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Chapter 7

Advancing industry 4.0, 5.0, and society 5.0 through generative artificial intelligence like ChatGPT

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Abstract: The Industry 4.0, Industry 5.0, and Society 5.0 are increasingly advanced by generative artificial intelligence (AI) typified by models like ChatGPT. As the researchers have placed an emphasis on further upgrading industrial sector, it is Industry 4.0 - using sensors, Internet of Things (IoT), and AI to automate and optimize production, as well as cyber-physical systems to monitor physical processes - that best fits the current needs of industries. Generative AI can further enhance these systems by enabling real-time data analysis, predictive maintenance, and automated decision-making, leading to improved efficiency, reduced downtime and fostering more innovation in manufacturing. Generative AI plays a role in helping the industry transition to Industry 5.0 and the reinforcement among human-centric applications with shared workflow by humans and machines. It helps in customization of user experiences, intelligent decision support systems, and human-robot cooperation. In the paradigm of Society 5.0, that is a next stage super-smart society where digital and physical spaces are fused into one guaranteed reality, generative AI is the other half of creating a viable, healthy and comprehensive neighbourhood. Technology, powered by Natural Language Processing (NLP) and generative AI like ChatGPT, facilitates the advancement of human-cantered and sustainable practices that can help create a more efficient societies and industries.

Keywords: Artificial intelligence, ChatGPT, Gemini, Natural language processing, Large language models, Machine learning, Deep learning.

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7.1 Introduction

Generative Artificial Intelligence (GAI) technology powered by, ChatGPT represents a major milestone in digital technology that is anticipated to have a serious impact on Industry 4.0, Industry 5.0, and Society 5.0 (Javaid et al., 2023; Rane, 2023a; Sherif et al., 2024). In its broadest sense, Industry 4.0, consists of incorporating cyber-physical systems, the Internet of Things (IoT), and cloud computing, from which the goal of creating intelligent factories and increasing production efficiency emerges. GAI services which enable advanced predictive maintenance, real-time data analytics, and intelligent automation - all geared towards achieving high productivity and production cost reduction (Rane, 2023b; Terziyan et al., 2024). Moreover, Industry 5.0 underlines the collaboration between humans and machines, developing an individualized and human-oriented method to production (Leng et al., 2022; Xu et al., 2021; Huang t al., 2022; Paramesha et al., 2024a). This synergy is facilitated through human-centered hardware and software as provided by GAI by intuitive interfaces and adaptive systems to emphasise technology augmentation of humans and not technology replacing human labour (Huang et al., 2022; Wang et al., 2023; Rane, 2023c). At the same time, the concept of Society 5.0, sees a future super-smart society of seamless integration between the physical and cyber spaces to tackle social issues and improve the way we live (Kiangala, & Wang, 2024; Pan et al., 2023). In this scenario, Generative AI is a vital part of the solution, with new innovations being created for health care, public services and education (Lo, 2023; Whalen, & Mouza, 2023; Wang et al., 2023; Muftić et al., 2023). Such as AI-driven personal learning systems that can address the individual needs of an educational experience, the intelligent healthcare systems also can provide predictive diagnostics and personalized treatment plans. In addition to that, GAI can enable the development of smart cities that harness data to increase the efficiency of urban planning, traffic flow, and environmental sustainability (Rathore, 2023; Khowaja et al., 2024; Raman et al., 2024).

Industry 4.0 remains focused on intelligent production, using, among other things IoT, cyber-physical systems, and AI to make it more efficient and even self-organized. ChatGPT is a vital tool for production line optimization by real-time data analysis, enabling compelling insights for predictive maintenance (Rane, 2023a; Sherif et al., 2024; Paramesha et al., 2024b). Transitioning into Industry 5.0, the focus shifts from human-centered innovation to human-machine symbiosis between humans and intelligent machines. In this case, ChatGPT makes human-robot collaboration smoother through its language processing features, facilitating more accessible interactions and decision-making. In Society 5.0, conceptualized in the future, a super-smart society could be attained through seamless technology integration in all walks of life, achieving improved public services and enhancing accessibility. Realtime information, advanced personal

assistance, and further automation-these three are the critical elements that ChatGPT can offer in improving the quality of life and further economic development. On the other hand, integrating Generative AI into these advanced frameworks is in one of the critical technological breakthrough but also carries serious ethical and social implications. Given the wide scale of these AI systems, proper considerations have to be made with regard to the privacy, security, and possible algorithmic bias that should be in place to guarantee their benefits.

This research makes the following contributions:

1) Performs an extensive review of the literature to chart a plan of the status of Generative AI in propelling Industry 4.0, Industry 5.0 and Society 5.0
2) Using keyword, co-occurrence, and cluster analysis to reveal main trends, challenges, and opportunities applying GAI.
3) Offers an in-depth look at the moral, social and technological outcomes of adding GAI to those complex commercial and societal frameworks.

7.2 Methodology

To make careful predictions about the role of new, generative AI, in particular ChatGPT, in pushing Industry forward, we use a systematic literature review. This review includes published peer-reviewed articles, conference papers and relevant industry reports. Searches through key databases including IEEE Xplore, ScienceDirect, and Google Scholar were performed using search terms such as "generative AI," "ChatGPT," "Industry 4.0," "Industry 5.0," and "Society 5.0." A bibliometric analysis was employed in VOSviewer in order to recognize the relevant trends and thematic clusters. Primary keywords were extracted from the literature to have a visualization between the keywords for checking the relationship between the extracted keywords. It helped in mapping the top problematic keywords and their relationships. Next, we conducted cluster analysis of the keywords, so we could organize related terms into thematic clusters and make sense of the research landscape. Core themes for each cluster were derived and emerging trends within generative AI affecting industrial / societal advancements were explored.

