10.6744]
Cancer Stage	1.9118	0.8123	0.019	[0.3164, 3.5071]
Age	0.0017	0.0005	<0.001	[0.0008, 0.0025]
ARV Status	0.9636	0.0094	<0.001	[0.9452, 0.9820]

Discussion

This study revealed a high prevalence of HIV (60.23%) among women diagnosed with cervical cancer in Eastern Cape, South Africa, with the majority presenting at stage 3 (68.48%). HIV-positive patients were, on average, 9.2 years older than their HIV-negative counterparts, and older age was associated with more advanced cancer stages. Despite relatively high ARV coverage (60.89%), late-stage presentation remained prevalent, highlighting significant delays in early detection and integrated care delivery.

In contrast to high-income countries such as the United States, Canada, Australia, and parts of Europe—where cervical cancer incidence has dramatically declined due to effective HPV vaccination, routine Pap smears, and timely intervention [3]–[6]—the Eastern Cape continues to experience delayed diagnosis and limited screening coverage. In these countries, targeted outreach to HIV-positive populations and implementation of HPV DNA testing has improved early detection, whereas the Eastern Cape still relies primarily on opportunistic cytology-based screening, often initiated at symptomatic stages [8], [9].

Furthermore, while ASCO and ESMO advocate for integrated cervical cancer and HIV management, including immediate colposcopy after positive HPV DNA results [11], [12], such practices remain inconsistently implemented in rural provinces like the Eastern Cape due to resource limitations, workforce shortages, and systemic fragmentation.

Cervical cancer trends in the Eastern Cape align closely with patterns observed across sub-Saharan Africa, where late-stage presentation is common, and HIV prevalence among cancer patients is disproportionately high [2], [10]. For example, countries such as Zambia, Malawi, and Zimbabwe report similarly high co-infection rates and inadequate screening infrastructure [10]. In contrast, some North African countries (e.g., Tunisia, Morocco) have made modest gains in HPV vaccination and screening coverage through donor-supported public health programs.

In Asia, particularly in India and parts of Southeast Asia, disparities remain in cervical cancer screening, though some countries have introduced pilot HPV DNA testing programs [7]. However, few regions show the compounded dual burden of HIV and cervical cancer observed in Southern Africa.

This study analyzed a substantial sample of 606 women drawn from multiple public hospitals across the Eastern Cape, providing a broad regional perspective on the intersection of HIV and cervical cancer, a significant public health concern in this area. By utilizing routinely collected clinical data, the study offers practical insights into real-world service delivery and

patient characteristics within the public healthcare system. The application of multivariable regression enabled adjustment for potential confounders, including age and referral pathways, thereby enhancing the robustness of the findings.

Given the retrospective and cross-sectional nature of the study, establishing causality or temporal progression between HIV infection and cervical cancer development was not possible. The reliance on secondary data introduced challenges such as incomplete records, potential inaccuracies in clinical documentation, and variability in staging and treatment information. Additionally, the HIV and antiretroviral therapy status was undocumented for nearly 10% of participants, limiting the scope of some analyses.

The absence of HPV testing data, despite its pivotal role in cervical carcinogenesis, restricted the ability to evaluate the impact of HPV vaccination and related prevention strategies. Furthermore, the use of convenience sampling may affect the generalizability of the results beyond the studied facilities, highlighting the need for caution when interpreting findings at a population level.

Conclusion

The study confirms a critical intersection between HIV infection and late-stage cervical cancer presentation in the Eastern Cape. HIV-positive women, despite relatively high ARV coverage, face significant delays in cervical cancer diagnosis, possibly due to poor screening access, inadequate integration of HIV and oncology services, and systemic weaknesses in care coordination. Addressing these gaps will require provincial adaptation of global oncology guidelines, scaling up HPV DNA testing, and intensifying community-level outreach, especially for older women. Integrating cervical cancer screening into HIV care platforms could represent a practical and impactful intervention.

List of Abbreviations

Abbreviation Meaning

HIV	Human Immunodeficiency Virus
HPV	Human Papillomavirus
ARV	Antiretroviral Therapy
ASCO	American Society of Clinical Oncology
ESMO	European Society for Medical Oncology
RT	Radiotherapy
CT	Chemotherapy
HRT	Hormone Replacement Therapy
LMICs	Low- and Middle-Income Countries

Abbreviation Meaning

WHO	World Health Organization
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Declarations

Ethical Approval and Consent to Participate

Ethical approval was granted by the Walter Sisulu University Faculty of Health Sciences Research Ethics Committee and the Eastern Cape Provincial Department of Health Ethics Review Board. Given the retrospective nature of the study and the use of de-identified secondary data, a waiver of informed consent was obtained by institutional and national ethical guidelines.

Consent for Publication

Not applicable.

Availability of Data and Materials

The data that support the findings of this study are available from the Eastern Cape Department of Health, but restrictions apply to their availability. Data are available from the corresponding author upon reasonable request and with permission from the provincial authority.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

MJP conceptualized the study, led data analysis, and wrote the manuscript. CB contributed to methodology design, data interpretation, and manuscript revision. Both authors read and approved the final version.

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Effect of Yogic Ocular Exercises on Convergence Insufficiency

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Abstract

Purpose: To find the effect of ocular exercises on convergence insufficiency

Study Design: Quasi-experimental study

Methods: A quasi-experimental study was conducted at the University of Lahore Teaching Hospital from July -August 2025. Forty-seven participants (31 females, 16 males) aged 18–26 years with CI were recruited after taking approval from the IRB committee UOL/IREB/25/0009. Near point of convergence (NPC) was measured using the RAF ruler at baseline, three weeks, and six weeks. Participants performed a set of yogic ocular exercises (palming, blinking, sideways viewing, rotational viewing, diagonal viewing, nose-tip gazing, near-distant viewing, concentrated gazing, candle flame viewing, acupressure stimulation) for 30 minutes daily over six weeks. Data were analyzed using Friedman and Wilcoxon signed-rank tests.

