INTEGRATION OF AI INTO INDUSTRY 4.0 TO ADDRESS CHALLENGES AND OPPORTUNITIES IN THE PACKAGING INDUSTRY

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DEDICATION

This dissertation is dedicated to my family, whose unwavering support and encouragement have been indispensable throughout this endeavour. I am profoundly grateful to my parents for their enduring love and sacrifices, and to my loved ones for the constant encouragement, inspiration, and joy they have brought into my life.

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Abstract

INTEGRATION OF AI INTO INDUSTRY 4.0 TO ADDRESS CHALLENGES AND OPPORTUNITIES IN THE PACKAGING INDUSTRY

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The existing study aims to explore integration of AI into industry 4.0 to address challenges and opportunities in the packaging industry. The goals of the study is to identify and analyse factors affecting artificial intelligence adoption in the packaging industry in India; to examine the challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India; to examine the opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India and to provide suitable recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry. The respondents for current study are employees from packaging industry of Small and Medium Sized Enterprises (SMEs) from India. The cities selected for survey from India are Bangalore, Delhi and Hyderabad. Therefore, Bangalore, Delhi and Hyderabad are universe for current research. In this study respondents are randomly selected using purposive sampling techniques. 600 employees from packaging industry from three distinctive cities of India are selected. The findings of challenges in AI integration in respondents' organisation assessed and stated that poor IT infrastructural support delays the use of AI in the packaging plants is the key challenge. The results related to opportunities in AI integration in respondents' organisation stated that AI-based predictive maintenance minimizes packaging-machinery downtimes is the opportunity the packaging industry look for. Lastly, recommendations for making AI adoption easy in respondents' packaging organisation is assessed. The results of the study stated that implement pilot projects to receive the advantages of AI in practice during packaging is the key recommendation of the study.

Keywords: artificial intelligence (AI), challenges, opportunities, packaging, Small and Medium Sized Enterprises (SMEs)

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CHAPTER-I

Introduction

The Industrial environment is undergoing a paradigm shift, which has been created by the technological revolution typically known as Industry 4.0; the shift incorporates new technologies, such as the artificial intelligence (AI), the Internet of Things (IoT), robotics, big-data analytics, and cybers-physical systems, into its context (Soni *et al.*, 2019). This disruption upends the traditional manufacturing and supply-chain functions and goes beyond large scale manufacturing to cover all industries and the packaging industry is no exception. The packaging industry therefore which is often considered as the point of contact between production and consumption has a significant role to play in the product safety, quality and availability, as well as influence the brand perception and consumer satisfaction. In this regard, one can view the codification of AI into industry 4.0 as a significant source of catalysis, empowering the packaging companies to take the lead in responding to the emerging market trends, the dynamics of business operations, and sustainability needs (Geisel, 2018).

Traditionally, packaging has been considered strongly as a practical requirement where the main role of the packaging is to protect the products during the process of storing, transporting and delivery (Soni *et al.*, 2020). Nevertheless, the packaging has been turning into a mandatory part of the supply chain and the added value within previous decades. To package goods today is now expected not only to protect and preserve the goods but also to be attractive to consumers, other brands, sustainable and enable easy logistics operations. Such an increased demand puts a significant strain on packaging businesses in order to adopt sophisticated technologies to raise business efficiency, reduce wastage and also to improve product differentiation (Sadiku, Fagbohungbe and Musa, 2020). In this respect, intelligent automation and decision-making artificial intelligence can be discussed as a solution to overcome the lasting problems which the packaging industry has been struggling to deal with.

In the context of Industry 4.0, the application of artificial intelligence to the packaging processes is not limited to the traditional automation, as it allows the system to learn about the data, adapt to changing conditions, and perform its tasks in the best way possible in real time (Chalmers, MacKenzie and Carter, 2021). As a result, machine learning, computer vision, natural language processing, and predictive analytics are some of the techniques that are being redefining the design, implementation, and oversight of packaging processes. As an example, artificial intelligence-based computer vision systems can spot the defects on the production lines with significantly fewer errors than human workers, and predictive maintenance algorithms can tell when a particular machine will break down, thus avoiding the wrongful use of machines (Leitch, 2021). AI-powered analytics will surely help predict demand better and use packaging materials more steadily. Moreover, it will create environment-friendly packaging methods that meet consumer needs and follow environmental rules.

It is noted that customer demand is only one of the main reasons why companies are using artificial intelligence faster in the packaging industry (Enholm et al., 2022). Today's customers surely demand more than durable and secure packaging. Moreover, they want personalized, engaging, and environmentally friendly products. Artificial intelligence surely helps businesses understand how customers behave and create products that fit different market groups. Moreover, this approach allows companies to build unique experiences that engage users effectively. Smart packaging with sensors and AI systems surely makes products more transparent and builds consumer trust. Moreover, it gives real-time details about how fresh the product is, where it came from, and whether it is safe to use. We are seeing artificial intelligence changing how companies think about packaging - it is moving from only basic operations to becoming a marketing tool that helps engage consumers and makes brands more competitive.

The opportunities of AI in the packaging engineering field are significant and considerable; however, at the same time, an array of challenges is generated. The initial investment costs involved in the implementation is a major setback especially to the small and medium sized enterprises that occupy most of the packages industry globally. Implementation of AI systems requires huge financial resources on digital infrastructure, human resource, and system maintenance. Furthermore, the lack of professionals with both AI technologies and knowledge of how the packaging industry functions is also present, thus creating the skills gap hindering the successful adoption. The lack of willingness to change by the employee and management team only complicates the integration process, whereas the issue of data security and privacy raise ethical and regulatory concerns.

The other urgent question is how the practices with AI integration can be aligned with the aims of sustainability. The packaging industry is a field that is coming under heavy scrutiny due to its effect on the environment especially waste making and the use of non-biodegradable substances. Despite the fact that artificial intelligence provides the opportunity to reduce material consumption, optimise recycling, and other processes surrounding the concept of circular economy, most organisations face serious issues when trying to apply this solution on large scale. There is a lack of standardised structures, regulatory approval, and best-practice frameworks that limit the potential of organisations to use AI to their advantage in terms of sustainability. As a result, it is highly necessary to explore the potential to implement AI as a part of Industry 4.0 strategically, thus striking the right balance between operational performance, competitiveness, and environmental sustainability (Jain, 2019).

Considering the global outlook, the competitive forces in the packaging industry also contribute to the importance of the implementation of AI. Both multinationals and emerging firms are in the midst of high-intensity competition over market share, and thus increasing the ability to innovate fast and to respond to consumer tastes and control needs as a key distinguishing factor. AI also prepares companies to be fast to respond to disruptions, including those witnessed in the COVID-19 pandemic, through the provision of real-time decision-making and implementation of adaptive production measures. The failure to implement AI-based Industry 4. 0 may result in institutions becoming irrelevant in a market with an ever-growing preference to digitization and sustainability (Anute *et al.*, 2021).

In this situation, we are seeing that artificial intelligence in Industry 4.0 for packaging is not only an opportunity but also a necessity. It actually provides clear direction that helps companies improve their work efficiency and definitely achieve sustainability goals. This approach increases customer response and strengthens their competitive position in global markets. Basically, implementing this process requires addressing major challenges related to cost, infrastructure, skills building, and governance at the same time. As per strategy design requirements, a smart review of AI benefits and problems is vital for maximizing advantages and reducing risks regarding implementation. This evaluation helps organizations use AI properly while avoiding potential issues.

This study will actually explore how artificial intelligence can definitely help the packaging industry overcome challenges and grab opportunities in Industry 4.0. The research aims to contribute to academic discussions on effective AI applications in modern industrial practices. Basically, this study examines how AI can make business operations more efficient, support environmental goals, and drive new ideas, showing organizations the same path to stay competitive in today's fast-changing industrial landscape. The research further identifies factors that prevent small and medium enterprises from adopting new technologies and suggests strategies to overcome these barriers. The study itself provides practical solutions to address adoption challenges in SMEs. We are seeing that the results show we need a better AI system for packaging that is not only useful but also good for the environment. This new way of using AI will only help make the packaging industry more sustainable and competitive in the future.

Relevance of Artificial Intelligence (AI)

Artificial Intelligence (AI) can be defined as a simulation of the intellectual abilities of humans within the computational systems developed to mimic the operations of the human mind, thought, learning, and decision making. In essence, AI provides computational platforms with the ability to perform the tasks, which were reliant on human mental processes, including problem solving, reasoning, decision-making, natural language processing, and pattern recognition (Mishra and Tripathi, 2021). As opposed to the usual programming where programs follow a set of laid down instructions to the letter, an AI system has the capability of processing data, reacting to new stimuli, and improving their performance via learn-back algorithms.

Artificial intelligence (AI) in its simplest form consists of several specialized subfields, which are machine learning (ML), natural language processing (NLP), computer vision, robotics, and expert systems. All these areas provide different methodological solutions as well as theoretical bases that, on the one hand, develop the functional capabilities of intelligent systems. Machine learning helps the system to learn through data and automatically optimizes performance subsequently leading to the development of adaptive and predictive behaviour. Instead, computer vision provides mechanisms through which the visual information can be interpreted and processed by the machines to make possible visual navigation, scene interpretation, and object recognition (Anute *et al.*, 2021). On the same note, natural language processing gives computers the ability to read and produce human language, thus, improving the natural and effective interaction between humans and machines.

Artificial Intelligence (AI) is neither a single type of technology, but a collection of tools, methods and applications. It can be divided into two general categories, namely narrow AI and general AI. Narrow AI is designed to perform targeted tasks, e.g. conversational agents, recommendation systems or quality control in a manufacturing facility. The more theoretical General AI, is hoped to be able to approximate human-level cognitive capabilities that are capable of solving a broad range of complex problems on their own.

In the context of Industry 4.0, artificial intelligence has a transformative effect as it helps to automate, make predictions, make more advanced decisions and optimize in real time.

Healthcare, finance, logistics, and packaging are among sectors that are increasingly adopting AI to enhance efficiency, reduce spending, improve quality and make processes more innovative (Mishra and Tripathi, 2021).

Relevance of Industry 4.0

Industry 4.0, also known as the Fourth Industrial Revolution, signifies the current transformation of the manufacturing and industrial process through the implementation of advanced digital technology. This shift forms a break of traditional automation and new smart, interconnected solutions, which support real-time communication, data-driven decision making, and highly flexible production processes(Ghadge *et al.*, 2020).

Industry 4.0 is a strategic initiative that was developed in Germany at the start of the 2010s to digitise manufacturing processes. It takes the ascent of the previous industrial revolutions: the first one which was propelled by steam power and mechanisation; the second by electrical power and mass production; and the third one by computerisation and automation (Garay-Rondero *et al.*, 2019).

Industry 4.0 is more than traditional automation because it incorporates cyber-physical systems, the Internet of Things (IoT), cloud computing, big data analytics, artificial intelligence (AI), robotics, and blockchain technologies into industrial systems (Zhou and Le Cardinal, 2019).

In its simplest form, Industry 4.0 enhances the implementation of the so-called concept of smart factories in which human operators, machinery, and processes are closely combined. As an illustration, sensors of Internet-of-Things can record real-time operational data of devices; it is then worked over by artificial-intelligence systems to predict equipment failure. The generated knowledge is shared on the cloud platforms within the supply chain. The advantages of this type of integration are a higher level of operational efficiency, less downtime, customized production, and increasing competitive advantage (Bär, Herbert-Hansen and Khalid, 2018).

The Industry 4.0 is an advanced concept, not exclusive to the traditional manufacturing but includes the logistics, packaging, healthcare, finance, and agriculture. It is important because it enhances higher intelligence, sustainability and responsiveness in accommodating the changing needs of consumers as well as global trends (Bag *et al.*, 2018).

To conclude, Industry 4.0 is a combination of digital and physical technologies and a new stage in the development of industry. It radically restructures the product designs, manufacturing and distribution of the products and re-use of the products after manufacture hence making the technology the foundation of economic growth in the future.

Relationship among Artificial Intelligence and Industry 4.0

The fourth industrial revolution also known as Industry 4.0 is indicative of paradigmatic change in the design of industrial processes. It includes cyber-physical platforms, the Internet of Things (IoT), big-data analytics, robotics, and artificial intelligence (AI) to give rise to a considerably more complicated, integrated, and automated infrastructural model (Gabriel and Pessl, 2016)l.

Artificial intelligence is a core element, the cognitive layer of modern, disruptive, technological ecosystems, and thus, it aids in the knowledge base of decision-making processes, learning, and gives flexibility to production and business processes.

Unlike the previous industrial revolutions which focused on the use of machines, electrification, and automation, Industry 4.0 lays more focus on autonomy and intelligence, thus making artificial intelligence inevitable. Due to possible data-driven insights and ability to identify trends, as well as make predictive analytics, AI has become the key to real-time optimisation and one of the drivers of innovations in various industries (Glas and Kleemann, 2016).

Artificial intelligence is a further extension of Industry 4.0, which allows making decisions on the basis of more complex and faster processes. In the manufacturing setting, the abundance of information produced by the tools and devices can be perceived using the AI algorithms only. The AI-based analytics, in addition to identifying trends, can predict the future occurrences of activities like equipment breakages, stock-order, and customer preferences. This foreseeable power would revolutionize the traditional reactionary models into forecasting and preventing designs, thus saving both time and money (Barata *et al.*, 2018). Using AI combined with Internet of things enabled sensors, industries are able to constantly monitor equipment and processes and this results in predictive maintenance and less downtime of equipment. In turn, AI serves as an enabler and brings into reality the potentialities of Industry 4.0 that are only theorized.

Artificial intelligence and Industry 4.0 nexus Personality and customization. The modern industrial requirements in the packaging industry demand more and more companies to provide customer-specific solutions to their needs (M. Reza, 2020a). The technologies of machine learning and deep learning, which are subfields of artificial intelligence, allow working with consumer data, predictive modelling of preferences, and dynamic adjustment of production lines in the real time. Industry 4.0 is agile in nature with mass customization taking the place of mass production. Artificial intelligence enables flexible automation through learning and adaptation of machine without having to reprogram it repeatedly. Consequently, companies will be able to save money, enhance productivity, and fulfil individual market needs at the same time, thus exhibiting the symbiotic connection between artificial intelligence and Industry 4.0.

