RESEARCH ARTICLE

Emerging Frontiers of Public Safety: Synergizing AI and Bioengineering for Crime Prevention

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Received: 05 August, 2023, Accepted: 17 September, 2023, Published: 19 September, 2023

Abstract
The convergence of artificial intelligence (AI) and biological engineering technology (BET) can potentially revolutionize public safety efforts. However, the responsible use of these technologies requires crucial considerations. This study employed an exploratory sequential mixed-method to examine the governance mechanisms apropos AI and BET in the context of crime prevention in the Philippines. It identifies several key components that contribute to establishing governance mechanisms, including multisectoral agencies, legislative initiatives, and regulatory frameworks. The study also identifies a 3-factor model for the governance convergence of AI and BET in public safety. These factors include empowerment and sufficiency, ethical considerations, and laws and regulations. The findings underscore the notable implications of integrating AI and BET into public safety efforts, such as improving surveillance systems, proactively preventing public health crises, and optimizing emergency response capabilities. However, ethical considerations and regulatory guidelines must be in place to address privacy concerns and mitigate potential risks associated with these technologies. The convergence of AI and BET also presents opportunities for sustainability. Nevertheless, concerns arise regarding its improper utilization. Based on the study's findings, policy recommendations are directed at ethical considerations, governance and regulation, and sustainability. These policy actions aim to address the opportunities and challenges associated with the convergence of AI and BET in public safety, ensuring responsible and beneficial use within the framework of Public Safety 4.0.

Keywords: sustainability; ethical considerations; frameworks; empowerment and sufficiency; emerging trends

Introduction

The realm of public safety in the Philippines has undergone significant transformations, tracing its roots to the historical periods of the Spanish Colonial Era and the Spanish-American War. A notable milestone during this period was the establishment of the Philippine Constabulary, which symbolized the integration of police and military forces aimed at tackling diverse security issues (Varona, 2010; Ladwig, 2014). To date, the landscape of the public safety in the country has now evolved immensely due the advent of technology which recalibrate the dynamics and trends of the security threats around the world.

Industry 4.0, characterized by the fusion of digital technologies and automation, is at the forefront of driving the development of Public Safety 4.0. As industries embrace advanced technologies like the Internet of Things (IoT), artificial intelligence (AI), biological engineering technology (BET), and big data analytics, there is a transformative impact on the field of public safety (Chang & Andreoni, 2020). Public Safety 4.0 leverages these advancements to enhance emergency response systems, optimize resource allocation, and improve situational awareness. Through intelligent sensors, real-time data analysis, and predictive modeling, it enables proactive and efficient management of emergencies, prevention of crimes, and safeguarding the communities (Kartskhiia, 2018). The integration of Industry 4.0 technologies into public safety operations is paving the way for a more interconnected, resilient, and effective approach to ensuring the well-being and security of individuals and society (Ding et al., 2019; Henman, 2020).

In one facet of public safety, the rapid advancements in technology have paved the way for new frontiers in public safety. The convergence of Artificial Intelligence (AI) and Biological Engineering (BET) has emerged as a promising avenue for enhancing crime prevention strategies. The synergistic potential of these two fields opens exciting possibilities for bolstering public safety measures in a holistic and efficient manner (Stahl, 2021). However, as AI and BET continue to mature, ensuring effective governance becomes paramount. Governance mechanisms play a crucial role in regulating and guiding the development, deployment, and utilization of these technologies (Cath, 2018; Medvedec, 2012).

In a nutshell, public safety in the Philippines faces multifaceted challenges arising from local to global security threats, and to include the convergence of emerging technologies, like the case of AI and BET. Hence, striking a balance between leveraging the benefits of these two powerful technologies while addressing the challenges are essential to ensure that public safety initiatives remain effective, responsible, and trusted by communities. Understanding and addressing these challenges are crucial for ensuring effective governance and safeguarding the well-being of society. Thus, it is imperative to understand the level of adoption and adherence to established frameworks, regulations, and guidelines. By evaluating the implementation status, this research aimed to shed light on potential barriers or bottlenecks that hinder the effective integration of AI and BET into public safety practices. Moreover, this study also delved into the ways forward of these frontier technologies to forecast its possibilities in the purview of public safety.