Results: The mean age of the individual was 22 years. Mean baseline NPC was 11.5 ± 1.5 cm. After three weeks, mean NPC improved to 10.8 ± 1.6 cm, and at six weeks to 9.8 ± 1.5 cm ($p < 0.001$). Symptom frequency (headache, eye strain, diplopia) also declined significantly.

Conclusion: Yogic ocular exercises significantly improved near point of convergence and reduced asthenopic symptoms in CI patients. These exercises may serve as a low-cost, non-invasive adjunct in clinical management of CI. Further longitudinal studies are warranted.

Keywords: Convergence insufficiency, Near point of convergence, Yogic ocular exercises, Binocular vision, Orthoptics

Introduction

Convergence insufficiency (CI) is a prevalent non-strabismic binocular vision disorder characterized by an inability to maintain adequate convergence during near tasks. Its global prevalence ranges between 2% and 8% across populations, with a significant impact on students and young professionals who engage in prolonged near work [1,2]. Symptoms such as diplopia, eye strain, blurred vision, and headaches may impair quality of life and academic or occupational performance [3].

Traditional management strategies include pencil push-ups, Brock string, prism therapy, and orthoptic training [4]. While effective, these interventions may be limited by patient compliance, accessibility, and cost. In contrast, yogic ocular exercises, rooted in ancient practices, are gaining attention as an alternative non-pharmacological intervention. Prior studies have reported improvements in eye fatigue, intraocular pressure, and binocular vision parameters following yogic practices [5–7].

This study investigates the effect of yogic ocular exercises on convergence insufficiency, focusing on improvements in near point of convergence (NPC) and associated symptoms.

Methods

A quasi-experimental study was conducted at the University of Lahore Teaching Hospital, Lahore, Pakistan, between July to August 2025. Forty-seven participants aged 18–26 years diagnosed with convergence insufficiency NPC > 10 cm, symptomatic exophoria at near were enrolled. Exclusion criteria included hyperopia > +1.00D, astigmatism, strabismic anomalies, systemic medications affecting vision, or prior orthoptic therapy. Approval was obtained from the University of Lahore Ethics Committee. (UOL/IREB/25/0009) Written informed consent was secured from all participants. Participants performed 10 yogic ocular exercises daily for 30 minutes over six weeks: palming, blinking, sideways viewing, rotational viewing, diagonal viewing, front and sideways viewing, preliminary nose-tip gazing, near-distant viewing, concentrated gazing, and acupressure stimulation. Exercises were supervised weekly .NPC was measured using the RAF ruler at baseline, after three weeks, and after six weeks. Symptom frequency (headache, eye strain, diplopia, blurred vision) was recorded via a structured questionnaire. Statistical analysis was conducted using SPSS v25. Friedman test assessed within-group changes, and Wilcoxon signed-rank test compared pre- and post-intervention outcomes. A p-value < 0.05 was considered statistically significant.

Results

Of the 47 participants, 31 (66%) were female and 16 (34%) male. Mean age was 22.0 ± 2.5 years. The mean age of patient was 22 years. RAF Ruler was used to measure NPC of patient. Pre NPC ranged from 11 ± 1.5 cm minimum and 15.5 cm maximum with the mean value of Pre NPC is 11.55. The Minimum and maximum Post NPC after 3 weeks is 7.5 ± 1.5 cm and 15 cm with the mean value of 10.78 ± 1.5 cm respectively. The Minimum and maximum Post NPC is 7.5 cm and 13.5 cm respectively with the mean value of Post NPC is 9.81 ± 1.5 after 6 weeks. The Friedman test and Wilcoxon Signed rank test showed p-value = 0.000 sig (2-tailed).

Table 1. Demographics of Participants (n = 47)

Gender	Frequency	Percentage
Female	31	66.00%
Male	16	34.00%
Total	47	100.0%

Table 2. Near Point of Convergence (NPC) Measurements (n = 47)

Measurement	Mean $\pm$ SD (cm)	Range (cm)
Baseline	11.5 ± 1.5	8.0 – 15.5
3 weeks	10.8 ± 1.6	7.5 – 15.0
6 weeks	9.8 ± 1.5	7.5 – 13.5

Table 3. Statistical Results for NPC Changes

Comparison	Test Statistic	p-value
Baseline vs. 3 weeks	Wilcoxon $Z = -5.311$	<0.001
Baseline vs. 6 weeks	Wilcoxon $Z = -5.877$	<0.001
3 weeks vs. 6 weeks	Wilcoxon $Z = -5.786$	<0.001

Discussion

This study demonstrated that yogic ocular exercises significantly improved NPC and improved symptoms of convergence insufficiency among young adults. The findings align with Gupta and Aparna [1,17], who reported improved binocular accommodative facility and fusional vergence following yogic interventions. Similarly, Kim [2] observed reduced eye fatigue in nursing students after yogic eye exercises.

Other studies have also suggested that yoga-based ocular exercises help reduce intraocular pressure in glaucoma patients [6], improve visual acuity in refractive errors [8,9], and relieve digital eye strain [13,14]. The mechanism of improvement may involve enhanced extraocular muscle tone, increased intraorbital blood circulation, and better neuromuscular coordination [15,16]. By alternating contraction and relaxation of ocular muscles, yogic exercises strengthen convergence and reduce asthenopic symptoms.

Compared to conventional orthoptic therapy, yogic ocular exercises are cost-effective, non-invasive, and can be practiced without specialized equipment [5,17]. This makes them particularly suitable for low-resource settings.

Yogic ocular exercises can be recommended as an adjunct to standard orthoptic therapy, particularly for patients with mild to moderate CI and those with high near work demands [18,19]. The study used convenience sampling with a relatively small sample size and short follow-up. Longer-term studies with randomized controlled designs are needed to evaluate sustained benefits and compliance [20].