In addition, artificial intelligence further increases the interconnectivity nature of Industry 4.0 by increasing the utility of big data. The Fourth Industrial Revolution relies on the systematized gathering and incorporation of massive volumes of information based on the supply chains, manufacturing systems, and consumer relations (Müller, Kiel and Voigt, 2018). Without AI, the existing mass and sophistication of these data would overpower industrial players. AI provides the necessary instruments of data cleaning, interpreting, and profitably using. As an illustration, in smart factories artificial intelligence will be used to analyse production data to optimize processes, denote activities that are not efficient and offer suggestions. These would enable self-optimizing systems which are a fundamental imperative of the intelligent automation paradigm of Industry 4.0.

AI is one of the supports of sustainability in the industry 4.0 paradigm. Feeling the growing pressure to act responsibly within the context of the environment, world industries start being more mindful of artificial intelligence (AI) as the tool that helps to control the way resources are distributed, the amount of waste is reduced, and the processes are developed with an environmental benign goal (Souza, 2020). As an example, AI can be used to design the packaging materials that have fewer environmental footprints or to optimize the logistical network so that it uses less fuel.

These applications are aligned with the sustainability agenda on a global level and illustrate a way in which AI could help Industry 4.0 respond to societal issues that are less about efficiency and profitability. As such, the introduction of AI in the Industry 4.0 goes beyond the technological advancement to a demonstration of an appropriate and responsible, sustainable, and inclusive model in industrialization.

As shown by empirical evidence, the artificial intelligence is intertwined with Industry 4.0, which is evidently mirrored in change in the way the workforce is organized. Although Industry 4.0 envisions mass automation and the increased cognitive abilities, the implementation of AI provides the machines with the necessary capability to carry out more elaborate cognitive tasks, which complements human skills, not replaces them (Salam, 2019). The vision systems developed based on AI are more accurate in detecting the defects than the human auditor during quality inspection and the decision-support platform provided by the artificial intelligence allows managers to develop knowledge-based decisions. This expansion of the human-machine partnership, which is facilitated by AI, is one of the key pillars of Industry 4.0 since it is believed that the use of computational intelligence can improve the productivity of humans along with redistributing human resources to creative, innovative, and strategizing activities.

This connection between the concept of artificial intelligence (AI) and the concept of Industry 4.0 reaches many implications upon the territory of supply chain management. When applied together with blockchain technology and the Internet of Things (IoT), AI enables designing transparent, traceable, and efficient supply chains, which is particularly important in the industries of packaging, food, and pharmaceuticals because quality and safety fill the first place in the priorities list. This intersection makes AI a single technology that puts complementary Industry 4.0 tools into perspective. Therefore, AI cannot be considered just one of the enabling technologies involved in Industry 4.0 it is the key enabler that brings the continued industrial revolution intelligence, flexibility, and future-oriented structures. (Reza, 2020).

The Internet of Things, though offering connectivity capabilities, and robotics, offering automation opportunities, artificial intelligence, endows the ability to these aspects to constitute autonomous decision-making bodily. Artificial intelligence and Industry 4.0 synergies make it possible to create smarter production and manufacturing, reactive chains, sustainable production, and customized solutions, which is a big shift compared to the previous paradigms in industry (Chalmeta and Santos-dele, 2020). This symbiotic connection, though, will not be achieved without the successful running of Industry 4.0; without artificial intelligence, the connectivity and automation will lack the wisdom to create such dramatic results.

Background: Industry 4.0 and AI Reshaping Industries Worldwide

The Industry 4.0, that denotes the beginning of the fourth industrial revolution, is a drastic shift in the transactions of global industries. Instead of the mechanization, electrification and automation that drove previous industrial revolutions, Industry 4.0 is driven by intelligence, interconnectivity and digital integration. This shift in paradigm is based on such high-tech innovations like the Internet of Things (IoT), analytics with Big Data, robotics, cloud computing, and Artificial Intelligence (AI). The combination of the technologies makes it easier to create smart factories and systems which are able to self-monitor, self-optimize, and, in some cases, make autonomous decisions (Ojo et al., 2018). Industry 4.0 is transforming the industrial landscapes all over the world by blurring the lines between the physical and digital world, creating new environments that are more efficient, elastic, and creative.

Artificial intelligence is one of the central aspects that form the basis of the modern technological metamorphosis, of which it is an intellectual reserve in intelligent automation systems, and which allows developing evidence-based decision-making processes. Artificial intelligence gives industries an edge over competitors by letting them manage complex operations in a more detailed and nuanced way due to the ability to handle large amounts of data, identify more complex patterns, and build predictive models (Ghadge *et al.*, 2020). In the manufacturing industry, such as the one, artificial intelligence is applied to carry out predictive maintenance, which helps to foresee the equipment failures and thus, address the downtime and costs related to it. Logistics and supply chain management: In logistics and supply chain management, AI optimises routing and predicts demand and improves inventory management, thus providing agility to organisations operating in a highly dynamic market environment. Industrial 4.0: With the integration of artificial intelligence into industry 4.0 systems, data collected from the Internet-of-Things sensors, robotics, and digital systems can be converted into actionable intelligence, which leads to faster and smarter industrial decisions (Müller and Voigt, 2018).

Industries all over the world are using Industry 4.0 and artificial intelligence to solve the major challenges and to open new opportunities. AI-powered robotics are being used in assembly lines in automobile manufacturing and autonomous vehicle development. Artificial intelligence is also incorporated in Industry 4.0 ecosystems in the healthcare sector to improve the accuracy of diagnoses, personalized therapy choices, and automate administrative work in hospitals (M. Reza, 2020b). Likewise, AI-facilitated Industry 4.0 systems are useful in the agricultural sector, where precision farming is an application involving sensor networks and unmanned aerial vehicles along with AI analytics to enable the maximisation of crop production and resource use. The presence of these examples demonstrates how artificial intelligence can be used to serve as a transformative technology in areas of implementation.

Industry 4.0 and artificial intelligence are becoming key elements of the global sustainability development. Since different industries are under stricter examination to ensure their environmental imprints are limited, AI-suspensible systems assist in the optimisation of resource use, reduction of waste and the creation of environmentally friendly processes. As an example, in industries that consume high amounts of energy, AI-based systems will be able to track and actively manage energy usage in real-time due to which greenhouse gas release will decrease significantly (Luthra and Mangla, 2018). Likewise, in the packaging and consumer goods industries, AI plays a role in the design of recyclable materials and in the reduction of the use of raw materials. These progressions resonate to international efforts to fulfil the United Nations Sustainable Development Goals, specifically them relating to responsible consumption, sustainable production and climate action.

Nonetheless, despite the speed at which Industry 4.0 and artificial intelligence have been deployed in the developed world, developing nations face unique challenges, such as prohibitive implementation costs, poor infrastructure and a lack of skilled workers. Difficulties notwithstanding, the underlying benefits of combining AI and Industry 4.0 are undeniable. Leading countries like Germany, Japan and the United States have taken the lead in this shift in action by heavily investing millions of dollars in smart factories and digital ecosystems. On the other hand, the developing economies (especially India and Brazil) are increasingly exploring these technologies to establish whether they can remain competitive in the international market (Kiel et al., 2017). The intensive pace of implementation of technologies based on artificial intelligence (AI) and Industry 4.0, in its turn, not only has reorganized the spheres of industries, but has also reorganized the whole economy, including the labour market on the global scale, specifically in the sphere of innovation.

Industry 4.0 is driven far further than just digitalisation, as it has been fueled by artificial intelligence which not only delivers predictive power and increased efficiency, but also makes some intelligent industrial ecosystems as well (Ivanov, Dolgui and Sokolov, 2019). It was predicted that with the growing adoption of these technologies by enterprises, the global process of production and service delivery will gradually become decentralised, interconnected and constantly innovative; therefore, the Industry 4.0 should turn out to be an inseparable part of the global industrial transformation.

Significance of Packaging Industry in India

The packaging business in India is currently seen to be under a massive growth thus creating an opportunity to be ranked as one of the most vibrant sectors in Indian economy. It is among the top five packaging markets in the world, which is attributed to rapid urbanization, rising consumer disposable income, and the spread of organized retail and e-commerce channels. Similarly, the industry's role is no longer isolated to the protection of products but also provides fundamental roles in branding, marketing and the enhancement of consumer experience making packaging an indispensable part of the value chain.

The food and beverage industry is having the largest share in the packaging sector and considered to be a major force in the packaging industry. An accelerated growth of frozen foods, convenience foods and read to eat meals have made companies to use new packaging processes and technologies. The use of new and safe packaging processes and technologies are influenced by strict regulations by the government.

The food and beverage market forms a core of the larger industrial system hence making a huge consumption in the packaging sector. The increase in the demand of ready-to-eat meals, frozen foods, and convenience foods have already urged players in the industry to incorporate the latest technologies in the packaging that are safe, hygienic, and long-lasting.

In spite of the dramatic expansion, the packaging industry in India has been faced by a plethora of challenges. To make the matter worse, there is widespread use of plastic materials, a move that has raised serious environmental issues. The lack of operational consistency and infeasibility of massive production that can be ascribed to the increasing cost of raw materials also worsen the situation. Another defining aspect of the industry is fragmentation and fissuring as a number of informal and minor entrants into the industry are forming. Besides, regulatory requirements and the increasing concern about sustainability force companies to invest in the creation and implementation of more sustainable and easily recyclable packaging options.

As it is shown, India demonstrates a certain tendency to the usage of sustainable and smart packaging. Business organisations are encouraging the application of biogradable and recyclable products, and they are designing products that will attract the environmentally conscious consumer base. Simultaneously, Industry 4.0 technologies, i.e. artificial intelligence (AI), the Internet of Things (IoT), and robotics, have drastically transformed the packaging industry redefining the industry. With the help of these technologies, the firms are able to automate, improve the quality of products through AI-driven computer-vision systems, minimize unused material, and expand supply-chain visibility.

The Indian packaging industry is now in a critical cross-road with numerous opportunities as well as strategy challenges to its size. The outlook of the future depicts a similar trend of sound growth, a trend that has been maintained by the changing consumerism demand patterns, market opening and the introduction of new technology. It has been argued that the increase in the ability to adopt sustainable practices and Industry 4.0 technologies by the sector is a cornerstone concept that would support its long-term performance success. Indian packaging will be able to become more globally competitive by using more environmentally friendly approaches and using the further artificial-intelligence technologies. These kinds of programs are necessary in keeping abreast with the requirements of consumers who are environmentally conscious.

Packaging SMEs in India:

SMEs form the main force behind the Indian packaging industry, which has a significant share in the industry in terms of growth, technological adaptation, and job creation. The market is very saturated and there exist thousands of SME firms producing flexible package, corrugated and newspaper cartons, labels and rigid boxes within the food, pharmaceutical and e - commerce and fast-moving consumer goods (FMCG) industries. Such businesses are quite instrumental in the local and regional demand of less-expensive, and tailored/preferred packaging options, such as to the minor and intermediate-sized corporations, which necessitate less expensive services.

A pure basis of the Indian packaging sector is the small and medium enterprises (SMEs), which proved to be the predominant aspect when it comes to the growth, development, and job creation of the industry. The industry is highly fragmented with a number of thousands of SMEs involved in the manufacturing of flexible packaging, corrugated box, labels and customized cartoon to the food, pharmaceutical, and e-commerce and fast-moving consumer goods (FMCG) industry. These companies play a central role in meeting the demand of the locals and regional, thus offering cost effective customized solutions, such as the small and middle size companies that require low-cost packaging arrangements.

Packaging: a Critical Domain to Integrate the Artificial Intelligence.

The packaging business is one of the most diversified and evolving branches of the global economy, which has interdependence with consumer goods, pharmaceuticals, food and drinks, and e-commerce. Its application is not only confined to containment, but packaging is a part of product safety and assurance of quality, logistics, marketing, and sustainability systems. The industry is under pressure to focus on innovation as a response to increased global competition, consumer expectations, and the increasing concern about the environmental issues.

In this regard, artificial intelligence (AI) is becoming a revolutionary technology in Industry 4.0, due to its ability to substantially improve operational efficiency, encourage sustainability, as well as provide comprehensive product customization, (Samans, 2019). The overlap of the three dimensions makes the packaging industry one of the most essential fields where AI can be technologies can be deployed as companies must balance cost-efficiency, innovation, and environmental responsibility.

Efficiency in Packaging through AI

The productivity has always been one of the fundamental qualities of the packaging industry; AI brings out new unseen benefits of achieving the high degree of optimization in the work within the whole chain of values. Repetitive and high-throughput operations usually found in packaging lines (labelling, filling, sealing, quality inspection) are vulnerable to human error and frequently become the bottlenecks in operations. These functions can be performed more efficiently, expedited and accurately, and with increased consistency using the artificial intelligence that can be used in automation and provides an improved machine-vision system (Matt, Modrák and Zsifkovits, 2020). In fact, robotic platforms which are provided with artificial-intelligence features have the ability to change their product size in real time alleviating downtime which is a usual outcome of manual reconfiguration worm of robots. Predictive analytics also contributes to higher levels of operational efficiency by observing the necessary maintenance of environments as a result of which startling issues will be prevented, the production itself will not be disrupted.

The artificial intelligence can be used to optimize the supply chain processes in the packaging industry to achieve greater operational efficiency in managing inventories, the dynamics of demand, and optimization of logistics. The machine learning methods will assist in the evaluation of any historical sales data, pattern, and economic situation and distribution of forecasts of demand as well as guarantee that the resources of packaging are not either wasted or underused (De Propris and Bailey, 2020).

Sustainability in Packaging through AI

Sustainability is a term that has proven to be a burning issue in the packaging industry. The growing number of regulatory requirements and the overall awareness of society about the environmental effects of manufacturing operations make organizations reduce the use of plastics and produce less carbon and shift towards materials that are considered to be environmentally benign (Castagnoli *et al.*, 2022).

Artificial intelligence is also important in helping the sustainability agenda as it helps to provide resource allocation efficiencies and helps to develop smart solutions. As an illustration, the AI- Ya platforms can support the simulation of a broad range of material synergies, which will allow the development of a durable and recyclable packaging that, at the same time, reduces the amount of material used. These kinds of technologies reduce the amount, occurrence of waste production, they support the idea of a circular economy, where materials could be recovered, re-used and could be again used in production of the product/service.

