



Generative AI and the Future of Software Engineering in Saudi Arabia: Governance, Innovation, and Workforce Transformation

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Abstract: As Saudi Arabia advances its Vision 2030 agenda, Generative Artificial Intelligence (GenAI) has emerged as a transformative force in software engineering. This paper is based on socio-technical systems theory, which considers GenAI adoption as an interplay between technological capabilities and social structures. This ensures that implementing GenAI in organizations aligns well with organizational goals within the established social structures. This study explores how GenAI technologies—such as GitHub Copilot, Baseer, and ChatGPT—reshape software development workflows, engineering roles, and governance practices in the Kingdom. Framed within socio-technical systems (STS) theory, the research examines technical applications, ethical challenges, and workforce implications of GenAI adoption in both public and private sectors. It also highlights national initiatives, including SDAIA’s Arabic Large Language Models (LLMs) and the Personal Data Protection Law (PDPL), as cornerstones of responsible AI deployment. The study synthesizes SDAIA, STC, and KAUST case studies to illustrate real-world integration and identifies key risks such as bias, explainability



gaps, and overreliance. Results indicate that adopting GenAI can minimize software development cycles, enhance code localization for Saudi Arabia's context, and ensure compliance with governance requirements. A proposed strategic roadmap emphasizes ethical alignment, localized innovation, and inclusive workforce development. This work contributes to academic scholarship and national AI policy by aligning GenAI deployment with cultural values, governance standards, and long-term digital transformation goals in Saudi Arabia.

Keywords: Generative Artificial Intelligence; Software Engineering; Saudi Arabia Vision 2030; Large Language Models (LLMs); AI Governance; Responsible AI (RAI); PDPL; Socio-Technical Systems; Prompt Engineering; Arabic Natural language Processing (NLP); Developer Ethics; Digital Transformation; Workforce Inclusion; SDAIA

1. Introduction

1.1 Background and Motivation

The Kingdom of Saudi Arabia (KSA) is undertaking an ambitious national transformation under its Vision 2030 initiative, aiming to transition from a resource-dependent economy to a diversified, knowledge-based society [1]. Central to this strategic transformation is adopting emerging technologies, particularly Artificial Intelligence (AI), to modernize industries, empower citizens, and stimulate innovation. Among AI subfields, GenAI stands out due to its capabilities in automating creative and cognitive tasks such as code generation, content creation, and data analysis. Globally, GenAI is redefining productivity in software engineering, healthcare, and education sectors. In Saudi Arabia, GenAI is seen as a technological asset and a strategic enabler aligned with the Kingdom's socio-economic goals. The launch of Arabic-focused LLMs like ALLM, the announcement of a \$40 billion national AI investment fund, and strategic partnerships with companies like IBM all signal a strong national commitment to AI leadership. GenAI also introduces governance, transparency, and workforce challenges despite the promise. KSA risks increasing digital inequality, over-reliance on foreign models, and ethical misalignment with its cultural values if not deployed strategically. To mitigate these risks, this study is framed within the STS theory, which views technological adoption within the interaction of technical, social, and institutional subsystems. As a result, technological adoption should be considered beyond merely technical aspects to include how human, policy, and organizational factors shape the integration. Including STS theory ensures that the paper situates GenAI adoption within the broader socio-economic transformation agenda in Saudi Arabia, providing recommendations that are not only technical but also socially sustainable [2].

1.2 Conceptual Framework

Figure 1 below is a conceptual framework showing the interdependence between GenAI adoption in software engineering, workforce transformation, governance, and ethical AI, and how they link in the realization of Saudi Arabia's Vision 2030. The model shows the importance of cultural alignment, localization innovation, and feedback loops in achieving sustainable digital transformation.

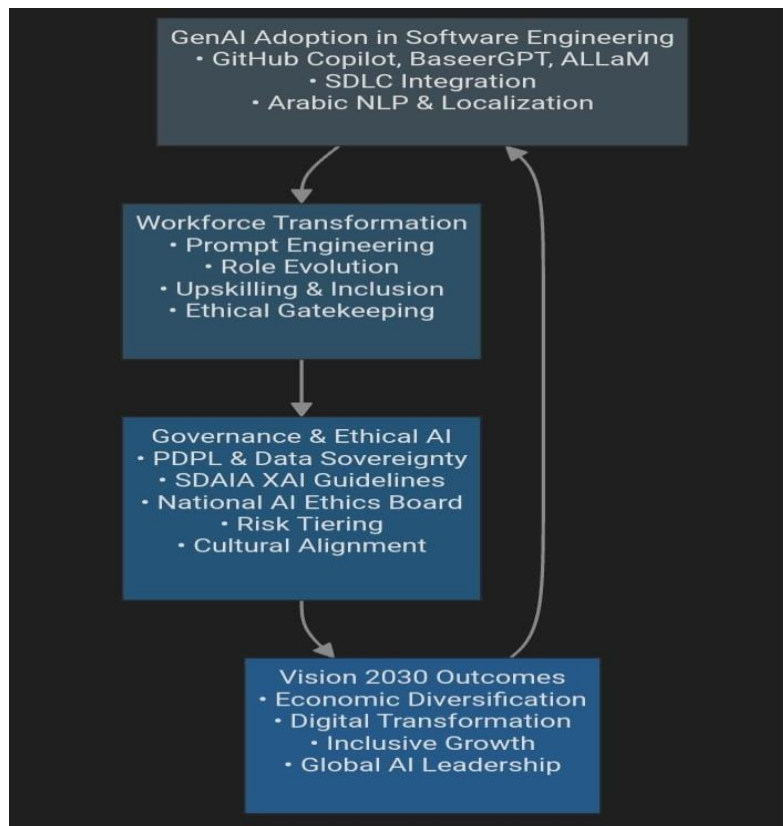


Figure 1: Conceptual Framework

1.3 Research Problem

While global adoption of GenAI is accelerating, there is a lack of localized research addressing how these tools intersect with national strategies in Gulf states. Specifically, there is limited scholarship on how GenAI is implemented within software engineering in KSA and the impact on software engineers' roles. The ethical, regulatory, and cultural challenges are involved. Moreover, most studies focus on global trends, with insufficient analysis of Vision 2030 alignment or localized GenAI tools [3]. Additionally, while the Gulf Cooperation Council (GCC) region continues to invest in GenAI, the comparatively limited academic-industry collaboration, fragmented innovation systems, and weak governance have slowed down efforts among the regional entities. These issues have underscored the suboptimal realization of GenAI deployment in GCC member countries, a critical gap this study seeks to address through the STS framework.

