Artificial intelligence for sustainable innovation in visual media: modernizing graphic design workflows in line with SDG 9

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Abstract

Artificial intelligence (AI) is rapidly transforming the creative industries by reshaping how visual communication, storytelling, and graphic design are produced and distributed. Despite widespread integration of AI tools such as generative models, diffusion systems, and transformer-based frameworks, limited research has systematically assessed their measurable impact on sustainable innovation in design practices. This study addresses this gap by developing a conceptual framework that compares traditional and AI-assisted design workflows through the lens of the United Nations Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure). Using a desktop research approach, the study synthesizes findings from academic literature, industry reports, and case studies to evaluate AI's contributions to efficiency, innovation, and sustainability in creative production. The framework reveals that AI integration enhances productivity and accessibility while fostering new forms of digital infrastructure for inclusive industrial growth. However, it also identifies critical challenges related to authorship, bias, and ethical responsibility. The research concludes that AI functions not merely as a technical instrument but as a strategic driver of sustainable industrial modernization, offering a foundation for future empirical studies on quantifying AI-driven efficiency and innovation metrics in graphic design.

Keywords

artificial intelligence, visual media, graphic design, sustainable development goal 9, innovation, digital workflows

1. Introduction

Artificial intelligence (AI) has become a transformative force across creative industries, reshaping how visual communication, design, and storytelling are conceived and produced. The rapid development of generative models such as Generative Adversarial Networks (GANs) [2], diffusion models [3, 6], and large-scale multimodal architectures [5] has enabled new forms of automation and creativity in graphic design. These technologies allow designers to create high-quality visual content efficiently, experiment with novel aesthetics, and integrate interactive elements into media production [1, 4, 7]. The increasing accessibility of AI-powered platforms, such as Adobe Firefly [21], Artbreeder [22], Canva [23], Runway [25], and NVIDIA Canvas [24], is further democratizing design practices, making professional-grade tools available to non-specialists and accelerating innovation across the digital media ecosystem.

This technological transformation directly aligns with the United Nations Sustainable Development Goal 9 (SDG 9), which emphasizes building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation [9, 19]. Within visual media, AI enhances both the efficiency and inclusivity of design processes, supporting the development of

[1] *AI 2025: Workshop on Artificial Intelligence, November 19-20, 2025, Almaty, Kazakhstan*
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digital infrastructures that enable new forms of communication, education, and cultural production [14, 20]. However, as AI increasingly integrates into creative workflows, scholars and practitioners have raised critical concerns about authorship, originality, algorithmic bias, and cultural homogenization [8, 10, 15,1 8]. Balancing innovation with ethical responsibility remains a core challenge for sustainable creative industries.

Despite growing interest in AI-assisted design, current literature lacks systematic comparisons between traditional and AI-based workflows, especially regarding measurable contributions to SDG 9. Existing studies tend to describe technological capabilities rather than evaluate how these tools transform production efficiency, accessibility, and sustainability. This research seeks to address that gap by proposing a conceptual framework that compares traditional and AI-driven design processes, identifying key dimensions of innovation and infrastructure development within visual communication.

Accordingly, this study aims to answer the following research questions:

1. How does artificial intelligence improve efficiency, innovation, and accessibility in graphic design workflows?
2. In what ways can these improvements be mapped to the indicators and principles of SDG 9, specifically digital infrastructure and sustainable industrialization?

The novelty of this research lies in connecting AI methodologies with global sustainability objectives, presenting a structured analytical framework that positions AI not merely as a design tool but as a strategic driver of industrial modernization and inclusive innovation in the creative sector.