Artificial intelligence helps in reduction of energy consumption in the manufacturing process. Smart sensors in combination with systems based on AI have the ability to monitor the power performance in real-time and suggest functional changes that will decrease consumption without supporting the generation of the output. Similarly, AI-enabled logistics optimization saves on fuel usage and subsequent emissions because it considers the most optimal path to ascertain the most efficient ways of using the delivery cars. Operation-wise, predictive analytics will be used to reduce excess production and, in this way, avoid unnecessary waste in packaging. In addition, AI as a consumer insight can help companies to measure the interest in products that are more environmentally friendly and thus, change its strategy in packaging.

Customization in Packaging through AI

In recent years, a dramatic cycle of the shift in the consumer preferences is observed as the focus shifts towards the purchase of individualized and unique products instead of standardized and mass-produced ones. The trend has propelled customization to a strategy point of vantage point in the packaging industry. AI makes the companies ready to provide solutions on a more basic, individualized scale and thus fills in the gap between focusing on customers on individual levels and the efficiency of the operations. The synthetic technologies related to cutting-edge digital printing and intelligent packaging based on AI promises the implementation of mass customization and culling the mush rush of skyrocketing production spending. Intelligent Smart Tagging of packaging using QR codes or NFC tags helps supply the consumers with interactive features, supplying detailed information about product provenance, sustainable guidelines and guidelines of use of the product. This custom design does not only magnify consumer interest and brand loyalty, but also enables artificial intelligence to undergo constant testing with its packaging design based on any emerging trends, seasonal differences, or other marketing efforts; thus, it assists organizations to maintain nimbleness in hyper-competitive sectors (Machado, Winroth and Ribeiro da Silva, 2020). The above is demonstrated by the fact that Uber Health can personalize its featured packaging and maintain high cost-effectiveness, which implies the substantive potential of integrating AI to meet modern consumer requirements.

The operational efficiency is increased significantly due to artificial intelligence because it automatizes operations, promotes quality assurance, and predicts aggregate demand trends. This is direct because AI indirectly impacts on sustainability through material optimisation, energy management and waste minimisation achieving the goals of the packaging sector with environment at large. In addition, artificial intelligence allows offering customized packaging to companies and, thus, enhancing customer experience and simplifying differentiation in competitive markets (Tay *et al.*, 2018). Altogether, the mentioned aspects lead to the emphasis on the importance of packaging as one of the spheres where the use of artificial intelligence can be implemented within the industry 4.0 framework. Mass placement of artificial intelligence is no longer a requirement that will grant competitive advantage into the future, that which will eventually serve as a defence in the future, and sustainability over a long period of time, but a necessity to take the lead over the short term, and provide competitive advantage in the industry placed at the confluence of production, consumption and innovation.

Challenges of Integrating AI into Industry 4.0 in the Packaging Industry

The integration of the concept of Artificial Intelligence (AI) into the Industry 4.0 model has a high potential to change the landscape of the packaging industry, and the overall goal is to improve the efficiency of operations carried out because of increasing environmental sustainability and innovation. However, despite the extensive advantages, the industry has been facing a plethora of challenges that hinder successful introduction and adoption of AI-based solutions (Taylor and Conexxus, 2018). These challenges put down to technological, organisational, economic and regulatory levels, which require to be overcome to enable the industry to use AI fully.

The main impediment to the popularisation of artificial intelligence (AI) is that is very expensive to implement. The application of AI-based systems, including machine-learning, predictive maintenance, and computer-vision-based tools of quality regulation, require significant investment in the infrastructure and software and in skilled level of staff. Though these expenses can be remedied fairly easily by large multinationals, similar to the Indian packaging industry, small and medium-sized enterprises (SMEs), a majority of which form the Indian packaging industry, are often not they in a position to undertake this financial investment. Thus, the lack of cost-efficient AI solutions in the SMEs slows down the total adoption of the technology in the industry.

Among such issues is the current shortage of qualified labour and the needed technical expertise. The efficient incorporation of AI would require individuals with interests in data science, machine learning, automation, and industrial engineering. The imbalance between available human resource and the industry needs is also a major challenge in India. Many of these packaging companies are faced with a challenge of upskilling their employees or finding personnel who can work in AI systems effectively and thus are not able to make use of the AI technologies that were already invested in by a business entity.

The packaging industry is equally disintegrated therefore contributing to the complexity of the industry. The spread of unregulated organizations, especially those in the developing economies like India, fosters lack of standardized processes and technologies, and consequently, it makes developing AI solutions to be duplicable to rest of the sector ever. As a result, such stalemate obstructs the development of generic AI interventions.

Issues associated with data are also a significant challenge. The computations of generating actionable insight are highly reliant on comprehensive archives of precise data of high quality, in which AI systems typically operate. Many packaging companies are faced with the major hindrance of Portia and homogenisation of such information and data because of the presence of old systems, and little digitalisation. Data privacy and cybersecurity-related problems also worsen the ability to completely enforce AI-based cloud solutions and IoT-based systems on the organizational level. Lack of adequate protection exposes organizations to intellectual- theft and cyber- attacks and complicate the integration process.

Pathogenicity to change and barriers to organizational culture serve as major factors to slow down the implementation of artificial intelligence. The conditioned employees and the managers may be reluctant to automation as they fear to be displaced or lose control as per the conventional modes of operation.

Devoid of strong leadership support and clearly undetermined change-management guidelines, the programs concerning AI implementation will be prone to internal pressure, which, in its turn, may lead to partially successful or premature execution results.

Lastly, one should consider other complications caused by regulatory and sustainability environment. It is also worth mentioning that, despite using artificial intelligence due to the minimization of waste and making the packaging more easily reused, since the environment rules and safety requirements change all the time, it requires a constant redesign. Small business also often do not have the resources necessary to streamline their work with AI-based processes with national and international standards, which allows limiting their ability to compete successfully with industries that develop in the world and appear to require a more environmentally friendly approach and adherence to digital standards.

Challenges of An Incorporation of Artificial Intelligence into Industry 4.0 Models in the Packaging Industry.

As per Industry 4.0 standards, AI gives the packaging sector good chances to update their work methods and follow global rules for green manufacturing. Regarding competition, this technology also opens new business opportunities for companies. When packaging companies use AI with other new technologies like IoT, big data, and robots, we are seeing that they can only change their old manual work into smart systems that respond to what customers want and business changes.

Among the opportunities, improving operational efficiency and productivity is actually the most important one to mention. This improvement can definitely help organizations work better and achieve more results. As per production line requirements, computer-vision systems help in effective quality checks regarding defect reduction and waste minimization. Basically, artificial intelligence will help packaging companies organize their complicated tasks and use resources better. The same technology will improve delivery times and make production more efficient and cost-effective.

The use in customization and innovation is one example of the usage of artificial intelligence, which has good opportunities in the sphere. Since the area of customer preference is more and more associated with one-on-one and individualized experiences with developing products, AI-based analytics can help in the development of discrete target audience packages. These innovations help the packaging companies rise above the conventional roles and thus the consumer satisfaction and market variation would be achieved directly.

Artificial intelligence (AI) implementation represents one of the major aspects of modern-day sustainability and the search of environmentally friendly practice. Considering the growing regulatory pressures and consumers being increasingly conscious about the issue of ecology, the packaging companies have to employ more environmentally friendly approaches (De Propris and Bailey, 2020). AI-based applications are used to optimise the use of materials, aid the design of lightweight packaging systems that maintain the integrity of the products, and provide the opportunity of simulation of the alternative application of recyclable or biodegradable materials. Additionally, AI-assisted analytics may be used to track vacations of the environment across the supply chain and thus help the packaging industry to be aligned to the circular economy principles and the United Nations Sustainable Development Goals (SDGs).

Another opportunity is related to enhancing competitiveness in the international market. It is with supply-chain optimization utilization of artificial intelligence that grants the firms with the ability to estimate demand at a reasonable level of accuracy, simplify inventory and delivery punctuality during market instability. The high responsiveness will help packaging companies, especially those in the emerging economies like India to be in favourable positions to be absorbed in the global value chains.

Lastly, AI itself presents an opportunity of statistical decision-making and strategic growth. Through high volumes of information created by production lines, consumer reaction, and the supply chain, AI will be able to provide vital knowledge at the corporate level. Such insights do not only consolidate daily processes, but also serve as the foundation of long run planning, innovation frameworks, and market expansion. The benefits of applying AI in packaging are achieved when the firms implement it, which goes beyond being a service-provider to being the strategic partners in the various industries, mainly food, pharmaceuticals, and cosmetics and e-commerce among others.

Research Problem

The packaging sector and especially those in the rising economies of the world like India are experiencing a total overhaul that is being driven by Industry 4.0 technologies. Faced with an increasing competitive pressure in the world markets where companies are required to be more efficient, sustainable, customized, and competitive, packaging companies are under extreme pressure to have advanced digital solutions. Being a powerful element of Industry 4.0, AI provides strong temptations to optimize production, improve supply-chain, increase the quality of products, and come up with the packaging designs that ensure being more environmentally friendly. However, regardless of its prospects, the introduction of AI in the packaging industry is limited, disjointed, and filled with critical issues.

Small and medium enterprises dealing with packaging, in particular, are faced with numerous challenges that include high implementation rates, lack of competent staff, concerns regarding the data safety, lack of interest in technological development, and a limited digital infrastructure. These issues hinder the successful implementation of new technologies in the industry.

At the same time, there are a lot of opportunities, the ones that are mostly untouched, i.e. predictive maintenance, smart packaging solution, demand forecasting, and environmentally sustainable design.

It leads to the dramatic gap in the research: despite the high potential of artificial intelligence as an agent of transformation inside the Industry 4.0, at this point, there is a lack of empirical information about the actual implementation of artificial intelligence in the packaging industry in mitigating the existing challenges and capitalizing on the opportunities that are presented.

The overall research issue, therefore, is aimed at building the systematic study of the ability of AI-based practice in the framework of Industry 4.0 logic to both alleviate current complications and exploit current opportunities through the facility to improve efficiency, sustainability, and competitiveness in the packaging segment.

Purpose of the Research

The main purpose of the research is to explore the opportunities of Artificial Intelligence (AI) as a core aspect of Industry4.0 with the purpose of enabling its effective introduction in the packaging industry to overcome the existing obstacles and use the forthcoming opportunities. The study aims to outline the barriers to AI implementation, which include cost factors, skills shortage, lack of infrastructures, and simultaneously the possible benefits, including the efficiency in operations, the introduction of smart packaging, increased sustainability, and the increased competitiveness in the market. The study aims at analyzing the dynamics by a critical review and review of secondary sources and peer reviewed literature, which will consequently produce a unified view on how AI changes the packaging industry. Its overall goal is to produce initiatives and suggestions to act upon to inform industry, policymakers and corporate players in strategic implementation of AI resulting in innovation, sustainability, and growth within the packaging sector.

Significance of the Study

The current study can be deemed significant because of a contribution to a growing body of academic knowledge that addresses the implementation of the Artificial Intelligence (AI) on the industry 4.0 platform, along with its usage in the packaging sector. Packaging industry serves as a critical facilitator of business operations in the sphere of fast-moving consumer goods (FMCG), pharmaceuticals, food, and e-commerce and is persistently challenged in the effort to streamline business operations, maintain environmental care, and comply with the changing consumer demands. The exploration, in relation to the ability of AI to alleviate the existing obstacles, such as pressure on costs, lack of quality control, waste, and performance limitations in the supply-chain management, provides the informative ground on the strategies contributing to the enhancement of operational efficiency and supporting competitive positioning.

This research has a great practical relevance to packaging small and medium enterprises (SMEs) which often suffer from limited resources and limited technology adoption. By identifying opportunities, such as predictive analytics, intelligent packaging systems and environmentally sustainable innovations, this research provides a guide for SMEs to utilize artificial intelligence in their efforts to grow and become more sustainable. Moreover, the insights are useful to policymakers, industry leaders, as well as technology providers, for the development of supportive frameworks and strategies that enable digital transformation. From an academic perspective, the current research helps fill a substantive gap by systematically investigating challenges and prospects related to AI in packaging to provide a basis for later empirical and applied research.

Research Questions

- To identify and analyse factors affecting artificial intelligence adoption in the packaging industry.
- To examine the challenges of integrating artificial intelligence into industry 4.0 in the packaging industry
- To examine the opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry
- To provide suitable recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry

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CHAPTER-II

REVIEW OF LITERATURE

Theoretical Background

The theoretical context of the conceptual frameworks explaining the analytical nature of how Artificial Intelligence (AI) can be incorporated to the industry 4.0 paradigm, have a theoretical foundation within the broader academic literature including the technological innovation theory, automation literature, and the socio-technical system theory (Baker, 2012). The industry 4.0 is considered a paradigm shift of the industry, past mechanization, electrification and digitization, and a convergence of cybers-physical systems and Internet of things, robotics, and intelligence which act through information (Handfield, Jeong and Choi, 2019). Within the analytical lens, the industrial players are shifting out of the conventional linear production systems and evolving into ecosystems that are more reliant and intelligent as machines, human operators, and digital platforms collaborate without a glitch.

The question of artificial intelligence in the given theoretical framework is the level of intellectuality in the give-off of the programming task, as well as the ability to assimilate the knowledge of the whole, lifelong learning and objective decision making. Thus, the industrial process can be re-structured with the introduction of AI technologies and it will be transformed not the mechanistic mode of operation but the knowledge-driven one, which is capable of responding dynamically to the alterations in the environment conditions under which it is operated (Madhavi, 2021). The innovation diffusion theory is a theoretical framework in which the process of implementing technologies such as AI in one of the aspects of the industry can be analysed. This paradigm argues that the technological uptake process is sequential by the fact that innovators and early adopters have the ability to preceding adoption that gains momentum in the end and encourages adoption. Using this dynamic to the packaging business refers to the fact that first of all in the market, such AI-based tools like predictive analytics, smart sensors, and automated inspection systems adopted by the largest businesses and then they become popular within the industry in the future. In this theoretical interpretation, the significance of technological readiness, organization culture, and external pressure lies in the process of setting the pace and extent of adoption of AI with the Industry 4.0 paradigm.