1.4 Research Objectives

This paper aims to analyze GenAI's adoption and contextual fit within KSA's software engineering sector. Identify ethical, transparency, and workforce-related challenges. Explore the role of national strategies in guiding GenAI deployment. Propose a multi-stakeholder framework for effective integration of GenAI.

1.5 Research Questions

RQ1: How is GenAI currently being implemented within software engineering practices in Saudi Arabia?

RQ2: What are the main challenges—ethical, regulatory, and workforce-related—that hinder effective GenAI integration in KSA?

RQ3: How can Saudi Arabia balance GenAI innovation with transparency, accountability, and cultural alignment in the context of Vision 2030?

1.6 Significance of the Study

This research is timely given Saudi Arabia's substantial AI investments and policy momentum. The outcomes are intended to assist Policymakers (e.g., SDAIA, DGA), Private firms integrating GenAI, Universities and training centers, and Developers navigating evolving roles. The study also aligns with inclusive development goals, including gender participation in AI innovation—an area supported by the Women in Data Science (WiDS) movement [4].

1.7 Research Scope and Limitations

This study focuses on Saudi Arabia's software engineering landscape and draws from secondary data and case analysis. Primary data collection is not included, and findings are interpreted within the conceptual boundaries of socio-technical systems theory.

1.8 Stakeholder Relevance

The study informs: Government entities implementing digital transformation, Software engineers adapting to GenAI workflows, Academia, especially AI education programs, Technology investors, and startup ecosystems

1.9 Research Contributions

1. Offers a Vision 2030-aligned analysis of GenAI adoption in software engineering.
2. Proposes actionable strategies for cross-sector collaboration.
3. Identifies socio-technical and governance challenges.
4. Suggests frameworks for responsible, ethical GenAI use.

2. Global and Local Landscape of GenAI

2.1 Global Market Outlook

The GenAI market is projected to grow from **USD 36.06 billion in 2024** to **USD 356.10 billion by 2030**, with a CAGR of **46.47%**. Adoption is robust in software development, media, finance, and education. IDC forecasts that GenAI will comprise **32% of global AI spending by 2028**, reaching **USD 202 billion** [5].

This global growth is concentrated in North America, China, and the EU, driven by:

- Venture-funded startups (e.g., OpenAI, Anthropic)
- Corporate R&D (e.g., Google DeepMind)
- Policy incentives (e.g., US AI Initiative, EU AI Act)

These regions also exhibit advanced **AI governance**, infrastructure, and local model training capabilities.

2.2 Strategic National Approaches

Saudi Arabia’s strategy focuses on **government coordination, Arabic localization, and economic diversification**. It aligns with the UAE’s 2031 strategy and Singapore’s AI Nation framework [6]. The table below provides a global benchmark with strategic national approaches to contextualize Saudi Arabia's position in relation to the international leaders. Table 1 below compares different countries and their approaches to GenAI deployment.

Table 1: Comparative National Approaches

Country/Region	Strategic Focus	Investment	Regulation	Talent Development
USA	Innovation-driven	VC/startup; public-private AI hubs	AI Initiative Act	University R&D and research hubs
China	State-led	Large-scale government funding	Centralized laws/directives	AI National reskilling programs
EU	Ethical, rights-based	Public-private partnerships	AI Act (2024)	Academic and industry collaboration
Singapore	“Smart Nation” strategy	State investment in R&D	Model Governance Framework	AI AI Singapore initiative; AI in school curricula
UAE	Government-led innovation	Government AI fund	National Ethics Guidelines	AI AI university; AI Summer Camps
Saudi Arabia	Vision 2030–aligned; government coordination; Arabic localization; economic diversification	\$40B Public Investment Fund	SDAIA Guidelines, PDPL	Gov–University–Industry bootcamps (e.g., Tuwaiq, KAUST, SDAIA)

Global benchmarking indicates that Saudi Arabia’s strategic focus, investment, and talent development initiatives have put it on the global map. Compared to the global leaders, the Kingdom is on the right trajectory to become a global leader and achieve Vision 2030.

2.3 The Saudi GenAI Ecosystem

Saudi Arabia’s GenAI ecosystem has matured through strategic natural initiatives. For instance, the Arabic Large Language Model (ALLaM) was developed by the Saudi Data & AI Authority (SDAIA) in partnership with IBM. ALLaM, an Arabic and English bilingual LLM, is a national chat application based on GenAI technologies that are available via IBM’s Watsonx platform. The flagship 13B-parameter “instruct” model was trained on about 3 trillion tokens, allowing it to outperform its peers on various metrics across Arabic benchmarks, allowing ALLaM to serve the country’s linguistic needs [7]. The establishment of the Saudi Public Investment Fund (PIF), the Kingdom’s sovereign wealth fund, has more than \$900 billion in assets under its management. PIF has already allocated over \$40 billion to AI-related initiatives [8]. The AI fund serves as a flagship platform for national AI infrastructure. The massive investments have

borne fruit with the Kingdom's market size expected to grow at an annual growth rate (CAGR 2025-2031) of 34.2% resulting in a market volume of 2.47 billion by 2030 [9]. Apart from the investments, the Digital Government Authority (DGA) has recognized the evolving public sector governance framework. DGA's policy mandates explainable AI in public systems, where government services must be transparent and explainable.

2.4 Governance and Policy in KSA

Regulatory frameworks in the Kingdom have evolved to ensure ethical, transparent, and responsible GenAI deployment. SDAIA XAI guidelines stipulate that all public AI systems must be transparent, interpretable, and verifiable to qualify for government adoption. PDPL, 2023, introduces strict protocols for consent, data minimization, and user rights over personal data in AI applications. The proposed AI Ethics Board to review high-risk GenAI deployments seeks to establish a multidisciplinary ethics council to review high-risk AI deployments [10]. These measures reflect a hybrid model balancing innovation with ethical accountability, transparency, data privacy, and oversight.