Methodology

This study adopted an exploratory mixed-methods approach, incorporating both qualitative and quantitative methodologies. The quantitative aspect involved analyzing numerical responses from the survey, while the qualitative aspect involved gathering narrative data through literature review, focus group discussions (FGDs), and participant narratives. The combination of these methods provided a comprehensive and robust analysis of the research topic, especially in developing the governance convergence model using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) through Structural Equation Modeling (SEM). By employing triangulation of approaches, the study obtained a more comprehensive understanding of the subject matter, enhancing the validity of the findings. Additionally, a foresight tool known as "Look Back To Look Forward" was employed to forecast the future of artificial intelligence and biological engineering technology in the context of public safety 4.0.

Primary sources of data for the study were obtained from survey questionnaires and narratives provided by participants. Secondary data were collected from various sources such as textbooks, peer-reviewed scholarly journal articles, published studies, and available reports and policies relevant to artificial intelligence and bioengineering technology in the country. The study covered the national level and various units/departments of the Philippine National Police (PNP) responsible for maximizing the benefits of these technologies in public safety. The participants included the heads of offices and personnel from these units, such as the Information Technology Management Service (PNP-ITMS), the Anti-Cybercrime Group (PNP-ACG), Regional Anti-Cybercrime Units (RACU), and the Explosive Ordnance Disposal and Canine Group (PNP-EOD/K9) across the country.

Qualitative data obtained from participants were transcribed systematically, preserving language mannerisms and code-switching. The BARD app and conventional thematic analysis were used to analyze the qualitative data, allowing for the identification of elements and indicators for a good governance convergence model. Quantitative data from the survey questionnaires were statistically analyzed using frequency distribution and employed EFA and CFA through SEM to explore and validate the latent variables and factors. Descriptive statistics were also used to describe the level of agreement among respondents regarding the governance mechanisms related to AI and bioengineering in the country.