A theory applied to understand Industry 4.0 is the systems theory. The analytical view of industrial entities comprises of complex networked entities which are seen as chains of supply, production lines, distribution systems and chain of parts dependency. Industry 4.0 refers to both the establishment of intelligent connection between these subsystems using digital platforms and the analytics based on artificial intelligence. The corresponding sphere of packaging, that has always been considered as a separate and discrete activity in the production milieu is reconfigured as a systems theory (relates to production, logistics, and consumer markets) participating in the process of interaction on the dynamic basis. Artificial intelligence is added to this level of system level integration to enable real-time monitoring and prediction maintenance, as well as production scheduling (Garay-Rondero *et al.*, 2019). The systems theory consequently puts the packaging industry as an indivisible component of a mutually supporting industrial ecosystem that thrives on information flow, cross-linkage and intelligent decision-making.

Resource-based view (RBV) of the firm is another theory that could be used to explain the integration of AI in packaging in Industry 4.0. The theory underlines that developed competitive advantage in the firms is sustainable when unique resources and capabilities are used, which are valuable, rare, inimitable and non-substitutable (Rodríguez-Espíndola *et al.*, 2022). In this regard, AI-powered technologies, including smart design software, automated quality control apps, and consumer insights based on data could be considered as strategic assets, by which firms in vacuously competitive markets maintain a competitive edge. In the case of the packaging business these features not only contribute to the increased efficiency of the operations but also to the possibilities of customization, innovation and added services. This is in line with the theoretical claim that high tech technologies are not simply the means but the critical assets of influence on long-term competitiveness.

The other theory that can be applied is the socio-technical systems theory in which excessive emphasis is placed on the interdependence of the technological systems and human actors. In the case of Industry 4.0, this view field presupposes that successful adoption of AI will depend on the potential of the technological progress in the context of their relevance to the processes within an organization, qualification of the workforce, and cultural integrations (Soni *et al.*, 2020). The theory has a platform upon which it can be used in the packaging processes which require the involvement of designers, engineers, operators, and marketing professionals. The systems driven by AI such as computer vision to locate defects or optimization algorithm to design packaging should be set in a way that helps in the human decision-making process and not fully to do it. The socio-technical perspective emphasizes that automation and human innovativeness should be made equal to ensure that in the situations of the industry 4.0, the limitations of AI in the sub-system of the packaging industry does not eliminate human knowledge (Chalmers, MacKenzie and Carter, 2021).

The theory of dynamic capabilities is particularly applicable as regards strategic management. The dynamic environments in this structure are time-bound and the companies must have mechanisms that enable them to amass, build and rebuilding the internal and external capabilities. This dynamic environment is evident within the packaging industry which incorporates production, logistics and interaction with consumers (Jain, 2019). Industry 4.0 based on AI can assist companies to develop dynamic capabilities due to the ever-changing the packaging process to address needs of consumers, regulatory, as well as sustainability goals. One such example is the ability to make companies reform the packaging materials and constructions in accordance with real-time information on the market and environment. This theoretical model demonstrates the disruptive and responsive effect of AI on helping the packaging industry to be resilient and responsive.

Finally, but not the least, the speculation of the AI and Industry 4.0 transforming the packaging can be made through value chain theory. Packaging has always been viewed as the upstream activity of the value chain in the downstream part of the value chain. However, Industry 4.0 repackaging is reformulated as a strategic component as well as a direct value creator. Using the conglomeration of AI, packaging might influence different sections of the value chain procedure, including production efficiency, quality, distribution, and the consumer experience (Geisel, 2018). This repositioning is associated with the theoretical causes, which are the elimination of traditional boundaries in the value chain of digital technologies, and every step of the chain can be turned into a source of differentiation and the value-creating.

Overall, the theoretical background of the provided piece is founded on a variety of theories including the innovation diffusion theory, the systems theory, the resource-based view, the socio-technical systems theory, the dynamic capabilities, the theory of value chain. All these opinions provide us with many dimensional explanations of the implications of the packaging industry by AI and Industry 4.0. They are concerned with its strategic, operational, and human facets of technological incorporation through which, packaging is no longer perceived as an unadulterated technical need but as a revolution of its very own; the crossroad, in industrial development, of intelligence and worth generating.

Integration of AI into Industry 4.0 in Packaging Industry

Industrial 4.0 or the fourth industrial revolution is a popular debate within the scholarly and industrial context as a paradigm shift, which is shaping the production industry and the other related sectors. According to literature, it is a combination of digital, physical, and biological systems through the support of the technologies of Internet of Things, robotics, cloud computing and Artificial Intelligence. Researchers emphasize that Industry 4.0 is not the extension of the previous revolutions extinguished because of its intelligence, interconnectivity, and versatility which leads to what researchers usually refer to as smart industries or smart factories. It is based on this ground also that the Artificial Intelligence can become the locomotive which gives a sense to the data, automation, and decision-making in the ever-complicated production conditions (Leitch, 2021).

It has been studied that Artificial Intelligence is a key facilitator of predictive, adaptive and cognitive functions of industrial ecosystem. Literature is concerned with the capacity to process the large volumes of structured and unstructured information and make the discovery about the hidden trends and provide the real-time information (Mishra and Tripathi, 2021). As it is implemented to the industrial setting, AI can be characterized as an opportunity to simplify the production process, enhance the accuracy of the quality evaluation, and introduce autonomous systems that may be operated by humans with the least disruption. Machine learning, computer vision, and natural language processing are also another undeniable sphere of AI where researchers find the highest values as these subtopics can apply directly to the industry 4.0 principles. These technological skills change the operating models into reactive based too proactive based (Anute *et al.*, 2021).

Packaging research has received more attention with reference to the digitalization and the advanced technologies. The broadened context of the field of packaging is also observed in the literature on packaging industries where way beyond the provision of the protective coating, it is now a component and constituent of the supply chain, marketing teams, and consumer relations. The modern era of the digital world has transformed the concept of packaging into a type of communication that reminds the brand identity, safety control, and adherence to the regulation system. Scholars believe that in the presence of the technological development of

Industry 4.0, the packaging system can be shifted towards automation, traceability, and consumer interaction. The development has made packaging a field of critical concern requiring smart technology, including Artificial Intelligence, to apply (Rathi and Asava, 2021).

Some of the sources about the packaging innovation highlight the use of automation to enhance the general packaging, sorting, labelling, sealing, and inspecting. It is a stable assist of large production lines and as per the literature, AI enables it to be quick, accurate, and versatile. Besides the automatization of the process, researchers have also cited the use of digital designing and design tools using AI that allow manufacturers to test virtual samples of a material used on packaging. These articles indicate that virtual simulations will result in the process of production consuming less time, improved quality of the design, and less waste. This is the existing body of literature which describes the gradual process of the transition of a once labour intensive and technology-restricted type of packaging to an ecosystem which is technologically based and in line with Industry 4.0.

The other crucial issue of the literature is the role of data analytics and smart technologies in the process of managing the packaging value chain. The information generated by machines, sensor and direct interaction with the consumer is more than essential to the decision-making process as theorized by scholars. Artificial Intelligence can be used as the analytical engine that obtains actionable insights using such data and, therefore, is capable of acting as a response through production and enhances coordination with suppliers and distributors (Sadiku, Fagbohungbe and Musa, 2020). The idea of packaging is introduced in the current stream of research as the part of an interdependent industrial ecosystem where the efficiency and agility are meditated by the digital intelligence. The given point of view emphasizes how AI will make the packaging systems more visible and responsive so that they become more intertwined with the general Industry 4.0 objectives.

The industry 4.0 strategy also places a special emphasis on literature because it dwells on the consumer aspect of packaging. Packaging is being discussed as not only as technical or Logistical issue, but in a new sense, as an interface between the brands and the customers. Solutions to change packaging into an interactive platform have been mentioned to include AI based smart packages solutions such as QR codes, sensor, and digital labels (Rathi and Asava, 2021). Researchers believe that the changes have altered the packaging as a passive security with the consumers being the active partners where they are informed about the quality and authenticity of the product and its use. The contemporary dynamics of the AI implementation with this consumer-based aspect are represented in the literature as the changing dynamic between the digital technologies and the market competitiveness.

The literature sources relate the Artificial Intelligence and Industry 4.0 to strategic transformation in the industries through expanded theoretical viewpoints. These technologies are convergent and researchers feel that convergence is assisting in redefining the value creation as well as business models (Roundy, 2022). This is where packaging is considered an industry with integration of technology implying general changes in industries. The transformation of AI in the packaging operations can be regarded as a mini-world of the transformation of smarter, more flexible, and more potent industries occurring in the world.

Overall, literature analysis shows that Industry 4.0 and Artificial Intelligence cannot be separated in terms of the industry development. One of the most important areas where these technologies are realized is the field of packaging where the productivity of the production lines is affected as well as communication with the consumers. The packaging aspect defined by the scholars is not a fringe activity anymore, but rather a significant part of an industrial ecosystem; as such, a bright future that can be explored to study the overall implications of AI-induced Industry 4.0 changes.

Factors Influencing AI in Industry 4.0 in the Packaging Industry

The Artificial Intelligence concept implementation under the industry 4.0 in the packaging industry is predetermined by the multifarious interdependent factors. One of those factors is the technological preparedness, as these are the most significant in this equation, and such a level is the one, to which the companies and other industries became ready to use and apply the recent technological methods (Palanivelu and Vasanthi, 2020). Military digital infrastructure such as sensors, automation, and data analytics platforms is also needed by the packaging companies to achieve the AI solutions success. In the absence of trusted connection, embedded data systems and compatible equipment, the most progressive AI solutions are never improved to a level that they were supposed to work. Technological preparedness would also entail the presence of knowledgeable human resource that has the prowess to operate, fix and continually upgrade AI-enabled processes. The lack of such preparedness will leave companies with no choice than to wrestle with high barriers to the implementation of AI, leading to inhomogeneous use of the technology throughout the industry.

The other important AI determinant in the packaging is the economic conditions and cost factors. The costs required to initiate AI-based Industry 4.0 technologies in the case of most companies particularly the small and medium-sized companies (SMEs) may be a disadvantage. Other forms of investment like AI-driven robotics, predictive maintenance or smart packaging technologies might be numerous high-upfront capital-intensive investments and this might not be well accessible to companies with resources limitations (Florido, Adame and Tagle, 2015). In the meantime, the long-term economic outcomes, such as reduction of waste, the improvement of efficiency, and high quality of the products, will be able to offset the original investments, in case the firms use the right strategies and receive adequate funding. Hence, low expenses of technology, financial resources, and apparent profits are major influences that define the degree and pace of AI adoption in the packaging sector.

Influence on AI introduction into Industry 4.0 also is strong, through regulatory and policy frameworks. Governments and other regulatory bodies usually build standards to determine how AI-based solutions can be used by the packaging companies particularly in markets that are sensitive such as food, pharmaceuticals, and healthcare. Laws that limit data protection, the ethical use of AI, environmental compliance, and, consumer safety establish the potential applications of AI in the packing procedures (Liu, 2010). Also, as an example, one has to have strict health and safety provisions to support intelligent packaging technologies that track the freshness of food or authenticity of pharmaceuticals. The application of AI should accelerate through government schemes, tax exemptions and innovation-supporting policies and strict / vague legislations will most probably slow it down. This technology-government interrelation drives the impact of external institutional circumstances on the digitalization of the packaging industries.

The other significant issue which is adversely affecting the packaging of AI is the demand and expectations of the consumers in the market. The existing consumers do not only require practical packaging, but recyclable, tailored and fulfilling. The introduction of online shopping and the direct-to-consumer-delivery designs have increased the requirement of effective and smart packaging systems. The transformed needs can be guided by the AI technologies of the predictive demand analysis, smart labelling and personalization tools. Take the replica as an example, depending on the taste of a particular customer, it is possible to design a package, with the help of AI-based design systems that will increase the rates of customer satisfaction and brand loyalty. In addition to that, the increasing environmental consciousness of the tourists makes the companies use AI to regulate the use of materials more effectively, generate less waste, and find alternatives that can be more environmentally friendly in terms of packaging. As such, transformation in consumer behaviour is a strong competitive driver of AI innovation in the industry 4.0 packaging systems (Hirschi, 2018).

The position of the organizational culture and leadership cannot be disregarded as well in the analysis of conditions that can influence AI in the packaging industry. Good implementation of AI not only involves the technological equipment but also good attitude within the organization. The dedication of the leaders, the numerous attempts at innovation, willingness to invest in digitalization assumes the leading position in the determination of the successful implementation of AI technologies (Taylor and Conexxus, 2018). Firms with a high hierarchical organizational culture or slow and slow to adapt to may not embrace AI in their operations. On the other hand, the likelihood of cashing in on the full potential of Industry 4.0 technologies is relatively high in organisations with the organisational culture of experimentation, training, and continuous improvement. Thus, vision leadership and organizational flexibility can be considered to be highly important in the packaging AI adoption.

Another factor that influences the level of collaboration is the system of packaging. The principle of the connection is the cornerstone of Industry 4.0, in other words, individual companies will not be capable of deploying AI solution individually. The packaging companies must collaborate with other technology suppliers, supply chain partners, the research institutes, and the government agencies in order to make the implementation successful. Expertise is also provided through sharing knowledge and also through joint ventures and alliances in the industry, risk reduction has also been facilitated and more innovation has been encouraged. A good example is that collaboration with AI solutions developers may help the packaging SMEs receive access to the newest technologies without being required to develop all of them by themselves. In this respect, networked partnerships are the motifs that determine the AI diffusion in the packaging industry.

Finally, the demand to be sustainable and international competition contribute to the use of AI in Industry 4.0 packaging. The threat of environmental concerns is reshaping the packaging exercise in every corner of the world and compelling businesses to identify new approaches, which would reduce their consumption of resources, improve on recycling and implementation of green policies. Artificial intelligence provides potent bases of streamlining material, carbon index, and creation of environment-friendly substitutes. Meanwhile, the world is becoming increasingly competitive and it is compelling companies to implement AI to enhance their performance besides cutting down on costs to help them stay afloat in the rapidly changing market. The said dual sustainability and competitiveness threat, in its turn, introduces a need and an opportunity of the packaging companies to consider the concept of artificial intelligence as a part of their Industry 4.0 policy.

