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Chapter 8

Artificial intelligence and big data analytics for the advancement of industry 4.0, 5.0, and society 5.0

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Abstract: The tidal wave of data created by connected devices and cyber-physical systems in an Industry 4.0 environment is utilized via advanced analytics to drive manufacturing efficiency, improve predictive maintenance, and empower real-time actions. The potential of big data analytics with artificial intelligence (AI) to transform the industrial landscape lies in its ability to enable the processing of enormous troves of data, revealing hidden patterns and trends that open up a range of avenues to enable industrial operations that are smarter and more responsive. Big data is equally important as moving forward to Industry 5.0. This phase focuses more on human-centric ways and human-machine collaboration matters here. This shift is supported by big data analytics which produces clever intelligence in systems that are complementary to human capabilities. With the analysis of vast pools of data, these systems can augment the way humans decide, create, and solve problems. In Society 5.0, big data analytics is an essential for super-smart society where digital transformation pervades virtually every life. Personalized services in healthcare, education, transportation, urban planning, public safety, sustainable development. It is essential to produce accessible machine learning (ML) tools that can meet the needs of both people and communities, unlocking broader economic benefits as well as enhancing overall quality of life. In a future where the volumes of data collected through the Internet of Things (IoT), introduction of file types that allows more data to be stored for adopting the big data analytics stack to the enterprises applications to provide resiliency and agility in a data driven world.

Keywords: Big data analytics, Artificial intelligence, Big data, Machine learning, Deep learning, Internet of things

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8.1 Introduction

The recent technology landscape has introduced a new era of artificial intelligence (AI) and big data analytics, which then accomplish the transformation of industries and society (Jagatheesaperumal et al., 2021; Sharma et al., 2021; Lampropoulos, 2023). This is where AI and big data analytics come into play, leading to the advancement of these disruptive paradigms. The AI technology based on Machine learning (ML), deep learning (DL), natural language processing (NLP) is great at dealing with a huge amount of data in order to detect patterns, predict outcomes, and re-engineer (Ding et al., 2023; Bharadiya, 2023; Rashid et al., 2024; Rane et al., 2024a). Big data calls for big data analytics model involving massive datasets and complexity in nature which consists of 3Vs- volume, velocity, and variety. Among other benefits, these technologies enable real-time decision-making, predictive maintenance, supply chain optimization, personalized customer experiences (CX), and creation of smart products and services. With the growth of Industry 4.0 and 5.0, influences not only spread venture far and wide with the help of manufacturing but it will also touch and shape various other industries like construction, healthcare, agriculture, finance, education etc. The research consists of a comprehensive literature review relevant to the study, elaborating on keyword analysis and co-occurrence, and cluster analysis which is used to identify main themes, trends, and gaps with a strategic focus on AI, Big Data Analytics and Industry 4.0, 5.0 and Society 5.0. Academics, practitioners, and policymakers will benefit from this synthesis by obtaining an understanding of existing research, emerging topics, and areas for generating new studies.

8.2 Methodology

This research adopts a systematic literature review methodology to investigate AI, big data analytics, Industry 5.0, and Society 5.0. Academic databases (IEEE Xplore, ScienceDirect, Google Scholar) were searched using keywords: artificial intelligence, big data analytics, Industry 4.0, Industry 5.0, Society 5.0. The inclusion of publication between 2010 and 2023 ensured that only some of the most recent developments with contemporary literature were emphasised. In this research, to analyse the data, the bibliometric method was utilized, and reviewing the published articles, the keywords co-occurrence and cluster analysis done. The VOSviewer software was used for the co-occurrence analysis with the purpose of visualizing the relationships among the terms which appeared most frequently in the selected articles.