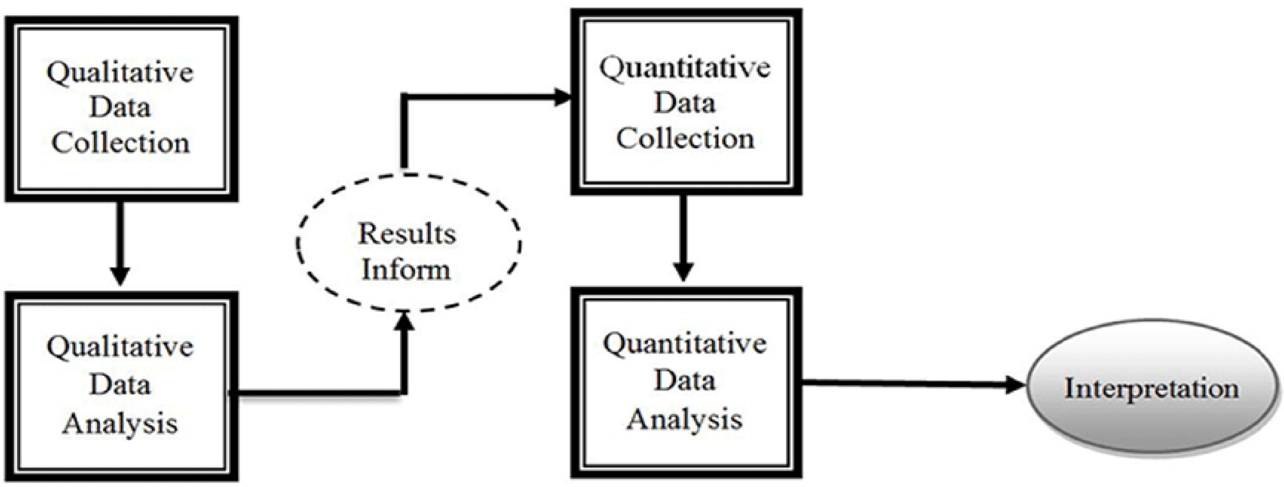


Figure 1. The Research Design of the Study

Results and Discussions

Philippine Status Quo on AI and BET

The governance mechanisms for Artificial Intelligence (AI) and Biological Engineering Technology (BET) in crime prevention in the Philippines involve multiple stakeholders, including government agencies, legislative initiatives, and regulatory frameworks. Key agencies include the National Privacy Commission (NPC), Department of Science and Technology (DOST), Commission on Higher Education (CHED), Philippine National Police (PNP), and Private Sectors (PVs). These agencies play important roles in formulating governance mechanisms, such as implementing data privacy policies, promoting development and utilization of AI and BET, integrating technologies into academic programs, and implementing them in crime prevention and public safety. Legislative initiatives and regulations, such as the Data Privacy Act, and Cybercrime Prevention Act, provide guidelines and penalties for the responsible use of these technologies. These governance mechanisms aim to ensure ethical and responsible use of AI and BET in crime prevention in the Philippines.

Although various frameworks and initiatives have been introduced in the Philippines, comprehensive governance mechanisms for artificial intelligence and biological engineering technology are still lacking (Chua et al., 2023; Simeon, 2022). Nevertheless, the government has recognized both the positive and negative potential impacts of these technologies on various sectors in the country (DailyGuardian, 2022).

Extent of Implementation of Governance Mechanisms Apropos AI and BET

The descriptive statistics in Table 1 provide an overview of the degree of existing governance mechanisms based on a sample of 1,268 observations. The range of responses for the governance mechanisms is represented by a minimum value of 1.00 and a maximum value of 5.00. The mean value of 3.3155 indicates that, on average, the degree of existing governance mechanisms is at a neutral point. The small standard deviation of 0.98004 suggests that most responses are clustered closely around the mean, indicating relatively little variability in the dataset.

Table 1. The Descriptive Statistics of the Degree of the Existing Governance Mechanisms

	N	Minimum	Maximum	Mean	Std. Deviation	Interpretation
Governance Mechanism	1267	1.00	5.00	3.3155	.98004	**Neutral**
N	1267					

Legend: 4.21-5.00 "Very High," 3.41-4.20 "High," 2.61-3.40 "Neutral," 1.81-2.60 "Low," 1.00-1.80 "Very Low"

Overall, the descriptive statistics suggest that the existing governance mechanisms for the convergence of AI and BET in the context of public safety are moderately true, leaning towards a neutral position. However, there are variations in the responses, as indicated by the range and standard deviation, implying that some participants may hold different perspectives on the governance mechanisms. It also highlights that the existing governance mechanisms are relatively less known, not only among the public but also within the public safety sector, indicating a need for greater awareness and understanding of legal frameworks and government initiatives related to AI and BET.

Governance Model for AI and BET

Exploratory Factor Analysis

The collected data underwent an Exploratory Factor Analysis (EFA), and the results are presented in the table below. The analysis included the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's test of Sphericity, which are used to determine the suitability of the data for factor analysis. The KMO measure ranges from 0 to 1, with values closer to 1 indicating better suitability for factor analysis. In this study, the KMO value obtained was 0.966, which is considered excellent. This high value suggests that the sample size used and the correlations among variables are highly appropriate for conducting factor analysis. Additionally, Bartlett's Test of Sphericity was performed, resulting in a chi-square value of 97719.871, a degrees of freedom (df) value of 780, and a p-value of 0.000 ($p<0.05$). These results indicate that the correlation matrix is significantly different from the identity matrix, providing evidence of underlying factors in the data. According to Kaiser (1974), a sampling adequacy value higher than 0.5 is considered suitable for exploratory factor analysis. Since the obtained KMO value surpasses this threshold, the data is deemed appropriate for analysis. If the KMO value had been lower, additional data would have been required, and more respondents would need to be added to achieve the necessary level of sampling adequacy.