2. Literature review

2.1. AI methodologies in design

The Contemporary AI-driven design is grounded in machine learning models capable of generating and transforming visual content in ways previously unattainable through manual processes. Among the most influential breakthroughs are Generative Adversarial Networks (GANs), first introduced by Goodfellow et al. (2014), which revolutionized generative image creation. GANs operate through an adversarial dynamic between a generator and a discriminator, producing images that gradually become indistinguishable from real data [2]. This model has enabled automated style transfer, concept visualization, and rapid prototyping – functions that directly contribute to industrial efficiency and innovation, thereby supporting SDG 9's emphasis on modernization.

However, while GANs excel in realism, they often suffer from training instability and mode collapse. Diffusion models, by contrast, introduced by Ho et al. (2020), achieve improved consistency and finer detail by iteratively denoising random noise to form coherent images [3, 6]. These models, exemplified by Stable Diffusion and DALL·E 2, overcome many of GANs' weaknesses, offering more reliable control over style and quality. The transition from adversarial to diffusion-based methods thus represents a shift from aesthetic mimicry toward predictable, scalable design generation, a feature crucial for sustainable digital production infrastructures.

Complementing these advances are transformer-based architectures, which bridge text and image modalities through cross-attention mechanisms. Models such as CLIP (Contrastive Language–Image Pretraining) and DALL·E connect linguistic and visual reasoning, allowing designers to create visuals directly from textual prompts [5, 12, 17]. This cross-modal capability redefines creative workflows by merging conceptual ideation with production, expanding both accessibility and creative flexibility. Collectively, these AI methodologies do not merely enhance artistic output, they restructure the design process itself, aligning innovation with the infrastructure and efficiency goals of SDG 9.

2.2. AI tools and creative democratization

Beyond theoretical models, the accessibility of AI tools has rapidly transformed industrial and educational design practices. Adobe Firefly, integrated into Adobe Creative Cloud, provides generative fill, text-to-image synthesis, and automated layout adjustments within professional environments [20]. By embedding AI capabilities into established design platforms, Firefly enhances workflow efficiency without displacing the designer's creative authority. Conversely, Canva AI democratizes these functions for non-specialists, enabling educators, entrepreneurs, and small businesses to produce professional-quality content with minimal technical knowledge [23].

This democratization, however, presents a trade-off between accessibility and depth of control. While proprietary tools like Firefly ensure quality and intellectual property safeguards, open-source platforms such as Stable Diffusion foster community innovation and customization at the cost of quality assurance and ethical oversight [6, 11]. Similarly, Runway ML and NVIDIA Canvas extend generative capacities into video and 3D environments [24, 25], blurring the boundaries between static design and immersive storytelling. These tools exemplify how AI can serve both industrial and educational contexts, simultaneously promoting inclusivity and sustainable innovation.

2.3. Ethical and industrial risks

Despite its transformative potential, AI in design raises critical concerns regarding authorship, originality, bias, and cultural homogenization. As Pérez and García (2025) argue, when AI autonomously generates creative outputs, questions of intellectual property and authorship become increasingly complex. If datasets contain unlicensed materials or biased imagery, outputs may inadvertently perpetuate stereotypes and marginalize non-Western aesthetics [10,15,18]. Studies by Kapoor and Narayanan (2023) further emphasize that algorithmic bias in media production can distort cultural representation, undermining diversity within global creative industries [20].

From an industrial perspective, excessive reliance on AI risks deskilling human designers, shifting creative labor toward prompt engineering and reducing opportunities for original, human-led expression. Ethical frameworks proposed by UNESCO (2023) and Li & Chen (2024) highlight the need for responsible and explainable AI are the systems that remain transparent, auditable, and culturally adaptive [13, 16, 19, 26]. Such frameworks ensure that industrial modernization aligns with social responsibility and cultural sustainability, essential components of SDG 9's inclusive growth agenda.