8.3 Results and discussions

Co-occurrence and cluster analysis of the keywords

In this new world, while Industry 4.0 was the biggest node the network, it is the hub that supports and connects different technologies and concepts. It links a network illustrating the wide range of Industry 4.0, which includes highly developed technologies and techniques in Industry 4.0. Jumping to present day, Industry 4.0 continues to be instrumental as a convergence between cyber and physical systems to pave the way for the modern industrial revolution. Now we can find out the key counterparts such as artificial intelligence and big data have a pivotal role in the process of "Industry 4.0". In the Fig. 8.1 we can see how the nodes are connected to illustrate the synergy between technology and industrial processes. AI uses big data analytics to tap into the volumes of data being generated to improve operations and predict maintenance. These days, the contribution of AI and big data is obvious in every smart, data-driven industrial scenario.

The Internet of Things (IoT) node as this is key to this network. The IoT means physical devices plugged into the internet so that real-time data can be collected and analyzed. This technology is vital for optimum Industry 4.0, as it allows AI and big data analytics to have the data needed to properly work. This is also reflected in some of the fundamental connections between IoT, AI, and big data in modern industrial ecosystems with interconnected devices, and their ability to drive industrial intelligence. Big Data and IoT are commonly associated with cloud computing. With such devices producing voluminous amounts of data, it is imperative to leverage cloud computing for data management. It allows to work with large datasets and run advanced AI algorithms without breaking a courtesy of the scalable computing resources. The utilization of cloud computing by this network demonstrates the need for a strong computing infrastructure that is able to support industrial applications that are becoming more advanced.

The network focuses its clusters around thematic areas that are important for Industry 4.0 and 5.0. One large cluster is centred around the ideas of "smart manufacturing" and " cyber-physical systems." Predictive analytics, maintenance, quality control is among the nodes that bind these terms together. In manufacturing, this cluster is about harnessing the power of AI and big data to get even more out of production and reduce downtime and scrap. To realize these ambitions, we need cyber-physical systems (CPS), which are systems combining physical processes with computational algorithms. Another cluster is dedicated to sustainability and sustainable development. These important keywords of a cluster include: supply chains, energy utilization, digital technologies. So, the use of AI, big data is the way the world is contributing to be sustainable in their industrial operations. To do this we need to improve supply chain efficiency, reduce energy consumption and embrace sustainable technologies. Aligning with sustainable development is only an example of how society is trying to keep industrial growth and development in balance with environmental protection, this is an attempt to do a complex reality in a simplified way.