2.5 Key Barriers to GenAI Adoption

Despite the momentum, GenAI in Saudi Arabia faces several challenges. Firstly, a talent gap exists due to a deficit in specialists experienced in training, fine-tuning, and deploying GenAI systems, especially those with Arabic NLP expertise [11]. Secondly, despite ALLaM's extensive training, localized data scarcity relies on broad Arabic and English datasets. The limited training on non-Arabic datasets limits the effectiveness of the models in the Kingdom context [12]. Thirdly, despite the heavy investment in GPU clusters, infrastructure limitations remain a challenge. Cloud scalability and specialized inference environments remain areas for further development. Additionally, overreliance on imported tools like OpenAI's GPT and Claude limits adaptability to Saudi needs. While these tools offer advanced capabilities, their integration is constrained, leading to a preference for locally governed alternatives like ALLaM. Lastly, public awareness is limited, especially for small and medium enterprises (SMEs), since they lack exposure to GenAI opportunities. Figure 2 below outlines GenAI readiness in Saudi Arabia.

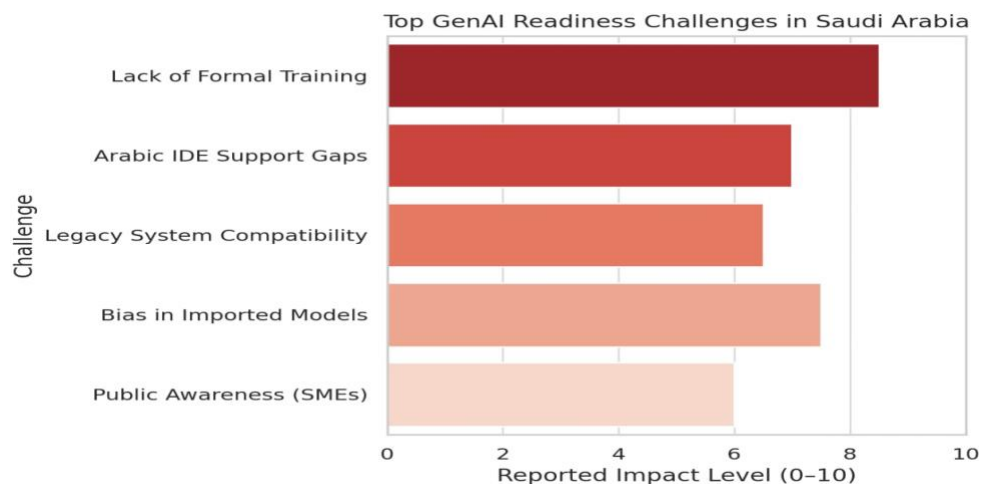


Figure 2: GenAI readiness challenges in Saudi Arabia include talent gaps, localization barriers, and infrastructure issues.

2.6 Industry Readiness and Perception

A Statista 2024 survey reveals exceptionally high GenAI adoption intent among Saudi executives. 92% of CEOs expect GenAI integration, 88% expect it to guide core strategy, while 89% link it to workforce transformation [13]. This high executive confidence underscores the need for aligned policy, education, and infrastructure. The datapoints demonstrate a strong executive buy-in and an anticipated structural shift in the labor market.

2.7 Summary

Saudi Arabia's GenAI ecosystem is rapidly evolving, driven by substantial state investment, localized models, and regulatory oversight. However, sustainable adoption in software engineering depends on expanding technical talent, building inclusive tools, and aligning innovation with national values.

The next section explores technical applications and real-world case studies, illustrating how GenAI is being integrated into Saudi software development workflows.

3. Technical Applications and Case Studies of GenAI in Software Engineering

3.1 Introduction

GenAI transforms software engineering by automating code generation, accelerating development pipelines, and enhancing documentation. It is becoming a key enabler of this transformation as Saudi Arabia advances toward its Vision 2030 goals, particularly in digital infrastructure and innovation.

This section outlines GenAI applications across the software development lifecycle (SDLC), presents Saudi-based case studies, evaluates developer experience, and addresses technical integration challenges.

3.2 GenAI Across the SDLC

Table 2: GenAI Tools Mapped to Software Development Lifecycle

SDLC Stage	GenAI Tool Examples	Functionality
Requirements Analysis	ChatGPT, Baseer	Generate specs, user stories
Design	DiagramGPT, Codex	Create UML models, UI layouts
Implementation	GitHub Copilot, CodeWhisperer	Code generation, semantic suggestions
Testing	DeepCode, CodeGuru, Tabnine	Unit test generation, static analysis
Documentation	GPT-4, Guelman et al. model	Inline documentation, README creation
Maintenance	Amazon Q, Replit AI	Bug detection, refactoring, patching

The tools in Table 2 above are intelligent collaborators, especially valuable in agile and resource-constrained development environments.

3.3 Case Study Selection Methodology

The case studies presented in this research were selected based on the following criteria. Firstly, priority was given to cases aligning with Saudi Arabia's Vision 2030, which prioritize digital transformation and

public sector innovation. Secondly, sectoral diversity was considered to ensure cases spanned multiple domains – public administration, enterprise software engineering, and academic research, to offer a multidimensional view of GenAI adoption. Lastly, the availability of public implementation details ensured verifiable details through credible academic publications, government portals, and industry disclosures. The visual below outlines the structured multi-step methodology for identifying the most relevant cases. This approach allowed for a triangulated approach to GenAI implementation across different industries and contexts in Saudi Arabia. A summary of the methodology is in Figure 3 below.

Methodology for Case Study Selection

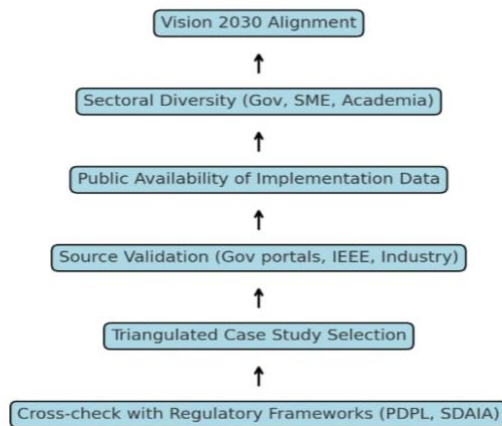


Figure 3: Methodology for Case Study Selection

Further, literature sources were selected using inclusion and exclusion criteria. Inclusion criteria included the following. Firstly, published materials relevant to GenAI in software engineering and governance were considered. Secondly, the materials published between 2018 and 2025 were considered since they were more current and up-to-date than those published before 2018. Thirdly, priority was given to peer-reviewed materials, government reports, and authoritative industry sources. Lastly, contextual relevance to Saudi Arabia or comparable international benchmarks was prioritized. Exclusion criteria included materials lacking verifiable authorship, opinion articles without empirical data, and materials published before 2018, unless they offered foundational theoretical frameworks like the socio-technical systems theory.