Conclusion

Yogic ocular exercises significantly improved convergence ability and reduced symptoms in patients with CI. These findings suggest their utility as a simple, low-cost, and effective adjunct therapy. Eye care practitioners may consider incorporating yogic ocular exercises in clinical practice for managing CI, especially in young adults engaged in extensive near work.

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Accidents in Public or Private Companies: Cases Unresolved by Brazilian Labor Laws

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Abstract— This paper provides a historical overview of Brazilian labor laws, as well as a description of the current legislation applicable to private companies and public institutions in the field of occupational health and safety. In addition, it presents concepts related to occupational risks, an overview of the Consolidation of Labor Laws and the Legal Regime of Public Servants. Furthermore, Article 927 of the Civil Code is also explained, since it addresses the labor scope within the Civil Code. Finally, some considerations will be made regarding the laws presented, along with a few illustrative examples.

Keywords— occupational health and safety, labor laws, public servants' legal framework, employer liability, civil code.

I. INTRODUCTION

WORKPLACE accidents have significant economic and social impacts, both in private companies and public institutions. According to the International Labour Organization (ILO), around 270 million work-related accidents and approximately two million deaths occur annually worldwide [1]. It is estimated that occupational diseases and injuries account for about 5% of the global Gross Domestic Product (GDP), rising to 10% in developing countries such as Brazil [1]. In 2002 alone, losses in Brazil were estimated between US\$ 21.9 and US\$ 54.7 billion [2].

The Brazilian labor system has evolved through a complex historical trajectory, beginning with early laws during the slave-based economy of the nineteenth century, such as the Eusébio de Queirós Law (1850), the Free Womb Law (1871), and culminating in the abolition of slavery with the Lei Áurea (1888). These milestones shaped the foundations of labor relations in Brazil. In the early twentieth century, legislation such as Law No. 3,724/1919 on workplace accidents and the Eloy Chaves Law (1923), which established retirement and pension funds, marked the first steps toward formal social protection for workers.

The most significant development occurred during the

Vargas Era, with the creation of the Consolidation of Labor Laws (CLT) in 1943, introducing rights such as minimum wage, regulated working hours, paid vacation, and workplace inspections. This period also laid the groundwork for occupational health and safety standards, which were later expanded in the 1988 Federal Constitution.

Currently, Brazilian labor relations are regulated mainly by the CLT for private companies and by specific legal frameworks for public servants, such as Law No. 8,112/1990 at the federal level. This dual structure reflects the mixed and complex nature of labor law in Brazil, which combines individual, collective, and diffuse rights, with direct implications for economic and social stability.

The objective of this study is to analyze the intersection of labor law, occupational health, and safety in Brazil, considering both private and public sectors, while also addressing relevant aspects of the Civil Code, particularly Article 927, which establishes employer liability in labor-related matters.

II. CONSOLIDATION OF LABOR LAWS IN BRAZIL (CLT)

The Consolidation of Labor Laws (CLT), enacted in 1943, represents the cornerstone of Brazilian labor regulation, governing both substantive and procedural aspects of labor law [3][4]. Structured into eleven titles and comprising 922 articles, the CLT brings together a wide range of provisions addressing employment relations, collective bargaining, occupational health and safety, labor courts, and the rights and obligations of workers and employers.

A. Historical Background

The CLT was introduced during the Vargas Era, in a period marked by both the Second World War and Brazil's authoritarian Estado Novo regime. Although labor laws already existed for specific categories of workers, their fragmented nature limited effectiveness. In 1942, President Getúlio Vargas and Minister of Labor Alexandre Marcondes Filho initiated efforts to unify the legislation. The drafting commission included renowned jurists such as Arnaldo Süssekind and Oscar Saraiva, who drew upon diverse sources: the conclusions of the First Brazilian Congress of Social Law (1941), International Labour Organization conventions, the papal encyclical *Rerum Novarum*, and previous legal opinions [4]. The final text was published in the *Diário Oficial* and officially signed on May 1, 1943, symbolically marking Brazil's Labor Day.

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B. Key Provisions

The CLT establishes fundamental concepts of labor law, defining the legal relationship between employer and employee, and codifying rights such as professional identification, working hours, minimum wage, vacation entitlements, and protections for women, minors, and specific professional categories. It also regulates union organization, collective bargaining, occupational health and safety measures, and creates the framework for the Labor Judiciary, including the Labor Courts and the role of the Public Prosecutor's Office.

While several provisions have been amended or repealed, particularly following the 1988 Federal Constitution and subsequent labor reforms, the CLT remains the backbone of Brazilian labor law. Its influence extends not only to the private sector but also, in many aspects, to the regulation of public service employment.

III. FEDERAL PUBLIC SERVICE LEGAL FRAMEWORK (LAW No. 8,112/1990)

The Federal Public Service Legal Framework in Brazil is governed by Law No. 8,112, enacted on December 11, 1990, during the presidency of Fernando Collor de Mello. This legislation established a single legal regime for federal civil servants, integrating the principles of Article 37 of the 1988 Federal Constitution, which had defined the foundations of public administration. The initiative originated under President José Sarney, who appointed a special commission to draft the regulatory framework, later promulgated by his successor Collor, despite partial presidential vetoes [5].

A. Structure of the Law

The statute is divided into nine titles and contains 253 articles, covering topics such as recruitment, career progression, remuneration, rights and duties, disciplinary measures, and social security. Among its provisions, the following stand out:

- Recruitment and Admission: public examinations, appointments, transfers, and removals.
- Remuneration and Benefits: salaries, bonuses, allowances, paid vacation, and various indemnities.
- Rights and Duties: professional obligations, prohibitions, and responsibilities of civil servants.
- Disciplinary System: sanctions including warnings, suspensions, and dismissal.
- Social Security: retirement benefits, health assistance through the Unified Health System (SUS), maternity and paternity leave, accident-related leave, and family allowances.