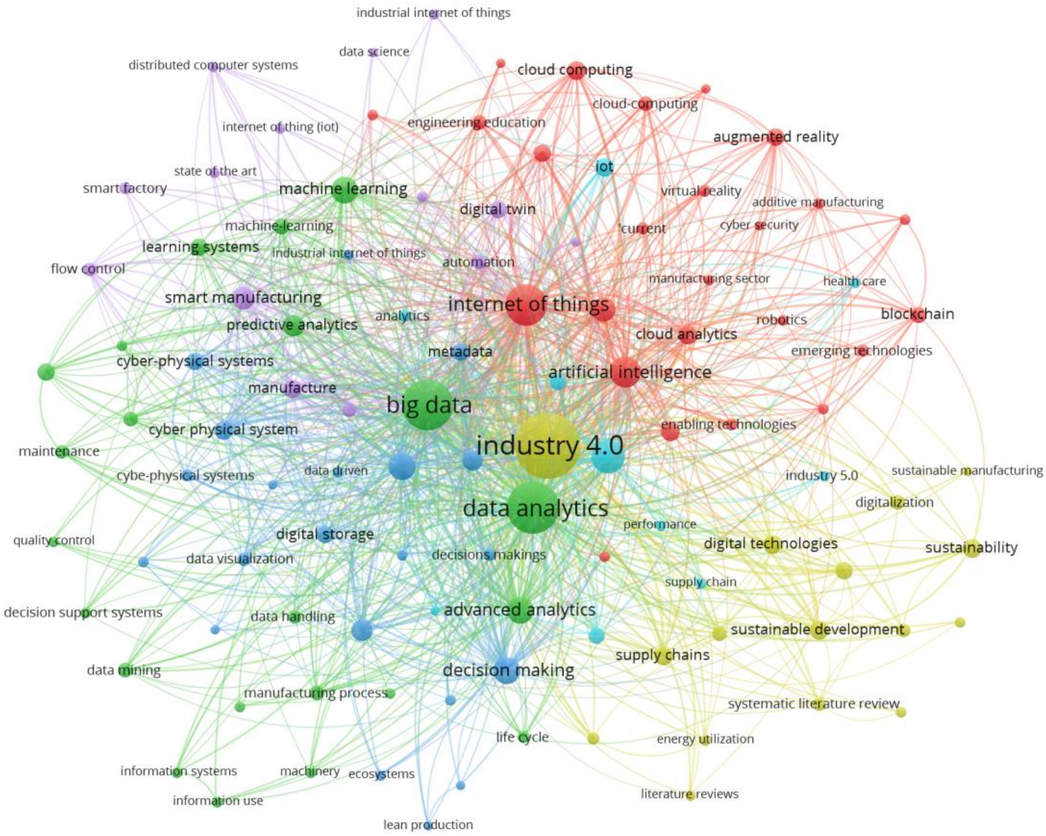

Fig. 8.1 Co-occurrence analysis of the keywords in literature

The largest priority for the network is also adapting new technologies such as blockchain and augmented reality. Connected to node to (IoT, smart factory, cloud computing), Secure and transparent data transactions, A blockchain is used to verify the provenance of the data and keep track of who has uploaded or changed the data, encouraging good stewardship of data and inhibiting potential rogue uses of a given data source. Augmented reality has provided several benefits for improving how humans and machines interface, such as immersive visualization tools for maintenance, training, design tasks and so on. These are just a few examples of the expanding technological world of Industry 4.0, and even Industry 5.0. Network comprises of the decision making and data analytics. Especially beside advanced analytic, data visualisation nodes. Organization is in need of using advanced analytics to make better decisions to operate faster and at lower costs as well as increase/expand performance. This is where decision support systems and data visualization tools come in handy to help us decode complex data and assist in strategic planning and execution. Society 5.0 can also be found in the network, but has fewer connections than Industry 4.0. Society 5.0 seeks a society that can meet human needs, solve various social challenges, and allow economies to thrive. It is clear from the network links that the technologies supporting Industry 4.0 are required in order to achieve the objectives of Society 5.0. Progress in Healthcare, In Education, in Public Services, every sector is being revolutionized and making an impact on the people, Benefits accruing to the masses. This has been enabled by advances in artificial intelligence (AI), big data, IoT and cloud computing, which allow remote servers to store and process an increasingly large amount of data.

Integration of artificial intelligence and big data analytics in advancing industry

Enhancing decision-making and strategy

Organizations have been able to make data-driven decisions at a level of accuracy and speed that was previously probably unimaginable, thanks predominantly to AI and big data analytics possibilities (Jagatheesaperumal et al., 2021; Bharadiya, 2023; Paramesha et al., 2024a). Historically, decision-making processes were based on intuition and data which was often scarce and the decision-making process was often error-prone and slow. In other words, big data analytics allows businesses to take advantage of large volumes of structured and unstructured data to identify patterns, trends, and correlations (Sharma et al., 2021; Lampropoulos, 2023; Rashid et al., 2024; Paramesha et al., 2024b; Rane et al., 2024b). How AI can amplify these powers AI algorithms are capable of doing those, predicting results and suggesting next best thing to do. In finance, for example, AI-aided predictive analytics aid in risk evaluation and fraud prevention, saving millions lost in finance to these issues. Similarly, in marketing, advanced AI model analyses the customer data to deliver personalised campaigns that help in improving the customer engagement as well as facilitate better conversion rates. Table 8.1 shows the applications and benefits of integrating AI and Big Data Analytics.