7.3 Results and discussions

Co-occurrence and cluster analysis of the keywords

The interrelations of different generative AI (ChatGPT) keywords are demonstrated in (Fig. 7.1). These links are essential to the progression of Industry 4.0, Industry 5.0 and

Society 5.0. This way we can realize the intercept and associations of the terms and sectors between them clearly, which demonstrates the way generative AI is blending and its effects on several sectors and concepts. ChatGPT is widely recognized as it hosts a variety of research discussions and applications. The following terms are closely related to it. The terms are show first and center to emphasize that they are integral to use of ChatGPT. The red cluster highlights several key words, including; "Industry 4.0," "digital transformation," "performance," "students" and "higher education." At the heart of digital transformation and innovation are Industry 4.0 initiatives. While AI is critical for bringing education up-to-date and boosting learning outcomes, it is even more crucial for training the next generation for a tech-primed world. This is clear because of the keywords like education and students.

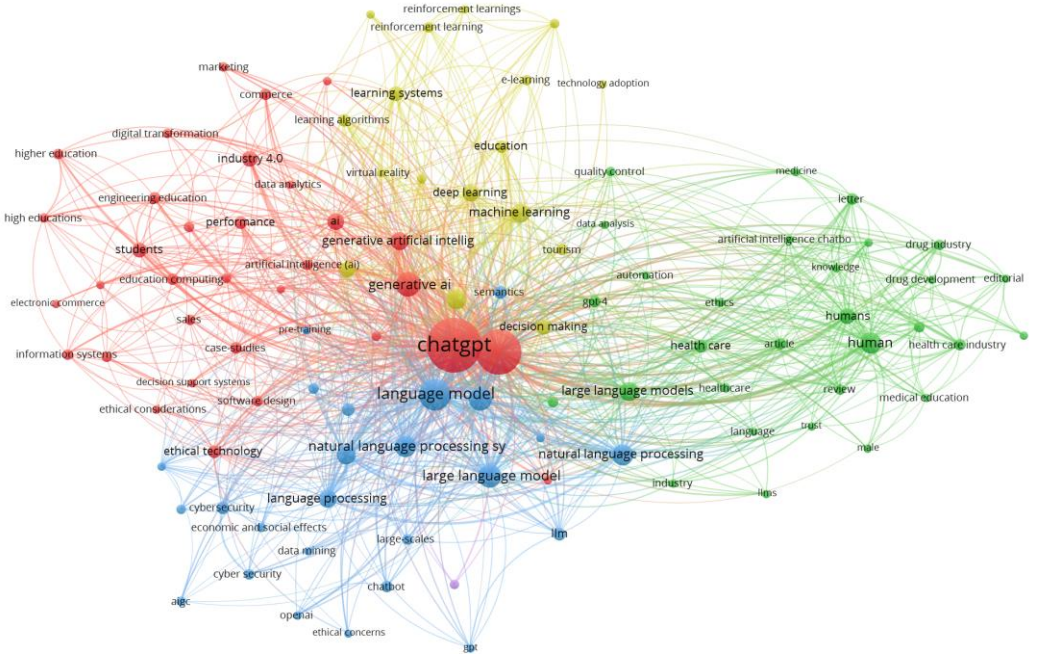

Fig. 7.1 Co-occurrence analysis of the keywords in literature

Cluster in yellow primarily related to concepts of machine learning, deep learning, learning system, reinforcement learning etc. Generative AI that is the main group of technological features and stroke of learning paradigms that lead to the rise of generative AI. It is reassuring that much work in these areas has continued to deepen focusing on deep learning and machine learning techniques. This, in turn, translates into more advanced as well as efficient AI models. Reinforcement learning plays a vital role in machine learning and underscores the necessity for AI systems to keep on learning and re-learning throughout their lifespan. The green cluster contains nodes connoting "health care," "humans," "medicine," "drug development," and "ethics" while the yellow one is

linked with words such as "blood cells," "antibiotics," "proteins," "treatment," and "bacteria." Highlighted in the cluster are two overarching themes surrounding the importance of healthcare generative AI and human-cantered applications. The note over ethical considerations is made as it highlights the current debate of the responsible use of AI especially in critical areas like health care. AI is transforming drug development and healthcare by speeding up research, enhancing diagnostics and personalizing treatments.

Cybersecurity, natural language processing, economic and social effects (blue cluster), ethical considerations and security are highlighted by AI technologies. NLP is key to efficient communication between humans and AI. This ensemble also underscores the broader impact on the economy, confirming the extent to which AI technologies could change the world. The links shown among the keywords had specific meanings showing other types of connectivity - with more significant relations leading to providing a swarm research path and application together. In this cluster, the close associations of "ChatGPT", "language model", and "natural language processing" suggest a focus on the language models and their real-world applications. Above all, we must realize that "AI" is defining itself into something that can bring revolutions to industry and improve the performance by making "Industry 4.0" and "digital transformation" work in a very inter-related manner.