B. Relevance to Occupational Health and Safety

Of particular importance is Title VI, which regulates social security rights and establishes policies related to health, safety, and well-being of public servants. This includes provisions on occupational accidents, sickness benefits, and health assistance, ensuring alignment between labor protection and the constitutional guarantee of social security.

Law No. 8,112/1990 thus represents a central pillar of the Brazilian public administration system, not only regulating employment relations but also linking them directly to the protection of health and safety in the workplace.

IV. CIVIL CODE IN THE LABOR CONTEXT

Although previous labor legislations ensure rights and duties for Brazilian workers, they are not always sufficient to address the diverse circumstances that can arise in the workplace. In such cases, provisions from the Brazilian Civil Code can be applied, particularly Article 927, which deals with civil liability and indemnification [6].

A. Article 927 of the Brazilian Civil Code

Article 927 (Civil Code, Law No. 10,406, January 10, 2002) establishes the obligation to repair damage caused by unlawful acts, including those committed with or without intent:

“Anyone who, by an unlawful act, causes damage to another is obliged to repair it. There is an obligation to repair the damage, regardless of fault, in cases specified by law or when the activity normally performed by the author of the damage involves, by its nature, risk to the rights of others.”

Unlawful acts are defined in Articles 186 and 187, covering actions or omissions caused by negligence, imprudence, or misuse of legal rights, even when the damage is solely moral. Consequently, a company may be held responsible for any accident occurring within its sphere, whether caused by negligence, recklessness, action, or omission.

V. OCCUPATIONAL RISKS

This section presents basic concepts of occupational risks, their classifications, examples covered by the CLT and the Federal Public Servant Legal Regime, and definitions of CIPA (Internal Commission for Accident Prevention) and CISSP (Internal Health Commission for Public Servants) [3][5].

A. Definitions Related to Occupational Risks

Occupational risks are hazards affecting workers' health and well-being, potentially causing temporary or permanent damage. Despite efforts by the state and private companies to minimize these risks, they cannot be entirely eliminated, as most are inherent to specific activities.

In the private sector, companies are required by the CLT to create a CIPA, responsible for statistical monitoring of workplace accidents, promoting safety practices, and disseminating information. Similarly, public institutions maintain a CISSP, which identifies workplace hazards, monitors risks, and ensures corrective measures.

Certain professions are naturally hazardous, such as divers, miners, firefighters, and police officers. Other jobs considered non-hazardous may still generate long-term risks, e.g., secretaries (ergonomic disorders) and postal workers (radiation exposure).

B. Classification of Occupational Risks

Occupational risks can be classified into environmental,

ergonomic, and mechanical categories (Table 1):

- Environmental risks are associated with the worker's surroundings and include physical, chemical, and biological hazards.
- Ergonomic risks arise from psychophysiological factors inherent to work activities.
- Mechanical risks result from poorly maintained infrastructure, equipment, or unsafe work procedures.

TABLE I
EXAMPLES OF EACH RISK CLASSIFICATION

Environmental			Ergonomic	Mechanical
Physical	Chemical	Biological		
Noise	Dust	Viruses	Intense physical effort	Inadequate physical arrangement
Vibrations	Fumes	Bacteria	Manual lifting and carrying of weight	Unprotected machinery and equipment
Radiation	Mists	Protozoa	Poor posture	Inadequate or defective tools
Hot/cold	Fog	Fungi	Excessive work pace	Inadequate lighting
Abnormal pressures	Gases	Parasites	Repetitiveness	Risk of fire or explosion
Humidity	Vapors	Microorganisms in general	Physical and/or psychological stress	Urban violence
–	General chemical compounds	Venomous animals	–	–

C. Inherent Risks in Public and Private Work Environments

Workers across banks, ministries, foundations, hospitals, energy sectors, and universities face multiple occupational risks regardless of the employment sector.

In banks, cashiers and managers face mainly ergonomic risks; janitors face chemical and biological risks; security personnel are exposed to urban violence.

In hospitals, medical staff face biological and chemical hazards, stress, and high work pace; janitors and security staff are exposed to physical strain, improper lifting, and unsafe equipment; radiologists encounter ionizing radiation.

The energy sector includes mining, wind, hydroelectric, nuclear, and oil activities, each presenting specific environmental, chemical, biological, mechanical, and ergonomic risks depending on the role.

In universities, administrative staff, janitors, and security personnel encounter risks similar to bank staff, while faculty and laboratory technicians face risks that vary according to department and research activities (Table 2).

TABLE II
EXAMPLES OF EACH RISK CLASSIFICATION

Research Area	Involved Risks	Risk Details
Financial Mathematics	Ergonomic	Inadequate posture, repetitive tasks, long working hours.
Industrial	Ergonomic	Inadequate posture, repetitive tasks, long

Research Area	Involved Risks	Risk Details
Chemistry		working hours.
	Chemical	Fumes, gases, vapors, chemical compounds.
	Physical	Noise, temperature changes, humidity.
	Mechanical	Inadequate physical setup, unprotected equipment, inadequate or defective tools, electricity, probability of explosion.
Electrical Machines	Ergonomic	Inadequate posture, repetitive tasks, long working hours.
	Physical	Noise, vibration, temperature changes.
	Mechanical	Inadequate physical setup, unprotected machines and equipment, inadequate or defective tools, electricity, probability of explosion.
Solar Energy	Ergonomic	Inadequate posture, repetitive tasks, long working hours.
	Physical	Solar radiation, temperature changes, humidity.
Human Pharmacology	Ergonomic	Inadequate posture, repetitive tasks, long working hours.
	Chemical	Fumes, gases, vapors, chemical compounds.
	Biological	Viruses, bacteria, protozoa, fungi, parasites, microorganisms in general.
Physical Education	Ergonomic	Intense physical effort, inadequate posture, repetitive tasks, long working hours.
	Physical	Solar radiation, temperature changes.
	Mechanical	Inadequate physical setup, unprotected equipment, inadequate or defective tools.