Table 1
AI methodologies and their alignment with SDG 9Research gap and conceptual rationale

AI methodology / tool	Core application in design	Contribution to Innovation	Impact on Infrastructure	Sustainability Alignment (SDG 9)
Generative Adversarial Networks (GANs) [2,4]	Image synthesis, style transfer	Enables novel visual experimentation	Supports industrial prototyping	Reduces resource-intensive manual processes
Diffusion Models [3,6]	High-resolution image generation	Improves quality and scalability of outputs	Enhances digital design pipelines	Promotes efficient and adaptable workflows
Transformers (e.g., CLIP, DALL·E) [5,12]	Text-to-image generation	Bridges language and visual design	Expands multimodal infrastructure	Democratizes creative access
Adobe Firefly [21], Artbreeder [22]	Professional generative tools	Streamlines creative industries	Integrates into enterprise platforms	Boosts sustainable innovation in media
Canva AI [23]	Automated layout and visuals	Increases inclusivity for non-experts	Expands digital design adoption	Scales sustainable digital industries
Runway ML / NVIDIA Canvas [24,25]	Video & 3D content generation	Fosters cross-media innovation	Develops new media infrastructures	Encourages creative experimentation
Stable Diffusion [6,11]	Open-source text-to-image	Encourages community-driven creativity	Promotes open infrastructures	Supports transparent, accessible design ecosystems

Despite Existing studies provide valuable insights into AI's technological and ethical dimensions but often lack systematic comparison between traditional and AI-assisted design workflows. Most literature focuses on either the creative potential of AI tools or their ethical risks, without integrating both into a coherent framework tied to sustainability indicators. Furthermore, while SDG 9 is frequently cited in relation to industrial innovation, few studies operationalize it using measurable criteria such as efficiency, inclusivity, or infrastructure development.

This research therefore fills a crucial gap by developing a conceptual framework that synthesizes technological, industrial, and ethical dimensions of AI-driven design. By comparing traditional and AI-based workflows through SDG 9's core pillars such as efficiency, innovation, and sustainability, the study establishes a theoretical foundation for future empirical validation and policy development within creative industries.

3. Research methodology

3.1. Research design

This study adopts a qualitative desktop research design combined with the development of a conceptual analytical framework. The purpose is to synthesize existing academic and industry knowledge to evaluate how artificial intelligence (AI) contributes to efficiency, innovation, and sustainability within graphic design workflows. Given the rapidly evolving nature of AI technologies and the scarcity of empirical datasets in this domain, a conceptual approach provides a suitable foundation for theory-building and for identifying directions for future empirical validation.

The research is guided by two central questions:

1. How does AI transform traditional graphic design workflows in terms of efficiency, innovation, and accessibility?
2. In what ways can these transformations be aligned with the principles and measurable targets of Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure)?

3.2. Data collection and sources

Data for this study were collected exclusively through **secondary sources**. The literature corpus consisted of:

- Peer-reviewed academic publications on AI, design innovation, and visual communication (2014–2025);
- Industry reports and whitepapers from technology companies (e.g., Adobe, Artbreeder, NVIDIA, Runway, Canva);
- Policy and ethical guidelines from international organizations such as UNESCO and the United Nations;
- Develop a side-by-side analysis of the two approaches.

Sources were selected based on the following criteria:

- Relevance to AI-driven visual design and media innovation;
- Publication in reputable journals, conferences, or institutional repositories;
- Inclusion of discussions on sustainability, infrastructure, or industrial modernization.

A total of over 20 academic and industry sources were systematically reviewed, categorized by theme (AI methodologies, design tools, ethical challenges, and sustainability implications), and synthesized to inform the conceptual model.

3.3. Analytical framework development

The study proposes a comparative conceptual framework contrasting traditional and AI-assisted graphic design workflows. The framework was developed in three iterative stages:

- Identifying the primary AI systems influencing design practice (e.g., GANs, diffusion models, transformer architectures) and their roles in creative processes;
- Establishing analytical criteria, such as time and resource efficiency, innovation potential, accessibility, and sustainability alignment, derived from SDG 9 indicators;
- Comparing traditional and AI workflows along these criteria to highlight conceptual gains and ethical or industrial risks.