3.4 Real-World Case Studies in KSA

3.4.1 SDAIA

Saudi institutions, both public and private, are embedding GenAI into critical processes. SDAIA-led platforms like Absher and Tawakkalna are streamlining the provision of digital services. Absher allows citizens to manage instant government services like driving licenses and passport appointments.

3.4.2 Tawakkalna

Tawakkalna is a super app that unifies government services into a single platform, organizing services, information, and documents for easier use. For instance, Tawakkalna was critical in offering health and safety services during the COVID-19 pandemic.

3.4.3 STC

The Saudi Telecom Company (STC) Group offers IT services in the Kingdom, the Middle East, and Europe. As a telecom giant, STC uses GenAI to automate bug detection through attention-based deep learning and the detection of real-time anomalies in network logs. GenAI also assists in deploying enterprise AI tools using Cohere's language models [14].

3.4.4 Baseer

Master Work's Baseer delivers Arabic NLP for SME, supports enterprise knowledge management, and hosts secure chatbot APIs [15].

3.4.5 KAUST

King Abdullah University of Science and Technology (KAUST) founded the Center of Excellence for GenAI to explore GenAI software development techniques, model optimization, and bias mitigation [16]. These efforts demonstrate a shift from pilot to production-grade GenAI across critical areas like telecom, government, enterprise, and academia.

3.4.6 HITHIRE

Moreover, HITHIRE is a model focusing on fair and accurate hiring in Saudi Arabia. The model enhances Llama 3.1 and has demonstrated significant improvements across gender, nationality, and intersections. These improvements are evaluated using standard fairness metrics defined as follows:

$$\text{Statistical Parity Difference (SPD): } P(\hat{Y} = 1 | A = 0) - P(\hat{Y} = 1 | A = 1)$$

$$\text{Disparate Impact (DI): } P(\hat{Y} = 1 | A = 0) / P(\hat{Y} = 1 | A = 1)$$

$$\text{Theil Index: } (1/n) \sum_{i=1}^n (y_i / \bar{y}) \times \ln(y_i / \bar{y})$$

$$\text{Average Odds Difference (AOD): } 0.5 \times [(FPR(A = 0) - FPR(A = 1)) + (TPR(A = 0) - TPR(A = 1))]$$

$$\text{Equal Opportunity Difference (EOD): } TPR(A = 0) - TPR(A = 1)$$

$$\text{Accuracy: } (TP + TN) / (TP + TN + FP + FN)$$

$$\text{Precision: } TP / (TP + FP)$$

$$\text{Recall: } TP / (TP + FN)$$

$$\text{F1-Score: } 2 \times (\text{Precision} \times \text{Recall}) / (\text{Precision} + \text{Recall})$$

$$\text{Area Under the Curve (AUC): } \int_0^1 TPR(FPR^{-1}(x)) dx$$

HITHIRE showed reduced Statistical Parity Difference (SPD) and Disparate Impact (DI) scores. It achieved a reduced SPD for gender of 0.0156 and DI improved to 0.978 (from baseline values of 0.0847 and 1.1892, respectively). At the same time, the nationality-based Theil Index dropped to 0.3747 from 0.6721, indicating enhanced equity across diverse groups. It also achieved a perfect Average Odds Difference (AOD) and Equal Opportunity Difference (EOD) values of 0.0000. HITHIRE has a high precision of 0.93, a recall of 1.0, an F1 Score of 0.96, and an ROC AUC of 0.95. As a locally developed hiring model, HITHIRE has the potential to integrate ethics in hiring, ensuring that candidates are not discriminated against but given equal opportunity regardless of their gender, age, religion, country of origin, or race.

3.5 Developer Experience Insights

Although GenAI tools offer speed and assistance, developer sentiment is mixed. Recent studies among software professionals have varied. The study indicated that 63% of the respondents reported improved productivity, citing autocomplete capabilities. 41% expressed concerns over trust in generated code, mainly when GenAI is used in regulated sectors like finance or health [17]. Additionally, junior developers were shown to over-rely on LLMs without fully understanding generated logic, raising concerns regarding cognitive offloading. In qualitative interviews, senior developers have raised concerns regarding GenAI hallucinations in sensitive domains. For instance, one backend developer explained: “GenAI once hallucinated a missing key in our database schema—it took me hours to debug.” This demonstrates the essence of structured validation layers and usage policies, especially in enterprise teams. Overall, there is a need for training, review of workflows, and hybrid intelligence – the combination of human oversight with machine suggestion.

3.6 Integration and Tooling Challenges

While GenAI promises significant software development efficiency gains, integrating GenAI tools into enterprise pipelines presents real hurdles. It creates compatibility issues with legacy codebases. Many enterprise systems were not initially designed with modular AI integration, making interacting with GenAI-generated code challenging. Additionally, there is a lack of support for Arabic-specific Integrated development environments (IDEs). The Arabic localization gaps are evident with the lack of support for Arabic-specific natural language prompts, creating a gap for non-English native developers in the Kingdom. Also, API rate limitations and proprietary model opacity limit usability in regulated domains. Overcoming these challenges requires investment in DevOps readiness, internal tooling, and local model customization.

3.7 Practical Example

One of the demonstrations of GenAI’s utility in software development is its ability to create code depending on the context. Consider the prompt: “*Write a function to validate a Saudi mobile number (starting with 05, 8 digits).*”

```
python
import re

def validate_saudi_number(number):
    pattern = r"^05\d{8}$"
    return bool(re.match(pattern, number))
```

This example illustrates how GenAI can encode culturally specific business rules in seconds. Such capabilities reduce developer effort in implementing routine validation rules, especially in e-government and telecom capabilities, where format compliance is essential.