To sum up, AI implementation in Industry 4.0 in the packaging sector is conditional upon the quantity of the factors, which are interdependent and comprises technological preparedness, economic limits, regulatory framework, consumer priorities, organizational culture, alliances and sustainability demands. All these will go towards the adoption rate of AI and the degree to which it will revolutionize the practices of packaging. These impacts would be appreciated by the firms, the policy makers, and stakeholders planning to use AI to modernize the packaging sector in regard to efficiency, sustainability, and innovation.

Challenges of AI in Industry 4.0 in the Packaging Industry

On the one hand, the implementation of Artificial Intelligence in the Industry 4.0 within the packaging industry possesses a revolutionary potential, and it is not a VUCA flow. It is among the highest obstacles as it is very costly to incorporate and implement. Small and medium sized enterprises (SMEs) and the packaging companies generally face economic pressure to invest and use AI enabled machines, predictive machines and other advanced data analytics systems. These technologies involve high capital investments at their inception, continued capital investments in upgrades and integration (Teitel, 2000). Unlike the larger multinational corporations that may find it possible to absorb such costs, the smaller players are faced with the issue of finding a balance between the two costs and low chances of returning on the investment. In turn, the barriers to the economy continue to have a fire branding effect on the rampant use of AI in the packaging arena.

The second issue is of importance is the technological preparedness and the digital infrastructure. IBM 4.0 based on Artificial Intelligence are highly reliant on the interconnective apparatus and appropriate data collection and the existence of a steady connection. However, such demands cannot be facilitated by most firms in the packaging sector particularly in the emerging economies due to their lack of the necessary infrastructure. Bad digital ecosystems, outdated machines, and fragmented information (systems) reduce performance and reliability of artificial intelligence implementations. In addition, redesign would be needed in the traditional systems, which are switching to the smart factories in most of the cases, and it can further interfere with business, leading to resistance by the company. Without taking into account such infrastructural issues, disproportional and piecemeal implementation of AI by the packaging industry is possible (Tay *et al.*, 2018).

More significant issues also include data management and cybersecurity. The application of AI systems works on the mega real time processes which take place in the production processes, customer interactions and supply chain. This data should be accurate, consistent, and available in order to stabilize an AI functioning. However, some of the problems that are encountered by the packaging companies include data silos, lack of information, and uneven patterns all of which reduce the performance of AI applications. In addition, greater dependency on interconnection system creates vulnerability to information assault and cyber-attacks. Fragile information concerning the level of consumer behaviour, the design of its products, and chain supply logistics are beckoning hackers who will lead to a loss of funds and a varied detriment. Therefore, lack of information control and cybersecurity have become serious problems in AI-controlled packaging.

The shortage of skills and willingness to work force also complicates the problem of handling AI to Industry 4.0. The processes within packaging organizations traditionally consume labour and adaption to AI-based automation demands labour that is competent of adapting to the new technical competencies such as acquisition of data analysis skills, knows about robotics programming and the capacity to integrate systems. However, the entire workforce is not well-informed enough to use AI systems and automatize them. This leads to two problems, the first one is that firms are now facing the problem of the shortage of proficiency skills and second, existing workers fear being automated out of the job. The socio-technical nature of the packaging operations not only serves as the guarantee to the investment approach through the purchase of new technologies but also in terms of upskilling and reskilling programs that help the workers gain new employment. The failure to consider human factor will make companies susceptible to the resistance of change, productivity, and cultural-artificial intelligence mismatch (Machado, Winroth and Ribeiro da Silva, 2020).

The virtual uncertainty of the regulation is also an issue in the AI implementation of the packaging. By the fact that packaging business is more likely to intersect with other continuously high demanding industries such as food, drugs, and healthcare, the companies are required to abide by high safety, labelling standards as well as sustainability standards. However, the legislations that cover the use of AI and digital technologies are at a transitional stage and the compliance requirements are thus ambiguous at the present. One such example would be using an AI-driven smart package to monitor the freshness of the food or the traceability which may contradict the existing labelling laws or the privacy policy of consumers. Moreover, the world is not uniform in its policies and this only adds to the plight of a company with more than one market. Absence of a dependable or clear regulatory system then creates a time out of nowhere in the process of implementing AI based solutions in packaging.

The question of sustainability provides the second dimension. Although, the AI can help maintain a greener attitude to the surrounding, better use of the material resources and fewer wastes, the development of AI systems, in its turn, most of the time concerns energy-consuming networks and electronic devices. The companies need to balance the utilisation of AI within the company to be able to survive and the environmental cost of digital transformation. In addition, the increasing pressure of biodegradable and recyclable packaging in the globe burdens the companies with an obligation to be creative in a responsible manner without undermining the issues of environmental awareness. Attaining sustainability to embrace the implementation of energy consuming AI systems is a delicate and tricky game to play.

And the last point is that the bigger supply chain may become one of the pitfalls towards the implementation of AI in packaging. The 4.0 Industry dwells on integrating the entire chain where packaging must correlate well with production, logistics and distribution. Supply chains are though generally non-linear and different players will be in diverse technology levels. The introduction of AI-driven systems to a packaging company may result in difficulties concerning the integration with other suppliers or distributors without similar functions. It decreases the efficacy of the end-to-end digitalization, as well as harms the chance of collaboration among Industry 4.0. The interoperability at the various stakeholder levels is however a major challenge to realize.

In conclusion, despite the fact that the AI can lead to tremendous opportunities in transforming packaging based on the industry 4.0 paradigm, firms are faced with various challenges that include loss of money in implementing the technology, absence of infrastructures, threats to data management and cybersecurity, skill shortage among the workforce, regulatory ambiguity, and supply chain integration. Such problems worsen the clumsy process of restructuring the traditional approach to packaging operations to AI-based ones. Their hostile bargaining would be a concerted action by the firms, governments, technology vendors, and employees to ensure that the AI integration is sustainable, inclusive and also, strategically profitable to the packaging industry (Castagnoli *et al.*, 2022).

Opportunities of AI in Industry 4.0 in the Packaging Industry

The introduction of the Artificial Intelligence (AI) into Industry 4.0 introduces opportunities that the packaging industry has never enjoyed before, thus it is the most dominant player in the technological transformation. The second chance is the attainment of efficiency in its operations. Automation of processes and predictive analytics can allow packaging companies promote the improvement of the production cycle, reduce the time of production, and optimize the utilization of the available resources due to AI (De Propris and Bailey, 2020)To give an example, AI-based predictive maintenance can be used to monitor the state of the equipment operation continuously and detect abnormalities before they lead to failures in the machine. This precaution will save time, declare life of machines and lower the maintenance cost. Companies have not only increased speed and accuracy by automating the process of sorting, labelling or inspection of quality, but also set the human resource free, allowing them to be put on more productive creative and strategic processes.

The second chance that AI can offer the industry 4.0 is the possibility of enhancing the quality of a product and its safety. Packaging is an essential factor in preservation of the product integrity in industries like food, beverage and pharmaceutical industry. Computer vision systems with the assistance of AI are capable of inspecting labelling line with high accuracy and identify them as having defects, including mislabelling, broken seals, or misprint in real-time. This enhances consumer security, reduces the likelihood of the recall of the product, and ensures that the rules in the industry are adhered to the latter. Similar to inspection, AI can also predict and prevent the quality issues according to the past trends of the historical data. Such degree of accuracy boosts the trust of the products and develops the image of packaging companies under the most competitive business conditions (Matt, Modrák and Zsifkovits, 2020).

AI can also be used in spacious innovation of intelligent packaging solutions. The more the necessity to raise the level of interaction, smartness and personalisation of packaging, the more AI will bring the chance to design and introduce the level of packaging that goes beyond the traditional design and functionality. Combining AI analytics and sensors and QR codes on smart labels can provide the consumers with the information regarding the authenticity of the products, their shelf life, or sustainability certificates. These inventions do not just enhance the customer experience, but also create brand loyalty in relation to fulfilling the consumer transparency and traceability needs. In addition to this, AI-powered design systems will allow corporations to make customized packaging, which will be tailored to the preference of the consumer and it will be able to tailor it in large productions. This type of interaction is a new dimension of communication between brand and consumer.

Sustainability is another area that AI can provide the packaging industry with revolutionary opportunities. With the growing concern of the environmental care issue, packaging firm have been under pressure to reduce material wastes, cut carbon emission and shift towards environmentally friendly solutions. Artificial intelligence-driven analytics enable the companies to justify the use of materials to make their packaging more cheap and even sustainable. Algorithms will be in a position to sample and simulate different packaging designs as a computer simulation before they are physically made without the influence of trial and error. Bio degradable materials can also be developed using AI by evaluating the great mass of data on performances and sustainability of materials (Stankovic, Gupta and Figueroa, 2017). These innovations are able to not only meet the regulatory pressure, but also to meet the need of the environmentally friendly consumers and thus assist the firms to put themselves at the forefront of the sustainable practices.

This is because AI enhances the integration of the supply chain within the packaging process and opens a new potential of integration and responsiveness. The industry 4.0 puts much focus on the interconnected systems, and AI is in the middle of harmonizing the activities of packaging processes with production, logistics, and distribution networks. AI-based real-time data analytics can enable packaging companies to identify changes in demand, match production timelines, and deliver products at the right time. The indicatives in the e-commerce sector are that AI can be applied to streamline the packaging design and quantities based on the purchasing pattern of the consumers and reduce overproduction and inventory holding. This responsiveness and agility enhance resiliency to the supply chain as well as provide businesses with competitive edge in unstable markets.

The other opportunity is a possibility to use AI-based analytics to boost the consumer insights and responsiveness to changes in the market. Packaging is not always a container but can be a major point of contact during the process of dealing with the consumers. By relying on AI, businesses can access consumer behaviour, preferences, and purchase patterns data, which they can use to develop the packaging that attracts specific segments. AI makes it possible to promote the individual packaging, make marketing through packaging tasteful, and instantly adapt to client trends. This increases the responsiveness of the market besides offering more channels through which the brands can differentiate themselves in the crowded markets through the consumer-led innovation.

On the one hand, the opportunities of the introduction of small and medium-sized packaging enterprises (SMEs) into the competitive realm of Industry 4.0 are opened through the introduction of AI. SMEs tend to be challenged in adopting new technologies and with the aid of AI, they will be able to have solutions that are scalable and can be customized to their specific requirements. The fact that advanced analytics and automation can be accessible to smaller companies through the reduction and elimination of the need to invest heavily in infrastructure is an example of cloud-based AI platforms. Through the introduction of AI, the SME will be able to be more productive and enhance quality and provide new packaging options to compete with larger businesses. This democratization in technology creates the prospects of increased people and expansions in packaging industry (Samans, 2019).

In conclusion of the existing situation in the AI integration in Industry 4.0, various opportunities are posed to the packaging industry and can be further extended to general efficiency of operation, quality enhancement, intelligent packaging, sustainability, collaboration of supply chain, communication with consumers, and competitiveness of SME. With these opportunities, the packaging firms are not only able to improve their operations in the internal environment but also redefine its place in the global chain of supply and the consumer market. As the Industry 4.0 continues to assume a new form, AI will continue playing a leading role in bringing change and will elevate the packaging industry to the same level both as an industrial growth agent and as an agent of sustainable development.

Relationship of AI and Industry 4.0 in the Packaging Industry

The introduction of Industry 4.0 has marked the initial stage of digitalization as per which the digital technologies such as the Internet of Things (IoT), robotics, cyber-physical systems, big data, Artificial Intelligence (AI) are transforming the traditional industries. Flexible learning, autonomous decision-making, and intelligent automation, especially those ensured by the application of AI, play a significant role in this scheme. The correlation between the AI and Industry 4.0 is revolutionizing and unavoidable to the packaging industry that is an essential linkage between the producer and the consumer. Packaging is no longer a good as there is a high probability that it is now safe, personalised and intelligent. Combining AI with the tools of Industry 4.0, the packaging companies would be more efficient, become sustainable, and, therefore, approach consumers in a more productive and sustainable manner, thereby becoming a competitive element of the global market (Roundy, 2022).

One application of AIs to Industry 4.0 in the packaging sector is through the implementation of AI in optimization of production. The traditional types of packaging often give a lot of reliance on human hands and standardisation which are also highly likely to bring about inefficiencies and human error. With the adoption of AI in the Industry 4.0, through integration, it will be possible to predict maintenance, machine automation, and real-time inspection. In order to elaborate on this further, AI is able to handle the data on the machine performance to forecast potential failure which can reduce downtime and limit productivity since it can focus on productivity. Similarly, AI-powered computers that drive smart vision demonstrate more capability to manage quality by identifying packaging material or product defects with high precision, which is virtually impossible when one relies on the human eye during the quality check. This AI-Industry 4.0 has led to the belief that the packaging work is more fast, accurate, and efficient.

The other facet of AI- Industry 4. 0 relationship in the packaging industry is in the sphere of the integration of supply chain and demand forecast. Industry 4.0 pays attention to digitalized interrelated systems that are integrated regarding supply chains. The AI assists by conducting an analysis of mass amounts of data of the consumer markets, logistics systems, and production processes and forecasting the demand far more correctly. This will ensure that the packaging firms are able to align the production levels with the real demand in the market when they are not caught between producing more than they are demanded and producing less than the demand. In addition, AI-controlled supply chain management helps businesses to identify the most appropriate sourcing, distribution, and inventory solutions, which reduces costs and environmental pressure. In such a way, AI supports the industry 4.0 goal of creating smart connections of values.

The other significant nexus point between AI and Industry 4.0 is sustainability that has the potential to affect the packaging industry. The world is currently in a crisis when it comes to interactive and flexible packaging that is eco-friendly and is progressive in terms of recycling, and AI technologies help companies design packaging and systems that produce limited amounts of waste and environmental harm. With machine learning and simulation, AI can create the package and material optimization to decrease the use of raw materials and attain the strength and durability. Such innovations are being facilitated by the 4.0 Industry sector through the high manufacturing technologies that cover 3D printing and robotization of the production that can enable the mass-producing of environmentally-friendly packaging. A transition to the decision-making practices, which result in a circular economy, can be made in the packaging industry with AI and Industry 4.0. The most important way in this developmental path is waste minimization and resource efficiency.

