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Understanding the Global Trends of 2025 Through the Defly Compass Methodology

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Abstract

This study aims to identify and synthesize the major global trends that shaped 2025 by applying the DeflyCompass methodology to a curated corpus of strategic foresight reports. The study synthesizes insights from 23 strategic reports published by leading international organizations, including the World Economic Forum, Accenture, Euromonitor, and major technology firms. Methodologically, DeflyCompass operationalizes a structured hybrid human–AI pipeline comprising the deployment of multi-agent AI systems, automated knowledge graph construction, semantic clustering, and hybrid human–AI validation processes, reducing an initial set of 816 preliminary signals to a validated catalog of 50 high-priority trends across six PESTEL domains: Political, Economic, Social, Technological, Environmental, and Legal/Governance. Key findings indicate that artificial intelligence functions as a systemic enabling technology across all domains, climate and sustainability imperatives permeate multiple domains, geopolitical fragmentation introduces systemic tension, and trust deficits emerge as a critical vulnerability. The study contributes a replicable and scalable framework for global-level strategic foresight that operationalizes human–AI integration within a rigorous expert-driven validation process, complementing existing hybrid analytical approaches in the literature. Implications extend to decision-making in technology governance, sustainability strategy, social adaptation, and scenario planning, highlighting the necessity of integrating AI augmentation with human expertise for effective future-oriented planning.

Keywords: global trends; strategic foresight; DeflyCompass; PESTEL; AI-augmented analysis; trend synthesis

1. Introduction

Strategic foresight has never been more critical or more challenging. The pace of technological change, the complexity of global interconnections, and the volume of available information have overwhelmed traditional analytical approaches. Organizations and governments require systematic methods to identify emerging trends, understand their potential impacts, and make informed strategic decisions in an era of unprecedented uncertainty.

The study of trends encompasses all dimensions of human society: technological innovations that reshape industries, psychological shifts that redefine cultural values, political transformations that alter power structures, and economic forces that redistribute wealth and opportunity. Leading organizations including the World Economic Forum [1–3], Accenture [4–6], and various United Nations agencies [7–9] invest substantial resources in

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systematic trend analysis, producing annual reports that synthesize vast amounts of data into strategic insights.

However, these analyses face significant challenges. The information landscape has exploded exponentially, with millions of research papers, industry reports, news articles, and policy documents published annually [10–12]. Expert analysts must navigate this deluge while maintaining analytical rigor and avoiding confirmation bias. Traditional approaches require teams of specialists months or years to process comprehensive document corpora, limiting the timeliness and scope of strategic foresight efforts [13,14]. Moreover, the interdisciplinary nature of contemporary challenges demands expertise spanning multiple domains, from artificial intelligence and biotechnology to geopolitics and climate science, creating coordination challenges that further strain analytical capacity. The siloed nature of expertise often results in fragmented analyses that fail to capture the interconnected dynamics driving systemic change.

Recent advances in artificial intelligence, particularly large language models and autonomous agent systems, present both opportunities and risks for strategic foresight. AI systems can process vast quantities of text, identify patterns across documents, and synthesize information at speeds impossible for human analysts. They excel at cross-referencing sources, detecting weak signals that might escape human attention, and maintaining consistency across large-scale analytical tasks [15–17]. However, they also introduce risks including hallucination of non-existent trends [18–22], algorithmic bias, loss of contextual understanding, and the potential marginalization of expert judgment that provides essential validation and strategic interpretation. The "black box" nature of many AI systems raises concerns about transparency and reproducibility—critical requirements for strategic decisions with far-reaching consequences. These concerns connect with a growing body of academic literature examining bias, explainability, and epistemological limitations in AI-assisted knowledge production and decision-support systems. Incorporating these perspectives is particularly important in foresight applications, where methodological transparency and interpretive accountability remain central challenges. Furthermore, AI systems trained on historical data may struggle to identify genuinely novel phenomena that lack precedent in their training corpora [22].

The DeflyCompass methodology addresses these challenges through a carefully designed hybrid approach that positions AI as an analytical accelerator while preserving expert judgment as the ultimate arbiter of strategic significance. The initial key elements of this methodology were presented in [23,24], where the approach was introduced under the name Deflexor. Additional methodological details can be found in these works and in the literature cited therein. In the present updated version of the framework, rather than replacing human expertise, the methodology creates a symbiotic relationship where AI handles scale-intensive tasks—document processing, pattern recognition, preliminary clustering—while human analysts contribute contextual understanding, strategic prioritization, and validation grounded in domain expertise [25–29]. The methodology comprises four distinct phases: Phase 1 involves expert-led selection of high-quality information sources, ensuring analytical rigor begins with credible inputs and avoiding the "garbage in, garbage out" problem that plagues many automated analyses. Phase 2 employs AI agents to process documents, extracting preliminary trends and patterns while maintaining provenance tracking that links every identified trend back to its source material. Phase 3 utilizes the DeflyCompass platform for trend search, semantic analysis, and knowledge graph construction, enabling analysts to visualize connections between trends and identify emergent patterns. Phase 4 returns to expert judgment for final validation, strategic interpretation, and decision-making, ensuring that analytical outputs are translated into actionable strategic intelligence.

This paper is organized around a central hypothesis that follows directly from the theoretical literature on human–AI complementarity [27,30,31] and augmentation [25,32]: a structured hybrid framework integrating multi-agent artificial intelligence with expert-driven validation produces trend analyses of greater analytical rigor, scalability, and interpretive coherence than approaches relying exclusively on human expertise or on fully automated AI systems. More specifically, we posit that neither modality alone is sufficient to address the volume, heterogeneity, and interdependence of contemporary global trend data. Human analysts possess the contextual judgment and domain expertise necessary to validate and interpret emerging signals, but are constrained in their capacity to process large-scale, multi-domain document corpora systematically and without confirmation bias. Conversely, AI systems excel at scale-intensive pattern recognition and semantic clustering but remain susceptible to hallucination, framing bias, and the absence of strategic contextualisation [18,19]. The DeflyCompass methodology is designed to exploit the complementary strengths of both modalities through their structured integration, and this study constitutes its first application at global scale. A secondary hypothesis follows from this primary claim: the relational structure of the identified trend landscape, captured through co-occurrence analysis and knowledge graph construction, will reveal significant cross-domain interdependencies, with artificial intelligence emerging as the dominant connective force across PESTEL dimensions. Both hypotheses are evaluated against the empirical results presented in Sections 3 and 4.

This design philosophy reflects a broader principle in human–AI collaboration: augmentation rather than automation [30–32]. While fully automated trend analysis might promise efficiency gains, it risks producing insights divorced from strategic context and organizational reality. The DeflyCompass approach recognizes that strategic foresight is fundamentally a sense-making activity that requires not just information processing but judgment, prioritization, and the integration of tacit knowledge that resists codification.

This paper presents the first application of the DeflyCompass methodology to global trend analysis. We applied the framework to understand the global landscape of 2025, analyzing 23 strategic reports from internationally recognized organizations spanning technology, economics, policy, environment, and social domains. These reports represent thousands of pages of expert analysis and primary research, collectively synthesizing insights from hundreds of subject matter experts worldwide. Our objectives were threefold: first, to identify and validate the most significant global trends shaping 2025 and beyond; second, to demonstrate the scalability and effectiveness of the DeflyCompass methodology at global scale; and third, to document methodological refinements including enhanced AI agent architectures, automated knowledge graph generation, and improved semantic clustering techniques.

The remainder of this paper is organized as follows: Section 2 details the DeflyCompass methodology and its implementation for global trend analysis, including technical specifications of the AI agent architecture and the platform's analytical capabilities. Section 3 presents our findings, organized by major trend domains using the PESTEL framework [33–35] (Political, Economic, Social, Technological, Environmental, Legal). Section 4 discusses the implications of identified trends, methodological learnings, including a critical evaluation of the methodology's strengths and limitations. Section 5 concludes with reflections on the future of AI-augmented strategic foresight and recommendations for organizations seeking to implement hybrid analytical approaches in their own strategic planning processes.

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2. Methodology

2.1. The DeflyCompass Framework

The DeflyCompass methodology operationalizes the principle that effective strategic foresight requires the complementary strengths of human expertise and artificial intelligence. The framework consists of four distinct phases, each characterized by specific objectives, processes, and validation criteria that ensure rigorous trend identification and analysis.

This paper represents a significant evolution of our previously published methodology [36], introducing substantial enhancements to both analytical processes and technical infrastructure. The current iteration advances the framework in four key dimensions: (1) the integration of state-of-the-art large language models with enhanced reasoning and contextual understanding capabilities, enabling more nuanced trend extraction and synthesis; (2) automated generation of interactive knowledge graphs that facilitate dynamic trend visualization, relationship mapping, and exploratory analysis; (3) improved semantic clustering algorithms that enhance pattern detection across heterogeneous document corpora; and (4) adoption of the PESTEL framework [33–35] as a systematic categorization schema, coupled with quantitative metrics for measuring inter-trend relationships and strategic significance.

These methodological advances substantially improve the framework's scalability, analytical depth, and reproducibility while preserving the human–AI collaborative approach that defines the DeflyCompass philosophy. The following subsections detail each phase of the methodology, highlighting both the foundational approach and the novel enhancements introduced in this iteration.

2.1.1. Phase 1: Expert Source Selection

Strategic foresight quality depends fundamentally on input quality. Phase 1 requires domain experts to identify and curate information sources based on explicit criteria. Source credibility is assessed by evaluating organizations with established track records in rigorous analysis, transparent methodologies, and accountability for their predictions. Qualifying sources include academic institutions, intergovernmental organizations, leading consulting firms, and respected industry research groups. Methodological rigor ensures that selected sources document their analytical approaches, disclose data sources, acknowledge limitations, and subject findings to peer review or expert validation. Diversity and complementarity are prioritized to achieve balanced representation across geographic regions, ideological perspectives, industry sectors, and analytical approaches, thereby minimizing echo chamber effects and confirmation bias. The general methodological framework underlying this expert-based source selection process is introduced in earlier work on the DeflyCompass methodology (see [23]; see also the foundational paper [24], in which this method is called Deflexor). The number of experts involved, as well as their disciplinary backgrounds, may vary depending on the specific prospective project under analysis. The complete list of reports used as input is provided in Appendix B.

2.1.2. Phase 2: AI-Powered Document Processing

Phase 2 employs a multi-agent AI system to process the curated document corpus, transforming unstructured reports into structured trend candidates through several algorithmic steps. The process begins with document ingestion and parsing, where each document undergoes format-specific parsing to extract text while preserving structural information including sections, headings, tables, and figures. Metadata such as publication date, author organization, and document type are captured for subsequent filtering and weighting operations. Following ingestion, documents are segmented into semantically coherent chunks designed to fit within model context windows while preserving conceptual integrity. This semantic chunking process maintains the semantic relationships within each chunk, enabling more accurate trend extraction.

The core of Phase 2 relies on agent-based trend extraction, where specialized AI agents powered by DeepSeek R1 32B [37] analyze document chunks to identify trend signals. We deployed two complementary agent types to ensure comprehensive trend identification. The Trend Extraction Agent identifies relevant ideas, emerging patterns, and potential trends by applying pattern recognition to detect signals of change across multiple domains. The Trend Refining Agent subsequently reviews extracted trends to refine their articulation, eliminate redundancies, and improve clarity and specificity.