3.8 Limitations and Risks

Despite the advantages of GenAI, GenAI-generated code presents various limitations and risks. GenAI is more likely to miss business-specific logic. While GenAI excels in generating sophisticated code, its lack of domain-specific context can result in flaws or the omission of critical constraints. Security vulnerabilities are possible due to automated code generation, which introduces exploitable patterns. For instance, if GenAI unwittingly replicated insecure coding practices during training, the same patterns will likely emerge during code generation. Lack of documentation or test coverage due to insufficient usage instructions or

unit tests can cause maintainability challenges, especially in complex systems. Mitigating these challenges requires human-in-the-loop validation and XAI auditing tools. SDAIA's policy to enforce XAI principles in government systems is critical in mitigating GenAI challenges.

3.9 Summary

This section has outlined how GenAI is empowering developers and institutions in Saudi Arabia to modernize workflows, reduce costs, and localize digital tools. However, sustainable integration requires attention to developer trust, tooling compatibility, and training in GenAI literacy.

4. Governance Challenges and Ethical Considerations in GenAI Deployment

4.1 Introduction

As GenAI systems are embedded into public and private infrastructure, governance becomes a prerequisite for trust and safety. Vision 2030 requires that digital transformation be fast and responsible. This section examines bias, transparency, accountability, privacy, and cross-border challenges in GenAI deployment within Saudi Arabia. Framed through Responsible AI (RAI) and AI4People ethics principles [32,33,35], the analysis highlights ethical risks and proposes practical solutions.

4.2 Bias and Fairness

Bias remains a foundational problem in GenAI, since model behavior largely depends on the training data. Most large-scale models are trained predominantly on Western and English language datasets, making the models more vulnerable to biased outputs [11]. In the Kingdom context, the global bias presents the risk of cultural misalignment in English-trained models. Such GenAI systems fail to reflect local norms and values, especially in critical sectors like public service chatbots, healthcare, and education. Bias and fairness challenges can be addressed by using localized LLMs (e.g. Baseer, ALLaM) to address the issue of bias by training on regionally curated Arabic corpora. Additionally, applying fairness audits like IBM's AI Fairness 360 should be implemented. Inclusivity benchmarks are essential in promoting the use of more representative data with women, rural users, and people with disabilities in GenAI datasets and applications [4].

4.3 Transparency and Explainability

The opaque nature of GenAI ("black box") remains a significant challenge to attaining explainability, especially in high-stakes systems. The Kingdom has started addressing the black box nature of GenAI systems through the SDAIA Explainability Guidelines, which mandate public-facing AI applications to provide decision logic with user-understandable explanations. Technical interventions like XAI techniques – LIME, SHAP, and attention visualizations can indicate the effect of inputs on model outputs. Further, confidence scores, token attribution, and salient maps can be integrated into GenAI tools to improve developers' and users' trust.

4.4 Accountability and Liability

In traditional software, errors can be directly attributed to the developers. However, assigning responsibility in systems that exhibit autonomous behavior like GenAI is complex. Hence, it is challenging to pinpoint who should take responsibility when errors lead to failure or harm. Despite this issue, international benchmarks like the European Union Act 2023 provide a viable framework. The Act requires

developers and deployers of high-risk AI to be transparent and manage risks. In the Saudi Arabian context, creating a National AI Ethics Board and enforcing PDPL-based responsibility clauses is critical.

4.5 Privacy and Data Sovereignty

GenAI introduces various threats, including prompt leaks, data misuse, and third-party access, mainly when models are accessed through public APIs hosted in other countries. To address privacy and data sovereignty concerns, Saudi PDPL emphasizes informed consent, encryption, minimization, and localization of sensitive data. As a result, prompt anonymization should be prioritized during user-model interactions [18]. Encrypting all API traffic with zero retention policies would be critical in minimizing the exposure of sensitive data in case of breaches. Hosting GenAI models within Kingdom's national infrastructure will facilitate data sovereignty and ensure proper compliance with PDPL.

4.6 Cross-Border Data Compliance

Saudi Arabian organizations and institutions use GenAI services from international providers like OpenAI, Amazon Bedrock, or Azure. These tools may process data from Saudi Arabian citizens in jurisdictions with inadequate privacy safeguards. Risks of PDPL violation and incompatibility with Sharia-compliant data governance principles will likely occur. A strategic response to this problem is prioritizing locally hosted LLMs like ALLaM, enforcing DPAs and cross-border contractual clauses which comply with PDPL's provisions, and undertaking Data Protection Impact Assessments (DPIAs) for GenAI tools which handle sensitive data.

4.7 Intellectual Property and Copyright

While GenAI promises to enhance the software development process, it raises serious intellectual property (IP) and copyright issues. GenAI tools may generate code fragments resembling copyrighted material from their training datasets, which exposes organizations to potential infringement risks. This can happen when GenAI coding tools are trained on public datasets with restrictive licenses or proprietary code. In Saudi Arabia, aligning GenAI tools with PDPL and national IP laws will allow developers to avoid legal disputes that may jeopardize organizations. Adhering to IP and copyright laws, both locally and internationally, will protect developers and end users while facilitating responsible commercial deployment.

4.8 Stakeholder Roles

Table 3 below summarizes stakeholders in Saudi Arabia and their roles.

Table 3: Stakeholder and Role

Stakeholder	Role
SDAIA	Regulator, audit authority for ethical compliance
Private Firms	GenAI integration, developer training, internal governance
Academia	Research, bias audits, and workforce education
Civil Society	Transparency, inclusivity watchdog

4.9 AI Literacy and Public Awareness

Technical governance alone is insufficient in addressing AI risks and challenges. It must be paired with cognitive readiness across the citizens and expatriates. Significant gaps exist in GenAI understanding, especially among SME's, developers, and policymakers. SME's lack awareness of the risks and opportunities GenAI presents. In an attempt to deploy GenAI tools quickly, developers often fail to

undertake proper risk assessment, jeopardizing their users' safety. Policymakers may not fully grasp bias, opacity, or model misuse. To mitigate GenAI understanding among the different groups, Saudi Arabia should fund national AI training programs under the supervision of SDAIA and the Ministry of Communications and Information Technology (MICT). Additionally, the Kingdom can integrate the GenAI curriculum in universities to improve AI literacy. Moreover, undertaking campaigns on data rights through mainstream media and social media would enhance public awareness.

4.10 Risk Tiering Framework

It is critical to tier risks to identify their level of threat. A summary of the risk tiering framework is shown below in Table 4.