Revolutionizing healthcare

The healthcare sector is no exception to this revolution and has recently seen a dramatic transformation in the form of AI and big data analytics (Adeghe et al., 2024; Carpentieri& Lecca, 2024). Analysing Big Data to improve diagnoses and tailored treatments big data analytics support better diagnoses and personalized treatment because of the power of large data (Gupta, & Kumar, 2023; Jhawat et al., 2023; Paramesha et al., 2024c). In pathology, anomaly detection systems in medical imaging are transformed as human radiologists. In healthcare, for example, predictive analytics can predict disease outbreaks and patient admittances to improve how resources are allocated and so on.

Optimizing supply chain and logistics

Supply chain and logistics is notoriously complex and multi-dimensional undertaking, where many pieces are involved to maximise as far as possible under sustainability and lead time-cost efficiency. These operations are optimized through ML and big data analytics that allow real-time visibility and insights into maintenance prediction driven by AI (Shah et al., 2023; Rashid et al., 2024; Paramesha et al., 2024d). These AI based demand forecasting models are highly accurate in predicting consumer demand which in turn can help in managing inventory better and avoiding stockouts or overstock situations. Furthermore, with big data analytics, there are route optimization which leads down transportation costs, and delivery times.

Driving innovation in manufacturing

Smart factories and Industry 4.0 emerge, with AI and Big Data Analytics being key in manufacturing (Rosati, et al., 2023; Raj et al., 2023; Rane et al., 2024c). Predicting this information is collected from sensors installed in the machines, which is analysed by AI-powered predictive maintenance systems and helps in predicting the possible health and breakdown of the machines before the event occurs reducing both downtime and maintenance cost. Another way in which big data analytics is used to ensure quality, is through the analysis of production data, aimed at finding out about any defects and production processes that need to be optimized.

Transforming retail

AI and big data analytics fuel the transformation of retail industry providing retailers with the means to better comprehend consumer choices and personalize their shopping experience (Bharadiya, 2023; Raji et al., 2024). Retailers can provide consumers with relevant product recommendations and targeted promotions by sifting through data from sources like social media, transaction records, and online browsing histories. Chatbots and virtual assistants enhance the customer service by offering instant support, more personalized shopping assistants etc. for this we need AI-driven assistants (Kandi, 2023; Bharadiya, 2023). In fact, retailer pricing strategies improve, and inventory situations get manage better with the assistance of big data analytics in this market. Walmart is one such example where the implementation of big data and AI benefits extending across not just an optimized supply chain, inventory management but also the personalized experience generates higher sales and customer satisfaction.

Table 8.1 Applications and benefits of integrating AI and Big Data Analytics.

References	Industry	Application Areas	AI Technologies	Big Data Analytics	Benefits
Gupta, & Kumar, (2023); Jhawat et al., (2023); Adeghe et al., (2024); Carpentieri& Lecca, (2024)	Healthcare	Predictive diagnostics, personalized medicine, drug discovery, patient care	ML, NLP, computer vision	Patient data analysis, genomic data analysis	Early disease detection, improved patient outcomes, reduced healthcare costs
Nguyen et al., (2023); Andronie et al., (2023); Ahmadi, (2024)	Finance	Fraud detection, risk management, customer service, algorithmic trading	ML, ML, NLP	Transaction analysis, market data analysis	Enhanced security, better risk assessment, personalized financial services
Kandi, (2023); Bharadiya, (2023); Raji et al., (2024)	Retail	Customer behaviour analysis, inventory management, personalized marketing	ML, NLP, recommendation systems	Sales data analysis, customer feedback analysis	Increased sales, improved customer satisfaction, optimized inventory
Shah et al., (2023); Rosati, et al., (2023); Raj et al., (2023); Rashid et al., (2024)	Manufacturing	Predictive maintenance, quality control, supply chain optimization	ML, computer vision, robotics	Sensor data analysis, production data analysis	Reduced downtime, improved product quality, efficient supply chain management
krishna Vaddy, (2023);	Transportation	Route optimization, autonomous	ML, ML, computer vision	Traffic data analysis,	Reduced operational costs,