Following agent-based extraction, trend candidates undergo initial clustering to consolidate the trend space from hundreds of candidates to a manageable core set. Let $\mathbf{X} = \{\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n\}$ represent the set of n trend embeddings, where each $\mathbf{x}_i \in \mathbb{R}^d$ is a d-dimensional embedding vector generated by EmbeddingGemma 8B models. We apply K-Means clustering with $k = 50$ clusters to identify the central trends.

$$\text{WCSS} = \sum_{j=1}^{k} \sum_{\mathbf{x}_i \in C_j} \|\mathbf{x}_i - \boldsymbol{\mu}_j\|^2 \tag{1}$$

where C_j represents the j-th cluster and $\boldsymbol{\mu}_j$ is the centroid of cluster C_j, computed as

$$\boldsymbol{\mu}_j = \frac{1}{|C_j|} \sum_{\mathbf{x}_i \in C_j} \mathbf{x}_i \tag{2}$$

The algorithm iterates between two steps: assignment of each embedding to its nearest centroid, and recomputation of centroids based on current assignments, until convergence or a maximum iteration threshold is reached. This process reduced our initial 816 raw candidates to 50 distinct, high-signal trends. To visualize these clusters, we utilized Principal Component Analysis (PCA) for low-dimensional visualization, as illustrated in Figure 1. Appendix A documents a partial sample of preliminary trend signals produced by the AI prior to clustering and consolidation.

2.1.3. Phase 3: Co-Occurrence Search and Knowledge Graph Construction

Phase 3 utilizes the DeflyCompass platform to quantify the interdependencies between the 50 distilled trends identified in Phase 2, ultimately synthesizing a global trend Knowledge Graph. This phase shifts from individual trend identification to relational mapping, providing an empirical basis for understanding how emerging patterns intersect.

To maximize the precision of this information retrieval process, trend descriptors are transformed into optimized search queries through a robust Human-in-the-loop (HITL) approach. The process begins with algorithmic expansion, where the DeepSeek R1 32B model [37] generates expanded query strings that incorporate synonyms, technical nomenclature, and complex boolean operators to capture the full semantic breadth of each trend. This is followed by expert supervision, where human domain specialists review and calibrate the queries to mitigate keyword drift and ensure that the results remain strictly relevant to the research context. The complete catalog of these optimized queries and the resulting co-occurrence matrix are detailed in Appendix C.

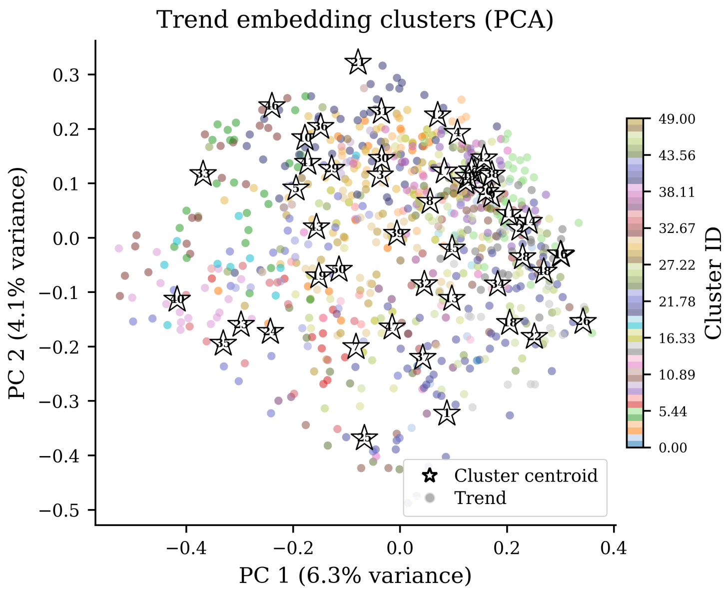

Figure 1. PCA-based visualization of the 50 identified trend clusters, demonstrating semantic separation in the embedding space.

Co-Occurrence Matrix Construction

For each pair of trends T_i and T_j, we query the Directory of Open Access Journals (DOAJ) using the Boolean search "T_i AND T_j" and record the number of publications r_{ij} containing both trend terms. This systematic process generates a symmetric 50×50 co-occurrence matrix $\mathbf{R}$ where each element r_{ij} quantifies the empirical relationship strength between trends i and j based on their joint appearance in the academic literature. The diagonal elements r_{ii} represent the total number of publications for each individual trend.

The resulting co-occurrence matrix reveals significant variation in relationship strengths, with values ranging from 0 (no documented co-occurrence) to several thousand publications (strong established relationships). Figure 2 presents a representative quadrant of this matrix, visualizing the relationship landscape among trends 1–25.

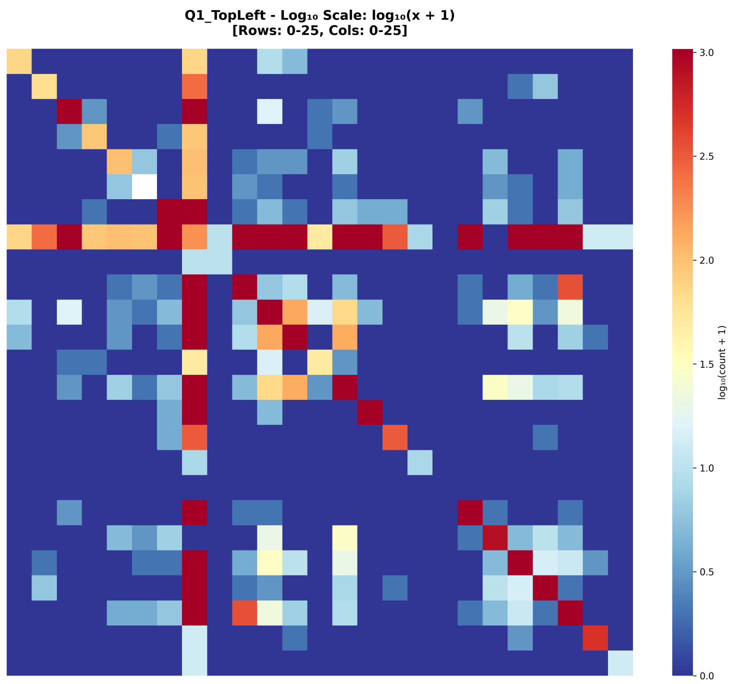

Figure 2. Co-occurrence heatmap for trends 1–25 (top left quadrant of the full 50×50 matrix).

The logarithmic transformation $\log_{10}(r_{ij} + 1)$ is applied for visualization purposes to compress the wide dynamic range of co-occurrence values while preserving the ability to distinguish between weak and strong relationships. The addition of 1 before applying the logarithm ensures that zero co-occurrences (representing no documented relationship) map to zero in the transformed space, maintaining interpretability. Without this transformation, the visualization would be dominated by the few strongest relationships, obscuring the nuanced patterns among moderately and weakly connected trends.

Knowledge Graph Construction

The co-occurrence matrix **R** forms the basis for constructing a weighted, undirected knowledge graph $G = (V, E, W)$, where:

- Vertices $V = \{v_1, v_2, \ldots, v_{50}\}$ represent the 50 validated trends
- Edges $E \subseteq V \times V$ represent empirically validated relationships
- Weights $W : E \to \mathbb{R}^+$ assign relationship strength to each edge

An edge (v_i, v_j) exists with weight $w_{ij} = r_{ij}$ if the co-occurrence count r_{ij} exceeds a significance threshold τ, empirically derived from the distribution of non-zero co-occurrence values in **R**. Specifically, τ is set at the 25th percentile of this distribution, a conservative threshold that retains the substantial majority of documented relationships while excluding co-mentions appearing in a single publication, which are insufficient to constitute evidence of a robust empirical association.

Trend Impact Quantification

To quantify the systemic importance of each trend within the global landscape, we compute the contextual impact score as the sum of all validated relationships:

$$I_i = \sum_{j=1, j \neq i}^{50} r_{ij} \tag{3}$$

where I_i represents the total impact score for trend i. This metric captures how extensively each trend interconnects with other identified trends, serving as a proxy for its systemic importance and cross-domain influence. Trends with higher impact scores represent cross-cutting forces that permeate multiple domains and influence diverse research areas, while lower scores may indicate more specialized phenomena, emerging trends with limited documentation, or domain-specific forces with fewer interdisciplinary connections.

The impact score I_i can be interpreted as a measure of *trend centrality*—trends that co-occur frequently with many other trends occupy central positions in the knowledge graph and likely represent foundational concepts or widely applicable phenomena.

2.1.4. Phase 4: Expert Synthesis and Strategic Interpretation

The final phase returns to human expertise, as analysts synthesize validated trends into strategic narratives and actionable insights. Through trend prioritization, experts assess trends across multiple dimensions including impact potential, defined as the magnitude of possible effects on organizations or societies; time horizon, distinguishing near-term from long-term manifestation; certainty level, ranging from well-established to highly speculative; and relevance to specific strategic contexts. Related trends are woven into coherent future scenarios through scenario development, exploring how different trends might interact, reinforce, or contradict each other. This approach enables examination of multiple plausible futures rather than single-path predictions.

For each major trend domain, experts articulate strategic implications for different stakeholder groups and identify potential responses or interventions through strategic implication analysis. The complete trend analysis undergoes final validation through peer review by the expert panel, with particular attention to identifying omissions, challenging questionable inclusions, and ensuring balanced representation across domains and perspectives. The composition of the expert panel is domain-dependent and varies according to the specific forecasting context. The DeflyCompass framework is designed as a general methodological pipeline, and therefore the selection of experts is determined by the thematic domain under analysis in each application. Consequently, the panel may coincide with the original methodological development team or may include additional domain specialists relevant to the specific forecasting task. Detailed criteria for expert selection, disciplinary backgrounds, and evaluation procedures are described in the methodological documentation of the framework (see [23,24]). Phase 4 produced the final set of 50 high-priority global trends organized into six major domains following the PESTEL framework, encompassing Political, Economic, Social, Technological, Environmental, and Legal dimensions, which form the core findings presented in Section 3.

2.2. Methodological Innovations

This application of DeflyCompass incorporated several methodological advances beyond the baseline framework. Rather than relying on a single language model, we employed a multi-model ensemble approach using DeepSeek R1 32B for nuanced interpretation and strategic synthesis, combined with EmbeddingGemma 8B for generating high-quality semantic representations during clustering and similarity analysis. This combination balances analytical depth with computational efficiency while leveraging specialized models for their respective strengths.

We implemented automated knowledge graph generation featuring dynamic, interactive visualization utilizing physics-based simulation algorithms, specifically force-directed layout methods, to represent trend relationships spatially. Related trends naturally cluster together through attractive forces proportional to their co-occurrence weights, while repulsive forces prevent overlap, enabling intuitive visual exploration of the trend landscape. This represents a substantial advancement over previous implementations that presented static graphs showing fixed relationships.