Table 2. The KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.966
Bartlett's Test of Sphericity	Approx. Chi-Square	97719.871
	df	780
	Sig.	.000

The dataset was subjected to an exploratory factor analysis (EFA), which revealed three factors with corresponding eigenvalues of 26.977, 6.252, and 1.060. Eigenvalues are indicators of the total variance explained by the identified factors. They offer valuable insights into how effectively the factors capture the underlying patterns of variation in the data, serving as an essential measure for assessing the goodness of fit of the EFA model.
Examining the Total Variance Explained table, we find that the first factor accounts for 67.442% of the total variance, indicating a substantial contribution to the dataset's variability. The second factor explains 15.629% of the variance, while the third factor explains 2.649%. Consequently, the first factor has the most significant impact in explaining the variance, while the third factor has the least impact. When considering all three factors together, they collectively account for 85.720% of the total variance explained, as indicated in the table. This demonstrates that these three factors effectively capture much of the underlying variation in the dataset, providing a meaningful representation of its structure.

Table 3. Total Variance of the Dataset

Total Variance Explained							
Initial Eigenvalues				Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings a
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	26.977	67.442	67.442	26.977	67.442	67.442	25.066
2	6.252	15.629	83.071	6.252	15.629	83.071	14.038
3	1.060	2.649	85.720	1.060	2.649	85.720	18.419

Extraction Method: Principal Component Analysis.
a When components are correlated sums of squared loadings cannot be added to obtain a total variance

Based on the result of the Exploratory Factor Analysis (EFA) through Principal Component Analysis, considering all the explored indicators, the three components/ dimensions extracted are namely: *Empowerment and Sufficiency, Ethical Considerations,* and *Laws and Regulations.*

Dimension 1 encompasses a wide range of aspects related to empowerment and sufficiency in the context of public safety programs that integrate AI and bioengineering technologies. It includes the adoption and implementation of these technologies in public safety initiatives, the promotion and sharing of knowledge through public forums and events, research studies and publications examining their impact and effectiveness, the formulation of policies and regulations by public safety organizations, educational programs provided by institutions, public outreach campaigns emphasizing responsible use, incident reporting and response evaluation, assessment of data accuracy and cost-effectiveness, collection of user feedback, monitoring of public opinion, addressing security risks and ensuring compliance with regulations, investments in research and development, patents and collaborations between organizations and technology companies, scientific publications, practical applications, conferences and workshops, government initiatives, and grants and scholarships specifically dedicated to AI and bioengineering technology in public safety.

Dimension 2 focuses on the ethical considerations associated with the application of artificial intelligence and biological engineering technologies in the field of public safety. This dimension emphasizes the need to develop and implement these technologies in a manner that respects and safeguards individuals' rights to privacy and autonomy. It underscores the importance of transparency, whereby technology companies are expected to provide relevant information to the public regarding the utilization of these technologies. Accountability is also highlighted, with technology companies assuming responsibility for any errors or shortcomings in their AI and bioengineering technologies. Non-discrimination is a fundamental principle, necessitating that these technologies treat all individuals fairly and impartially, without any biases based on factors such as race, gender, age, or ethnicity. The dimension further emphasizes the significance of accuracy and reliability, urging technology companies to strive for precise outcomes in their AI and bioengineering technologies. Additionally, it stresses the need for robust security measures to protect against malicious attacks, ensuring the integrity and confidentiality of these technologies.

Dimension 3 of the analysis highlights the importance of laws and regulations that govern the utilization of artificial intelligence and biological engineering technology in the context of public safety. This dimension focuses on specific guidelines, rigorous standards, and responsible protocols that dictate the proper use of these technologies. It places a strong emphasis on privacy and data protection protocols to ensure the security of personal information. Furthermore, well-defined protocols for certification and accreditation, along with robust oversight and monitoring mechanisms, are established to ensure compliance and accountability. The dimension also encompasses evaluation processes and reporting requirements for incidents involving AI and bioengineering technology, aiming to maintain transparency and accountability throughout their implementation.

Confirmatory Factor Analysis

The factors resulting from the Exploratory Factor Analysis (EFA) were further subjected to Confirmatory Factor Analysis (CFA) using AMOS to test the measurement model. CFA evaluates the alignment between observed variables (indicators derived from survey questions) and a proposed factor structure or pre-defined theory/model. It examines whether the observed variables effectively capture the underlying latent constructs or factors. Throughout the process of conducting CFA, an iterative approach was followed to achieve desirable fit indices by adjusting the model specification. This involved covarying error values and removing items with high residuals.