Given the common ethical issues of security and cybersecurity, the issue of protecting AI systems and promoting responsible use is extremely critical and rather interesting. Industry 4.0 refers to the digital technologies that streamline the manufacturing and industrial processes, and it involves a high level of automation, data exchange, and efficiency. Generative AI (e.g., ChatGPT) is a model that is delved into and critically emerges subject to the bankruptcy circumstance as it scopes across the network and includes related lingo. This vision of humans and machines working in concert to develop increasingly customized and eco-friendly industrial practices is extended by the notion of Industry 5.0. This vision is then aligned with AI toward human-centric and healthcare applications focus of the green cluster, reflecting how AI can develop human potential on an interactive basis and how it can contribute to more humane and sustainable industrial processes. Society 5.0, as it is being referred, is looking to build the smart society where everything in life is fully connected to digital technology which are part of how humans will improve the human condition in the years ahead.

Generative AI such as ChatGPT utilization in Industry 4.0, 5.0, and Society 5.0

Table 7.1 presents a comparative landscape of the key characteristics, technologies, and goals defining Industry 4.0, Industry 5.0, and Society 5.0 concerning what generative AI—like ChatGPT—has added. Industry 4.0 corresponds to smart manufacturing driven

by IoT, cyber-physical systems, and AI, aimed at efficiency and automation. ChatGPT optimizes production processes through advanced data analysis and predictive maintenance. Industry 5.0, human-centered innovation, must now drive equal attention to collaboration and sustainability in the most advanced AI-human-robot collaboration. ChatGPT enhances such interaction to smoothen decision-making and personalized manufacturing. Society 5.0: A more than innovative society that merges technology into day-to-day life, thus setting up economic growth that doesn't affect quality of life. Of note, some of what ChatGPT can contribute at this stage includes improving public services and access through personalized assistance or real-time information; one sees through these evolving paradigms how deep an impact generative AI will make.

Table 7.1 Summary of ChatGPT and Generative AI utilization in Industry 4.0, 5.0, and Society 5.0

Sr. No	Aspect	Industry 4.0	Industry 5.0	Society 5.0
1	Focus	Smart manufacturing	Human-centric innovation	Super-smart society
2	Key Technologies	IoT, Cyber-Physical Systems, AI	Advanced AI, Human-Robot Collaboration	IoT, AI, Big Data, Robotics
3	Goals	Efficiency, Automation	Collaboration, Sustainability	Integration, Quality of Life
4	Characteristics	Data-driven decision making	Symbiotic relationships between humans and machines	Seamless technology integration
5	Examples	Smart factories, Predictive maintenance	Co-working robots, Personalized manufacturing	Smart cities, Enhanced public services
6	ChatGPT's Contributions	Optimizing production lines through real-time data analysis and predictive maintenance insights	Enhancing human-robot collaboration with natural language processing, facilitating smoother interaction and decision making	Improving public services and accessibility by providing real-time information, personalized assistance, and advanced automation

Generative AI in Industry 4.0

Transforming construction with generative AI

A number of groundbreaking advancements are now being made by generative AI in the construction industry by changing the way buildings, and infrastructure is conceptualized and composed (Prieto et al., 2023; Aladağ, 2023; Uddin et al., 2023; Nyqvist et al., 2024; Rane et al., 2024a). By evolving challenges Generative AI, actually creates next-level designs in more optimized fashion, enabling higher structural integrity, reduced waste of material and overall increase in efficiency (Prieto et al., 2023; Nyqvist et al., 2024; Paramesha et al., 2024c). One of the principal use cases of Generative AI in the construction industry is during the design phases. AI/ML algorithms can examine multiple design parameters and constraints and produce several alternatives of architectural and structural design (Rane et al., 2023d; Rane et al., 2024b). Architects and engineers can create designs, making the most efficient use of available space as well as cost-effective energy-saving and eco-architecture. For example, an AI-powered design tool can generate building layouts that maximise daylight and airflow, minimising the amount of artificial lighting and Heating, Ventilation, and Air Conditioning (HVAC) systems required. AI can generate elaborate construction plans for construction and schedules to execute a project on time as well within a cost-benefit budget in the construction phase. Furthermore, AI algorithms can identify possible problems proactively and in worst-case scenarios propose solutions to reduce delays and cost overflows. Additionally, AI-driven robots, and autonomous construction machinery are increasingly being used to perform repetitive, high-precision tasks, such as bricklaying and concrete-pouring, quickly and efficiently on construction sites. Table 7.2 shows the Generative AI such as ChatGPT in industry 4.0, 5.0, and society 5.0.

Revolutionizing product design and development

One of the most profound impacts of Generative AI such as ChatGPT in Industry 4.0 is in product design and development (Filippi, 2023; Özpolat et al., 2023; Paramesha et al., 2024d; Rane et al., 2024c). Conventional product design tends to be a painstaking, time-consuming, and iterative exercise, heavily reliant on human creative and engineering prowess. Using algorithms, generative AI quickly creates a wide variety of design choices as powered by specific input parameters, and constraints. For example, in the automotive world, Generative Design algorithms have enabled companies like General Motors to design lighter yet stronger parts for cars which are also more fuel-efficient and perform better. Such AI-driven designs tend to be significantly more complex (in ways that human designers could never have conceived of by themselves). In fact, it can quickly prototype and test these designs in virtual environments, having a major impact on the cost and time associated with physical prototyping (Özpolat et al., 2023). As there is a high degree of precision and tailoring that is required within areas such as aerospace, this enables

companies like Airbus to employ AI to design aircraft components that can meet very exacting performance and safety requirements.