Using PESTEL categorization, we systematically identified trends operating across multiple categories through cross-domain bridge detection, revealing cross-domain dynamics often missed in siloed analysis. Trends received multiple category tags when appropriate, with a substantial portion of the 50 final trends classified as spanning two or more PESTEL domains, highlighting the interconnected nature of contemporary global challenges.

To ensure robust classification, we employed multiple distance metrics for PESTEL categorization. Let $\mathbf{e}_i$ denote the embedding vector for trend i and $\mathbf{c}_p$ denote the centroid embedding for PESTEL category p. We computed six distinct metrics to assess the proximity of each trend to PESTEL category centroids. The Euclidean distance is defined as

$$d_{\text{euc}}(\mathbf{e}_i, \mathbf{c}_p) = \|\mathbf{e}_i - \mathbf{c}_p\|_2 = \sqrt{\sum_{k=1}^{d} (e_{ik} - c_{pk})^2} \quad (4)$$

The cosine similarity is computed as

$$\text{sim}_{\cos}(\mathbf{e}_i, \mathbf{c}_p) = \frac{\mathbf{e}_i \cdot \mathbf{c}_p}{\|\mathbf{e}_i\|_2 \|\mathbf{c}_p\|_2} \quad (5)$$

with corresponding cosine distance $d_{\cos} = 1 - \text{sim}_{\cos}$. The Manhattan distance, also known as the L_1 norm, is given by

$$d_{\text{man}}(\mathbf{e}_i, \mathbf{c}_p) = \sum_{k=1}^{d} |e_{ik} - c_{pk}| \quad (6)$$

The Chebyshev distance, or L_∞ norm, is defined as

$$d_{\text{cheb}}(\mathbf{e}_i, \mathbf{c}_p) = \max_k |e_{ik} - c_{pk}| \tag{7}$$

The dot product is computed as

$$\text{dot}(\mathbf{e}_i, \mathbf{c}_p) = \sum_{k=1}^{d} e_{ik} \cdot c_{pk} \tag{8}$$

Finally, the Pearson correlation coefficient is given by

$$\rho(\mathbf{e}_i, \mathbf{c}_p) = \frac{\text{cov}(\mathbf{e}_i, \mathbf{c}_p)}{\sigma_{\mathbf{e}_i}\sigma_{\mathbf{c}_p}} \tag{9}$$

where $\text{cov}(\mathbf{e}_i, \mathbf{c}_p)$ denotes the covariance between vectors $\mathbf{e}_i$ and $\mathbf{c}_p$, and $\sigma_{\mathbf{e}_i}$ and $\sigma_{\mathbf{c}_p}$ represent their respective standard deviations.

Each trend was assigned to the PESTEL category minimizing distance or maximizing similarity and correlation according to each metric. This multi-metric approach revealed remarkable consistency across most methods.

3. Results

Our analysis identified 50 validated global trends across the six categories of the PESTEL framework, representing a comprehensive mapping of contemporary forces shaping organizational and societal futures. This section presents the distribution of trends across domains and synthesizes key findings within each category, emphasizing patterns of convergence, tension, and transformation that characterize the contemporary global landscape.

A striking pattern emerges from the PESTEL distribution analysis. Technological trends constitute the dominant category with 15 of the 50 validated trends according to most distance metrics. Social trends comprise the second largest category with 10 trends, political, environmental and economic trends with 7 each and legal trends with 4. This distribution reflects the reality that technology, particularly artificial intelligence, has become the primary driver of change across all other domains. The technological dominance is not merely quantitative but qualitative, as technological innovations increasingly mediate and transform political processes, economic structures, social interactions, environmental solutions, and legal frameworks. This finding validates the perception that 2025 represents an inflection point where technological acceleration outpaces change in other domains, creating the adaptation challenges that permeate contemporary strategic planning.

3.1. Political Domain Analysis

The political landscape reveals fundamental tensions between established democratic systems and emerging authoritarian pressures, alongside shifting geopolitical alignments that redefine international relations. Several validated trends characterize this domain. Geopolitical shifts manifest through intensifying multipolar competition, particularly between the United States and China, reshaping global supply chains as nations prioritize economic security over efficiency. This fragmentation produces technology decoupling, competing trade blocs, and the weaponization of economic interdependence, creating a more complex and unstable international system as regional alliances realign to navigate between competing power centers. Concurrently, declining trust in institutions and democracy reflects unprecedented erosion of public confidence in government effectiveness, media credibility, and electoral integrity, fueled by disinformation campaigns, social media polarization, and visible institutional failures to address major challenges. This trust deficit extends beyond government to encompass traditional media, scientific institutions, and international organizations, creating vulnerabilities that authoritarian actors systematically exploit. AI-driven decision-making is transforming governance and policy development, as governments and organizations integrate artificial intelligence systems into strategic planning, resource allocation, and crisis response mechanisms. This shift toward algorithmic governance promises enhanced efficiency and data-driven insights while raising concerns about transparency, accountability, and the potential marginalization of human judgment in critical decisions.

Real-time crisis management has become essential as technological infrastructure enables immediate response to emerging threats, from public health emergencies to natural disasters and security incidents. Advanced monitoring systems, rapid communication networks, and coordinated response protocols allow governments to detect, assess, and address crises with unprecedented speed, though this capability also creates expectations for instant governmental action that may exceed realistic capacities. Space-based communication and global connectivity is expanding political and economic influence beyond terrestrial boundaries, as satellite networks provide internet access to underserved regions and enable new forms of surveillance, navigation, and military capabilities. The democratization of space access, driven by commercial spaceflight and reduced launch costs, allows more nations and private actors to participate in space activities, redistributing geopolitical power and creating new arenas for international competition and cooperation.

3.2. Economic Domain Analysis

Economic patterns reveal tensions between globalization and fragmentation, with technology reshaping production systems, consumer behavior, and market structures while inequality reaches critical thresholds. Several primary trends characterize this domain. Trade tensions and supply chain risks drive systematic restructuring of global supply chains in response to geopolitical tensions, pandemic vulnerabilities, and climate risks, as nations pursue strategic autonomy in critical sectors including semiconductors, pharmaceuticals, rare earth materials, and food security.

Reshoring and friendshoring initiatives aim to reduce dependence on potentially hostile nations, fundamentally altering decades of globalization logic, though creating short-term disruptions, inflationary pressures, and efficiency losses. Enterprise investment in artificial intelligence accelerates dramatically as organizations across sectors recognize AI as a transformative general-purpose technology. Beyond technology companies, traditional industries including manufacturing, healthcare, finance, and agriculture deploy AI for optimization, prediction, and automation, driving productivity gains while raising concerns about job displacement, competitive concentration, and the widening gap between AI-enabled and AI-excluded organizations. ICT supplier capability assessment has become critical as organizations evaluate technology vendors not merely on price and features but on security standards, geopolitical alignment, and long-term viability, reflecting heightened awareness of supply chain vulnerabilities and the strategic importance of digital infrastructure dependencies.

Innovative last-mile delivery solutions are transforming retail logistics through autonomous vehicles, drones, and micro-fulfillment centers that reduce delivery times and costs while addressing urbanization challenges and environmental concerns. Consumers increasingly value AI recommendations for shopping, relying on personalized algorithms to navigate product abundance, with recommendation systems driving significant portions of e-commerce revenue and reshaping traditional marketing approaches by enabling hyper-personalized consumer experiences. Generation Alpha's unique characteristics are beginning to drive future market trends and consumer insights, as this digitally native cohort exhibits distinct preferences for interactive experiences, visual communication, and values-aligned brands, requiring businesses to anticipate fundamentally different consumption patterns and engagement strategies. The growth of direct-to-consumer luxury brands challenges traditional retail hierarchies as premium brands bypass intermediaries to establish direct relationships with customers, leveraging digital platforms to offer personalized experiences, maintain brand control, and capture higher margins while democratizing access to luxury goods previously confined to exclusive physical locations.

3.3. Social Domain Analysis

Social transformations reflect shifting demographics, evolving work paradigms, changing consumer values, and the complex interplay between digital and physical existence. Several validated trends characterize this domain, revealing diverse pressures on contemporary social structures. Aging population impact creates profound social and economic pressures, particularly in developed nations and East Asia, straining healthcare systems, pension funds, and public finances while creating labor shortages in key sectors. These demographic patterns drive innovation in age-tech, healthcare delivery, and automation, forcing difficult societal choices regarding retirement ages, immigration policy, and intergenerational equity. Autonomous vehicles are transforming transportation and urban planning by promising reduced traffic fatalities, increased mobility for non-drivers, and more efficient land use as parking requirements diminish, while simultaneously disrupting employment in transportation sectors and requiring substantial infrastructure investments and regulatory frameworks to address liability, cybersecurity, and ethical decision-making in accident scenarios.

AI in urban planning and smart cities enables data-driven approaches to infrastructure development, traffic management, energy distribution, and public services, optimizing resource allocation and improving quality of life while raising concerns about surveillance, algorithmic bias in resource distribution, and the digital divide between connected and disconnected urban populations. Immersive digital identities are emerging as individuals cultivate parallel personas in virtual environments, gaming platforms, and social media, with digital identity sometimes carrying equal or greater significance than physical identity, particularly among younger generations who invest substantial time and resources in avatar customization, virtual goods, and online reputation management. VR travel experiences offer immersive exploration of distant locations without physical travel, democratizing access to cultural and natural wonders while reducing environmental impact, though raising questions about the authenticity of mediated experiences and potential substitution of virtual for physical travel.

The internationalization of sports leagues reflects globalization of entertainment as major leagues expand beyond traditional geographic boundaries through international games, foreign player recruitment, and global broadcasting rights, creating worldwide fan bases while navigating cultural differences and time zone challenges. Social rewilding and digital-physical balance reflect a cultural movement advocating intentional reconnection with nature and reduction of digital consumption, driven by concerns about mental health, environmental disconnection, and technology addiction. This trend manifests through outdoor recreation, digital detoxes, and nature-based education, reflecting growing recognition that constant connectivity imposes psychological costs. The rise of slow movements across domains including food, fashion, travel, and work prioritizes quality over quantity, mindfulness over multitasking, and sustainability over convenience. While remaining minority practices, slow movements influence mainstream culture and consumption patterns, particularly among affluent consumers seeking meaning beyond material accumulation. Nostalgia as a modern design trend emerges across industries, blending vintage aesthetics with modern functionality to provide emotional connection, authenticity, and stability amid rapid change. Music streaming faces industry consolidation and layoffs due to intense competition, as platforms struggle with thin profit margins, rising content costs, and market saturation, forcing companies to differentiate through exclusive content, superior algorithms, or integration with broader entertainment ecosystems while artists navigate changing revenue models and distribution power dynamics.

3.4. Technological Domain Analysis

Technology trends demonstrate accelerating convergence and deepening integration into all aspects of life, with artificial intelligence emerging as the defining technology of the era while complementary innovations from quantum computing to biotechnology mature toward practical application. Several technological trends span diverse domains yet exhibit strong thematic coherence around core dynamics. Artificial intelligence permeates multiple categories, reflecting its character as a general-purpose technology with applications across decision-making, content creation, mental health support, healthcare delivery, urban planning, retail personalization, and numerous other domains. AI tools for content creation are democratizing creative production by enabling non-experts to generate text, images, video, and audio through natural language interfaces, transforming creative industries while raising concerns about authenticity, copyright, misinformation, and the economic viability of human creators. AI-powered personalized mental health apps provide accessible therapeutic support through conversational interfaces, mood tracking, and cognitive behavioral therapy techniques, addressing gaps in mental healthcare access while requiring careful consideration of clinical efficacy, data privacy, and appropriate boundaries between automated support and professional intervention. AI enhancing patient experience and outcomes transforms healthcare delivery through diagnostic assistance, treatment personalization, administrative automation, and predictive analytics that identify high-risk patients, though implementation requires addressing algorithmic bias, liability questions, and integration with existing clinical workflows.