Liu et al., (2023); Taniguchi et al., (2023)		vehicles, predictive maintenance		vehicle data analysis	improved safety, enhanced passenger experience
Li et al., (2023); Hsu et al., (2023); Mhlanga, (2023)	Energy	Smart grid management, predictive maintenance, energy consumption optimization	ML, IoT, NLP	Sensor data analysis, consumption data analysis	Increased efficiency, reduced operational costs, better resource management
Rosati et al., (2023); Ochuba et al., (2024); Ochuba et al., (2024)	Telecommunications	Network optimization, customer service, predictive maintenance	ML, NLP, computer vision	Network data analysis, customer data analysis	Improved network performance, enhanced customer service, reduced maintenance costs
Purnama, & Sejati, (2023); Javaid et al., (2023)	Agriculture	Precision farming, crop monitoring, supply chain management	ML, IoT, computer vision	Sensor data analysis, weather data analysis	Increased crop yield, optimized resource use, efficient supply chain management
Anmadwar et al., (2023); Demirbaga et al., (2024)	Entertainment	Content recommendation, audience analysis, automated content creation	ML, ML, NLP	User data analysis, content consumption analysis	Enhanced user experience, targeted advertising, streamlined content production
Ahaidous et al., (2023); de Souza Zanirato Maia et al.,	Education	Personalized learning, administrative automation, student performance analysis	ML, NLP, computer vision	Student data analysis, educational content analysis	Improved learning outcomes, efficient administration, personalized education

(2023); Berkat et al., (2024)					
Naeem et al., (2023); Thayyib et al., (2023)	Real Estate	Property valuation, market analysis, personalized services	ML, NLP, computer vision	Market data analysis, customer preference analysis	Accurate property valuations, improved market predictions, personalized property recommendations
Mühlhoff, & Ruschemeier (2024); Thayyib et al., (2023)	Legal	Document analysis, predictive case outcomes, legal research	NLP, ML, robotic process automation (RPA)	Legal document analysis, case data analysis	Reduced legal research time, improved case outcome predictions, streamlined document processing
Rane, (2023a); Mnyakin, (2023)	Hospitality	Customer experience personalization, demand forecasting, operational efficiency	ML, NLP, recommendation systems	Customer data analysis, booking data analysis	Enhanced guest experience, optimized pricing strategies, improved operational efficiency
Wilkinson et al., (2024); Aderemi et al., (2024); Paramesha et al., (2024e)	Insurance	Risk assessment, fraud detection, customer service	ML, NLP, predictive analytics	Claims data analysis, customer data analysis	Better risk assessment, reduced fraud, improved customer service
Li et al., (2023);	Construction	Project management, safety	ML, computer vision, IoT	Project data analysis,	Improved project timelines,

Rane, 2023b; Datta et al., (2024)		monitoring, cost estimation		sensor data analysis	enhanced safety, accurate cost predictions
Yeung, (2023); Chao, et al., (2023)	Public Sector	Policy analysis, public safety, service delivery	ML, NLP, computer vision	Social data analysis, crime data analysis	Better policy decisions, improved public safety, efficient service delivery
Stanton et al., (2023; Mohammed et al., (2024)	Aerospace	Predictive maintenance, flight optimization, manufacturing processes	ML, ML, IoT	Sensor data analysis, flight data analysis	Enhanced safety, reduced maintenance costs, optimized flight operations
Bag et al., (2023); Gupta, & Kumar, (2023)	Pharmaceuticals	Drug discovery, clinical trials, supply chain management	ML, ML, computer vision	Clinical data analysis, supply chain data analysis	Faster drug discovery, efficient clinical trials, streamlined supply chain
Anmadwar et al., (2023); Demirbaga et al., (2024)	Media	Audience segmentation, content creation, advertising optimization	ML, NLP, recommendation systems	Viewer data analysis, content performance analysis	Targeted content, improved viewer engagement, optimized advertising strategies
Dayo-Olupona et al., (2023); Rosati et al., (2023)	Mining	Resource exploration, predictive maintenance, operational efficiency	ML, IoT, computer vision	Geological data analysis, sensor data analysis	Improved resource discovery, reduced operational downtime, enhanced safety

Enhancing cybersecurity

As cyber-attack take place more and more often, these techniques have become more important in cyber security. They can analyse large quantities of network data in real-time and with the help of AI algorithms they can identify irregular patterns that may be a threat. ML models have higher aims of successful predictions to detect malware, phishing messages, and other cyber-threats as compared to older methods. By giving companies a big-picture perspective of the security world, they can quickly stop vulnerabilities before they manifest into issues, and quickly respond to incidents when they occur.