Enhancing manufacturing processes

Generative AI is very useful for manufacturing processes such as reducing the lead time by optimizing the production line; predictive maintenance (Leng, 2022; Kiangala, & Wang, 2024; Paramesha et al., 2024e). In smart factories, AI algorithms combine with sensor data from equipment to anticipate when a machine will fail and require maintenance. With predictive maintenance, businesses can prevent downtime and prolong the lifespan of the equipment they use, which results in substantial cost savings. Generative AI can help businesses improve manufacturing workflows by showing the most efficient ways to deliver any and all production-related tasks (Leng, 2022; Kiangala, & Wang, 2024). Many industries have started integrating AI as part of its manufacturing set-up to allow for more flexible and adaptive production systems. These systems can automatically fine-tune production schedules and allocate resources as and when required on the fly, based on changes in demand or other parameters, enabling them to be as efficient and responsive as possible.

Personalizing customer experiences

Generative AI is key to every next-gen product and service in the age of customization (Harahap et al., 2023; Abas et al., 2023; Demir, & Demir, 2023). The AI looks at the customers and comes up (by learning) a solution designed specifically for each one of them. A case in point is the potential for AI to unleash and personalization on industries from fashion through to the food and beverage sector - the former who could utilize it for custom clothing design and the later a tool to produce soup-to-nuts tailored recipes and meal plans. Generative AI also empowers companies to engage with customers in richer ways like personalized marketing and customer service (Abas et al., 2023; Demir, & Demir, 2023). This leverages AI-driven chatbots and virtual aids to give personalized answers and recommendations for increasing customer satisfaction, thereby for faith. Consumers increasingly are looking for personalized experiences that cater uniquely to them, making this at least to some degree a competitive differentiator across industries.

Table 7.2 Generative AI such as ChatGPT in industry 4.0, 5.0, and society 5.0

References	Aspect	Industry 4.0	Industry 5.0	Society 5.0
Raj et al., (2023); Alshami et al., (2023); Javaid et al., (2023)	Automation and Efficiency	Enhances automation processes, reducing human intervention.	Balances automation with human creativity and craftsmanship.	Improves societal functions through intelligent

				automation, leading to better quality of life.
Singh, (2023); Jusman et al., (2023)	Data Analysis and Decision Making	Analyzes large datasets to derive actionable insights for optimizing production and operations.	Uses AI for collaborative decision-making, enhancing human-AI partnerships.	Facilitates informed decision-making at individual and community levels through personalized AI insights.
Harahap et al., (2023); Abas et al., (2023); Demir, & Demir, (2023)	Customization and Personalization	Enables mass customization in manufacturing, providing personalized products and services.	Focuses on hyper-personalization, integrating human touch into automated processes.	Promotes personalized healthcare, education, and other services, catering to individual needs and preferences.
Wang et al., (2023); Rane, (2023c)	Human-Machine Collaboration	Facilitates human-machine collaboration, improving productivity and innovation.	Advances human-robot symbiosis, where machines assist and augment human capabilities.	Encourages AI-human collaboration for societal benefits, such as in healthcare and education.
Chen, (2023); Jha, (2024)	Innovation and R & D	Accelerates research and development through predictive analytics and simulation.	Drives innovation by integrating human creativity with AI's analytical power.	Supports societal advancements through innovative AI applications in public services and infrastructure.
Frederico, (2023); Rathor, (2023); Kmiecik, (2023)	Supply Chain Optimization	Enhances supply chain management with predictive analytics and real-time monitoring.	Integrates sustainability and ethical considerations into supply chain optimization.	Promotes sustainable and resilient supply chains for societal well-being.

George et al., (2023); Rane, (2023d)	Workforce Transformation	Reskills and upskills workforce to adapt to automated and AI-driven environments.	Emphasizes on human-centric skills and roles, complementing AI capabilities.	Ensures equitable access to AI-driven opportunities, fostering inclusive growth.
Rathore, (2023); Khowaja et al., (2024); Raman et al., (2024)	Sustainability	Optimizes resource utilization and reduces waste through AI-driven processes.	Integrates sustainable practices into manufacturing and operations, balancing profit with purpose.	Promotes sustainable living through AI solutions in energy, transportation, and urban planning.
Skandali et al., (2023); Tarabah & Amin (2024)	Customer Engagement	Enhances customer interaction and support with AI-driven chatbots and virtual assistants.	Personalizes customer experiences by understanding and predicting individual needs.	Improves public engagement and service delivery through conversational AI and personalized interfaces.
Rao, (2023); Stahl, & Eke, (2024); Wakunuma, & Eke, (2024)	Ethics and Governance	Develops ethical AI practices, focusing on transparency and accountability.	Ensures AI aligns with human values and ethics, fostering trust in AI systems.	Promotes ethical AI deployment for societal good, addressing privacy, fairness, and transparency.
Al-Hawawreh et al., (2023); Gupta et al., (2023); Alawida et al., (2023)	Cybersecurity	Implements AI-driven security measures to protect industrial systems from cyber threats.	Enhances cybersecurity through advanced threat detection and response, ensuring system integrity.	Secures personal data and public infrastructure against cyberattacks, ensuring privacy and safety.
Filippi, (2023); Özpolat et al., (2023)	Product Development	Speeds up product development cycles with AI-driven	Enables co-creation of products with consumers, leveraging AI for	Facilitates the development of community-driven products and services,