VI. ACCIDENTS IN WORKPLACES NOT COVERED BY LABOR LAWS

This section discusses examples of workplace accidents and the applicability of the CLT, the Federal Public Servant Legal Regime, and the Brazilian Civil Code in situations not fully covered by labor regulations [3][5][6].

A. Accidents in Federal Universities

Under the Federal Public Servant Legal Regime, public employees are covered by social security benefits that ensure protection in cases of illness, disability, accidents at work, maternity, paternity, and healthcare. Professors, administrative staff, janitors, and security personnel are covered in case of occupational accidents.

However, students involved in research laboratories face similar risks as professors but do not have employment ties. They are not protected under the Federal Public Servant Legal Regime, nor under the CLT, leaving them uncovered by traditional labor protections.

B. Accidents in Bank Branches

Employees in private banks, such as cashiers, managers, janitors, security staff, and accountants, are protected by the CLT, which provides benefits for accidents occurring during their work.

Outsiders, such as clients or third-party contractors, face the same occupational risks but are not covered by labor laws unless employed by the institution. Therefore, clients in bank

branches are not protected by the CLT, and third-party contractors' protection depends on their employment status.

C.Accidents Caused by Aggression

Both public and private employees are protected against third-party aggression. Under the Federal Public Servant Legal Regime (Arts. 211–228), and the CLT (Arts. 168–229), employees can receive compensation, pensions, or funeral assistance.

However, students and clients remain unprotected by these regulations. Compensation for them depends on other legal frameworks, such as the Civil Code.

D.Accidents Not Covered by Brazilian Labor Laws

Despite not being formal employees, students and clients are entitled to workplace safety under Civil Law principles of objective liability. Institutions are responsible for accidents resulting from negligence, omission, or unsafe conditions, and victims may seek compensation.

Aggressions present a specific case: while the aggressor is primarily responsible, the institution may also bear partial liability if inadequate security contributed to the incident (e.g., a robbery at an ATM on campus).

VII. FINAL CONSIDERATIONS

Historically, before the abolition of slavery, workers in Brazil had no labor protections. Following abolition, the Proclamation of the Republic, and the Industrial Revolution, labor laws became necessary to protect the emerging class of employees. Early worker health initiatives aimed to prevent negative impacts on the productivity and economy of the new Republic [3][5].

The CLT, established during Getúlio Vargas's government, consolidated all existing labor laws and continues to protect employees in the private sector. For federal public servants, the Federal Public Servant Legal Regime regulates careers, with Title VI addressing social security and occupational protection [5].

Occupational risks remain inherent to professions and can only be minimized through internal prevention programs, such as CIPA and CISSP, and initiatives like PPRA (Environmental Risk Prevention Program) and PCMSO (Occupational Health Medical Control Program) in private companies. Risks are classified as environmental, ergonomic, and mechanical, and their diversity complicates complete mitigation.

In federal public institutions, especially universities, occupational risks vary widely depending on the nature of the work. Gaps in the CLT and the Federal Public Servant Legal Regime are complemented by Civil Law, particularly the Civil Code, which establishes liability and the obligation to compensate. Both private companies and public institutions are responsible for employees, visitors, contractors, and third parties. Even with robust safety policies, organizations bear responsibility for incidents resulting from negligence,

imprudence, action, or omission [6].

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Second Cycle Audit: Re-Audit on: Management of Epididymo-orchitis

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Abstract— Epididymo-orchitis is a common urological condition characterized by inflammation of the epididymis and testis, which can mimic the presentation of testicular torsion — a surgical emergency. Accurate diagnosis and appropriate management are crucial to avoid unnecessary imaging and ensure timely intervention when required. This re-audit was conducted in the Urology Department at Frimley Park Hospital to evaluate the impact of implemented changes following the first audit cycle, particularly regarding adherence to NICE and BAUS guidelines and the rational use of scrotal ultrasound scans. Data were collected retrospectively from patients presenting with acute testicular pain. The re-audit demonstrated a marked reduction in unnecessary ultrasound requests (from 73% to 40%) without missing any cases of torsion or epididymo-orchitis requiring surgical intervention. Incorporating the TWIST score (Testicular Workup for Ischemia and Suspected Torsion) improved diagnostic confidence, enhanced clinical decision-making, and promoted better guideline adherence. The results highlight the importance of continuous education, structured assessment tools, and evidence-based protocols in improving patient care and resource utilization in urological practice.

Keywords— Epididymo-orchitis reaudit, Scrotal Ultrasound scan, Testicular torsion and twist score, NICE guidelines.

Comprehensive Phyto Pharmacognostical Profiling, Isolation of Strophanthidin, HPTLC Method Development and Anticancer Evaluation of *Corchorus aestuans* L., *Corchorus olitorius* L., and *Corchorus trilocularis* L.

Carol P. Macwan, Tejal G. Soni, B. N. Suhagia

Abstract—

Context: The research focuses on the pharmacognostical, phytochemical, and anticancer evaluation of three species of *Corchorus* plants, commonly known as 'Jute', which are traditionally used in Ayurveda for various medicinal purposes. Research

Aim: The aim is to establish the pharmacognostic and phytochemical profiles of the plants, isolate the cardiogenic compound strophanthidin, develop and validate an HPTLC method for its quantification, and evaluate the anticancer potential of the plant extracts.

Methodology: The research employs pharmacognostical studies, physicochemical analysis, preliminary phytochemical screening, isolation and characterization of phytoconstituents, development and validation of an analytical method, and evaluation of anticancer activity.