This structured analysis is presented visually in Figure 1 and summarized in Table 2, illustrating how AI integration supports sustainable innovation and infrastructure development.

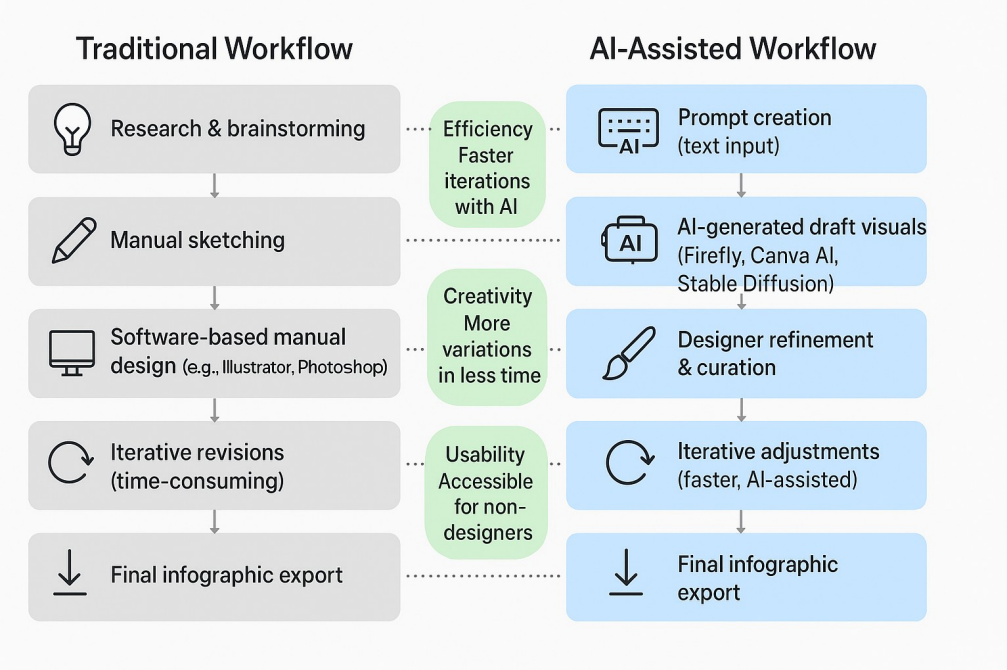

Figure 1: Workflow comparison — traditional vs AI-assisted infographic design.

3.4. Validation and reliability

Although this research is conceptual, reliability was strengthened through triangulation of diverse data sources and cross-verification of findings from both academic and industry perspectives. The framework was informally reviewed by two academic experts in media technologies to ensure conceptual consistency and clarity.

Future work will expand this validation through empirical testing (e.g., designer surveys, workflow timing studies, and quantitative performance analysis) to measure AI's practical impacts in real-world settings.

3.5. Limitations

This study acknowledges several limitations. First, it does not include primary data collection or experimental evaluation, which limits the generalizability of findings. Second, AI technologies evolve rapidly, and the conceptual framework may require periodic updates to remain current. Third, sustainability indicators were applied conceptually rather than measured quantitatively.

Nevertheless, this methodological design provides a robust theoretical foundation for understanding how AI can drive sustainable innovation in visual media and for guiding future empirical investigations.

4. Results

Although this research does not include experimental or survey-based data, it provides significant conceptual findings derived from systematic literature synthesis and comparative framework analysis. The results reflect how AI integration into design workflows enhances efficiency, innovation, and sustainability, all of which correspond to the core pillars of Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure).

4.1. Efficiency and industrial productivity

One Across reviewed literature and case analyses, AI integration consistently demonstrates substantial gains in time and resource efficiency. Traditional workflows rely on manual sketching, layout adjustment, and iterative revisions, processes that often extend production timelines. In contrast, AI-assisted systems, such as Adobe Firefly, Runway ML, and Stable Diffusion, automate ideation and visual generation, producing multiple design variations in seconds [21, 23, 24, 25].