The relationship is also extended to the consumer interaction and personalization. Consumers today desire to be able to see a functional, interactive and customized packaging. The AI-driven Industry 4.0 systems can be used to reach smart packaging when QR codes, sensors, and even augmented reality can be used to provide a consumer with all the information about a product, trace its origin, and provide an individual experience. To give an example, customer information can be processed with the help of AI so that a company can develop packaging that can be adjusted to the individual preferences or regional market needs. Such a design is then adaptable and automated using infrastructure 4.0. This integration is making packaging to act as a communication channel which enhances the brand-consumer relations and the value created is not just a protection of a product (Palanivelu and Vasanthi, 2020).

Besides, the connection between the AI and Industry 4.0 has improved the safety, compliance, and traceability in the packaging sector. Packaging of food, pharmaceutical and cosmetic is subjected to high levels of regulations. Compliance can be guaranteed by the AI algorithms that will keep under control the quality data and detect the deviations. This data can be distributed throughout the supply chain when applied in Industry 4.0 systems to offer traceability of production to the end-user. AI-based smart packaging can even track the state of products or track their tampering, which can also provide a level of security that is becoming an important factor in consumer markets. This not only makes it compliant to the regulations but also develops consumer trust.

Notably, the connection between AI and Industry 4.0 has not been that smooth, particularly in developing economies such as India. Large companies can afford to apply these high-tech practices, but since most packaging industries in India are SMEs, they cannot afford expensive

AI solutions, do not have enough qualified employees, and have inadequate infrastructure. However, the implementation of AI in packing Industry 4.0 will become less challenging, as the government policies, collaborative projects, and the technology vendors begin to cooperate in favour of the SMEs. Such inter-relationship between these two forces will democratise innovation in the long-term in the sense that even the smaller players would share the digital transformation (Bhalerao, Kumar and Pujari, 2022).

In conclusion, the AI and Industry 4.0 are symbiotic and trans figurative in the packaging business. The AI provides the intelligence and scalability, and power of data processing, and Industry 4.0 provides the infrastructure, interconnection and automation in their applications, rendering its deployment on a large scale feasible. They all are concerned with such urgent needs as efficiency, sustainability, customization, compliance, and consumer interaction. Nevertheless, in spite of the complications that are present, particularly regarding the case of the SMEs of the emerging markets, the integration of AI into the Industry 4.0 can be characterized as a highly powerful means of the packaging industry taking the necessary steps towards becoming competitive and expanding in the long run. This transforming interdependence is defining packaging as a support position as a fundamental source of innovation, sustainability and value creation in the new economy.

Roles of SMEs in the Packaging Industry in India

The SMEs play a pivotal role in the Indian packaging industry because they are the providers of innovation, flexibility, integration of the supply chains. It is argued that, the packaging industry in India is among the booming industries across the globe as e-commerce, food processing, pharmaceuticals, and FMCG have led to a phenomenal growth in the packaging industry. SMEs within this ecosystem are a big percentage and therefore they are involved in the process of generating employment, local production and development of the area. They are also able to respond to changing market needs very quickly owing to their agility and as such, they are providing customized packaging solutions that may not be provided by larger organizations owing to their inability to respond similarly in terms of speed as well as cost. This elasticity ensures that the relevancy of the SMEs in the packaging sector in the country is not lost in the sense that the country does not only cater to the local market but also to the global market in terms of exports.

Innovation is one of the most important functions of SMEs in the Indian packaging business. Although the multinational corporations control the large-scale production, SMEs tend to specialize in niche markets, and on experiments. They often introduce new packaging material, including those that are biodegradable and environmentally friendly laminates and light containers, which resonates with the increasing concerns of sustainability in India. Through innovation of localized solutions to regional preferences, SMEs enhance diversification of the packaging formats and technologies. Most of these businesses are the first to adopt the new trends, as the interface between the old and new demands, and being the pioneers of scalable innovations within the large industry (Svatošová, 2017).

The importance of SMEs in the generation of employment in the packaging industry is also significant. Having labour-intensive and high density of operation in the regions, SMEs present potential to semi-skilled and skilled man-power in the urban and semi-urban locations. They are no longer confined to the metropolitan cities, but to smaller towns and industrial clusters and therefore lead to inclusive growth. This labour force plays a critical role not only in production, but also in other side activities such as printing, labelling, logistics as well as recycling. Having absorbed the majority of workplaces, SMEs in the field of packaging allow to minimise unemployment despite such opportunities as blocking a possibility of skills acquisition and training in innovative technologies. This increases the human capital base of India and promotes the move towards digitally powered operations in industry 4.0 (Brijlal, Enow and Isaacs, 2014).

The other major contribution that the SMEs are making to the packaging industry in India is the supply chain integration. The interrelation between producers, distributors and consumers focuses on packaging which is an important factor to make sure that the chain of the relationship is efficient and responsive to SMEs. They also offer packaging services to local manufacturers who might not have access to the bigger packaging companies therefore being inclusive in the growth of the industry. In addition, the SMEs tend to cooperate very closely with suppliers and distributors to develop packaging solutions among different product requirements, regulatory, and customer expectations. This high coordination leads to increased supply chain efficiency, minimization of delays and increased competitiveness of Indian products both in the domestic and the international markets.

SMEs have been playing an increasingly important role in ensuring that the Indian packaging industry is sustainable in the recent past. With the growing environmental concerns, government regulations to embrace environmentally friendly practices compel the SMEs to be the first in trying the biodegradable materials, recyclable materials, and reusable materials. Different SMEs do collaborate with research, startup, and technology providers to develop low-cost sustainable alternative packaging as well. Not only regulatory compliance, but also to a growing consumer requirement of products that are more amiable to the environment, they are add contributors. This sustainability orientation makes Indian SMEs active followers of the world in the direction of a circular economy being more significant and relevant in the packaging environment.

SMEs can also serve the demands of the new sectors including e-commerce, health care, and food delivery. The packaging that is done in these sectors must be durable, lightweight, and cost-effective, also maintaining safety and hygiene. These industries have got SMEs as essential partners given their capacity to quickly design and develop customized solutions that can be quickly replicated (Sharma *et al.*, 2021). What has happened is that demands are emerging due to the increased online food delivery sites to provide leak-proof, ecologically-friendly, and tamper-proof packaging and in this case, SMEs have taken an initiative to supply the solution of the problem. Equally, when the world experienced the COVID-19 pandemic, SMEs were important in providing medical and pharmaceutical packaging that were prepared as per the high safety standards. Their responsiveness brings out their need in responding to industry-related problems in real time.

Lastly, SMEs assist in the Indian export competitiveness through maintenance of packaging requirements all over the world. There is a significant number of SMEs that provide international markets with specialized packaging solutions at reasonable prices. They can be effective partners in the supply chains across the world since they concentrate on quality, innovation and, cost-effectiveness. By complying with international standards and certifications, SMEs will increase the visibility of India in the excellent packaging markets globally but will also assist the country to present itself as a place of innovative, sustainable packaging solutions. This is a crucial position in the view of the fact that global markets are becoming more sensitive to the environmental friendliness of its operations and budget-friendliness.

To conclude, SMEs have a compound role in the Indian packaging industry as they result in the creation of innovations, creation of jobs, assurance of integration of supply chain, promotion of sustainability, catering to new sectors, and export promotion. Their adaptability, flexibility, and local as well as global needs make them unavoidable to the development of the industry. Though smaller businesses are outdone in numbers by the large corporations, the small businesses offer the much-needed support, innovativeness, and include-ability that the industry needs to survive in a competitive and sustainable environment. Supporting the expansion of SMEs by providing policy incentives, financial incentives, and digital skill training will also help increase contributions and make India a leader in the global package innovation in the industry 4.0 paradigm.

Suggestions for Integrating AI into Industry 4.0 in the Packaging Industry

The implementation of an Artificial Intelligence (AI) in Industry 4.0 is a paradigm shift of the packaging industry, and the migration should be carefully planned and implemented strategically. An important recommendation is to start with the capacity building and the training of the workforce. Small and medium-sized enterprise (SME) in the packaging companies in many cases have no ready talents to run AI-enabled technologies. Resistance to adoption can be greatly mitigated by investing in training programs that help equip the employees with knowledge about machine learning, robotics and smart sensors. Also, developing relationships with universities and research centres will provide a permanent update on skills as well as staying in touch with new technologies on the part of employees. Even the most powerful AI systems will not be fully exploited without an educated and intelligent labour force (Sadiku, Fagbohungbe and Musa, 2020).

Another important recommendation is to implement a gradual and step by step policy. The high expenses and judgment on novel technologies make many firms not fully adopt AI. Pilot projects in certain domains such as predictive maintenance, automated quality inspection or supply chain forecasting should be introduced to the company instead of enforcing large-scale changes. The smaller applications are obtainable with some quantifiable benefits, and also the firms are able to gradually transition to digital operations. In the long run, with increasing levels of confidence and returns on investment, businesses will be able to ramp up and increase the use of AI in a variety of functions. The approach minimizes risks, makes the operations financially viable, and develops lower transitions.

A powerful data management framework is also necessary in order to utilize AI effectively. The industry 4.0 relies on the real time data on the production line, logistics and consumer behaviour. The companies should invest in the digital infrastructure that will be most active in collecting, storing, and analyzing the data to give AI tools an amazing performance. To give an example, the process of integration will be realized without issues and lower the level of errors because uniform data collection systems will be used in all the operations. At the same time, organizations must have effective cybersecurity initiatives that will improve the security of the valuable data and protect against the attacks of their systems. Having effective data governance will not only result in high degree of efficiency in its operations but will also instil trust to the customers, regulators or other stakeholders.

The idea of AI needs to be shaped by environmental objectives as sustainability is among the most topical demands of a modern packaging enterprise. The artificial intelligence-based solution can automatize consumption of raw materials, reduce the amount of energy consumed, and develop environmentally conscious packaging solutions that would be able to meet the needs of the market. The move to make AI sustainable is also capable of enabling packaging companies to align itself to the global environmental expectations besides fulfilling the rising consumer demands in more eco-friendly products. The goals of the circular economy can be also achieved with the help of smart recycling solutions and AI-based waste management solutions that can not only make the packaging companies more competitive but also form their reputation (Soni *et al.*, 2020).

Collaboration is another important tip that can be considered. Since most SMEs may not have the financial and technical resources to purchase and install such technologies personally, it can be defeated by forming a partnership with technology vendors, larger businesses, and industry organizations. The more AI technologies are distributed in the innovation hubs or on shared digital platforms, the more accessible and less expensive they will be. To provide an example of how SMEs can be helped, AI-based logistics systems created within the sector can reduce the expenditures; simultaneously, promoting the effectiveness. Sharing of knowledge and innovation on a group level is also encouraged by this model of teamwork.

On a higher scale, the development of AI-based Industry 4.0 in the packaging industry depends on policy support and the role of the government. The policymakers should provide certain incentives, such as subsidies, credit schemes, and tax incentives on the firms making investments in AI-based solutions. In the meantime, the legislation must ensure that it is morally sound, privacy of information, and cyber strength. With appropriate policy frameworks, the business nature will be friendly and, in this way, the businesses will be motivated to adopt AI. The government-led innovation centres focusing on the technologies of packaging can be created as well that will motivate the startups and SMEs to experiment with the AI-driven solutions without the prohibitive costs.

And finally, the packaging sector will need to implement AI using a customer-oriented innovation. The artificial intelligence technologies will be capable of telling them what they want, thereby providing them with personal solutions of packaging and developing a stronger brand loyalty. The use of AI to forecast the customer needs will enable the firms to design intelligent packaging that is not only functional, but also incorporates other functionalities such as QR codes, interactive design, real-time product details, etc. This does not only improve consumer experience, but also creates new sources of revenues. The companies that apply AI to be customized and innovative will gain more benefits of creating a competitive edge in the saturated markets.

Lastly, AI should undergo a holistic approach to transformation into Industry 4.0 in the packaging industry, which will rely on the formation of the workforce, incremental deployment, sound data management, sustainability, collaboration, enabling policies, and customer-centred innovations. Under the influence of such recommendations, the packaging firms will be capable of overcoming the current problems and harnessing the opportunities of competitive advantage and growth in the long-term. It not only should be concerned with the transformation of technology but should also strive towards establishing an ecosystem where the individuals, processes, and policies are aligned so that the benefits of AI become self-fulfilling.

Research Gap

Although a lot has been studied on Artificial Intelligence (AI) and Industry 4.0 in the manufacturing, logistics, and supply chain areas, what is a gap is seen in the case of the packaging industry. The existing literature has been identified to provide the general benefits of AI- automation, predictive analytics and operational effectiveness, but normally lacks the specific packaging nature and requirements, including the aspects of the sustainability, customization, and consumer engagement. Lack of industry-specific knowledge implies that it is not clear how well AI can be moulded to the demands of packaging, such as material optimization, environment-friendliness, and regulatory concerns.

The other weak point is the surrounding knowledge on the emerging economies like the Indian market. Even though developed countries have steps already taken to connect AI in Industry 4.0 models, not much literature was discovered regarding the challenges and opportunities of connecting AI with the Indian packaging industry that is largely dominated by SMEs. The issues such as the complexity of cost, unavailability of well qualified manpower, non-availability of advanced technology, and poor digital infrastructure are very seldom examined with much detail. This makes it difficult to develop realistic AI integration models that meet the need of the Indian firms.

Also, the current literature is more focused on the technological component of AI implementation, yet research is seldom conducted on the managerial, organizational, and cultural considerations leading to the successful integration.. In a similar vein, the optimum options of AI based can packaging offer under the larger goals of sustainability, a circular economy practices and customer-centred innovations lack empirical support.

Therefore, the gap in the research will be the opportunities to devise a particular approach to the implementation of AI in Industry 4.0 to the industry of packaging and to the local manufacturing of India in particular. The gap should be filled to show the business, policy-makers and researchers' feasible strategies that would result in the improvement of competitiveness, sustainability and innovation in the industry.

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Chapter-III

Methodology

3.1.Overview of Research Problem

The packaging sector and especially those in the rising economies of the world like India are experiencing a total overhaul that is being driven by Industry 4.0 technologies. Faced with an increasing competitive pressure in the world markets where companies are required to be more efficient, sustainable, customized, and competitive, packaging companies are under extreme pressure to have advanced digital solutions. Being a powerful element of Industry 4.0, AI provides strong temptations to optimize production, improve supply-chain, increase the quality of products, and come up with the packaging designs that ensure being more environmentally friendly. However, regardless of its prospects, the introduction of AI in the packaging industry is limited, disjointed, and filled with critical issues.