Findings: The study identified comprehensive pharmacognostic characteristics, isolated strophanthidin, developed a validated HPTLC method for its quantification, and demonstrated the anticancer potential of the plant extracts, highlighting their cytotoxic effects on various cancer cell lines. Theoretical Importance: This research contributes by providing a detailed profile of the three *Corchorus* species, isolating strophanthidin, developing an analytical method for its quantification, and demonstrating the anticancer properties of the plants. Data Collection and Analysis Procedures: Data was collected through various standard pharmacognostical and phytochemical techniques, analytical methods, and anticancer evaluations. The analysis involved quantitative microscopy, phytochemical screening, and validation studies for the HPTLC method. Questions Addressed: The study addressed research questions related to the pharmacognostical, phytochemical, and anticancer properties of *Corchorus* species, aiming to contribute to the scientific understanding of these plants' medicinal potential.

Conclusion: The research successfully achieved its objectives by establishing pharmacognostical profiles, isolating strophanthidin, developing an HPTLC method for its quantification, and demonstrating the anticancer effects of the plant extracts on various cancer cell lines.

Keywords— corchorus, pharmacognosy, phytochemistry, anticancer.

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Exploring Psychophysiological and Endocrine Dynamics of Kundalini Practice

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Abstract — Kundalini practice has historically been described as a practice influencing both mind and body, yet empirical research on its endocrine effects remains scarce. This study examined whether kundalini-based facilitation, considered a psychotherapeutic approach, could affect thyroid hormone regulation in women with hypothyroidism. A total of 22 participants were recruited and randomized into two groups: an intervention group practicing kundalini energy facilitation and a control group. Clinical endpoints included levels of TSH, T3, and T4, alongside self-reported well-being measures. Results showed a positive trend in the intervention group, with reductions in TSH and increases in T3/T4 compared to controls. Participants also reported improvements in perceived energy, mood stability, and overall well-being. No adverse effects were observed. These findings suggest that kundalini-based facilitation, viewed as a form of psychotherapeutic practice, may have regulatory effects on the hypothalamic–pituitary–thyroid axis and could represent a complementary pathway to improving both physiological and psychological well-being.

Keywords — Neuroscience, kundalini, hypothyroidism, psychology, hypothalamic-pituitary-thyroid axis

INTRODUCTION

Hypothyroidism is among the most prevalent endocrine disorder globally, affecting 4-10% of the population [1]. It is associated with fatigue, low energy, mood instability, and impaired quality of life, all of which can persist over time and significantly reduce daily functioning.

Hypothyroidism is characterized by insufficient production of thyroid hormones — thyroxine (T4) and triiodothyronine (T3) — which are essential regulators of metabolism, thermoregulation, cognitive activity, and cardiovascular function. Deficiency of these hormones leads to a generalized metabolic slowdown, resulting in symptoms such as weight gain, cold intolerance, concentration difficulties, and emotional instability. In its chronic form, hypothyroidism not only affects physical health but also contributes to increased fatigue, depressive mood, and reduced motivation, reflecting its strong interaction with both neuroendocrine and psychological systems.

Traditional treatment approaches provide biochemical regulation, which helps individuals to increase levels of hormones and improves their quality of life. However, the average duration of therapy can last several months [2-3]. Despite biochemical normalization many patients continue to experience residual symptoms, such as cognitive slowing, emotional flatness, and reduced motivation, suggesting that

hormonal correction alone may not fully restore psychophysiological balance.

Recognition that endocrine regulation is closely linked to stress and psychophysiological dynamics. The hypothalamic–pituitary axis, including the thyroid axis [4]. Which partial sensitive to autonomic balance and chronic stress exposure. Interventions that target stress and emotional regulation have been shown to influence hormonal activity and autonomic function, highlighting the need for integrative approaches that address both biological and psychological aspects [6].

In particular, activation of the hypothalamic–pituitary–adrenal (HPA) axis during chronic stress has been shown to inhibit thyroid-stimulating hormone (TSH) secretion, alter thyrotropin-releasing hormone (TRH) signaling, and suppress peripheral conversion of T4 to T3 [5].

These mechanisms may explain why emotional and physiological stressors frequently aggravate hypothyroid symptoms even when biochemical parameters appear normal.

Therefore, interventions capable of modulating stress-related physiological pathways could indirectly promote thyroid recovery and improve overall quality of life.

Mind-body practices such yoga, meditation and mindfulness have been studied extensively for their ability to reduce stress, enhance autonomic balance and improve quality of life [7]. Controlled studies and systematic reviews demonstrate consistent effects on heart-rate variability, emotional stability and subjective well-being [8-10]. Regular yoga breathing has been shown to improve cardiac autonomic modulation, with a significant shift towards parasympathetic predominance after six months in healthy adolescents. There findings support the role of yoga-based interventions in enhancing autonomic balance and reducing sympathetic dominance [8]. Moreover, yoga and meditative practices have been associated with measurable endocrine effects, including reduced cortisol secretion, increased parasympathetic tone, and improved regulation of metabolic hormones [7–9].

Such findings reinforce the theoretical basis for exploring mind–body approaches as adjunctive therapies in endocrine disorders.

However, current evidence on thyroid-specific responses to such interventions remains limited, with most studies focusing on cardiovascular or stress-related outcomes rather than endocrine function [10].

Evidence also suggests that these interventions may exert indirect effects on endocrine systems. Yoga practices have been shown to modulate cortisol levels and autonomic nervous system activity, which may affect thyroid regulation [9]. Nevertheless, despite growing evidence for psychophysiological

benefits, studies specifically examining thyroid function remain scarce and fragment [10]. This lack of targeted research underscores the need to evaluate whether integrative practice such as kundalini facilitation can provide measurable benefits for individuals with hypothyroidism.

Taken together, this body of work supports the rationale for exploring combined strategies - standard endocrine care complemented by psychophysical interventions. Such approaches may provide a broader framework for improving both physiological and psychological outcomes in individuals with thyroid dysfunction.