Automation of newsroom tasks reshapes journalism as AI handles routine reporting, data analysis, and content distribution, allowing journalists to focus on investigation and analysis while raising concerns about employment, editorial judgment, and the homogenization of news content. Infrastructure and architectural innovations address the scaling challenges created by AI proliferation. Energy-efficient AI computing architectures and custom AI chips respond to exploding computational demands, developing specialized hardware and algorithmic efficiency improvements essential for sustainable AI scaling and edge deployment in energy-constrained environments.

Cloud-native applications reflect fundamental shifts in software architecture toward designs optimized for distributed, containerized, microservices-based systems that enable scalability, resilience, and rapid development cycles. Enhanced cybersecurity measures and zero-trust architectures respond to intensifying cyber threats through AI-powered threat detection, quantum-resistant cryptography, and security models that verify every access request regardless of origin, assuming breach and limiting damage through microsegmentation. Emerging computational paradigms position themselves as successors or complements to conventional computing. The democratization of quantum computing transitions this technology from research curiosity to accessible tool through cloud-based quantum services, while quantum-inspired algorithms and hybrid classical-quantum approaches deliver practical benefits in optimization, simulation, and machine learning. Future computing technology trends encompass neuromorphic computing mimicking brain architectures for energy-efficient AI, photonic computing using light for ultrafast data processing, and DNA computing exploring biological systems for massively parallel computation. Blockchain technology matures beyond cryptocurrency speculation toward practical applications in supply chain transparency, credential verification, and decentralized finance for trust and transactions, though facing persistent challenges in energy consumption, scalability, regulatory uncertainty, and adoption gaps.

Biotechnology innovations promise transformative impacts on health and environment. CRISPR tree optimization applies gene-editing technology to enhance forest resilience, carbon sequestration, and commercial timber properties, offering tools to accelerate adaptation to climate change while raising ecological concerns about unintended consequences and genetic diversity loss. Personalized nutrition based on DNA analysis tailors dietary recommendations to individual genetic profiles, microbiome composition, and metabolic characteristics, moving beyond one-size-fits-all guidelines toward precision nutrition that optimizes health outcomes. Synthetic biology engineering enables design and construction of novel biological systems for applications including biofuel production, pharmaceutical manufacturing, and environmental remediation, representing convergence of biology and engineering that requires careful governance to address biosafety and biosecurity risks.

Transportation technologies advance toward autonomous operation. Advanced Driver Assistance Systems (ADAS) serve as intermediate steps toward full autonomy, incorporating features like adaptive cruise control, lane-keeping assistance, and automatic emergency braking that reduce accidents and driver workload while familiarizing consumers with automated driving capabilities and establishing technical foundations for higher automation levels. Emotional intelligence in marketing reflects evolution beyond rational persuasion toward emotional resonance and values alignment, with brands investing in understanding and responding to customer emotional states through AI-enabled sentiment detection and personalized messaging, though raising ethical concerns about manipulation and privacy boundaries.

3.5. Environmental Domain Analysis

Environmental trends reveal the urgent imperative of climate adaptation and mitigation alongside the technological and systemic transformations required to achieve sustainability goals. Several validated trends characterize this domain, reflecting both the acceleration of environmental challenges and the emergence of potential solutions. Energy sector transformation under climate pressures drives fundamental restructuring of energy systems away from fossil fuels toward renewable sources, electrification of end uses, and distributed generation models. This transition, accelerated by policy commitments, declining renewable costs, and investor pressure, fundamentally reshapes energy markets, geopolitics, and industrial competitiveness while creating challenges in grid stability, energy storage, and managing the social costs of transitioning workers and communities dependent on legacy energy industries.

Nuclear energy experiences renewed interest as a low-carbon baseload power source capable of complementing intermittent renewables, with advanced reactor designs including small modular reactors promising enhanced safety, reduced costs, and faster deployment, though facing persistent challenges in waste disposal, public acceptance, regulatory frameworks, and construction timelines that have historically exceeded projections. Green hydrogen production emerges as a critical enabling technology for decarbonizing hard-to-electrify sectors including heavy industry, shipping, and aviation, produced through electrolysis powered by renewable electricity to create a versatile, carbon-free energy carrier, though requiring substantial infrastructure investment, cost reductions, and efficiency improvements to achieve commercial viability at scale. Advanced energy storage technologies address the intermittency challenges of renewable energy through innovations beyond lithium-ion batteries, including flow batteries, compressed air energy storage, gravity-based systems, and thermal storage that enable seasonal energy shifting and grid stabilization essential for high-renewable penetration scenarios.

Energy-efficient AI computing architectures respond to the environmental footprint of artificial intelligence systems, developing specialized hardware, algorithmic optimizations, and cooling innovations that reduce the energy consumption and carbon emissions associated with training and deploying large-scale AI models, balancing technological advancement with environmental responsibility. Green and sustainable engineering practices integrate environmental considerations throughout product and system lifecycles, emphasizing circular economy principles, lifecycle assessment, sustainable materials selection, and design for disassembly and recycling that minimize resource consumption and environmental impact while maintaining functionality and economic viability. Engineered crops for carbon capture explore agricultural biotechnology approaches to enhance photosynthetic efficiency and increase carbon storage in plant biomass and soil, offering potential negative emissions pathways that remove atmospheric carbon dioxide while producing food, fiber, and biomass, though requiring careful assessment of ecological impacts, land use implications, and governance frameworks for genetic modification. Global healthcare challenges and climate change impacts on health recognize the direct and indirect health consequences of environmental degradation, including heat-related illness, vector-borne disease expansion, air quality deterioration, food and water insecurity, and climate migration-related health burdens, necessitating healthcare system adaptation, enhanced disease surveillance, and integration of climate considerations into public health planning and medical training.

3.6. Legal and Governance Domain Analysis

Legal and governance trends reflect the challenges of adapting regulatory frameworks and institutional structures to rapid technological change, evolving security threats, and shifting societal expectations regarding transparency, accountability, and public service delivery. Several validated trends characterize this domain, revealing tensions between innovation enablement and risk mitigation. Enhanced cybersecurity measures become essential governance priorities as cyber threats intensify in sophistication and frequency, targeting critical infrastructure, government systems, and private enterprises with ransomware, espionage, and destructive attacks. Governments respond through mandatory security standards, incident reporting requirements, public-private threat intelligence sharing, and investment in defensive capabilities, while grappling with attribution challenges, international law gaps, and the balance between security imperatives and civil liberties in surveillance and data collection.

Digital twins for urban planning and infrastructure maintenance enable municipal governments to create virtual replicas of physical systems integrating real-time sensor data for simulation of policy interventions, infrastructure modifications, and emergency scenarios before physical implementation. This technology supports evidence-based decision-making, predictive maintenance that reduces costs and service disruptions, and stakeholder engagement through visualization, though requiring substantial data infrastructure, technical expertise, and governance frameworks addressing data ownership, privacy, and algorithmic accountability in automated decision systems. Urban development toward sustainable and resilient cities reflects evolving governance approaches that integrate environmental sustainability, climate adaptation, social equity, and economic vitality into comprehensive planning frameworks.

Cities adopt green building standards, expand public transit and active transportation infrastructure, implement nature-based solutions for stormwater and heat management, and pursue circular economy principles in waste and resource management, responding to both climate imperatives and resident demands for livability while navigating financing constraints, regulatory fragmentation across jurisdictional levels, and tensions between density and neighborhood character. Preserving essential public information in news deserts addresses the crisis of local journalism as economic pressures force closures of community newspapers and broadcasters, leaving populations without access to local government coverage, community information, and civic dialogue essential for democratic participation. Governments, foundations, and communities experiment with public funding models, nonprofit news organizations, journalism cooperatives, and digital platforms to maintain information infrastructure, while confronting questions about editorial independence, sustainable business models, and the appropriate role of government support in maintaining a free press without compromising journalistic autonomy.

4. Discussion

4.1. Hypothesis Evaluation

The empirical results reported in Section 3 provide strong support for both hypotheses advanced in the introduction. With respect to the primary hypothesis, the DeflyCompass pipeline successfully reduced 816 raw trend candidates extracted from 23 heterogeneous strategic reports through multi-agent AI processing to a final set of 50 validated, non-redundant trends, a compression ratio that would be analytically intractable within realistic timeframes using exclusively human review. Crucially, this efficiency gain was achieved without sacrificing interpretive coherence: the human-in-the-loop validation embedded in Phases 1 and 4 ensured that every retained trend was substantiated by credible source material and assessed for strategic relevance by domain experts, addressing the hallucination and framing bias risks inherent to fully automated extraction [18,19]. The stable clustering outcomes across the semantic embedding space further attest to the methodological robustness of the hybrid approach, as the K-Means procedure converged to a coherent and semantically interpretable partition of the trend space. Taken together, these results support the claim that structured human–AI integration constitutes a superior paradigm for large-scale trend identification relative to either modality operating independently, consistent with the broader theoretical literature on human–AI complementarity [26,27,30].

With respect to the secondary hypothesis, the co-occurrence analysis and knowledge graph structure reveal a trend landscape characterized by extensive cross-domain interdependencies rather than siloed categorical clusters. Consistent with the secondary hypothesis, artificial intelligence emerges as the dominant connective force: technological trends record the highest mean impact score $\bar{I}_{\text{tech}}$ among all PESTEL categories, and AI-related trends account for four of the five highest individual impact scores in the global knowledge graph. This centrality is not merely quantitative, it is corroborated by the qualitative analysis in Section 3, which documents AI's mediating role across political governance, economic restructuring, social transformation, environmental management, and legal adaptation. The DeflyCompass framework's capacity to surface these cross-domain meta-trends, which would be difficult to identify through domain-siloed expert panels or through unsupervised AI clustering alone, illustrates the specific analytical value generated by the hybrid approach and validates the explanatory ambitions of the initial hypothesis.

4.2. Interpretation of Findings

The 50 validated trends collectively depict 2025 as a pivotal year characterized by patterns of transformation, tension, and acceleration across multiple domains. Systematic analysis of their interrelationships yields several overarching interpretations.

A central dynamic is the simultaneous convergence and divergence of global systems. Technological platforms increasingly converge as artificial intelligence integrates across domains, generating globally interconnected infrastructures and shared technological dependencies [38,39].

Concurrently, geopolitical systems fragment into competing blocs characterized by strategic rivalry and trade restrictions, reshaping supply chains and producing technology decoupling [40,41]. This creates structural tension between globally integrated technological ecosystems and increasingly separated political-economic spheres, requiring strategies that leverage technological convergence while mitigating geopolitical fragmentation through reshoring and friendshoring initiatives.