		prototyping and testing.	better user experience.	enhancing societal well-being.
Megahed et al., (2024)	Quality Control	Utilizes AI for real-time monitoring and quality assurance in manufacturing.	Integrates AI to predict and rectify defects, enhancing product quality.	Ensures high-quality public services and infrastructure through continuous monitoring and improvement.
Frederico, (2023); Li et al., (2023); Javaid et al., (2023)	Predictive Maintenance	Implements AI for predictive maintenance, reducing downtime and operational costs.	Enhances maintenance strategies with AI, ensuring longevity and reliability of equipment.	Promotes proactive maintenance of public utilities and infrastructure, ensuring uninterrupted services.
Rane, (2023e); Zhang et al., (2023); Hu et al., (2023)	Energy Management	Optimizes energy consumption and efficiency in industrial operations using AI.	Integrates renewable energy sources with smart grid management for sustainable operations.	Enhances energy management in communities, promoting sustainable and efficient energy use.
Adeshola, & Adepoju, (2023); Lo, (2023); Whalen, & Mouza, (2023)	Education and Training	Provides AI-driven training programs to upskill employees in new technologies.	Develops personalized learning paths integrating human expertise with AI guidance.	Enhances lifelong learning opportunities and accessibility through AI-driven education platforms.
Javaid et al., (2023); Wang et al., (2023); Muftić et al., (2023)	Healthcare Integration	Utilizes AI for predictive diagnostics and personalized treatment plans in industrial health management.	Advances health and safety practices by integrating AI for real-time monitoring and response.	Promotes AI-driven healthcare solutions, ensuring accessible and personalized

				medical care for all.
George, & George, (2023); Chowdhury, (2023); Jarco, & Sulkowski, (2023)	Market Analysis	Uses AI to analyse market trends and consumer behaviour, optimizing business strategies.	Enhances market prediction and customization by integrating human insights with AI analytics.	Supports community-based economic development through AI-driven market analysis and insights.
George et al., (2023); Agathokleous et al., (2023); Pursnani et al., (2023)	Environmental Impact	Reduces environmental footprint through AI-optimized processes and resource management.	Balances industrial growth with environmental stewardship, leveraging AI for sustainable practices.	Enhances environmental conservation efforts through AI-driven monitoring and management systems.
Abdullah et al., (2022); Cao, (2023); Tabone, & de Winter, (2023)	Social Interaction	Facilitates seamless communication and collaboration among workers through AI platforms.	Enhances social interaction by integrating human emotional intelligence with AI capabilities.	Promotes social cohesion and community engagement through AI-driven platforms and initiatives.
Trent, (2023); Wu, (2024)	Economic Growth	Drives economic growth by optimizing industrial processes and enhancing productivity.	Balances economic growth with human well-being and societal progress, leveraging AI innovations.	Supports inclusive economic development, ensuring AI benefits are widely shared across society.

Driving innovation in supply chain management

Generative AI is also transforming supply chain management (Frederico, 2023; Rathor, 2023; Kmiecik, 2023). The fact of global supply chains simply results in into advanced logistics, inventory management, and demand forecasting. These models can be created based on numerous factors including lead times, transportation costs, and demand variability, and AI algorithms can be used to optimize them. Companies are using AI to

speed up and better manage their manufacturing and production process from the supply chain, lowering costs and enabling on-time delivery. The application of AI in supply chain management can predict disruptions and propose an alternative solution which makes the supply chain more resilient and flexible (Rathor, 2023; Kmiecik, 2023). This is an essential function now more than ever in today's volatile global market, when supply chain disruptions can cripple business operations.

Enabling smart infrastructure and cities

Generative AI is equally important here as well. AI is being used in creating Architecture (Sustainable, Efficient buildings, transportation, and public spaces) - For urban planners and architects, everything from energy usage, traffic flow, environmental impact, and more into consideration, resulting in smarter, more liveable urban environments (Al Fouri, & Sakher, 2023; Al-Hawawreh et al., 2023; Sonkor, & García de Soto, 2024). In the construction sector, we have AI scenarios that can create the most efficient building designs that would allow for the greatest use of space without generating high energy costs (Al Fouri, & Sakher, 2023; Sonkor, & García de Soto, 2024). For example, in transportation, AI algorithms can model traffic and optimize signals to reduce congestion and increase mobility. Required for tackling the challenges of urbanisation and building cities which not only work but are sustainable.

Facilitating autonomous systems and robotics

Generative AI also performs a crucial role for Industry 4.0 in the area of autonomous systems and robotics (Wake et al., 2023; Vemprala et al., 2024). Control strategies and decision-making models can be generated by AI algorithms to enable robots to perform higher- skill level activities independently. On the logistics side - autonomous drones, robots, and management for inventory, and delivery, tools like these are more efficient and require less human intervention. AI-powered autonomous systems are revolutionising farming, far and wide, in the agricultural field. Self-driving tractors and machine learning-powered drones can monitor the health of crops, control the amount of irrigation, or dispense fertilizers in areas that need them the most. Increased demand for food security in a sustainable way is driving the adoption of these technologies which in turn improves productivity and sustainability in agriculture.

Enhancing energy management and sustainability

Generative AI also plays a role in the energy management and sustainability that is addressed in Industry 4.0 (Rane, 2023e; Zhang et al., 2023; Hu et al., 2023). For Example, AI algorithms can outline models to save and reduce energy consumption in industrial process to a great extent thereby limiting the overall emissions of CO_2. AI can analyse

data from different sensors in a factory to automatically optimize heating, cooling, and lighting settings to alleviate energy wastage. In addition to this, AI can support the grid when renewable energy sources are added to the mix by predicting energy production patterns and helping with energy storage and delivery.