Table 4: Risk Tiering Framework

Risk Level	Description	Example Use Cases	Controls Required
High	Rights-critical AI	Justice, finance, and education	Ethics review, XAI, PDPL
Medium	Internal productivity tools	Code generation, HR automation	Oversight, opt-out features
Low	Informational or creative AI	Chatbots, marketing content	Light-touch monitoring

4.11 SWOT Analysis

To get a comprehensive view of GenAI in Saudi Arabia, it is critical to undertake a SWOT analysis to identify the strategic strengths, risks, and limitations of its integration. Table 5 below shows the SWOT analysis of GenAI implementation in the Kingdom.

Table 5: GenAI Governance in Saudi Arabia

Category	Details
Strengths	• Strong government involvement through Vision 2030 and SDAIA • Huge public funding for GenAI development (e.g., \$40B) • Significant investment in local LLMs like Baseer and ALLaM • Alignment with PDPL and explainability frameworks
Weaknesses	• Limited GenAI talent pipeline and formal education • Over-reliance on international APIs and models like OpenAI's GPT • Limited early-stage explainability and audit tools • Uneven adoption across public vs. private sectors
Opportunities	• Lead in Arabic GenAI localization and ethical AI in MENA • Empowerment of women and remote workers via natural language interfaces • Public-private-academic innovation hubs (e.g., KAUST, Tuwaiq Academy) • Strategic collaborations with the UAE, Singapore, and OECD
Threats	• Cultural and ethical misalignment in imported GenAI tools • Privacy risks due to cross-border data flows • Risk of job deskilling among junior developers • Public mistrust or regulatory backlash if incidents occur

4.12 Summary

Thanks to PDPL, SDAIA, and Vision 2030's moral imperatives, Saudi Arabia is positioned to lead in ethical GenAI deployment. To scale responsibly, Saudi Arabia should establish a National Ethics Board, enforce transparency and privacy laws, adopt localized LLMs, and train all stakeholders. This approach will ensure GenAI strengthens—not undermines—trust, inclusion, and innovation in Saudi society.

5. The Evolving Role of Software Engineers in the GenAI Era

5.1 Introduction

GenAI is transforming the software engineering landscape. In Saudi Arabia, where Vision 2030 prioritizes digital innovation, GenAI adoption redefines how engineers work, learn, and engage with ethical responsibilities. This section explores how GenAI affects software engineering roles, skills, and organizational structures—focusing on Saudi-specific workforce trends and policy responses.

5.2 Changing Nature of Software Engineering Work

5.2.1 From Code Creators to Code Curators

Traditionally, developers dedicated a large part of their work to coding. However, with GenAI tools like GitHub Copilot, Tabnine, and Baseer now assisting engineers with tasks like code generation, documentation, testing, and debugging, the role of engineers has changed from line-by-line construction to high-level orchestration. Instead of spending a lot of time writing code, engineers can rate model outputs, evaluate AI-suggested decisions, and focus on high-level architecture and prompts. The adoption of GenAI among software engineers is evident in GitHub's 2023 report, which established that developers using Copilot completed tasks 56% faster. Still, some over-relied on AI outputs without a deep understanding [19].

5.2.2 Public vs. Private Sector Adoption

GenAI adoption varies by sector. Private firms like STC and fintech startups rapidly integrate GenAI to gain speed and innovation. Public sector entities (e.g., government ministries) proceed cautiously due to data sensitivity and compliance constraints. This segmentation affects how engineers engage with GenAI—and the urgency with which skills are adapted.

5.2.3 Expanded Roles and Responsibilities

Table 6 below summarizes the expanded roles GenAI has created and the new responsibilities for software developers.

Table 6: Expanded Roles and Responsibilities

Traditional Role	GenAI-Augmented Role
Code developer	Prompt engineer, code validator
Debugger	Model output auditor, explainability analyst
Document writer	Context enabler for AI-driven documentation
Collaborator	Cross-functional AI-human team integrator

5.3 Emerging Skills for the GenAI Developer

As GenAI becomes a core aspect of the software engineering stack, developers should acquire new competencies to utilize the available tools and capabilities. Engineers now require the following skills in Table 7 below.

Table 7: Emerging Skills for the GenAI Developer

Skill Area	Description
Prompt Engineering	Designing adequate instructions for LLMs: prompt abstraction and chaining.
Risk Awareness	Recognizing hallucinations, unsafe code patterns, and bias in outputs
Explainability	Applying XAI tools to understand model decisions
Policy Fluency	Familiarity with PDPL, copyright, and ethical standards
Cross-Domain Thinking	Collaborating with domain experts in law, healthcare, and education

5.4 Workforce Implications in Saudi Arabia

5.4.1 Upskilling and Education

Saudi Arabia has strategically invested in education programs like Tuwaiq Academy and KAUST AI boot camps. At the same time, SDAIA’s AI Literacy Initiative is expanding rapidly across the Kingdom. Yet a 2024 MCIT report found that 58% of developers use GenAI weekly, and only 22% have received formal GenAI training. This mismatch between GenAI usage and understanding is worrying, especially considering a LinkedIn KSA (2024) report of a 200% increase in job listings requesting GenAI skills over 18 months. Figure 4 below shows GenAI-related job opportunities in Saudi Arabia from January 2023 to July 2024, with a base index of 100.

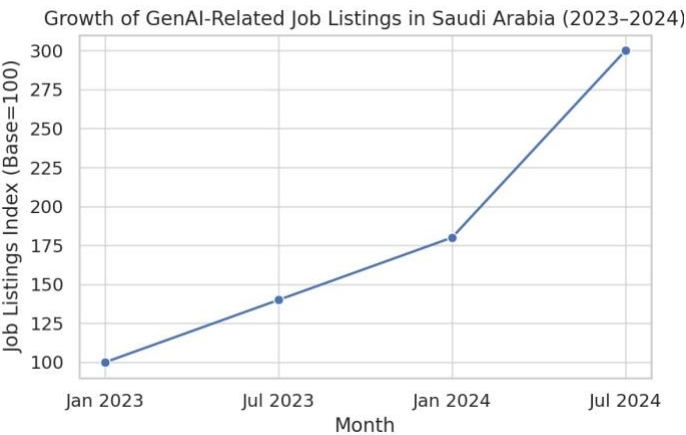


Figure 4: Rise in GenAI-related job postings in Saudi Arabia

Further, a 2025 survey among 78 software engineers in Riyadh and Jeddah indicated that 62% of the respondents experienced enhanced productivity by reducing the time spent on boilerplate code. However, 47% of the respondents were concerned with the reliability of the GenAI-generated outputs. Hence, the findings indicate need for structured code reviews and GenAI trust calibration. Figure 5 below shows the developer sentiment from a 2025 Saudi survey, highlighting improved productivity, concerns over code trust.