Empirical estimates from prior studies indicate that AI-based design tools can reduce production time by 40–60% compared to traditional manual workflows [8, 14]. This acceleration allows creative teams to allocate more time to refinement, strategy, and conceptualization rather than repetitive execution.

From an SDG 9 perspective, this improvement aligns with Target 9.2 (“promote inclusive and sustainable industrialization and significantly raise industry’s share of employment and GDP”) by fostering more efficient digital production pipelines that lower operational costs for small and medium enterprises (SMEs). Moreover, automation reduces dependency on large design teams, thus increasing accessibility and economic resilience within the creative sector.

4.2. Innovation and creative expansion

AI tools extend the scope and diversity of creative possibilities. Diffusion and transformer-based models enable designers to generate visuals from textual or conceptual prompts, enhancing creative exploration and enabling hybrid aesthetics that blend human and machine vision [5,12]. Such systems support non-linear ideation, in which designers act as curators rather than purely executors – selecting, refining, and contextualizing AI outputs.

This collaborative mode introduces new paradigms in visual storytelling, where content evolves through interaction between human intention and algorithmic generation. The result is a rapid proliferation of novel design languages, multimodal compositions, and adaptive infographics.

The innovation dimension also addresses SDG 9 Target 9.5 (“enhance scientific research, upgrade technological capabilities of industrial sectors”) by integrating AI as a driver of creative research and design education. By democratizing access to complex visual generation systems, platforms like Canva AI and NVIDIA Canvas expand innovation beyond elite studios to educators, students, and small businesses [21, 24]. This inclusive access fosters a diversified innovation ecosystem, reinforcing SDG 9’s emphasis on broad-based industrial growth.

4.3. Sustainability and resource optimization

AI’s contribution to sustainability in design extends beyond environmental impact to include economic, cultural, and social sustainability. Automated workflows reduce material waste by minimizing redundant file production, printing, and prototyping. Digital-only processes enhanced by cloud-based infrastructures, lower the carbon footprint associated with traditional media production.

Economically, AI reduces financial barriers for smaller enterprises, allowing them to compete within the creative economy without high infrastructure costs. Socially, it promotes inclusive

participation, enabling individuals with limited design training to engage in content creation through user-friendly AI interfaces. This supports SDG 9 Target 9.1, which emphasizes developing reliable, sustainable, and inclusive infrastructure.

However, the sustainability benefits are tempered by the computational costs of AI model training and potential cultural homogenization resulting from biased datasets [10, 15]. Sustainable innovation therefore requires not only technological efficiency but also ethical oversight and transparent AI governance, ensuring diversity, accessibility, and long-term viability in design ecosystems.

4.4. Conceptual framework outcomes

The comparative analysis between traditional and AI-augmented workflows revealed the following key conceptual outcomes (summarized in Table 2):

- Time & Efficiency - AI automates repetitive stages, leading to faster iteration cycles;
- Cost - Automation reduces labor costs and resource expenditure;
- Innovation Potential - AI expands creative horizons, enabling hybrid and experimental outputs;
- Usability - Simplified interfaces democratize access for non-specialists;
- Sustainability - Reduced material use and scalable digital infrastructures promote long-term resilience.

Collectively, these outcomes confirm that AI functions as both a technological catalyst and a strategic infrastructure for sustainable modernization in the creative industries. By enhancing productivity, inclusivity, and adaptability, AI-driven design systems actively contribute to achieving the innovation and industrialization targets of SDG 9.