Generative AI in Industry 5.0 and Society 5.0

Generative AI and collaborative robotics

At the heart of Industry 5.0 are collaborative robots (cobots), which are programmed to work side-by-side with human operators to carry out tasks that call for an extra degree of accuracy, and flexibility. Finally, the functionality of cobots is improved with Generative AI that over time has enabled cobots to learn from human actions and improve their performance as they evolve (Wake et al., 2023; Vemprala et al., 2024). One example might be in assembly lines where cobots with generative AI can watch human workers and then figure out how to do a new task rather make without as much reprogramming. Second, generative AI helps create human-like human/machine interfaces, which is an obvious benefit for workers who must work with advanced robots. Through NLP and computer vision technologies, workers can communicate with cobots via simple voice commands or gestures to get it to do things for them, thus achieving streamlined workflows and an increase in overall efficiency.

Urban planning and smart cities

Generative AI has been prominent in the emergence of smart cities as well as urban planning (Al Fouri, & Sakher, 2023; Al-Hawawreh et al., 2023; Sonkor, & García de Soto, 2024). Through the collection of data from different sources (such as traffic, environment or even from social media), AI systems can provide insights that can help us in the effective management of the urban infrastructure and services. As an example, generative AI may be used in optimising transport networks, lowering energy needs or in developing waste management systems. Improvements like these are furthering development in creating environmentally and socially friendly urban spaces. In fact, the generative AI are behind the notion of digital twins which are the virtual models of physical assets and systems. City planners and administrators use digital twins to run simulations and contemplate urban development projects before they become a reality. In this way we minimize risks, costs, and plan infrastructure to accommodate the needs of urban population.

Personalization and customization

The most advocating of networks attributes a new market insight to Industry 5.0: hyper-personalization of products and services (Harahap et al., 2023; Abas et al., 2023; Demir, & Demir, 2023). Due to the high volume of consumer data, generative AI plays a huge role by analyzing and providing specific solutions (Abas et al., 2023; Al-Hawawreh et al., 2023). In the fashion industry, AI can create tailored clothing by AI based on the preferences and body measurements of the individual. AI can also tailor treatment through patient history and genetic data (healthcare). By paying attention to these details, and really understanding individual consumers on a one-to-one level overall profitability can increase exponentially.

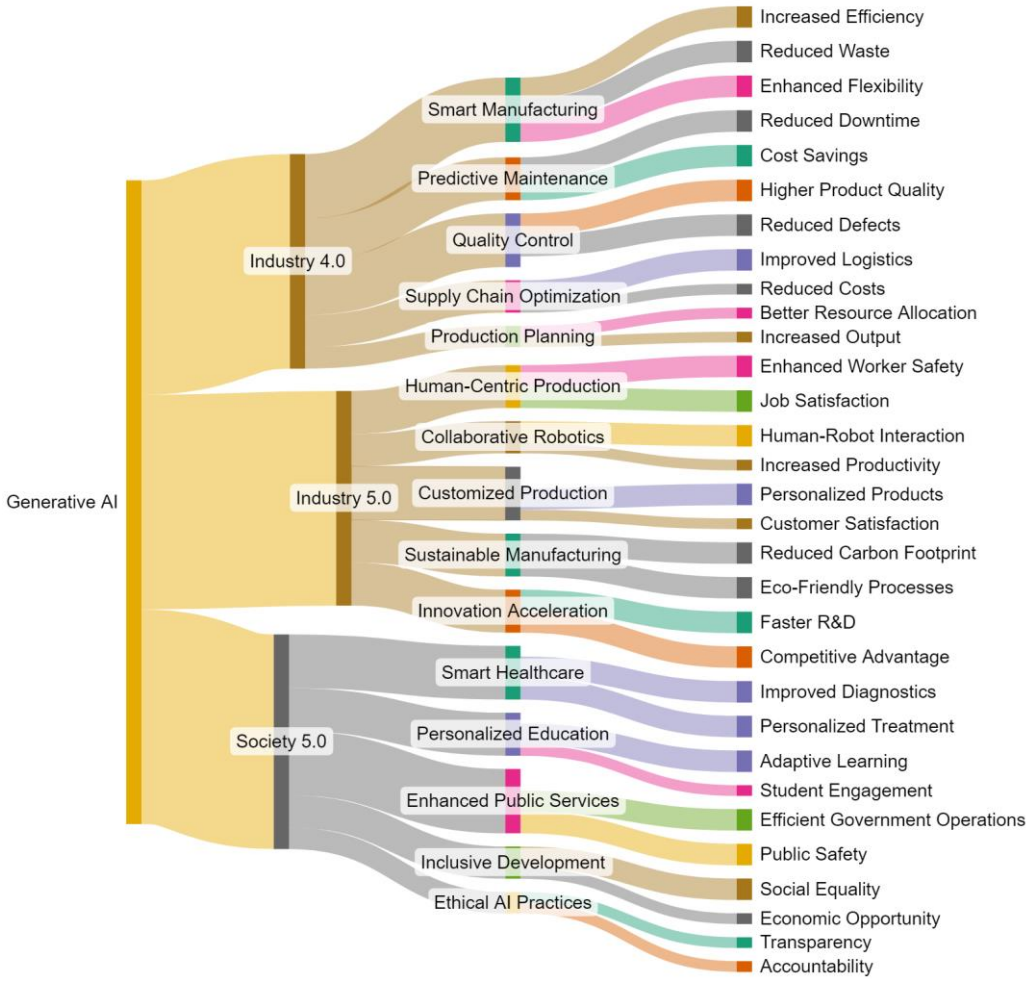

Fig. 7.2 Generative AI (like ChatGPT) in Industry 4.0, Industry 5.0, and Society 5.0