The present study was therefore designed to investigate psychophysiological and endocrine dynamics in women with hypothyroidism, comparing outcomes between an intervention group and control group. The intervention consisted of Kundalini facilitation, as an interactive psychophysiological practice of interpersonal engagement, in which the facilitator serves as a mediator and initiator of changes in the participant's psycho-emotional state, through subjective bodily sensations, enhanced emotional attunement, and a sense of inner balance. Within a research context, facilitation is regarded as a potential modulator of psychophysiological regulation, capable of influencing both emotional perception and endocrine outcomes.

We specifically focused on thyroid function as a reliable biomarker, since the synthesis and regulation of thyroid hormone require a long time frame. This characteristic makes thyroid markers informative for assessing sustained psychophysiological effects of mind-body intervention. Accordingly, we examined the key indices of thyroid activity, including thyroid-stimulating hormone (TSH), free triiodothyronine (FT3), and free thyroxine (FT4), alongside psycho-emotional measures of stress, mood and perceived energy.

METHODS

Participant information —

The study sample consisted of 22 women (aged 25-40 years), all of whom had a confirmed diagnosis of hypothyroidism based on clinical and laboratory criteria. All participants underwent a preliminary medical examination that included a full thyroid hormone profile and clinical interview to rule out hidden comorbidities. Participants were free of other endocrine, psychiatric or systemic disorders and none reported a history of cardiovascular, neurological or metabolic conditions that could confound outcomes.

Exclusion criteria included pregnancy, recent use of psychotropic or hormonal medications, and participation in any other facilitation before. All women had first experience of kundalini facilitation practice, which minimized the risk of prior conditioning or familiarity influencing outcomes. To minimize variability in hormonal fluctuations and ensure accurate assessment, all participants were during study in the same phase of menstrual cycle.

Following screening, participants were randomly assigned into two equal groups ($n = 11$ per group): an intervention group receiving kundalini facilitation sessions and a control group receiving placebo sessions.

Study design —

A double-blind, randomized, placebo-controlled design was implemented to minimize bias. Randomization was performed using a computer-generated algorithm, thereby eliminating any investigator influence on group allocation. All participants had a confirmed clinical diagnosis of hypothyroidism, ensuring homogeneity of the sample. Placebo sessions were structurally identical: same schedule, identical conditions, same duration and format but did not include the element of facilitation, thus controlling for expectancy effects.

Each session lasted 60 minutes, provided on study days 1, 3, and 5. Both groups followed an identical schedule, and blood sampling was performed twice – at baseline (day 0) and after completion of the protocol (day 6). The sampling window was restricted to morning hours in a fasting state to exclude circadian fluctuations in hormonal levels. Adherence to the protocol was monitored by an independent assistant, further strengthening the blinding procedure. In addition, after each session, participants completed a self-report questionnaire in which they rated energy level, stress level, described emotional state and recorded any subjective changes experienced during the practice.

Endocrine assessments - endocrine outcomes were defined as primary endpoints. Venous blood samples were collected under standard conditions as baseline (day 0) and after final intervention (day 6). We observed dynamics of thyroid-stimulating hormone (TSH), free triiodothyronine (FT3) and free thyroxine (FT4).

Psycho-Emotional Assessments - were evaluated using validated psychological instruments administered at the same points (day 0 and day 6). The following measures were included:

(I) *Perceived Stress Scale (PSS)*: widely used 10-item questions the degree to which situations in life are appraised as stressful.

(II) *Mood Profile*: adapted version of the Profile of Mood States (POMS-SF), developed by a clinical psychologist, which provides a detailed evaluation of anxiety, fatigue, tension, and mood stability.

(III) *Somatic Perception Rating*: participants reported bodily sensations and perceived energy levels on a 10-point scale, allowing quantification of subjective vitality and psychophysical well-being.

Together, these instruments provided a multidimensional assessment of both endocrine regulation and psychophysiological states, enabling integrated analysis of neuroendocrine and emotional outcomes.

RESULTS

Psycho-Emotional response:

At baseline (Day 0), both groups reported comparable stress levels (mean = 3.5/10). By Day 6, a clear divergence was observed between conditions (Table 1). Participants in the facilitation group demonstrated a reduction in stress from 3.5 to 3.0, corresponding to a 14.28% decrease. In contrast, the control group exhibited a slight increase in stress from 3.5 to 3.7, as a +5.71%.

These findings indicate, that facilitation was associated with a measurable reduction in subjective stress, where the absence of facilitation was linked to stable or slightly worsening stress levels.

Group	Thyroid Status	Facilitation	Stress (day 0)	Stress (day 6)	% Change
I (n=11)	Hypothyroid	Yes	3,5	3,0	↓ 14,28%
II (n=11)	Hypothyroid	No	3,5	3,7	↑ 5,71%

Table 1. Stress Response

Participants in the facilitation group reported a sense of calmness, mental clarity, and body relaxation after following each session, consistent with stress reduction trends. Control group reported the same emotional state, as before and after session. These convergent subjective and quantitative findings underscore the potential of kundalini facilitation to modulate psycho-emotional regulation.

Participants were asked to rate their subjective level of psycho-physical energy and overall well-being on a 10-point scale, where 1 represented minimal vitality and 10 indicated a strong sense of internal energy and emotional balance. As shown in Table 2, the facilitation group reported a pronounced increase in perceived energy, rising from a mean 5.0 at baseline to 9.0 after intervention – an 80% improvement. In contrast, the control group demonstrated only a modest 20% increase, likely reflecting general expectancy or relaxation effects rather than true physiological shift.

Group	Thyroid Status	Facilitation	Energy (day 0)	Energy (day 6)	% Change
I (n=11)	Hypothyroid	Yes	5,0	9,0	↑ 80,00%
II (n=11)	Hypothyroid	No	5,0	6,0	↑ 20,00%

Table 2. Somatic Perception Rating

These findings suggest that kundalini facilitation produces measurable distinct psychophysical activation, supporting its role in enhancing embodied awareness and subjective vitality beyond placebo-level influence.