Acceleration and adaptation gaps constitute another critical pattern with potentially destabilizing implications. Technological advancement and climate impacts accelerate at rates that social institutions, governance frameworks, and human adaptive capacity struggle to match [42,43]. Regulatory frameworks designed for twentieth-century industrial economies are applied to twenty-first-century innovations including CRISPR gene editing, synthetic biology, and AI-driven decision-making; democratic processes face disruption from real-time crisis management demands; and educational systems prepare students for careers being fundamentally reshape d by automation and enterprise AI investment [44,45]. The ability to accelerate institutional and social adaptation emerges as a key determinant of whether technological and environmental transitions are manageable or destabilizing.

Sustainability has transitioned from aspiration to systemic imperative [46,47]. Environmental constraints now drive innovation across energy, agriculture, urban governance, and computing architectures, redefining competitive advantage as regulatory frameworks tighten and stakeholder expectations evolve [35]. Organizations that treat sustainability as peripheral risk strategic misalignment as climate impacts intensify across all domains [46].

Trust deficits emerge as a structural vulnerability across political, social, technological, and governance domains. Declining institutional confidence, algorithmic opacity, cybersecurity threats, and the collapse of local journalism collectively point to a legitimacy crisis with direct consequences for technology adoption, regulatory effectiveness, and social cohesion [48,49]. Rebuilding trust demands structural reforms demonstrating accountability and transparency rather than communication strategies alone [1].

Finally, demographic and generational divergence creates simultaneous and opposing pressures. Aging populations strain healthcare and labor markets in developed nations [50], while Generation Alpha's digitally native consumption patterns and values-aligned preferences reshape markets, education, and cultural production [51]. Organizations must develop differentiated strategies that address these coexisting demographic realities rather than assuming unified market approaches [52].

4.3. Methodological Learnings

Applying DeflyCompass at global scale provided valuable insights into the methodology's strengths and limitations, informing both the interpretation of current findings and the refinement of future applications.

The methodology demonstrated strong scalability, successfully processing 23 substantial documents that would require months using purely manual analysis, while maintaining consistent application of extraction criteria across all sources. Explicit documentation of parameters including model versions, embedding dimensions, clustering algorithms, and validation criteria supports replication by independent researchers and addresses long-standing criticisms that strategic foresight lacks scientific rigor.

However, several significant limitations emerged. Source selection remains a fundamental constraint: despite deliberate diversification efforts, sources skewed toward Western organizations, and biases in Phase 1 curation propagate through the entire pipeline. This limitation suggests that source diversification represents the highest-leverage improvement for future global foresight applications. Recency bias also represents a subtle but important challenge, as both AI models and human reviewers aware of current discourse may over-weight recent developments relative to slower-moving but equally significant trends.

4.4. Implications for Strategic Foresight Practice

This study yields concrete, stakeholder-specific implications for organizations seeking to improve their strategic foresight capabilities in an era of accelerating change.

Technology governance bodies and policymakers.

Regulatory frameworks must shift from static, legislated standards toward adaptive mechanisms capable of evolving at a pace commensurate with technological change. Concretely, policymakers should establish regulatory sandboxes for high-velocity domains such as AI governance and synthetic biology, with mandatory review cycles of 12–18 months rather than the multi-year cycles typical of conventional legislation. Multilateral investment in regionally diverse, multilingual foresight infrastructures is equally urgent: the Western-centric bias identified in this and similar studies systematically underrepresents developments emerging from Asia, Africa, and Latin America, creating blind spots precisely where consequential shifts may originate. Addressing trust deficits requires structural mechanisms, algorithmic transparency requirements, independent auditing of AI-driven public decision-making, and investment in local journalism infrastructure rather than communication campaigns.

Organizational strategists and executives.

Organizations should transition from periodic foresight exercises, typically conducted on annual or multi-year cycles, to continuous AI-augmented environmental scanning with quarterly trend updates and explicit early warning protocols triggered when monitored indicators reach predefined significance thresholds. Hybrid team structures that pair domain experts with AI deployment specialists should be formalized: AI provides processing scale and pattern detection, while human expertise remains irreplaceable for contextual validation, scenario construction, and strategic interpretation. Organizations operating across geopolitical fault lines, particularly those exposed to US-China technology decoupling, should develop bifurcated supply chain strategies and assess technology portfolio dependencies against plausible fragmentation scenarios. Finally, sustainability performance should be integrated into core competitive strategy rather than treated as a compliance function, as environmental constraints increasingly determine market access, investment eligibility, and regulatory exposure.

Academic and foresight research communities.

Methodological progress requires the development of standardized uncertainty quantification metrics for trend validation, enabling rigorous cross-study comparability and cumulative knowledge building in foresight practice. Source diversification beyond English-language, Western-institutional corpora represents the most impactful methodological improvement for global foresight studies. Longitudinal validation studies tracking whether trends identified through AI-augmented methods materialize as anticipated would substantially strengthen the empirical basis of hybrid foresight methodologies. Interdisciplinary collaboration integrating computational social science, domain expertise, and organizational theory would further advance the analytical rigor and applied relevance of strategic foresight as a field.

4.5. Limitations of This Study

Several limitations should be considered when interpreting findings and applying insights to strategic planning contexts.

Geographic and linguistic bias affects results despite diversification efforts. Overrepresentation of Western, English-language sources creates potential blind spots regarding trends more prominent in other regions or cultural contexts, particularly affecting social and political trends that exhibit greater regional variation than globally diffusing technological trends. This geographic concentration has direct implications for the generalizability of findings: the 50 identified trends should be interpreted as a mapping of globally prominent forces as represented in predominantly Western institutional discourse, rather than as a universally exhaustive taxonomy. Researchers or practitioners applying this framework in non-Western contexts are advised to supplement the source corpus with region-specific foresight literature to correct for this structural bias.

The analysis represents a temporal snapshot reflecting trends as of late 2025 based on sources published primarily in 2024 and early 2025. The rapidly evolving landscape means some findings may be superseded by unexpected developments by publication time, and point-in-time analysis risks missing inflection points occurring after data collection.

Validation challenges are fundamental to foresight work. Expert consensus used as a short-term validation proxy risks groupthink, while literature co-occurrence analysis favors trends already receiving attention over genuinely novel weak signals. Ultimate validation comes years later when predicted developments either materialize or fail to do so.

Organizational source bias may systematically underrepresent disruptive innovations emerging from smaller entities, startups, or overlooked geographies, as large established organizations producing major foresight reports naturally focus on trends affecting incumbent industries and large-scale systems.

The AI-driven components of the analytical pipeline introduce limitations that warrant explicit acknowledgement. Large language model-based trend extraction, while enabling systematic processing at scale, is susceptible to well-documented failure modes including hallucination, wherein models generate plausible but unsupported trend formulations, and framing bias, wherein the phrasing of extraction prompts may systematically privilege certain conceptual framings over others. Although the human-in-the-loop validation embedded in Phases 1 and 4 is designed to detect and correct such errors, it cannot be assumed to eliminate them entirely, particularly for subtle or domain-specific inaccuracies that may not be apparent to generalist reviewers. Additionally, the semantic embeddings generated by the EmbeddingGemma 8B model carry the distributional biases of their pre-training corpora, which are themselves predominantly English-language and Western in origin, compounding the geographic bias discussed above. The K-Means clustering procedure introduces a further sensitivity: results are dependent on random centroid initialization, and while convergence to a stable solution is expected, different initializations may yield distinct cluster configurations of equivalent objective quality. In this study we report results for a single initialization; future work should conduct sensitivity analyzes across multiple random seeds to characterize the stability of the resulting trend taxonomy.

Reproducibility constraints merit explicit discussion. Several components of the Defly-Compass pipeline are non-deterministic: language model outputs vary across inference runs due to temperature sampling, embedding models may be updated or deprecated by their providers, and the DOAJ corpus evolves continuously as new publications are indexed. Consequently, independent replication of this study using the same protocol at a later date would be expected to yield a broadly consistent but not identical set of trends and co-occurrence counts. Full pipeline reproducibility would additionally require version-locking the language and embedding models employed, a practice we recommend for future iterations of this and analogous AI-assisted foresight methodologies.

Uncertainty quantification limits affect the translation of findings into strategic decisions. Trend identification suggests possibilities and likelihoods rather than certainties, requiring robust strategies that perform adequately across multiple potential futures rather than optimization for single predicted outcomes.

4.6. Complete List of Validated Trends

The following enumeration presents all 50 validated trends organized by primary PESTEL classification. This comprehensive list enables readers to assess the complete scope of identified trends and serves as reference for subsequent analysis and application.

4.6.1. Political Trends

1. AI-driven decision-making
2. Democratization of space access
3. Tech-driven change
4. Geopolitical Shifts
5. Real-time crisis management
6. Declining trust in institutions and democracy
7. Space-based communication global connectivity

4.6.2. Economic Trends

8. Trade tensions and supply chain risks
9. ICT supplier capability assessment
10. Innovative last-mile delivery solutions
11. Consumers value AI recommendations for shopping
12. Generation Alpha's unique characteristics drive future market trends and consumer insights
13. Enterprise investment in AI
14. The Growth of Direct-to-Consumer Luxury Brands

4.6.3. Social Trends

15. Immersive Digital Identities
16. VR Travel Experiences
17. Internationalization of Sports Leagues
18. Social Rewilding Digital Physical Balance
19. The Rise of Slow
20. Music streaming layoffs due to competition
21. Autonomous vehicles impact transportation and urban planning
22. Aging population impact
23. Nostalgia Modern Design Trend
24. AI in urban planning smart cities

4.6.4. Technological Trends

25. The Democratization of Quantum Computing
26. Automation of newsroom task
27. AI Tools for Content Creation
28. AI enhancing patient experience and outcomes
29. AI-powered personalized mental health apps
30. Cloud-native applications

31. Emotional Intelligence Marketing
32. Custom AI chips
33. Zero-trust architectures
34. Future computing tech trends
35. Advanced Driver Assistance Systems (ADAS)
36. CRISPR tree optimization
37. Blockchain trust and transactions
38. Personalized Nutrition DNA-Based
39. Synthetic biology engineering

4.6.5. Environmental Trends

40. Energy-Efficient AI Computing Architectures
41. Green hydrogen production
42. Green and sustainable engineering practices
43. Energy Sector Transformation Climate Pressures Nuclear Energy
44. Global healthcare challenges and climate change impacts on health
45. Advanced Energy Storage
46. Engineered crops carbon capture

4.6.6. Legal and Governance Trends

47. Digital twins urban planning infrastructure maintenance
48. Urban sustainable resilient cities
49. Enhanced cybersecurity measures
50. Preserving essential public info in news deserts

5. Conclusions

This study demonstrates that the DeflyCompass methodology can be effectively applied at a global scale to identify, synthesize, and validate the major trends shaping contemporary and near-future societal, economic, and technological dynamics. Through the systematic analysis of 23 strategic foresight and industry reports produced by leading global organizations, the research reduced an initial set of 816 preliminary signals to 50 validated global trends distributed across the full PESTEL framework. The resulting trend set provides a coherent and evidence-based snapshot of the global landscape in 2025.