Human-cantered design

A fundamental tenet of Industry 5.0 is that technology and processes should be designed with human welfare at the forefront (Leng et al., 2022; Xu et al., 2021; Huang t al., 2022). This is facilitated by Generative AI which offers tools that enable user-oriented priority (Xu et al., 2021; Sonkor, & García de Soto, 2024). An example of this might be AI-powered interfaces that are more instinctual and user-friendly for end users with various abilities. AI, for instance reviewing employee interactions, synergies, and positive work habits, can be used for rational and mutual workplace design. Human-cantered design will increase overall satisfaction and productivity.

Sustainability and efficiency

Generative AI aids in advancing the sustainability ambition of Industry 5.0 by cutting down on the consumption of resources and wastage (Rathore, 2023; Khowaja et al., 2024; Raman et al., 2024). AI can predict narrower energy consumption patterns in the energy sector and aid with reductions to overall usage, which in turn can generate substantial cost savings and environmental improvements. For example, AI in agriculture can use soil data and weather patterns to forecast planting schedules and irrigation, producing larger crop yields with less resource consumption. These innovations help a cleaner, more economic industrial system.

Healthcare and well-being

Generative AI such as ChatGPT is altering the face of healthcare by allowing near-personalized and preventative care (Javaid et al., 2023; Wang et al., 2023; Muftić et al., 2023). It uses patient data to help predict health issues, suggest preventative services, and cater treatments (Wang et al., 2023; Muftić et al., 2023). From wearables that monitor chronic conditions to predictive models that can alert healthcare providers to health issues before they become acute, AI here may seem like a step toward the dream of personalized medicine. For example, in the case of mental health, AI chatbots can offer temporary support and point individuals to the right resources (unmanned chatbots, manned chatbots). The latter enables better health outcomes and leverages health system resources.

Education and lifelong learning

AI empowers personalized learning experiences of education in Society 5.0 (Adeshola, & Adepoju, 2023; Lo, 2023; Whalen, & Mouza, 2023). From personalized lesson creation and relevance to real-time feedback and designing curriculums in line with the learning precedence of each talent, for example, students who might be struggling with certain subjects could be provided extra resources. It can discover skill gaps and suggest relevant

training programs for employees hence ensuring a skilled adaptable workforce. This individualized educational practice encourages lifelong learning and building skill.

Economic and social inclusion

Longer term, Generative AI has the potential to serve as a bridge between economic and social divides: providing access to informational advantages that lead to learning and opportunity (Trent, 2023; Wu, 2024). These AI-powered platforms can match job seekers with job providers as per the skills and preferences, which can help better employment outcomes. In financial services, AI analyse financial data and provide specific investing tips and offer different financial planning to the user making financial services accessible to all. AI also has the capability to translate languages on the spot which could result in cross-cultural communication and cooperation. These capabilities stimulate the inclusion of all and equip them to compete on a level playing field in society.

Environmental sustainability

By helping to streamline resources, reducing waste and lessening the environmental impact of humans, generative AI is better equipped to make our world more sustainable (George et al., 2023; Agathokleous et al., 2023; Pursnani et al., 2023). For instance, AI algorithms can be deployed to analyse climate data to predict patterns of extreme weather, and to recommend how best to respond to these. With respect to conservation, AI is able to monitor wildlife populations and habitats and ultimately guide particular efforts for conservation. These applications helping in the better place of self-sustainability and environmental stewardship.

The Fig. 7.2 illustrates the role of generative artificial intelligence (AI) technologies, such as ChatGPT, in advancing the realms of Industry 4.0, Industry 5.0, and Society 5.0. Generative AI, at the central node (thick node), plays a role as a major contributor filling out these three big nodes-Industry 4.0, Industry 5.0, and the Society 5.0. Smart manufacturing, predictive maintenance, quality control, supply chain optimization and production planning are among various enhancements in industry 4.0 facilitated with AI summarization. When we talk of smart manufacturing, AI is exercised to operate all three dimensions, productivity (the efficient way to use inputs), efficiency (waste free type of operation) and flexibility (the multi-faceted type of operation). Predictive maintenance gets decreased downtime and cost savings, whereas quality control yields more reliable products and less defects. On the one end, these include logistics efficiency and cost reductions (supply chain optimization), and on the other end, resource allocation and output maximization (production planning). ai-driven human-centric production, which leverages collaborative robotics for industry 5.0 - human-centric manufacturing for custom mass production and sustainable manufacturing, along with innovation

acceleration. Human-Centric production benefits worker safety and job satisfaction while collaborative robotics enhances human-robot interaction and productivity. Personalized product ending in delighted customers as well sustainable manufacturing - eco-friendly processes and footprints. This will lead to innovation acceleration driven by expedited research and development (R & D) and competitive advantages as well. Smart healthcare, personalized education, enhanced public services, inclusive development, and ethical AI practices are also focused. Diagnostics and personalized treatment plans evolve under smart healthcare personalized education meets students on their unique learning journey which creates greater engagement. Efficient government operations, enhanced public safety, and enhanced public services. Inclusive development assist in social equality and economic opportunities, to guarantee that advancements dedicated to attaining the targets will continue to the benefit of the entire society. This focus is articulated by principles that stress transparency and accountability in the development of AI consistent with societal values and moral standards, known as ethical AI practices. This wide-ranging graphic illustrates the many ways in which generative AI is a game-changer across sectors and levels of the eco-system, from efficiency and customization to environmental compatibility, breakthroughs and ethical stewardship. The connected nodes and flows highlight AI in all of its diversity; a vision of advanced AI technologies complementing manufacturing, human-centric innovations, and inclusive societal advancements-hence a vision of a future that is conjoined and sustainable, enabled by AI.