Advancing autonomous vehicles

Autonomous vehicles are also modern-day proof of the very potent synergy of AI and big data analytics, working towards commercial reality. AI algorithms process the live data feeds from different sensors - like cameras, LiDAR and radar - to help the autonomous vehicle safely travel from point A to point B. How these AI models are trained to be accurate and safe - Training these AI models require data - a lot of data, which is where big data analytics comes in by analysing the large volumes of driving data to make our autonomous systems safe and accurate.

Improving financial services

Integration of AI and Big Data with smart banking applications certainly in the financial services industry beneath the layers has been a winner-takes-all-scenario (Nguyen et al., 2023; Andronie et al., 2023; Ahmadi, 2024). AI-based robo-advisors offer tailored investment recommendations based on analysis of personal financial information and market patterns (Nguyen et al., 2023; Ahmadi, 2024). Using ML for stolen card detection, stealing of credit cards is a well-known example of fraud that can be detected by ML. For example, banks and financial institutions can use big data analytics to understand consumer behaviour and preferences, fine-tune their pricing strategies, assess risk over a multitude of products.

Supporting environmental sustainability

Where large datasets on climate, energy consumption, natural resources, etc., can be processed by AI models to identify patterns and predict future changes in the environment. It allows organizations and governments to create response strategies to reduce the environmental footprint and build a sustainable future. As an example, AI-enabled energy management systems minimize energy consumption in buildings, which can help cut back carbon footprints and save energy costs. Big data analytics is used in agriculture to oversee crop health, irrigation optimization, and yield improvement resulting to sustainable farming practices.

Enhancing education

AI and big data analytics are also being used to transform the education sector (Ahaidous et al., 2023; Berkat et al., 2024). AI work on algorithms to analysis student data to provide an adaptive learning environment, is the most efficient way to personalize education. It enables educators to identify at-risk students earlier and prompt timely academic intervention. Moreover, learning tools that leverage AI, like virtual tutors and automatic grading systems, improve the learning experience and lighten the educational burden.

Table 8.2 Cyber-Physical Space: Key Operational Areas and Scheduling for Predictive Innovation

Sr. No.	Category	Sub-category/Activity	Details
1	Functional	Programming, Robotics	Zero failure and waste
		Conceptual and Detailed Design	Big-data analytics, Data acquisition and analysis
		Analysis	Data science, Business intelligence, Advanced diagnostics
2	Global	Renovation and Finalized Recovery	Internet of Things (IoT) and e-CPS, Inter-operative efficiency
		Operation and Maintenance	Smart manufacturing, Sustainability
		Logistic Design	Augmented and Virtual Reality, Total quality management
3	Informatics	Documentation	Cloud computing, Data curation
		Fabrication	Cybersecurity, Data storage and usage
		4D/5D Definition	Digital twin simulation, Operative processes
		Feasibility and Zero Failure	Big-data and advanced diagnostic processes

Table 8.2 points out essential elements and steps in developing Industry 4.0, 5.0, and Society 5.0. Herein, it has been explained how the future industry shall provide improvement means through artificial intelligence (AI) and big data analytics for operational efficiency, predictive maintenance, and human-robot collaboration in cyber-physical systems.