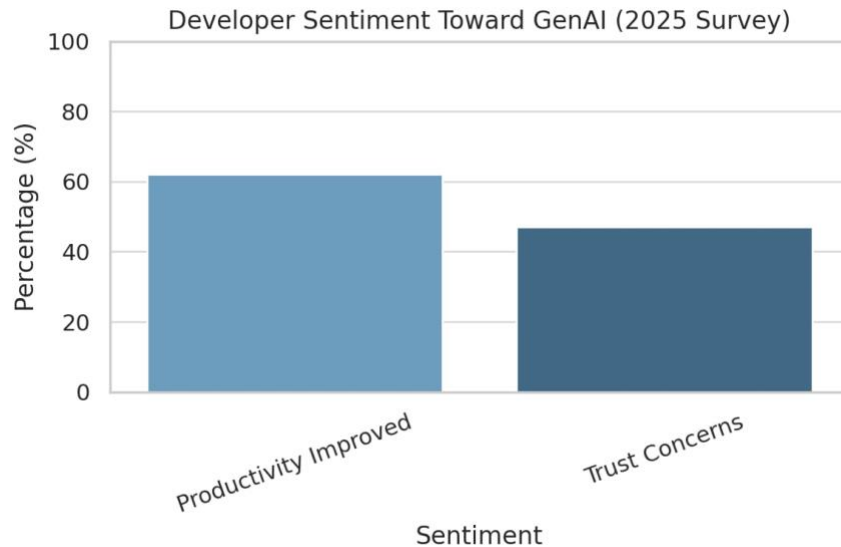


Figure 5: Developer Sentiment Survey

5.4.2 Risk of Job Polarization

While GenAI enhances the software development process, it introduces a polarization risk among the software engineers. While senior developers adapt to GenAI as reviewers or designers, the junior developers risk deskilling, since they write up to 40% less original code, as GenAI fills routine tasks typically assigned to them [20]. The gap could widen due to the inability to establish structured and hybrid workflows, adversely affecting long-term competence. To mitigate the problem, there is a need to pair GenAI use with mentoring, hybrid workflows, and contextual learning.

5.4.3 Gender Inclusion and Equity

GenAI presents a massive opportunity for advancing gender equity, especially in today's world, where the exclusion of women continues to plague many countries. In particular, women remain excluded from the workplace, reducing the opportunities available for advancement. Gender inclusion issues have been remarkably addressed by GenAI in the workforce, especially in the tech industry. Natural language prompts are core in GenAI, minimizing entry barriers for women unfamiliar with traditional programming. Natural prompts allow women an equal chance with their male counterparts, allowing them to participate fully in the ever-growing tech space. Additionally, GenAI enables women to pursue remote careers. This offers women flexible participation, allowing them to develop software while attending to other family needs, like caring for children. Since Vision 2030 targets 50% female tech participation, GenAI can support this if tools are accessible and culturally inclusive [4].

5.4.4 Ethical Decision-Making at the Developer Level

Software engineers increasingly operate as ethical gatekeepers. Developing software that handles sensitive and high-level activities requires high adherence to ethical principles. Despite the high expectations of developers, high-stakes ethical dilemmas exist. Questions have been raised about their ability to trust GenAI-generated code, responsibility for errors, and whether they should override the model

in sensitive contexts. These issues mandate developers to move beyond mere implementers to ethical gatekeepers, whose actions are based on accountability and responsibility.

5.4.5 Adoption Hesitancy and Resistance

Younger engineers have embraced GenAI in code generation, allowing them to develop high-level applications they would otherwise not develop. GenAI tools have proved fundamental in augmenting the entire software development process, allowing junior developers to engage more deeply in the field. Despite this progress, senior developers express reservations. They fear overreliance on GenAI tools in software development will deskill junior developers and cause massive job displacement. There are also concerns of reduced code quality and transparency. Issues of automation without responsibility weigh heavily on senior developers, who question who should be responsible for GenAI outcomes. In particular, the perception that GenAI reduces codebase transparency is disturbing for more experienced software engineers, who know the danger that GenAI-generated software can introduce and compromise security and privacy. Addressing these concerns requires trust-building, phased adoption, and transparent training.

5.5 Organizational Adaptations

Firms must prioritize the areas listed in Table 8 below to succeed with GenAI.

Table 8: Organizational Adaptations

Priority Area	Strategic Action
Tool Governance	Evaluate GenAI APIs for transparency and security.
Talent Development	Create GenAI onboarding programs and ethical literacy plans.
Productivity Metrics	Measure collaboration and quality—not just LOC.
Ethics Culture	Assign AI code reviewers and implement prompt review protocols.

Emerging roles include a prompt architect specializing in multi-step prompt workflows, a trust engineer undertaking model reliability and security, and a GenAI integration lead to bridge engineering, design, and compliance.

5.6 Long-Term Role Evolution and Career Forecast

Over the next 5–10 years, software roles may specialize in the following areas, as shown in Table 9 below.

Table 9: Long-Term Role Evolution and Career Forecast

Future Role	Primary Focus
Prompt Engineer	Model tuning, task abstraction
GenAI Ops Specialist	Model deployment, version control, and auditing
AI-Ethics Integrator	Policy compliance, risk translation
GenAI Curriculum Designer	Building training modules for future devas

These trends demand **interdisciplinary education** and ongoing workforce mapping.

5.7 Summary

Software engineering is no longer just about writing code. In the GenAI era, engineers must be ethical reviewers, interdisciplinary thinkers, prompt innovators, and policy-aware builders. The future requires an

investment in GenAI tools, human capital development, and regulatory oversight. Saudi Arabia's Vision 2030 can catalyze these new roles, but success depends on inclusive training, policy agility, and cultural alignment.

6. Conclusion and Future Outlook

6.1 Summary of Key Insights

This study explored how GenAI is reshaping software engineering in Saudi Arabia—technically, ethically, and strategically. It presents a forward-looking perspective based on Saudi Arabia's Vision 2030 aspirations for digital innovations and national capacity building. Key contributions include the development of a framework for ethical GenAI deployment aligned with Vision 2030, case studies of Saudi initiatives (e.g., SDAIA, KAUST, Baseer), and a critical assessment of skill trends, organizational shifts, and governance proposals. It also proposes a detailed roadmap for workforce and policy adaptation.