Covarying variables allowed for the inclusion of correlated error terms between specific observed variables within the model. By accounting for the shared variance not explained by the latent factors, the model's alignment with the observed data was enhanced, leading to improved fit. High residual items represented discrepancies between the observed and predicted values, indicating that the model did not adequately explain the variance in those observed variables. Therefore, these items were removed to enhance the fit to the observed data. In total, 24 out of 40 items were removed during this process.

Various model fit measures were employed to assess the overall goodness of fit of the model. The CMIN/df ratio evaluated the fit between the model and the observed data, with a lower value indicating a better fit. The GFI (Goodness-of-Fit Index) measured the proportion of variance and covariance accounted for by the model, with values ranging from 0 to 1. A GFI value of 0 indicated a complete lack of fit, while a value of 1 indicated a perfect fit. The CFI (Comparative Fit Index) compared the fit of the proposed model with that of a baseline model in which all variables were uncorrelated. A CFI of 1 indicated a perfect fit, and values above 0.90 were generally considered acceptable. The TLI (Tucker-Lewis Index) also assessed model fit, penalizing complexity more than the CFI. A TLI of 1 indicated a perfect fit, and values above 0.90 were generally considered acceptable. The SRMR (Standardized Root Mean Square Residual) measured the average discrepancy between the observed and predicted correlations from the model, with values below 0.08 indicating a good fit. Lastly, the RMSEA (Root Mean Square Error of Approximation) evaluated the discrepancy between the model-implied and observed covariance matrices, adjusted for model complexity and sample size. The obtained values for these fit indices fell within commonly accepted levels of goodness of fit, as suggested by Ullman (2001), Hu and Bentler (1998), and Bentler (1990).

Fit Indices

The 3-factor model exhibited a good fit to the data, as indicated by various fit indices. The CMIN/df ratio was 7.019, slightly higher than the threshold suggested by Schumacker and Lomax (2004). It is important to note that with a sample size of 1,268, the test becomes more sensitive, meaning even minor differences between the model and the data can result in a significant chi-square value and a higher CMIN/DF ratio. However, despite this slight discrepancy, all other fit indices met their respective threshold values, indicating a favorable fit of the model to the observed data in this study. The other fit indices assessed were as follows: the Comparative Fit Index (CFI) was 0.984, the Tucker-Lewis Index (TLI) was 0.977, the Goodness of Fit Index (GFI) was 0.945, the Standardized Root Mean Square Residual (SRMR) was 0.032, and the Root Mean Square Error of Approximation (RMSEA) was 0.069. These indices provide further evidence that the model fits well with the observed data, indicating a satisfactory alignment between the proposed model and the collected information in this study.

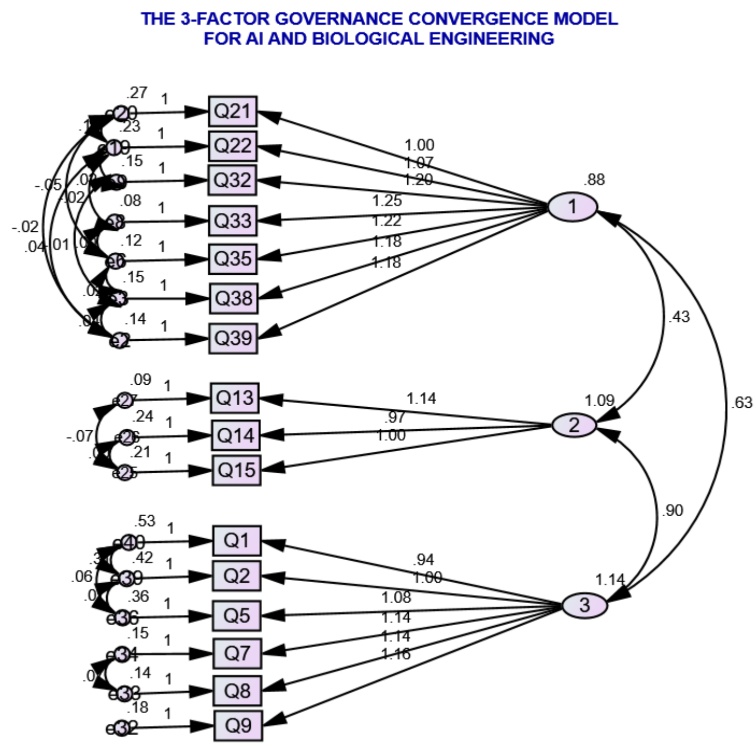
Table 4. The Model Fit Indices of Governance Convergence Model for AI and Biological Engineering