Hormonal response

Endocrine analysis was performed based on venous blood sample collected at baseline (day 0) and after final intervention (day 6). Revealed consistent differences between groups (Table 3). To calculate endocrine responsiveness, absolute percentage change was applied using the formula:

$$|\Delta\%| = |(\text{Post-intervention value} - \text{Baseline value}) / \text{Baseline value}| * 100$$

This standardizes reactivity regardless of direction and allowed direct comparison across individuals with varying baseline concentrations.

Group	Thyroid Status	Facilitation	\Delta\% TSH	\Delta\% T3	\Delta\% T4
I (n=11)	Hypothyroid	Yes	30,76%	9,2%	13,43%
II (n=11)	Hypothyroid	No	9,63%	6,25%	3,72%

Table 3. Hormonal response (Absolute % Change)

TSH: Facilitation group showed a substantial reduction (-30.76%), whereas controls demonstrated only a minor decrease (-9.63%).

FT3: Increased by 9.2% in group facilitation, compared to 6.25% in controls.

FT4: Increased by 13.43% in the facilitation group, relative to a modest 3.72% increase in controls.

These findings indicate that kundalini facilitation elicited a more endocrine response, particularly reflected in the downregulation of TSH and the concurrent elevation of FT3 and FT4 levels. Such pattern is consistent with improved thyroid efficiency and reduced hypothalamic stimulation, implying a functional normalization of the hypothalamic-pituitary-thyroid (HPT) axis.

Statistical evaluation confirmed that magnitude of TSH reduction in the facilitation group approached significance ($p < 0.05$), while changes in FT3 and FT4 demonstrated positive trends. Moreover, the observed hormonal shifts paralleled reduction in perceived stress, reinforcing the psychophysiological nature of intervention impact.

DISCUSSION

The study demonstrated that kundalini facilitation in women with hypothyroidism was associated with consistent improvement across both endocrine and psycho-emotional domains. The intervention group showed a marked reduction in thyroid-stimulating hormone (TSH) and a parallel increase in free triiodothyronine (FT3) and free thyroxine (FT4), accompanied by reductions in perceived stress and notable improvements in mood stability, emotional regulation, and perceived energy. In contrast, the control group exhibited only minimal or inconsistent changes, highlighting the specificity and potential effectiveness of the facilitation process.

The convergence of hormonal and psychological improvements suggests that kundalini facilitation may exert a modulatory influence on the hypothalamic-pituitary-thyroid (HPT) axis and overall psychophysiological balance. Lower stress perception could reduce the inhibitory impact of chronic stress on hypothalamic signaling and pituitary secretion of thyrotropin-releasing hormone (TRH), thereby facilitating normalization of thyroid activity. Simultaneously, enhanced thyroid function may contribute to increased energy, motivation, and emotional stability, creating a feedback loop between endocrine regulation and psychological state.

These findings align with previous research demonstrating the interplay between stress regulation and endocrine homeostasis [4–6]. Mind-body interventions such as yoga and meditation have been shown to modulate cortisol levels, heart-rate variability, and emotional resilience [7–9]. However, Kundalini facilitation differs conceptually and mechanistically from traditional yoga, as it includes an interpersonal and energetic component, in which the facilitator actively mediates psychophysiological states. This element of guided energy transmission and relational attunement may enhance both subjective and physiological responsiveness, explaining the more pronounced changes observed in the facilitation group.

From a neurophysiological perspective, it can be hypothesized that kundalini facilitation activates pathways connecting limbic, hypothalamic, and autonomic circuits, potentially involving modulation of vagal tone and oxytocin release. These mechanisms could explain the observed reduction in stress and improvement in endocrine parameters through enhanced parasympathetic dominance and emotional co-regulation. Future studies should test this hypothesis using neuroendocrine and neuroimaging methods such as salivary cortisol assessment, EEG, or fMRI. Expanding future trials to include larger samples, follow-up periods, and additional biomarkers—such as cortisol, oxytocin, and prolactin—will allow for a deeper understanding of the psychoneuroendocrine effects of this method.

CONCLUSION

The present study provides preliminary evidence that kundalini facilitation may support both endocrine regulation and psycho-emotional well-being in women with hypothyroidism. The intervention was associated with a significant reduction in thyroid-stimulating hormone (TSH) and a corresponding increase in free triiodothyronine (FT3) and free thyroxine (FT4), indicating improved thyroid function. In parallel, participants reported measurable improvements in perceived stress, mood stability, and subjective energy levels. These convergent outcomes suggest that Kundalini facilitation exerts a regulatory influence not only on hormonal balance but also on emotional and psychophysiological resilience.

The combined improvement across both physiological and psychological domains supports the interpretation of an integrated mind-body mechanism of action. Reduced stress perception may alleviate inhibitory effects on the hypothalamic-pituitary-thyroid (HPT) axis, while improved thyroid function could contribute to enhanced cognitive and emotional stability. This bidirectional relationship highlights the potential of kundalini facilitation as an interdisciplinary psychophysiological approach that bridges emotional self-regulation, autonomic balance, and endocrine function. Unlike simple relaxation or placebo effects, facilitation involves an interactive process of energetic and emotional co-regulation, which may account for its distinct outcomes.

While the findings are preliminary, they open new directions for scientific exploration. Future studies will include larger samples, longer follow-up periods, and an expanded set of biomarkers—such as cortisol, oxytocin, and heart rate variability (HRV)—to clarify the underlying neuroendocrine pathways. Integrating neuroimaging and electrophysiological methods could further illuminate how facilitation influences brain-body communication and hormonal feedback loops. In summary, the current results represent the first empirical step toward understanding the neurophysiological basis of Kundalini facilitation and suggest its potential as a complementary approach in managing both endocrine and psycho-emotional dimensions of hypothyroidism.

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