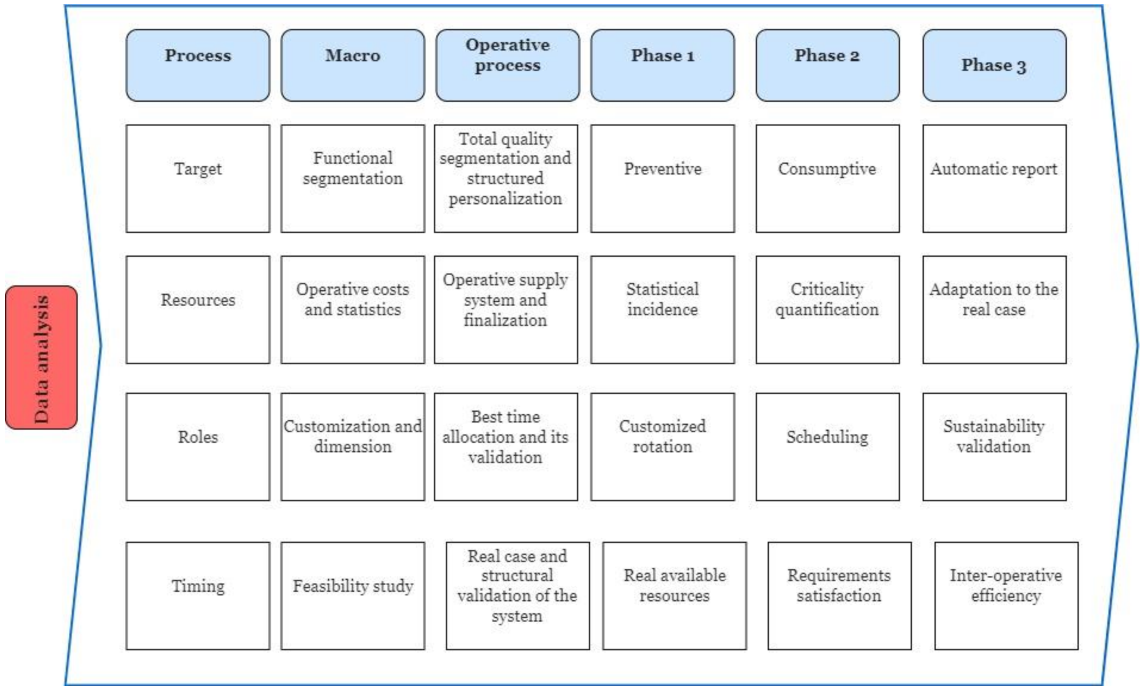

Fig. 8.2 Data analysis diagram for high interoperability efficiency

Fig. 8.2 illustrates high efficiency in interoperability for automated predictive innovation. Beginning with the macro level of the goals, moving them into operative processes, it finally breaks down into three phases: from the first preventive one until the last of automatic reporting. In this way, efficient use of resources, optimized role allocation, and timely execution are guaranteed; tasks leveraging AI and big data analytics for improved decision-making and innovation.

8.4 Conclusions

As we advance in Industry 4.0, 5.0, and Society 5.0, the integration of AI and big data analytics has served as a pillar of each, driving a significant transformation in the way we do business, among other industries. In the Industry 4.0 era, AI-powered big data analytics is transforming industrial production such as predictive maintenance, real-time monitoring, and supply chain optimization, which in turn help manufacturers to enhance efficiency and lower operational expenses. Humans also become a significant stakeholder in the Industry 5.0 era where application of AI and big data result in collaborative robotics, personalized production processes, and taking into account sustainability concerns, technology advancements from the viewpoint of human beings and environment. In Society 5.0, the meeting of AI and big data does not end at the factory gates, and instead penetrates every area of life, creating a smarter, more connected society where the power of data improves healthcare, education, and public services. By analysing huge datasets, AI algorithms can forecast pandemics, tailor educational instruction for individualized learning, and optimize urban planning to enhance living conditions and resolve societal issues. The rapidly evolving AI landscape and scale-able big data analytics are highly suggestive of their prominence to drive innovation and sustainable development, stressing the necessity to implement strong data governance, ethical AI practices and collaborative cross-sector efforts to fully benefit from their immense capabilities. This will then go on to lay the foundations for a future that is not only technologically enriching but also financially inclusive and sustainable.

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