Fit Indices	**Recommended value**	**Source**	**Obtained Value**
P-value	< .05	Bagozzo and Yi (1988)	0.000
CMIN/df	< 5	Less than 2 (Ullman, 2001) to 5 (Schumacker & Lomax 2004)	7.019
Comparative Fit Index (CFI)	> .9	Bentler (1990)	0.984
Tucker-Lewis Index (TLI)	> .9	Bentler (1990)	0.977
Goodness of Fit Index (GFI)	> .9	Hair et al. (2010)	0.945
SRMR	<.08	Hu & Bentler (1998)	0.032
RMSEA	<.08	Hu & Bentler (1998)	0.069

Model Path Diagram

In order to develop an acceptable model, it is necessary that the specifications of fit indices have been met. Since the initial model did not acquire satisfactory values, respecification was done by removing residual items (items with high measurement errors) or those exhibiting correlation deviations to correct discrepancies in the model.

Figure 2. Governance Model of AI and BET in Public Safety.



The model of governance convergence between artificial intelligence (AI) and biological engineering technology in the context of Public Safety 4.0 revealed three essential dimensions for the successful and ethical implementation of these technologies. These dimensions are Empowerment and Sufficiency, Ethical Considerations, and Laws and Regulations.

Dimension 1: *Empowerment and Sufficiency*

One of the dimensions identified in the study is Empowerment and Sufficiency, which emphasizes the importance of raising public awareness. The research emphasizes the need to empower individuals and communities by enhancing their understanding of AI and biological engineering technology in the context of public safety. Key components of this dimension include public awareness campaigns, educational initiatives, and platforms for sharing knowledge.

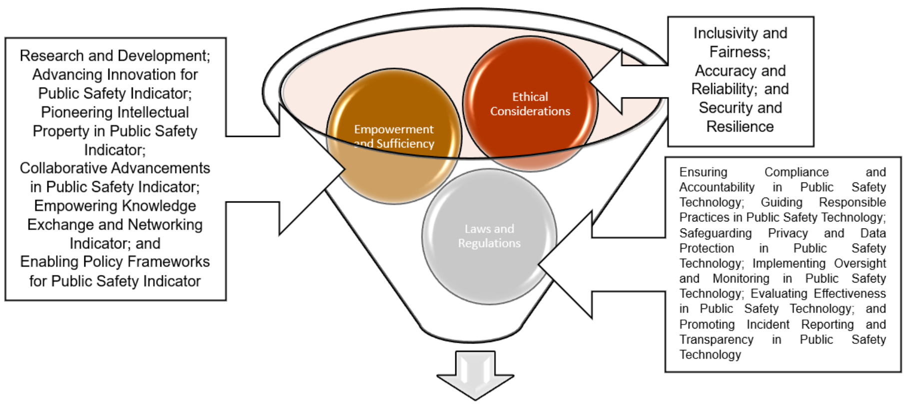
Dimension 2: *Ethical Considerations*

The second dimension that emerged is Ethical Considerations, which recognizes the significance of ensuring inclusivity, fairness, accuracy, reliability, security, and resilience in the use of AI and biological engineering technology in public safety. This dimension highlights the need for these technologies to treat all individuals fairly, provide accurate and reliable results, and protect against malicious attacks.

Dimension 3: *Laws and Regulations*

The third dimension identified is Laws and Regulations, which emphasizes the necessity of comprehensive and effective legal frameworks to govern the use of AI and biological engineering technology in public safety. This dimension encompasses various aspects, including ensuring compliance and accountability, guiding responsible practices, safeguarding privacy and data protection, implementing oversight and monitoring mechanisms, evaluating effectiveness, and promoting incident reporting and transparency.