Multimodal Generative artificial intelligence such as ChatGPT in advancing industry

Advancements in multi-modal generative artificial intelligence (AI) systems such as models similar to ChatGPT, are now being rapidly adopted across industries that are becoming transformative tools (Haver et al., 2024; Yang et al., 2024; Wu et al., 2023). The physical form of video content is only one of four ways in which these AI systems process, and generate content across various modalities (text, images, audio, video) granting them a greater focus, and applicability in most domains of interest (Huang et al., 2023; Liu et al., 2023). Multi-modal AI in the entertainment and media industry is transforming content creation. From realistic images and videos to music, now creative professional can use these tools to boost their creativity. For example, AI can support in special effects generation, virtual actors generation and even scripting scenes. Not only does this capability cut production time and cost, it also allows for new forms of storytelling that was never possible before. DALL-E and ChatGPT are also being used to

generate concept art, preliminary scripts, and even communicate with fans in innovative ways, further exploring audience interaction.

Another area of the healthcare industry where multi-modal generative AI is very beneficial. These systems can analyse medical images, parse clinical notes, and even diagnose diseases. For example, training AI models on imaging data can provide precise diagnostic suggestions and treatments compared to those trained on patient records only. They are also used in medical training, in which they simulate various complex medical scenarios allowing future specialized doctors to practice with those real-life situations. Together this increases the accuracy of diagnoses and upskills both medical education and patient care. Similarly, the sector of education is taking advantage of multimodal AI. These can deliver customized learning experiences by changing content to the way that each pupil learns, and at the speed that he/she keeps up with. Through AI, educational videos, interactive simulations, personalized reading, etc. can be created that can help in different types of education. Similarly, language models such as ChatGPT could act as tutors who can provide explanations to problems and answer questions real-time, making provision of support possible out of traditional classroom experiences. Improves availability of quality education and enables lifelong learning.

But arguably no industry is more poised to see massive change than customer service, where the multi-modal generative AI as seen in the example above is changing the way companies interact with their customers. Chatbots and virtual assistants powered by disruptive AI technology, understanding natural language or to better and assist customers through text or voice, or even visually in the form of visual. These benefits providing profound and rapid responses, helps reduce the workload on human agents and is capable of working 24/7. Similarly, companies could use AI to establish the common denominators in customer touchpoints with the objective of enhancing their service. The multi-modal AI is currently in use by the marketing and advertising industry to deliver personalized and interactive experiences. AI is getting into it, when it comes to programmatic display advertising. For instance, AI test can be used to automatically create visuals and copy customized for each segment customer (due to preference and behaviour). This tactic makes marketing campaigns more targeted, and so improves conversion rates. Using more consistent brand voice in other channels and media, AI generated content also can be used. Multi-modal AI is transforming manufacturing and logistics with predictive maintenance, quality control, and supply chain operations. If stakeholders decide to be pro-active rather than re-active, with the right implementation, AI has the potential to analyse visual information from the production lines to detect defects and, in some cases, even predict a failure in equipment before it happens, hence significantly reducing downtime and maintenance costs. For example, AI can help in

routing and scheduling optimization in logistics which will help in efficiency and cost reduction. The idea of AI in this way helps to keep resources in mind too leading to a more productive outcome.

7.4 Conclusions

Generative AI can boost precision manufacturing through predictive maintenance, optimize supply chains and enable product design innovation in the Industry 4.0. It analyses large datasets that optimizes operations, minimizes downtime and maximizes efficiency - ultimately pushing productivity to new heights. As we move into the Industry 5.0 era society finally returns to be the focal area, and AI works alongside humans to make industrial processes more sustainable and robust. This transition is being accelerated by AI which is successfully augmenting human creativity and decision-making, and is also capable of personalizing manufacturing and relieving the integration bottlenecks between human and machine intelligence. Generative AI is one of the cornerstones of the super-smart society features in Society 5.0, where digital and physical spaces intersect to improve quality of life. From healthcare and education to urban planning, AI-based solutions have the potential to provide what each individual citizen requires, thereby promoting inclusivity and ensuring that the benefits of technology are shared in an equitable manner. In healthcare, generative AI can help with early detection, individualized therapy recommendations, and drug discovery, transforming patient care. AI-driven personalized learning platforms are helping people learn on their own time and according to their interests in ways that are both more accessible and more likely to be effective in education. Additionally, the use of generative AI helps to solve world's issues like climate change by reducing energy consumption and making the green practices more advanced. Predictive analytics and scenario modeling are critical to developing strategies to address the environmental impacts, and that is where life cycle assessment can offer invaluable insight. With generative AI being developed at such rapid pace, its adoption into and across Industry 4.0, 5.0 and Society 5.0 will generate enormous social impacts globally by improving the conditions for innovation, sustainability and human well-being.

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