Four key findings emerge from the analysis. Artificial intelligence operates as a general-purpose enabling technology across all PESTEL domains, functioning as a systemic strategic variable. Environmental and sustainability-related dynamics emerge as equally systemic. Geopolitical fragmentation is reshaping the global order toward a more fragmented and multipolar one, with direct consequences for supply chains, technology governance, and market access. Finally, the erosion of trust constitutes a structural vulnerability, with consequences for technology adoption, regulatory effectiveness, and social cohesion.

From a methodological perspective, the study validates the DeflyCompass approach as a robust framework for global-scale strategic foresight. The hybrid human–AI model effectively balanced analytical rigor with processing efficiency, demonstrating that AI augmentation can substantially accelerate trend identification, clustering, and prioritization without compromising quality when embedded within a structured expert-driven validation process. The methodology proved scalable, enabling the processing of 23 complex documents and hundreds of signals within a relatively short timeframe using a small expert team. The central methodological contribution lies in demonstrating that neither AI nor human expertise alone is sufficient: their deliberate integration enables a more rigorous, transparent, and scalable approach to strategic foresight.

The study is not without limitations. These include potential source selection bias, the dominance of English-language materials, and the expert validation bottleneck in later phases, all of which constrain the geographic and cultural representativeness of the findings.

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Appendix A. Partial List of Preliminary Trends Identified via AI Processing

This appendix documents a small set of preliminary trends generated through AI-assisted analysis. The trends listed below represent unfiltered outputs from the AI processing pipeline and were used as input material for clustering, synthesis, and higher-level thematic interpretation in this paper.

- Consumers prioritize long-term health by adopting preventive solutions
- Vitamin and supplement sales grow steadily as consumers seek targeted health benefits
- 54% of consumers actively choose vitamins and supplements aligned with personal health goals
- New online brands with cellular health attributes gain significant market share
- Health-focused snacks targeting brain, joint, and eye health show strong growth potential
- Only 18% of consumers frequently make impulse purchases as economic uncertainty influences buying habits
- 50% of consumers willing to pay for time-saving solutions despite rising costs
- Premium beauty products outsell mass alternatives as consumers value quality over cost
- Sustainability remains a key factor with 72% of consumers concerned about rising costs
- Sustainable product offerings expand across multiple sectors with over 5 million SKUs available online
- 35% of consumers desire simpler website navigation to enhance online shopping experiences
- 42% of consumers use live-streaming for clearer product information during purchases
- 1 in 4 consumers value AI-generated product recommendations as a key shopping advantage
- 65% of businesses plan to invest in generative AI technology over the next five years

- AI-mediated reality
- Quantum computing
- Enterprises are increasingly prioritizing scalable solutions that blend emerging technologies like AI, 5G, and edge computing.
- Customers expect vendors to articulate how different technologies can be integrated for added value.
- Businesses are dissatisfied with vendors' use cases not adequately addressing sustainability needs.
- Vendors are falling short in explaining how 5G and IoT can be combined with other emerging technologies like AI and edge computing.
- Enterprises want vendors to provide more specific, tailored use cases rather than generic solutions.
- ICT providers must improve their understanding of customers' business priorities and articulate technology capabilities better.
- Security, sustainability, and risk mitigation are becoming critical factors in vendor selection decisions.
- Businesses prioritize vendors that can orchestrate partner ecosystems and integrate multiple technologies.
- Enterprises expect vendors to emphasize differentiated expertise in areas like ESG and GenAI.
- Enterprises are increasing spending on emerging technologies like AI, IoT, and 5G-IoT.
- IoT and 5G-IoT investments are becoming critical for business growth.
- AI is being leveraged to drive innovation across industries.
- Sustainability benefits from emerging technologies are a key focus.
- Enterprises face challenges in implementing advanced tech solutions.
- Assessing ICT supplier capabilities is essential for successful tech adoption.
- Engagement with supplier ecosystems is crucial for tech strategy.
- Connectivity solutions are reshaping the digital society.
- Digital transformation acceleration is a top priority.
- Emerging technologies are being integrated into long-term strategies.
- Lunar resources.
- The global wellness economy is projected to reach $9 trillion by 2028, driven by increasing consumer demand for health and well-being solutions.
- Generative AI is becoming a critical tool for managers, enabling more efficient decision-making and problem-solving in the workplace.
- There is growing interest in voice user interfaces (Voice UI) as a natural and intuitive way to interact with technology, reshaping how people engage with devices.
- The integration of GPS and AI into shopping carts is revolutionizing retail experiences by enhancing navigation and personalization for consumers.
- Digital tools are playing a pivotal role in improving women's health outcomes and promoting gender equality globally.
- A new generation of app-less AI smartphones is emerging, offering seamless and integrated AI capabilities without the need for multiple apps.
- Doctors are expressing concerns about the reliability and ethical implications of wearable devices in healthcare.
- Engineered biology is gaining traction as a transformative field, with applications across industries such as medicine, agriculture, and manufacturing.
- Public trust in bioengineering technologies is being closely monitored to ensure their responsible development and adoption.

- AI-powered wellness solutions are enabling personalized health benefits for employees, reflecting a shift toward holistic workplace well-being.
- The integration of face authentication into car displays is advancing biometric security and user experience in automotive technology.
- Emotional intelligence is becoming a key focus in marketing strategies, as brands seek to connect more deeply with their audiences.
- Pixel art design is increasingly incorporating emotional storytelling elements to create more impactful and engaging experiences.
- Personalized gifts are gaining popularity as consumers seek meaningful connections through tailored and thoughtful gifting options.
- The use of generative AI tools in customer service is expected to rise, with the potential to resolve issues efficiently across various industries.
- Quantum computing breakthroughs are poised to revolutionize fields such as cryptography, drug discovery, and optimization problems.
- Collaborations between financial institutions like American Express and other organizations are enhancing data-driven services for customers.
- NASA's microgravity strategy is advancing research in space-based applications, contributing to scientific and technological advancements.
- Princeton University's innovation in satellite design is improving the efficiency of Low Earth Orbit (LEO) constellations, supporting global communication needs.

Note. These trends represent preliminary, AI-generated signals and are not weighted, validated, or prioritized. Subsequent analytical steps were applied to derive the consolidated themes presented in the main sections of the paper.

Appendix B. Sources Used for AI Analysis and Processing

This appendix lists the primary external reports, foresight studies, and strategic publications used as input material for the AI-based trend extraction and synthesis process. These sources informed the preprocessing, semantic clustering, and signal detection stages of the analysis but were not individually weighted or ranked.

- Accenture. *Accenture Life Trends 2025*.
- MC&Co. *2025 Trends Design Show*.
- Dentsu Creative. *Trends 2025*.
- ESPAS. *Global Trends to 2040*.
- Euromonitor International. *Top Global Consumer Trends 2025*.
- Copenhagen Institute for Futures Studies. *Exploring the Futures of Technology*.
- EY. *Reimagining Industry Futures Study 2024*.
- frog. *Futurescape 2025 Insight Report*.
- TRENDS Research & Advisory. *Future Trends Report*.
- Zukunftsinstitut. *Megatrend Map*.
- Dubai Future Foundation. *Megatrends Report 2025*.
- Dubai Future Foundation. *Future Opportunities Report: The Global 50 (2025)*.
- NTT DATA. *Technology Foresight 2025*.
- Capgemini Research Institute. *Top Technology Trends 2025*.
- Future Today Institute. *2024 Technology Trends Report*.
- World Economic Forum. *The Global Risks Report 2025* (20th Edition).
- WGSN. *Top Trends for 2025 and Beyond*.
- Ecosistema Inova. *What's Next: Direction 2035*.
- VML Intelligence. *The Future 100: Trends and Change to Watch in 2025*.
- Kinetic. *Global Colors and Design Trends 2025*.
- Suramericana. *Megatendencias Informe*.

https://doi.org/10.3390/bdcc10040124

- *The State of Social Rewilding the Web*.
- Infographic. *Top Technology Trends 2025*.

Appendix C. Co-Occurrence Matrix Visualization

This appendix presents the complete visualization of the 50 × 50 trend co-occurrence matrix **R** described in Section 2.1.3. The matrix is divided into four quadrants for enhanced readability and resolution. Each quadrant shows a portion of the symmetric matrix, with color intensity representing the logarithmic transformation $\log_{10}(r_{ij} + 1)$ of publication counts obtained from the Directory of Open Access Journals (DOAJ).

Appendix C.1. Interpretation Guide

- *Color scale:* Darker red indicates stronger co-occurrence (higher publication counts), blue indicates weak or no co-occurrence
- *Symmetry:* The matrix is symmetric across the diagonal since $r_{ij} = r_{ji}$ (co-occurrence is bidirectional)
- *Diagonal:* Shows self-occurrence counts (total publications for each individual trend)
- *Transformation:* $\log_{10}(r_{ij} + 1)$ compresses the dynamic range while preserving zero values

Appendix C.2. Trend Index Reference

The 50 validated trends are indexed 1–50 and listed below with their corresponding optimized search queries used in the DOAJ database:

1. **Energy-Efficient AI Computing Architectures**
   Query: "(energy-efficient OR low-power) AND "AI computing architectures""
2. **Digital Twins for Urban Planning and Infrastructure Maintenance**
   Query: "digital twins" AND ("urban planning" OR "infrastructure maintenance")
3. **Urban Sustainable and Resilient Cities**
   Query: "sustainable cities" OR "resilient urban"
4. **Immersive Digital Identities**
   Query: "immersive digital identities" AND ("virtual personas" OR "digital avatars")
5. **Trade Tensions and Supply Chain Risks**
   Query: ("trade tensions" OR "global trade conflicts") AND ("supply chain risks")
6. **VR Travel Experiences**
   Query: (VR OR "virtual reality") AND "travel experiences"
7. **ICT Supplier Capability Assessment**
   Query: "supplier capability assessment" AND "ICT"
8. **Green Hydrogen Production**
   Query: "green hydrogen production" AND ("sustainable hydrogen")
9. **Innovative Last-Mile Delivery Solutions**
   Query: "last-mile delivery" AND (innovative OR logistics)
10. **Internationalization of Sports Leagues**
    Query: "internationalization of sports leagues" AND ("global sports organizations")
11. **The Democratization of Quantum Computing**
    Query: "quantum computing" AND (democratization OR accessibility)
12. **Social Rewilding and Digital-Physical Balance**
    Query: "Social Rewilding" AND "Digital Physical Balance"
13. **AI Recommendations for Shopping**
    Query: "AI recommendations" AND (shopping OR e-commerce)
14. **Automation of Newsroom Tasks**
    Query: "automation" AND ("newsroom" OR "newsroom tasks")