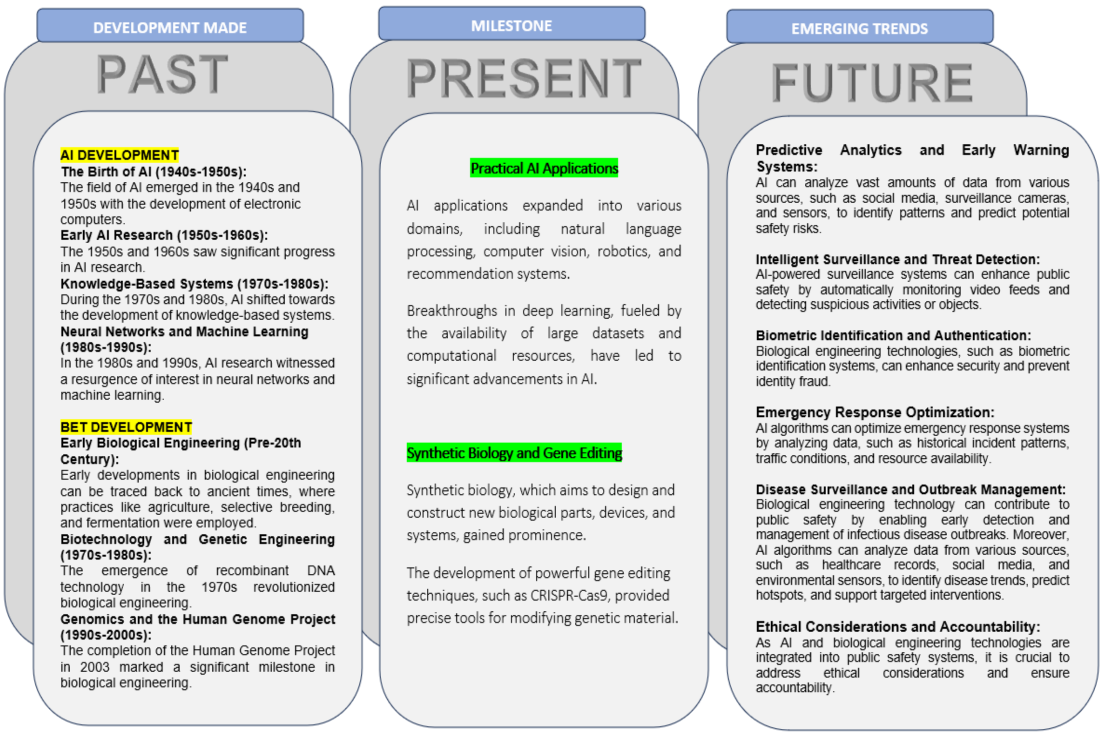
Figure 3. Proposed Governance Model Between Artificial Intelligence (AI) and Biological Engineering Technology in the Context of Public Safety



Ways Forward of AI and BET Apropos Public Safety

Based on the stages of development of AI and BET, it can be gleaned that the emerging trends of AI and BET in public safety are shaping the future of how we ensure security and well-being in society. One prominent trend is integrating AI-powered surveillance systems with biological engineering technologies, enabling more effective threat detection and response to potential biological hazards or bioterrorism threats. Additionally, using predictive analytics and early warning systems, empowered by AI and genomics, is becoming prevalent, allowing proactive measures to prevent public health crises and optimize emergency response efforts (The Alan Turing Institute, 2019). Combining AI algorithms and robotics enhances disaster response capabilities and enables autonomous systems for public safety tasks. However, the ethical considerations surrounding using AI and BET in public safety are gaining attention, especially in synthetic biology and gene editing, prompting the development of responsible frameworks and regulatory guidelines to address privacy concerns and mitigate potential risks. These advancements have opened up new avenues for manipulating and engineering biological systems—offering unprecedented opportunities for targeted modifications at the genetic level and enabling breakthroughs in medicine, biotechnology, and environmental applications (Harvard Gazette, 2020). These emerging trends highlight the immense potential of AI and BET to revolutionize public safety and create a safer and more secure environment for communities when used and regulated properly. Hence, it is important to note that the development and deployment of AI and biological engineering technologies in public safety should be accompanied by appropriate regulations, ethical guidelines, and ongoing evaluation to ensure their responsible and beneficial use for society.