6.2 Limitations of the Study

Despite the breadth of this forward-thinking analysis, it has several limitations. Firstly, the study is qualitative and conceptual, drawing from secondary sources, publicly available documents, and policy announcements. Hence, the study lacks field data like productivity benchmarks across different sectors. Additionally, the research has a limited cross-national comparative depth, constraining global generalizability. Future work should focus on developer interviews, codebase audits to evaluate the quality of AI-generated content, and productivity benchmarking across sectors.

6.3 Strategic Alignment with Vision 2030

GenAI's evolution and its software engineering application closely align with Vision 2030's digital transformation. GenAI holds the potential to advance the transformation in several ways. Firstly, GenAI will enable smart government by creating more responsive government platforms. For instance, GenAI-enhanced Absher will offer government services through natural language interfaces. Secondly, GenAI will support talent development and female inclusion. It will provide flexible learning and working environments for women, allowing them to work remotely, which will increase the participation of women in software engineering. Thirdly, GenAI will reinforce data sovereignty through Arabic LLMs, allowing the Kingdom to create independent, secure digital platforms that better serve citizens and expatriates.

6.4 Benchmarking Saudi Arabia Globally

Saudi Arabia has emerged as a regional and global leader in GenAI deployment. The heavy investment into local LLMs like ALLaM is accelerating local adaptation of AI. Additionally, Saudi Arabia is establishing national ethics regulation through SDAIA and PDPL. Compared to its MENA peers, the Kingdom is ahead in infrastructure and regulation. Saudi Arabia's GenAI deployment and governance approach parallels forward-thinking nations like Singapore, Canada, and South Korea. Singapore is known for balancing national strategy and ethical deployment. South Korea majors in AI talent pipelines through government-university guidelines and offers an AI engineer certification. Canada is a leader in embedding AI ethics into national innovation policy through public AI audits. The integration of GenAI into vision-backed national transformation places Saudi Arabia at a strategic position not just as an adopter, but as a

potential benchmark for GenAI localization and culturally-aware

6.5 Future Research Directions

Future studies should prioritize the following:

1. Field studies on GenAI integration in Saudi software teams to understand GenAI's real-world impact on workflows.
2. Developer trust and AI overreliance audits to understand how developers perceive and respond to GenAI recommendations.
3. Inclusive prompt design in Arabic/NLP contexts to ensure diverse usage across a diverse environment like Saudi Arabia.
4. Curriculum trials in AI ethics and prompt engineering can be integrated into university education and vocational training.
5. Frameworks for developer-policy feedback loops to ensure better regulation of GenAI outputs.
6. Establish an Arabic Prompt Engineering Benchmark (APEB) to test performance based on culturally and linguistically localized tasks.
7. Developing a "GenAI Readiness Maturity Model" (GRMM) for evaluating how Saudi software teams scale GenAI tools across development, documentation, and governance phases.

6.6 Strategic Roadmap (Recap)

The operationalization of GenAI transformation in the Kingdom requires a multi-pillar approach, emphasizing both technological and societal dimensions. Table 10 below summarizes the strategic roadmap to deploy GenAI in Saudi Arabia. The visual summary below in Figure 6 shows the five-pillar summary approach—spanning governance, infrastructure, education, inclusion, and public trust—mapped to Vision 2030 priorities and operational implementation pathways.

6.7 Policy-Practice Feedback Loop

GenAI requires iterative learning to comply with ever-evolving regulatory frameworks. Effective governance must evolve with the tech itself. As GenAI reshapes engineering practice, developer feedback must inform future policies, creating an iterative loop between real-world use and regulatory evolution. This co-evolution is critical in enhancing societal trust and ensuring high accountability.

6.8 Call to Action

All stakeholders need to work together to take advantage of GenAI's benefits in the future of software engineering in Saudi Arabia.

1. The government must accelerate ethics enforcement and sovereign AI strategy
2. Universities should develop interdisciplinary GenAI curricula that blend AI literacy with ethics, policy awareness, and design thinking.
3. The software development industry should invest in reskilling, trust-building, and hybrid workflows
4. Developers need to embrace their new role as ethical architects of AI systems

6.9 Final Reflection

Saudi Arabia stands at the frontier of responsible AI. Combining GenAI innovation with ethical leadership can build an AI ecosystem that is technically advanced, culturally respectful, and globally influential. The future of software engineering in KSA is brighter and more human-centered, inclusive, and values-driven.

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Appendix A

Methodology for Case Study Selection

The selection of Saudi case studies (e.g., SDAIA, KAUST, STC, Baseer) was guided by the following criteria:

- Vision 2030 Alignment: Priority was given to entities contributing directly to national digital transformation.
- Sectoral Diversity: Inclusion of the public sector, telecom, academia, and SMEs for a well-rounded picture.
- Data Transparency: Cases with publicly verifiable implementation data were prioritized. Sources included government publications, academic research (IEEE, ACM), industry white papers, and official portals (e.g., SDAIA, KAUST, STC).

Table 10: Strategic Roadmap

Pillar	Key Actions
Governance	National AI Ethics Board, PDPL enforcement, risk-tiering
Infrastructure	Local GenAI platforms, sovereign hosting, Arabic model tuning
Education	GenAI bootcamps, prompt design in curriculum, and ethics integration
Workforce Inclusion	Equity-focused tools, upskilling for women/youth
Public Trust	Awareness campaigns, transparency dashboards, and public feedback

Appendix B

HITHIRE Model Evaluation Metrics

The HITHIRE model was built on an enhanced LLaMA 3.1 foundation, fine-tuned using anonymized Saudi hiring datasets in compliance with PDPL. The model was evaluated using key fairness and performance metrics:

Bias Metrics:

- Statistical Parity Difference (SPD): 0.0156
- Disparate Impact (DI): 0.978

- Theil Index (Nationality-based): 0.3747

Performance Metrics:

- Precision: 0.93
- Recall: 1.0
- F1 Score: 0.96
- ROC AUC: 0.95



Figure 6: Strategic Roadmap for GenAI Deployment in Saudi Arabia