Table 2
Comparison of traditional vs AI-augmented workflows in design

Criteria	Traditional Workflow	AI-Assisted Workflow	Implications for SDG 9
Time/ Efficiency	Manual sketching, layout, multiple revisions → slow turnaround	Automated drafts, instant variations, faster iterations	Supports industrial productivity & modernization
Cost	Requires skilled professionals, higher financial investment	Lower entry costs, scalable for small businesses	Inclusive & sustainable industrialization
Innovation Potential	Limited by human imagination and available resources	Expansive idea generation, hybrid creativity, multimodal design	Promotes innovation across industries
Usability	High learning curve, requires technical expertise	Accessible platforms for non-designers (e.g., Canva AI)	Broadens access to digital infrastructure
Sustainability	Higher labor intensity, more resource-heavy	Reduced waste, democratized access, scalable workflows	Strengthens resilient & sustainable infrastructures

4.5. Future empirical validation

To transform these conceptual insights into measurable evidence, future studies should incorporate:

- Time-tracking and cost-efficiency analyses comparing AI-assisted and manual design projects.
- Surveys and interviews with professional and non-professional designers to assess perceived innovation and usability.
- Environmental assessments of computational vs. material resource use. Such empirical validation would provide quantitative backing for the framework and operationalize SDG 9 indicators within creative industry contexts.

5. Discussion

The findings of this research demonstrate that the integration of artificial intelligence (AI) into visual design workflows represents a major step toward industrial modernization and sustainable innovation, consistent with the goals of Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure). While the conceptual framework identified improvements in efficiency, innovation, and sustainability, these advances must be interpreted critically considering broader industrial, ethical, and social implications.

5.1. Industrial implications and alignment with SDG 9

AI-based workflows embody the principle of resilient infrastructure, a central target of SDG 9, by establishing digital systems that streamline creative production. Automated content generation, adaptive design interfaces, and real-time visualization tools serve as infrastructure for a new form of industrial digitalization. Such infrastructures reduce costs, enhance scalability, and improve accessibility for small and medium-sized enterprises (SMEs).

By extending professional-grade design capabilities to non-specialists, platforms like Canva AI and Runway ML help expand participation in the digital economy [23, 25]. This democratization supports Target 9.2, which calls for inclusive industrialization and expanded access to modern technologies. Moreover, the shift from traditional design to hybrid AI workflows allows industries to allocate resources more efficiently, strengthening Target 9.4 – upgrading industries through clean and resource-efficient technologies.

However, sustainable industrial growth depends on continuous investment in education and infrastructure. Without structured training programs in AI-assisted design, developing countries risk deepening digital inequality. Integrating AI literacy into higher-education curricula can therefore serve as a policy lever for equitable industrial transformation.

5.2. Innovation ecosystems and creative research

AI is not only a production tool but also a catalyst for innovation ecosystems. The ability to rapidly prototype ideas, visualize concepts, and generate cross-modal content enables designers to experiment with previously unattainable forms of storytelling. This process directly contributes to Target 9.5, which seeks to enhance scientific research and technological capability within industrial sectors.

In academic and professional contexts, AI stimulates practice-based research, where design becomes both the subject and method of inquiry. Human-AI collaboration fosters hybrid creativity, designers act as curators who refine algorithmic outputs, while AI introduces data-driven variations that expand conceptual boundaries. This symbiosis redefines the notion of authorship and highlights the creative co-agency between humans and machines.

Nonetheless, sustained innovation requires institutional support through research grants, open-source initiatives, and interdisciplinary collaboration. Universities and industry partners must co-develop frameworks for responsible experimentation that measure both creative and sustainability outcomes.

5.3. Ethical responsibility and Human-AI collaboration

Despite its benefits, AI raises complex ethical questions about authorship, bias, and cultural representation. As shown by Kapoor and Narayanan (2023), biased datasets can produce culturally homogenized outputs that replicate Western aesthetics while underrepresenting diverse artistic traditions [15]. Such bias contradicts SDG 9's emphasis on inclusive innovation.