Figure 4. Look Back to Look Forward of AI and BET Vis-à-vis Public Safety



The Implications of AI and BET in the Pillars of Sustainability

The integration of artificial intelligence (AI) and biological engineering has far-reaching effects on sustainability, covering economic, political, and environmental aspects.

From an economic perspective, this convergence presents both opportunities and challenges. On one hand, it stimulates innovation and the emergence of new industries, leading to economic growth and job creation. AI-powered precision agriculture and genetically modified crops, for example, can enhance food production and address global food security issues. Similarly, AI-driven biomanufacturing can revolutionize pharmaceutical and biofuel production, offering sustainable alternatives and driving economic development. However, concerns arise regarding economic inequalities, limited access to these technologies, ethical considerations surrounding the commercialization of biological resources, and potential concentration of power among dominant players in the field.

In the political sphere, the convergence of AI and biological engineering raises governance, ethical, and privacy concerns. It becomes essential to establish policy frameworks and regulations that address ethical issues related to human genetic manipulation, the privacy of genetic data, and the responsible use of AI technologies. Achieving a balance between scientific progress, innovation, and ethical considerations is crucial to ensure responsible and equitable development. Moreover, geopolitical dynamics may be affected as countries and regions compete for dominance in AI and biological engineering, necessitating international cooperation and governance frameworks.

Environmental sustainability is another critical area impacted by this convergence. AI and biological engineering applications can contribute to mitigating environmental challenges by enabling early detection and response to climate change, natural disasters, and ecosystem disruptions. Techniques such as genetic modification and synthetic biology offer opportunities for developing sustainable solutions, including bio-based materials, clean energy production, and ecological restoration. However, it is vital to assess and regulate these technologies carefully to minimize ecological risks and unintended consequences.

Overall, the convergence of AI and biological engineering holds tremendous potential for advancing sustainability across economic, political, and environmental domains. However, it is essential to consider the ethical, social, and environmental implications to prevent adverse outcomes. Collaboration among governments, scientists, industry, and civil society is crucial to establish robust governance frameworks, ensure equitable access, and guide the responsible development and deployment of these technologies in line with sustainable principles and values.

Conclusion and Recommendation

The findings of this study provide important insights for policy recommendations concerning the artificial intelligence (AI) and biological engineering technology (BET) in the context of public safety during the era of Industry 4.0. The study highlights the opportunities and challenges associated with applying AI and BET in various public safety domains while also acknowledging the ethical, legal, and social risks involved. The recommended policy actions encompass several key areas, including Ethical Considerations, Governance and Regulation, Sustainability and Environmental Impact, Capacity Building and Equity, and Pilot Projects and Continuous Evaluation. Moreover, by implementing these recommendations, policymakers, researchers, and stakeholders can work together to address the challenges and opportunities presented by the convergence of AI and BET in public safety, ensuring responsible and equitable development that aligns with sustainable principles and values.

Acknowledgment. The authors of this research work acknowledge the unwavering support and guidance of Dr. Ricardo F. De Leon, Dr. Romeo S. Magsalos, Dr. Rec E. Eguia, Dr. Prescillano D. Campado, and Dr. Alfie Maria R. Custodio. The authors also share the successful completion of this research to Dr. Alvin Q. Romualdo and Dr. Cheryl Marie C. Cipriano.

Funding. This research is entirely self-funded and does not receive any financial support from public, private, or not-for-profit sectors.

Contribution/Originality. This research expands the scope of knowledge by presenting a pioneering body of insights concerning the intersection of Artificial Intelligence (AI) and Biological Engineering technology within the context of public safety. The study employs an exploratory sequential mixed-method approach, analyzed using Sequential Equation Modeling (SEM). This independent and original work is appropriately attributed to the sources from which the ideas have been drawn.

Declaration of Conflicting Interest. The authors affirm that there are no conflicts of interest involved in the conduct and development of this research project.

Availability of Data: The authors affirm that the data underpinning the study's findings are accessible within the article and its Supplementary material. For those seeking access to the raw data that support the study's conclusions, they can make a reasonable request to the corresponding author.

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