Small and medium enterprises dealing with packaging, in particular, are faced with numerous challenges that include high implementation rates, lack of competent staff, concerns regarding the data safety, lack of interest in technological development, and a limited digital infrastructure. These issues hinder the successful implementation of new technologies in the industry. At the same time, there are a lot of opportunities, the ones that are mostly untouched, i.e. predictive maintenance, smart packaging solution, demand forecasting, and environmentally sustainable design. It leads to the dramatic gap in the research: despite the high potential of artificial intelligence as an agent of transformation inside the industry 4.0, at point, there is a lack of empirical information about the actual implementation of artificial intelligence in the packaging industry in mitigating the existing challenges and capitalizing on the opportunities that are presented.

The overall research issue, therefore, is aimed at building the systematic study of the ability of AI-based practice in the framework of Industry 4.0 logic to both alleviate current challenges and exploit current opportunities through the facility to improve efficiency, sustainability, and competitiveness in the packaging segment.

3.2.Operationalizing the theoretical constructs

The theoretical context of the conceptual frameworks explaining the analytical nature of how Artificial Intelligence (AI) can be incorporated to the industry 4.0 paradigm, have a theoretical foundation within the broader academic literature including the technological innovation theory, automation literature, and the socio-technical system theory (Baker, 2012). The industry 4.0 is considered a paradigm shift of the industry, past mechanization, electrification and digitization, and a convergence of cybers-physical systems and Internet of things, robotics, and intelligence which act through information (Handfield, Jeong and Choi, 2019). Within the analytical lens, the industrial players are shifting out of the conventional linear production systems and evolving into ecosystems that are more reliant and intelligent as machines, human operators, and digital platforms collaborate without a glitch.

The question of artificial intelligence in the given theoretical framework is the level of intellectuality in the give-off of the programming task, as well as the ability to assimilate the knowledge of the whole, lifelong learning and objective decision making. Thus, the industrial process can be re-structured with the introduction of AI technologies and it will be transformed not the mechanistic mode of operation but the knowledge-driven one, which is capable of responding dynamically to the alterations in the environment conditions under which it is operated (Madhavi, 2021). The innovation diffusion theory is a theoretical framework in which the process of implementing technologies such as AI in one of the aspects of the industry can be analysed. This paradigm argues that the technological uptake process is sequential by the fact that innovators and early adopters have the ability to preceding adoption that gains momentum in the end and encourages adoption. Using this dynamic to the packaging business refers to the fact that first of all in the market, such AI-based tools like predictive analytics, smart sensors, and automated inspection systems adopted by the largest businesses and then they become popular within the industry in the future. In this theoretical interpretation, the significance of technological readiness, organization culture, and external pressure lies in the process of setting the pace and extent of adoption of AI with the Industry 4.0 paradigm.

A theory applied to understand Industry 4.0 is the systems theory. The analytical view of industrial entities comprises of complex networked entities which are seen as chains of supply, production lines, distribution systems and chain of parts dependency. Industry 4.0 refers to both the establishment of intelligent connection between these subsystems using digital platforms and the analytics based on artificial intelligence. The corresponding sphere of packaging, that has always been considered as a separate and discrete activity in the production milieu is reconfigured as a systems theory (relates to production, logistics, and consumer markets) participating in the process of interaction on the dynamic basis. Artificial intelligence is added to this level of system level integration to enable real-time monitoring and prediction maintenance, as well as production scheduling (Garay-Rondero *et al.*, 2019). The systems theory consequently puts the packaging industry as an indivisible component of a mutually supporting industrial ecosystem that thrives on information flow, cross-linkage and intelligent decision-making.

Resource-based view (RBV) of the firm is another theory that could be used to explain the integration of AI in packaging in Industry 4.0. The theory underlines that developed competitive advantage in the firms is sustainable when unique resources and capabilities are used, which are valuable, rare, inimitable and non-substitutable (Rodríguez-Espíndola *et al.*, 2022). In this regard, AI-powered technologies, including smart design software, automated quality control apps, and consumer insights based on data could be considered as strategic assets, by which firms in vacuously competitive markets maintain a competitive edge. In the case of the packaging business these features not only contribute to the increased efficiency of the operations but also to the possibilities of customization, innovation and added services. This is in line with the theoretical claim that high tech technologies are not simply the means but the critical assets of influence on long-term competitiveness.

The other theory that can be applied is the socio-technical systems theory in which excessive emphasis is placed on the interdependence of the technological systems and human actors. In the case of Industry 4.0, this view field presupposes that successful adoption of AI will depend on the potential of the technological progress in the context of their relevance to the processes within an organization, qualification of the workforce, and cultural integrations (Soni *et al.*, 2020). The theory has a platform upon which it can be used in the packaging processes which require the involvement of designers, engineers, operators, and marketing professionals. The systems driven by AI such as computer vision to locate defects or optimization algorithm to design packaging should be set in a way that helps in the human decision-making process and not fully to do it. The socio-technical perspective emphasizes that automation and human innovativeness should be made equal to ensure that in the situations of the industry 4.0, the limitations of AI in the sub-system of the packaging industry does not eliminate human knowledge (Chalmers, MacKenzie and Carter, 2021).

The theory of dynamic capabilities is particularly applicable as regards strategic management. The dynamic environments in this structure are time-bound and the companies must have mechanisms that enable them to amass, build and rebuilding the internal and external capabilities. This dynamic environment is evident within the packaging industry which incorporates production, logistics and interaction with consumers (Jain, 2019). Industry 4.0 based on AI can assist companies to develop dynamic capabilities due to the ever-changing the packaging process to address needs of consumers, regulatory, as well as sustainability goals. One such example is the ability to make companies reform the packaging materials and constructions in accordance with real-time information on the market and environment. This theoretical model demonstrates the disruptive and responsive effect of AI on helping the packaging industry to be resilient and responsive.

Finally, but not the least, the speculation of the AI and Industry 4.0 transforming the packaging can be made through value chain theory. Packaging has always been viewed as the upstream activity of the value chain in the downstream part of the value chain. However, Industry 4.0 repackaging is reformulated as a strategic component as well as a direct value creator. Using the conglomeration of AI, packaging might influence different sections of the value chain procedure, including production efficiency, quality, distribution, and the consumer experience (Geisel, 2018). This repositioning is associated with the theoretical causes, which are the elimination of traditional boundaries in the value chain of digital technologies, and every step of the chain can be turned into a source of differentiation and the value-creating.

Overall, the theoretical background of the provided piece is founded on a variety of theories including the innovation diffusion theory, the systems theory, the resource-based view, the socio-technical systems theory, the dynamic capabilities, the theory of value chain. All these opinions provide us with many dimensional explanations of the implications of the packaging industry by AI and Industry 4.0. They are concerned with its strategic, operational, and human facets of technological incorporation through which, packaging is no longer perceived as an unadulterated technical need but as a revolution of its very own; the crossroad, in industrial development, of intelligence and worth generating.

3.3.Research Purpose

The main purpose of the research is to explore the challenges and opportunities of Artificial Intelligence (AI) as a core aspect of Industry4.0 with the purpose of enabling its effective introduction in the packaging industry to overcome the existing challenges and use the forthcoming opportunities. The study aims to outline the barriers to AI implementation, which include cost factors, skills shortage, lack of infrastructures, and simultaneously the possible benefits, including the efficiency in operations, the introduction of smart packaging, increased sustainability, and the increased competitiveness in the market. The study aims at analyzing the dynamics by a critical review and review of secondary sources and peer reviewed literature, which will consequently produce a unified view on how AI changes the packaging industry. Its overall goal is to produce initiatives and suggestions to act upon to inform industry, policymakers and corporate players in strategic implementation of AI resulting in innovation, sustainability, and growth within the packaging sector.

3.3.1. Research Questions

- To identify and analyse factors affecting artificial intelligence adoption in the packaging industry in India.
- To examine the challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India.
- To examine the opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India.
- To provide suitable recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry.

3.3.2. Hypothesis of the study

- **H01:** There are no significant key factors affecting artificial intelligence adoption in the packaging industry in India.
- **Ha1:** There are significant key factors affecting artificial intelligence adoption in the packaging industry in India.

- **H02:** There are no significant challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India.

- **Ha2:** There are significant challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India.

- **H03:** There are no significant opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India.
- **Ha3:** There are significant opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India.

- **H04:** There are no significant recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry.
- **Ha4:** There are significant recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry.

3.4.Research Design

The existing study adopts a decriptive and exploratory approach supported by quantitative research design to assess the integration of AI into industry 4.0 to address challenges and opportunities in packaging industry in india. Moreover, purposive sampling method is applied in the study

3.5.Sampling Design

(i) Respondents' Type: - The respondents for current study are employees from packaging industry of Small and Medium Sized Enterprises (SMEs) from India. The cities selected for survey from India are Bangalore, Delhi and Hyderabad. Therefore, Bangalore, Delhi and Hyderabad are universe for current research.

(ii) Sampling technique: - In this study respondents are randomly selected using purposive sampling techniques.

(iii) Sample size: - 600 employees from packaging industry from three distinctive cities of India are selected. Total Population of employees in 50 SMEs found to be: 4,23,458.

(iv) Determination of Sample Size:

Determining the sample size using **Cochran's formula**:

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{e^2 + \left(\frac{Z^2 \cdot p \cdot (1-p)}{N}\right)}$$

Where:

- $Z = 1.96$ (Z-score for a 95% confidence level)
- $p = 0.5$ (assumed proportion)
- $e = 0.05$ (margin of error)
- N= 4,23,458

The sample size is approximately **384**. For existing study, the sample size is decided **600** as more the sample size more will be conclusive and accurate results.

S.No.	Name of City	Total population of Buyers in Real Estate	Number of respondents selected for data collection
1.	Bangalore	216785	200
2.	Delhi	147060	200
3.	Hyderabad	59613	200
Total		4,23,458	600

3.6.Participant Selection

The participant for current study is employees from packaging industry of Small and Medium Sized Enterprises (SMEs) from India. The cities selected for survey from India are Bangalore, Delhi and Hyderabad.

3.7.Instrumentation

For quantitative analysis Statistical Package for Social Sciences (SPSS) software version 23.0 used.

3.8. Data Collection Procedures

3.8.1. Questionnaire design: Based on 5-point Likert scale, responses from strongly agree to strongly disagree applied in the study. Self-structured questionnaire adopted in the current study.

3.8.2. Sources of data

(i) **Primary data:** The existing study adopts both descriptive and exploratory approach. Therefore, survey is conducted and responses collected from self-structured questionnaire filled by employees of 50 SMEs of packaging industry.

(ii) **Secondary data:** Secondary data collected for the purpose of doing extensive literature survey based on prior research work from published research articles, working papers, published thesis, conference papers, books, authentic reports, websites.

3.9.Tools and techniques of data analysis

SPSS 26.0 version is used to obtain results from the coding sheet after addressing the missing values. Various statistical tools of SPSS applied to provide quantitative information for concepts clarity.

Details of Tools applied in data analysis

1. **Frequency and percentage Method:** Frequency and percentage distribution used to determine the percentage usually for data on profile (age, occupation, gender, marital status tec.)

Formula:

$$\% = \frac{f}{N} \times 100$$

Where: % = Percent
f = Frequency
N = Number of cases

2. **Mean:**

The *mean* is the average or the most common value in a collection of numbers. The mean (average) of a data set is found by adding all numbers in the data set and then dividing by the number of values in the set.

$$\text{Mean} = \frac{\text{Sum of All Data Points}}{\text{Number of Data Points}}$$

$$\text{Mean} = \text{Assumed Mean} + \frac{\text{Sum of All Deviations}}{\text{Number of Data Points}}$$

3. Standard Deviation

The *standard deviation* is a *statistic* that measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance.

$$\sigma = \sqrt{\frac{\sum (x - \overline{x})^2}{n}}$$

σ = standard deviation

$\sum$ = sum of

x = each value in the data set

$\overline{x}$ = mean of all values in the data set

n = number of value in the data set

4. T test

A t-test is a statistical test that is used to compare the means of two groups. It is often used in hypothesis testing to determine whether a process or treatment actually has an effect on the population of interest, or whether two groups are different from one another.

Type	T-statistic	Degrees of freedom
One-sample t-test	$t = \dfrac{\overline{x} - \mu_0}{s/\sqrt{n}}$	df = n – 1
Paired t-test	$t = \dfrac{\overline{X}_D - \mu_0}{s_D/\sqrt{n}}.$	df = n – 1

5. Chi-square Test

The Chi-Square analysis is most frequently used to estimate condition of Independence test while applying a crosstabulation also referred as a bivariate table. Crosstabulation helps in assessing the dispersals of two categorical variables at once, with the connections of the groups of the variables appearing in the cells assembled in the bivariate table. The Independence test measures whether a relationship among the two variables by relating the responses from observed pattern in the cells to the responses from expected pattern if the variables were truly independent of each other. Assessing the Chi-Square statistic and then comparing it in contrast to a critical value from the distribution of Chi-square permits the scholars to measure whether the observed cell totals are significantly unlike from the expected cell totals.

An assessment of the Chi-Square analysis is quite straight-forward and also based on intuition. The formula of Chi-square is as follows:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

X^2= The test static

$\sum$= The sum of

O= Observed frequency

E= Expected frequency

As represented in the above formula, the Chi-Square analysis based on the difference between what is the actual observed frequency in the data and what would be expected frequency if there was no association exist among the variables.

6. Correlation Analysis

Correlation test is used to evaluate the association between two or more variables. Correlation coefficients are used to measure how strong a relationship is between two variables.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

7. Regression Analysis

In statistical modeling, regression analysis is a set of statistical processes for estimating the relationships between a dependent variable and one or more independent variables.

$$Y = a + bX$$

$$b = \frac{N\sum XY - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X)^2} \qquad a = \frac{\sum Y - b\sum X}{N}$$

Where,
N = number of observations, or years
X = a year index (decade)
Y = population size for given census years

8. ANOVA

Analysis of variance (ANOVA) is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyse the differences among group means in a sample.

9. Exploratory Factor Analysis:

Exploratory factor analysis (EFA) and structural equation modeling (SEM) are techniques commonly used in the field of language assessment. EFA is a data-driven approach which is generally used as an investigative technique to identify relationships among variables.