15. **AI Tools for Content Creation**
    Query: AI AND (“content creation” OR applications)
16. **AI Enhancing Patient Experience and Outcomes**
    Query: AI AND (“patient experience” OR “patient outcomes”)
17. **Green and Sustainable Engineering Practices**
    Query: (green engineering OR sustainable engineering) AND “sustainable practices”
18. **AI-Powered Personalized Mental Health Apps**
    Query: (AI OR “artificial intelligence”) AND “mental health apps”
19. **Generation Alpha’s Market Trends and Consumer Insights**
    Query: “Generation Alpha” AND (“market trends” OR “consumer insights”)
20. **Cloud-Native Applications**
    Query: “cloud-native applications” OR containerization
21. **The Rise of Slow Living**
    Query: “slow living” OR “slow movement”
22. **AI-Driven Decision-Making**
    Query: “AI-driven decision-making” OR “artificial intelligence decision-making”
23. **Enhanced Cybersecurity Measures**
    Query: “cybersecurity measures” AND (enhanced OR improved)
24. **Emotional Intelligence in Marketing**
    Query: (“Emotional Intelligence” OR EQ) AND Marketing
25. **Enterprise Investment in AI**
    Query: “enterprise investment” AND (AI OR “artificial intelligence”)
26. **Custom AI Chips**
    Query: “custom AI chips” OR “AI accelerators”
27. **Zero-Trust Architectures**
    Query: (zero-trust OR “zero trust” OR “zero trust architecture”)
28. **Future Computing Technology Trends**
    Query: (“emerging technologies” OR “next-generation computing”) AND (“AI advancements”)
29. **Music Streaming Industry Competition and Layoffs**
    Query: “music streaming” AND (layoffs OR competition)
30. **Democratization of Space Access**
    Query: “space access” AND (democratization OR “open access”)
31. **The Growth of Direct-to-Consumer Luxury Brands**
    Query: “direct-to-consumer” AND “luxury brands”
32. **Tech-Driven Change**
    Query: “tech-driven change”
33. **Geopolitical Shifts**
    Query: “geopolitical shifts” OR “power dynamics”
34. **Advanced Driver Assistance Systems (ADAS)**
    Query: (“Advanced Driver Assistance Systems” OR ADAS) AND “vehicle safety technology”
35. **Energy Sector Transformation and Climate Pressures**
    Query: “Energy Sector Transformation” AND (“Climate Pressures” OR “Nuclear Energy”)
36. **Preserving Essential Public Information in News Deserts**
    Query: “information preservation” AND (“news deserts” OR “public data access”)
37. **Autonomous Vehicles Impact on Transportation and Urban Planning**
    Query: “autonomous vehicles” AND (transportation OR “urban planning”)
38. **CRISPR Tree Optimization**
    Query: CRISPR AND (“tree” OR “plant”)

39. **Blockchain for Trust and Transactions**
    Query: "blockchain" AND (trust OR transactions)
40. **Aging Population Impact**
    Query: "aging population" AND (effect OR consequence)
41. **Global Healthcare Challenges and Climate Change Impacts on Health**
    Query: "global healthcare challenges" AND "climate change impacts on health"
42. **Personalized DNA-Based Nutrition**
    Query: "personalized nutrition" AND ("DNA-based" OR genetic)
43. **Nostalgia in Modern Design**
    Query: ("nostalgic AND modern") OR ("retro modern")
44. **Real-Time Crisis Management**
    Query: "real-time" AND "crisis management"
45. **Advanced Energy Storage**
    Query: "energy storage" OR "renewable energy storage"
46. **Declining Trust in Institutions and Democracy**
    Query: "trust in institutions" AND (declining trust OR democracy)
47. **Synthetic Biology Engineering**
    Query: "synthetic biology" AND (engineering OR bioengineering)
48. **AI in Urban Planning and Smart Cities**
    Query: "artificial intelligence" AND (urban planning OR smart cities)
49. **Engineered Crops for Carbon Capture**
    Query: "engineered crops" AND "carbon capture"
50. **Space-Based Communication and Global Connectivity**
    Query: "space-based communication" AND ("global connectivity")

Appendix C.3. Matrix Quadrant Visualizations

The following four figures present the complete co-occurrence matrix divided into quadrants for enhanced resolution and readability.

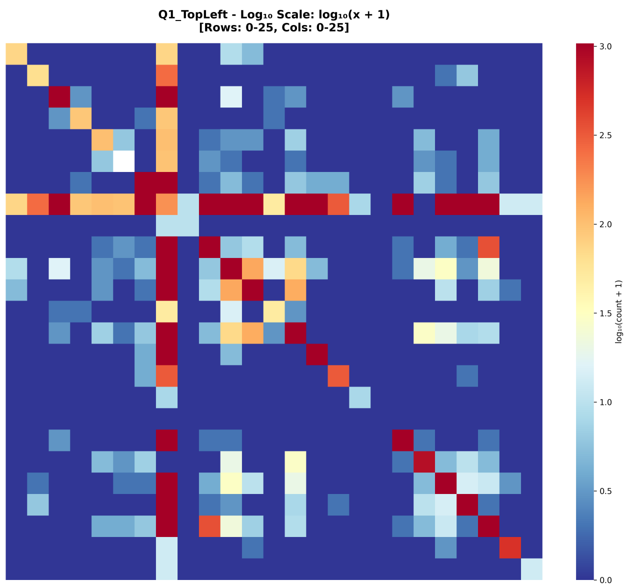

Figure A1. Quadrant I (Top-Left): Trends 1–25 × Trends 1–25. This quadrant shows co-occurrence patterns among the first 25 trends.

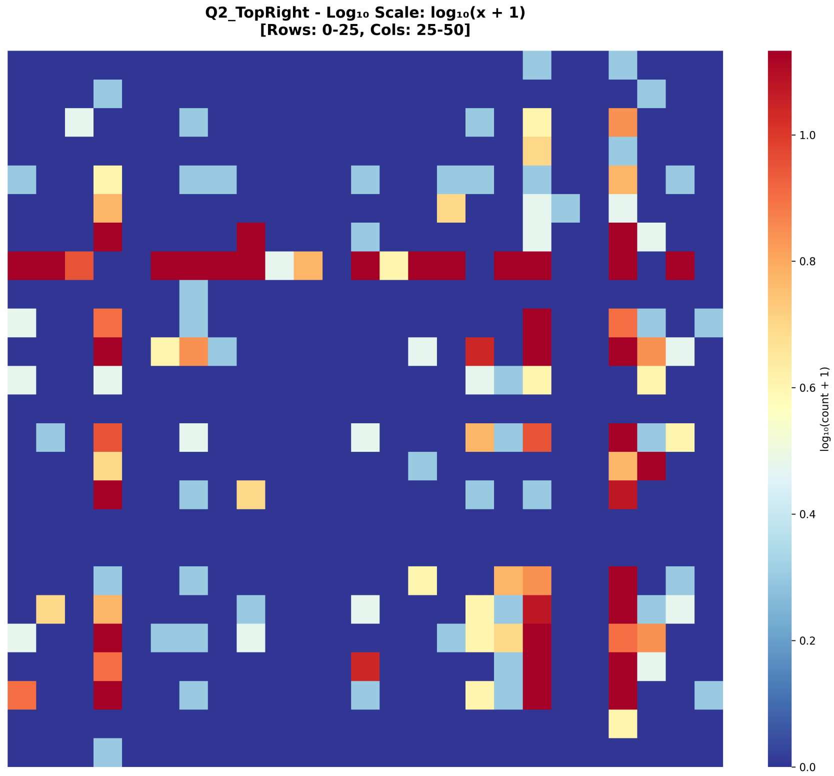

Figure A2. Quadrant II (Top-Right): Trends 1–25 × Trends 26–50.

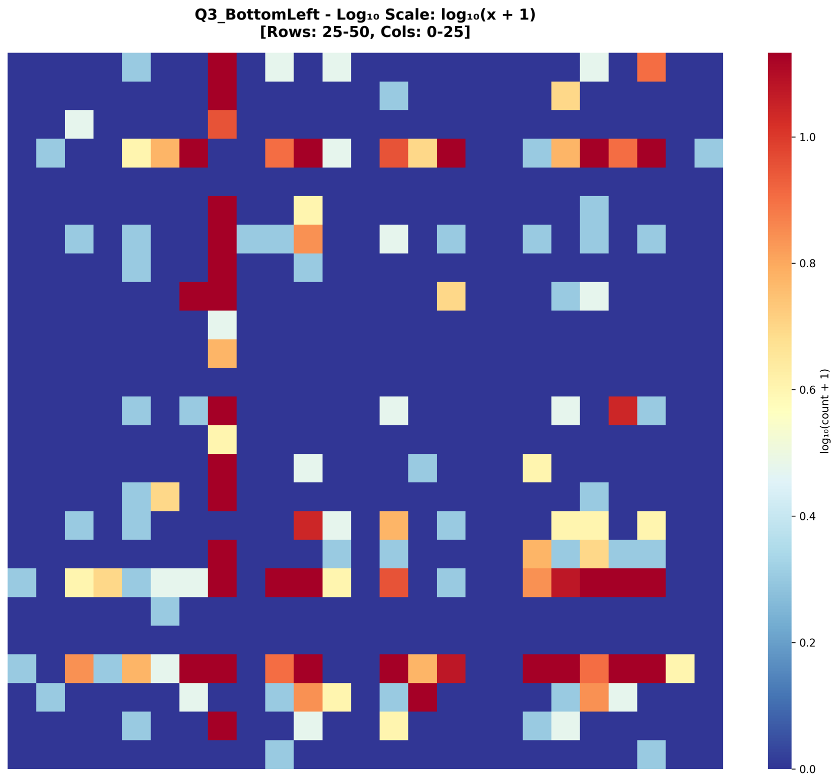

Figure A3. Quadrant III (Bottom-Left): Trends 26–50 × Trends 1–25.

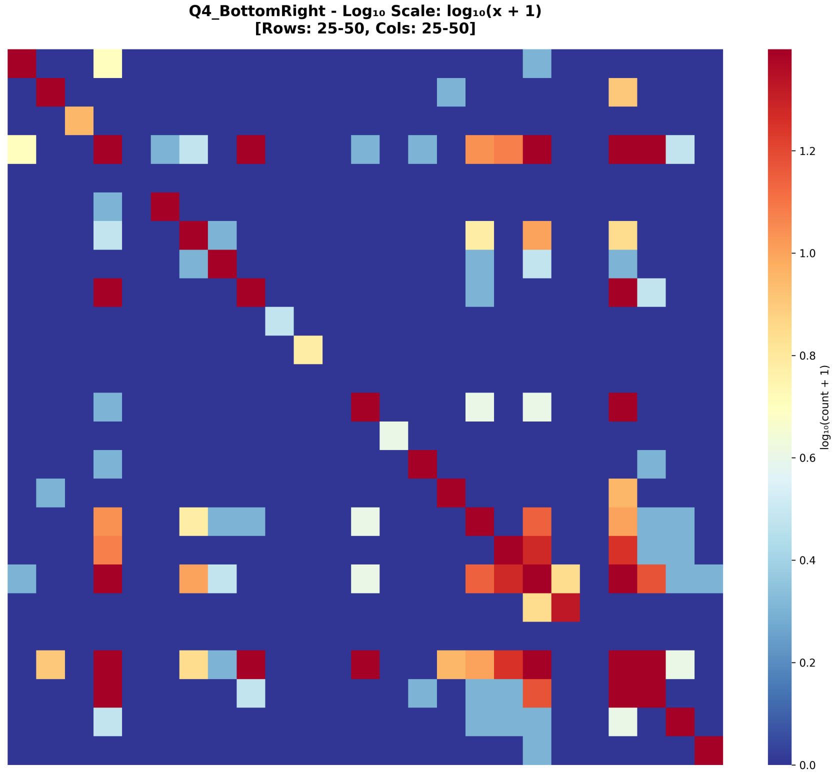

Figure A4. Quadrant IV (Bottom-Right): Trends 26–50 × Trends 26–50.