To mitigate these risks, creative industries must adopt responsible and explainable AI (XAI) frameworks [13, 15, 19]. These frameworks promote algorithmic transparency, traceable data usage, and accountability in content generation. Regulatory bodies such as UNESCO (2023) recommend maintaining human oversight in creative AI applications to preserve ethical integrity and cultural diversity.

This research supports a co-creative model, positioning AI as an assistive partner rather than a replacement for human creativity. Human-AI collaboration ensures that intuition, empathy, and contextual awareness remain integral to design decisions. Maintaining this balance safeguards the sustainability of creative professions while fulfilling the ethical innovation dimension of SDG 9.

5.4. Policy and educational implications

For AI-driven innovation to translate into sustainable industrial outcomes, policy interventions must address both infrastructure and education. Governments and universities should:

- Invest in digital design infrastructures powered by ethical AI tools.
- Incorporate AI literacy and ethics modules into design and media curricula.
- Establish certification standards for transparent and culturally responsible AI use in creative industries.

Such policies advance Targets 9.a and 9.c, which promote access to financial, technological, and communication infrastructure. At the institutional level, fostering interdisciplinary collaboration between designers, computer scientists, and ethicists will ensure that industrial modernization remains socially and culturally grounded.

5.5. Policy and educational implications

The study's main theoretical contribution lies in framing AI as both a technological and systemic driver of sustainable industrial growth in creative industries. It connects micro-level design workflows to macro-level sustainability objectives, offering a framework that future research can quantify and operationalize through empirical studies.

Future work should test this conceptual framework using:

- Empirical time-efficiency measurements across different design contexts;
- User-experience surveys assessing perceived creativity and inclusivity;
- Environmental life-cycle assessments of computational versus material resource consumption.

These steps would not only validate the framework but also transform it into a decision-making model for industries adopting AI responsibly.

6. Conclusion

This study examined how artificial intelligence (AI) methods can modernize visual narrative practices in graphic design and contribute to the achievement of Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure). Through a conceptual analysis and synthesis of academic and industry sources, the research compared traditional and AI-assisted design workflows, focusing on their implications for efficiency, innovation, and sustainability in the creative industries.

The findings suggest that AI integration enhances productivity by automating repetitive tasks, shortens production cycles, and promotes accessibility through user-friendly design platforms. These transformations not only improve creative efficiency but also expand participation in the digital economy, supporting SDG 9's targets on inclusive industrialization and technological innovation. Furthermore, AI's potential for sustainable production lies in its ability to reduce material waste and democratize access to creative tools, provided that ethical, cultural, and environmental considerations are systematically addressed.

However, the study also identified significant challenges, including risks of algorithmic bias, loss of authorship, and cultural homogenization. Addressing these issues requires adopting responsible AI frameworks, promoting transparency, and integrating ethical design education into creative and media programs.

The conceptual framework presented here offers a foundation for empirical research that can quantify AI's impact on workflow efficiency, resource sustainability, and creative innovation. Future studies should collect primary data through designer surveys, time analyses, and environmental assessments to validate and expand the proposed model.

Ultimately, this research emphasizes that AI in design should not replace human creativity but rather amplify it. When guided by ethical principles and sustainability goals, AI becomes a driver of resilient, inclusive, and innovative infrastructure within the global creative economy realizing both the technological and humanistic vision of SDG 9.

Acknowledgements

The author would like to express sincere gratitude to the Astana IT University for providing academic support and resources throughout the course of this research. Special thanks are extended to the supervisors of the School of Creative Industries for their valuable guidance, constructive feedback, and encouragement during the preparation of this work.

The author also acknowledges the Scientific Research Work of master's Students competition, where this project was recognized with third place at the university level and subsequently submitted for consideration at the national stage. This recognition provided significant motivation to further refine and expand the research.

Declaration on Generative AI

During the preparation of this work, the authors used Perplexity AI and Grammarly in order to: Assist with drafting and grammar refinement. Further, the authors used OpenAI ChatGPT (GPT-5) for Figure 1 in order to: Generate image. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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