Note. The listed sources were used exclusively as qualitative input signals for AI-driven trend discovery. Inclusion in this appendix does not imply endorsement, prioritization, or direct attribution of individual findings to specific sources.

References

1. World Economic Forum. *The Global Risks Report 2026*; Technical Report; World Economic Forum: Geneva, Switzerland, 2026.
2. World Economic Forum. Global Risks Report 2026: Geopolitical and economic risks rise in new age of competition. *Press Release*, 14 January 2026.
3. Brende, B.; Zahidi, S. Top 10 Risks in 2026: Geoeconomic Confrontation Tops the List. World Economic Forum. 2026. Available online: https://www.weforum.org/stories/2026/01/global-risks-2026-top-10-two-and-ten-year-horizon/ (accessed on 25 January 2026).
4. Accenture. *Technology Vision 2025: New Age of AI to Bring Unprecedented Autonomy to Business*; Technical Report; Accenture: New York, NY, USA; Las Vegas, NV, USA, 2025.
5. Accenture. Life Trends 2025: Predicts New Dynamics of Trust Will Reshape Relationships Between People and Businesses. 2025. Available online: https://newsroom.accenture.com/news/2024/accenture-life-trends-2025-predicts-new-dynamics-of-trust-will-reshape-relationships-between-people-and-businesses (accessed on 10 October 2025).
6. Accenture. *Pulse of Change: Business and Technology Trends*; Technical Report; Accenture: Singapore, 2025.
7. United Nations Department of Economic and Social Affairs. *The Sustainable Development Goals Report 2025*; Technical Report; United Nations: New York, NY, USA, 2025.
8. Sachs, J.D.; Lafortune, G.; Fuller, G.; Iablonovski, G. *Financing Sustainable Development to 2030 and Mid-Century: Sustainable Development Report 2025*; Dublin University Press: Paris, France; Dublin, Republic of Ireland, 2025. [CrossRef]
9. Guterres, A. The Sustainable Development Goals have improved millions of lives over the past decade, but progress remains insufficient, UN report finds. *United Nations Press Release*, 14 July 2025.
10. Bornmann, L.; Mutz, R. Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *J. Assoc. Inf. Sci. Technol.* **2015**, *66*, 2215–2222. [CrossRef]
11. Shahrzadi, L.; Mansouri, A.; Alavi, M.; Shabani, A. Causes, consequences, and strategies to deal with information overload: A scoping review. *Int. J. Inf. Manag. Data Insights* **2024**, *4*, 100261. [CrossRef]

12. Eppler, M.J.; Mengis, J. Information overload in the information age: A review of the literature from business administration, business psychology, and related disciplines with a bibliometric approach and framework development. *Bus. Res.* **2018**, *12*, 479–522. [CrossRef]
13. Blair, A. *Too Much to Know: Managing Scholarly Information Before the Modern Age*; Yale University Press: New Haven, CT, USA, 2010.
14. Wolff, M.; Knill, C. Dealing with information overload: A comprehensive review. *Front. Psychol.* **2020**, *11*, 1560. [CrossRef]
15. OECD; World Economic Forum. *AI in Strategic Foresight: Reshaping Anticipatory Governance*; Technical Report; OECD Publishing: Paris, France, 2025.
16. Pärnänen, D. The Dual Horizon: How AI is Reshaping Strategic Foresight for the Better and the Riskier. FIBRES Foresight. 2025. Available online: https://www.fibresonline.com/blog/dual-horizon-ai-reshaping-strategic-foresight (accessed on 10 October 2025).
17. Bauhaus Luftfahrt. *Trend Monitor: AI-Powered Strategic Foresight*; Technical Report; Bauhaus Luftfahrt: Taufkirchen, Germany, 2024.
18. Huang, L.; Yu, W.; Ma, W.; Zhong, W.; Feng, Z.; Wang, H.; Chen, Q.; Peng, W.; Feng, X.; Qin, B.; et al. A survey on hallucination in large language models: Principles, taxonomy, challenges, and open questions. *ACM Trans. Inf. Syst.* **2024**, *43*, 45. [CrossRef]
19. Kalai, A.T.; Nachum, O.; Vempala, S.S.; Zhang, E. Why language models hallucinate. *arXiv* **2025**, arXiv: 2509.04664.
20. Xu, Z.; Jain, S.; Kankanhalli, M. Hallucination is inevitable: An innate limitation of large language models. *arXiv* **2025**, arXiv:2401.11817.
21. Alansari, A.; Luqman, H. Large language models hallucination: A comprehensive survey. *arXiv* **2025**, arXiv:2510.06265. [CrossRef]
22. OpenAI Research. *Why Language Models Hallucinate*; OpenAI: San Francisco, CA, USA, 2025.
23. Manetti, A. El Pensamiento de Diseño Aplicado al anàLisis de Tendencias Para Navegar en Futuros Inciertos. Una Propuesta Metodológica Para el Estudio, Análisis de Tendencias y Planificación estratéGica de Innovación Basada en el Design Thinking. Doctoral Thesis, Universitat Oberta de Catalunya, Barcelona, Spain, 2023.
24. Manetti, A.; Ferrer-Sapena, A.; Sánchez-Pérez, E.A.; Lara-Navarra, P. Design Trend Forecasting by Combining Conceptual Analysis and Semantic Projections: New Tools for Open Innovation. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 92. [CrossRef]
25. Ransbotham, S.; Vaccaro, K.; Malone, T.W. Roles of artificial intelligence in collaboration with humans: Automation, augmentation, and the future of work. *Manag. Sci.* **2024**, *70*, 3712–3728. [CrossRef]
26. Vaccaro, K.; Zhou, D.; Malone, T.W.; Bernstein, M.S. When Humans and AI Work Best Together—And When Each Is Better Alone. MIT Sloan Management Review. 2025. Available online: https://mitsloan.mit.edu/ideas-made-to-matter/when-humans-and-ai-work-best-together-and-when-each-better-alone (accessed on 10 October 2025).
27. Vössing, M.; Kühl, N.; Lind, M.; Satzger, G. Complementarity in human-AI collaboration: Concept, sources, and evidence. *Inf. Syst. J.* **2025**, *35*, 245–268. [CrossRef]
28. Raftopoulos, M.; Hamari, J. Human-AI collaboration in organisations: A literature review on enabling value creation. In Proceedings of the ECIS 2023 Research Papers, Kristiansand, Norway, 11–16 June 2023; p. 381.
29. Sophie, B.; Alina, T.; Greta, O.; Bjorn, G.; Corinna, P.; Annette, K. Defining human-AI teaming the human-centered way: A scoping review and network analysis. *Front. Artif. Intell.* **2023**, *6*, 1250725. [CrossRef]
30. Zhou, J.; Chen, F.; Holzinger, A. *Human and Machine Learning: Visible, Explainable, Trustworthy and Transparent*; Springer: Berlin/Heidelberg, Germany, 2021.
31. Licklider, J.C.R. Man-computer symbiosis. *IRE Trans. Hum. Factors Electron.* **1960**, *HFE-1*, 4–11. [CrossRef]
32. Tian, H.; Zhang, Y.; Wang, Y.; Li, X. Human-generative AI collaboration enhances task performance but undermines human's intrinsic motivation. *Sci. Rep.* **2024**, *15*, 98385. [CrossRef]
33. Andersen, P.D. The PESTEL framework and its variants for analysing the strategic environment: Evolution, limitations and adoption in energy policy research. *SSRN Electron. J.* **2025**. [CrossRef]
34. Yuksel, I. Developing a multi-criteria decision making model for PESTEL analysis. *Int. J. Bus. Manag.* **2012**, *7*, 52–66. [CrossRef]
35. Sousa, M.J.; Castañeda-Ayarza, J.A. Sustainable development and PESTEL analysis: An integrated framework. *Int. J. Sustain. High. Educ.* **2022**, *23*, 1089–1108.
36. López Bordao, M.; Ferrer Sapena, A.; Pérez, C.A.R.; Sánchez Pérez, E.A. Defly Compass Trend Analysis Methodology: Quantifying Trend Detection to Improve Foresight in Strategic Decision Making. *Information* **2025**, *16*, 605. [CrossRef]
37. Guo, D.; Yang, D.; Zhang, H.; Song, J.; Wang, P.; Zhu, Q.; Xu, R.; Zhang, R.; Ma, S.; Bi, X.; et al. DeepSeek-R1 incentivizes reasoning in LLMs through reinforcement learning. *Nature* **2025**, *645*, 633–638. [CrossRef]
38. Brynjolfsson, E.; McAfee, A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*; W.W. Norton & Company: New York, NY, USA, 2014.
39. Cockburn, I.M.; Henderson, R.; Stern, S. The Impact of Artificial Intelligence on Innovation. In *The Economics of Artificial Intelligence: An Agenda*; Agrawal, A., Gans, J., Goldfarb, A., Eds.; University of Chicago Press: Chicago, IL, USA, 2019; pp. 115–146.

40. Farrell, H.; Newman, A.L. Weaponized Interdependence: How Global Economic Networks Shape State Coercion. *Int. Secur.* **2019**, *44*, 42–79. [CrossRef]
41. Witt, M.A. De-Globalization: Theories, Predictions, and Opportunities for International Business Research. *J. Int. Bus. Stud.* **2019**, *50*, 1053–1077. [CrossRef]
42. Perez, C. *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*; Edward Elgar: Cheltenham, UK, 2002.
43. North, D.C. *Institutions, Institutional Change and Economic Performance*; Cambridge University Press: Cambridge, UK, 1990.
44. Acemoglu, D.; Restrepo, P. Tasks, Automation, and the Rise in US Wage Inequality. *Econometrica* **2022**, *90*, 1973–2016. [CrossRef]
45. Manyika, J.; Lund, S.; Chui, M.; Bughin, J.; Woetzel, J.; Batra, P.; Ko, R.; Sanghvi, S. *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*; Technical Report; McKinsey Global Institute: San Francisco, CA, USA, 2017.
46. IPCC. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Technical Report; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2023. [CrossRef]
47. Rockström, J.; Steffen, W.; Noone, K.; Persson, R.; Chapin, F.S.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. A Safe Operating Space for Humanity. *Nature* **2009**, *461*, 472–475. [CrossRef]
48. Edelman. *Edelman Trust Barometer 2025*; Technical Report; Edelman: Chicago, IL, USA, 2025.
49. Levi, M.; Stoker, L. Political Trust and Trustworthiness. *Annu. Rev. Political Sci.* **2000**, *3*, 475–507. [CrossRef]
50. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Ageing 2023: Challenges and Opportunities of Population Ageing in the Least Developed Countries*; Technical Report; United Nations: New York, NY, USA, 2023.
51. McCrindle, M.; Fell, A.; Buckerfield, S. *Generation Alpha: Understanding Our Children and Helping Them Thrive*; Hachette Australia: Sydney, Australia, 2021.
52. Challoumis, C. Economocracy: Global Economic Governance. *Economies* **2025**, *13*, 230. [CrossRef]