3.10. Limitations of the Study

- Three cities, namely, Bangalore, Delhi and Hyderabad were only possible for survey.
- 600 employees and only 50 SMEs of packaging industry taken for study.
- Only packaging industry is explored in the current research.

Conclusion

The current study can be deemed significant because of a contribution to a growing body of academic knowledge that addresses the implementation of the Artificial Intelligence (AI) on the industry 4.0 platform, along with its usage in the packaging sector. Packaging industry serves as a critical facilitator of business operations in the sphere of fast-moving consumer goods (FMCG), pharmaceuticals, food, and e-commerce and is persistently challenged in the effort to streamline business operations, maintain environmental care, and comply with the changing consumer demands. The exploration, in relation to the ability of AI to alleviate the existing obstacles, such as pressure on costs, lack of quality control, waste, and performance limitations in the supply-chain management, provides the informative ground on the strategies contributing to the enhancement of operational efficiency and supporting competitive positioning.

This research has a great practical relevance to packaging small and medium enterprises (SMEs) which often suffer from limited resources and limited technology adoption. By identifying opportunities, such as predictive analytics, intelligent packaging systems and environmentally sustainable innovations, this research provides a guide for SMEs to utilize artificial intelligence in their efforts to grow and become more sustainable. Moreover, the insights are useful to policymakers, industry leaders, as well as technology providers, for the development of supportive frameworks and strategies that enable digital transformation. From an academic perspective, the current research helps fill a substantive gap by systematically investigating challenges and prospects related to AI in packaging to provide a basis for later empirical and applied research.

CHAPTER-IV

RESULTS

This chapter is number 4 which discusses results section. For results execution and interpretation of that results, various statistical tools applied. For objective 1, tools such as reliability statistics, descriptive statistics, correlation analysis and regression analysis tools applied. For objective 2 and 3 exploratory factor analysis which includes, KMO Bartlett test of Sphericity, communalities, total variance explained and rotated component matrix applied. For objective 4, reliability statistics, descriptive statistics, t test, ANOVA and Chi-square test applied. After application of statistical test from SPSS Version 26., hypothesis test is conducted and summary and conclusion are discussed. The result section is divided into two parts. First part delas with demographic analysis and second part deals with factors, challenges, opportunities and recommendations related to study's context.

AGE DISTRIBUTION TABLE

PART-I

Age Distribution	Frequency	Percentage
Below 25 years	118	19.67%
25 to 35 years	197	32.83%
36 to 45 years	179	29.83%
Above 45 years	106	17.67%

AGE DISTRIBUTION BAR GRAPH

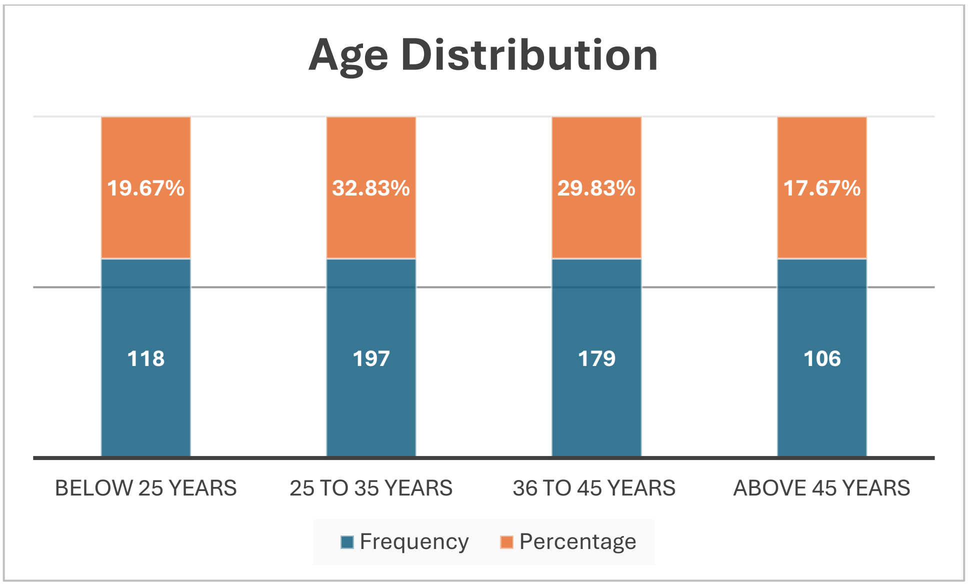


Table 4.1 analysed the demographic statistics factor of age distribution and stated that majority of respondents comes under the age range of 25 to 35 years (N=197, 32.83%) followed by 36 to 45 years (N=179, 29.83%). Age range of above 45 years (N=106, 17.67%) found to be least in the study.

GENDER FREQUENCY AND PERCENTAGE TABLE

Gender	Frequency	Percentage
Male	363	60.50%
Female	237	39.50%

GENDER FREQUENCY AND PERCENTAGE BAR GRAPH

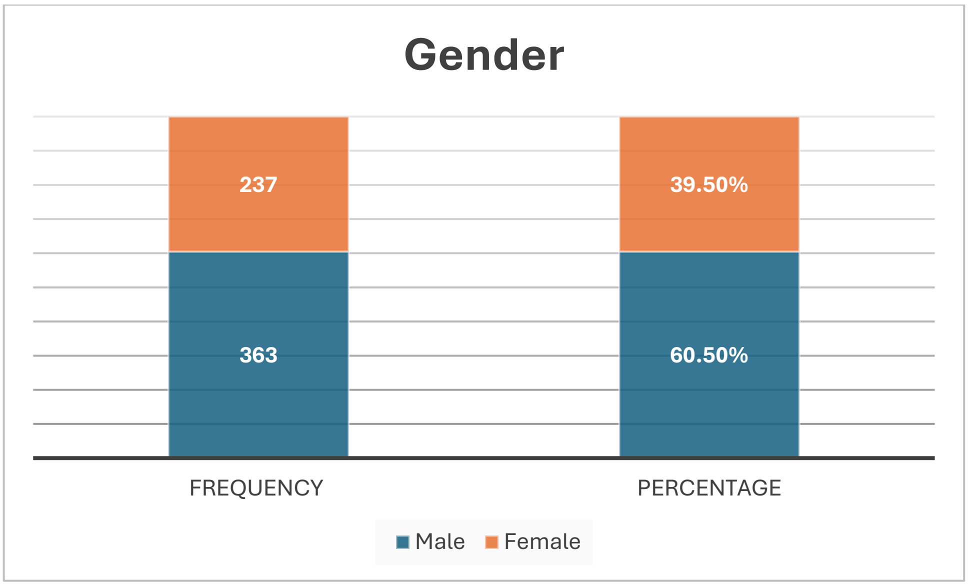


Table 4.2 analysed the second factor of demographics which is gender. The study assessed gender distribution and stated that majority of respondents in the study are Male (N=363, 60.50%). Only few female (N=237, 39.50%) found to be participative in the study.

MARITAL STATUS TABLE

Marital Status	Frequency	Percentage
Single	236	39.33%
Married	257	42.83%
Others	107	17.83%

MARITAL STATUS BAR GRAPH

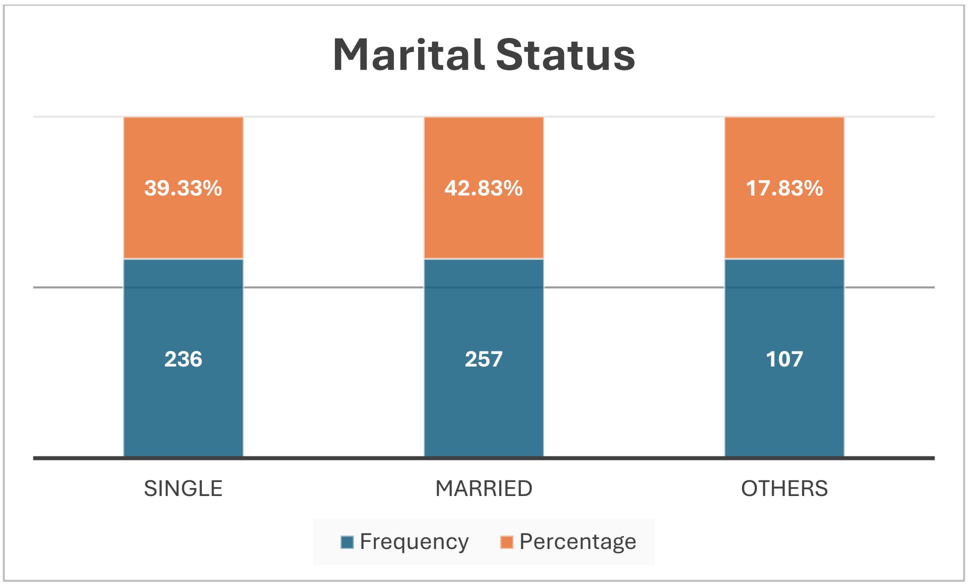


Table 4.3 analysed the marital status which is the third factor of demographic analysis. The findings of marital status stated that majority of respondents in the study are married (N=257, 42.83%) followed by single status (N=236, 39.33%). Others (N=107, 17.83%) found to be least in the study.

EDUCATIONAL QUALIFICATION TABLE

Educational Qualification	Frequency	Percentage
Below Graduate	165	27.50%
Graduate	138	23%
Post Graduate	238	39.67%
Above Post Graduate	59	9.83%

EDUCATIONAL QUALIFICATION BAR GRAPH

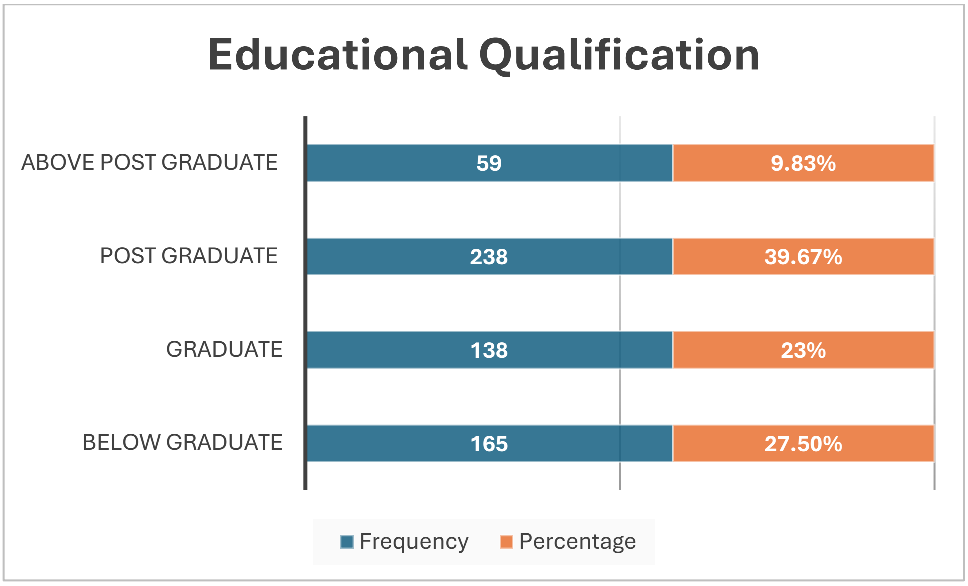


Table 4.4 analysed the educational qualification which the fourth demographic factor in the study. The results of educational qualification assessed that majority of respondents in the study are post graduate (N=238, 39.67%) followed by below graduate (N=165, 27.50%). Above post graduate (N=59, 9.83%) found to be least participative in the study.

MONTHLY INCOME TABLE

Monthly Income (in Rs.)	Frequency	Percentage
Below 45,000	96	16%
45,001 to 55000	213	35.50%
55001 to 65000	252	42%
Above 65000	39	6.50%

MONTHLY INCOME BAR GRAPH

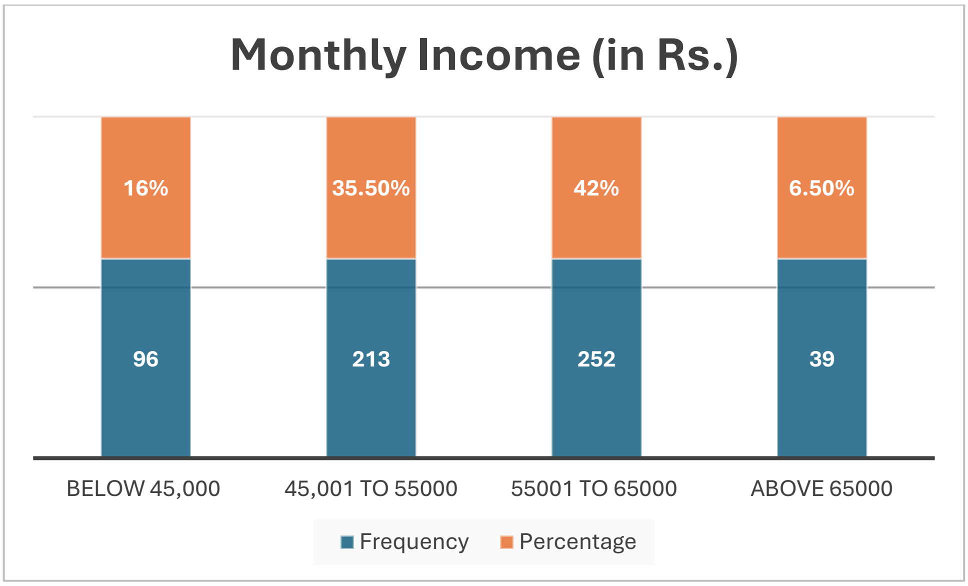


Table 4.5 analysed the monthly income (in Rs.) which is found to be the fifth demographic factor of the study. The majority of respondents in the study found to be having monthly income of Rs. 55001 to 65000 (N=252, 42%) followed by Rs. 45,001 to 55000 (N=213, 35.50%). Above 65000 (N=39, 6.50%) found to be the least monthly income range of respondents.

YEAR OF EXPERIENCE TABLE

Years of experience in packaging industry	Frequency	Percentage
Less than 1 year	32	5.33%
2 to 5 years	211	35.16%
6 to 10 years	204	34%
More than 10 years	153	25.50%

YEAR OF EXPERIENCE BAR GRAPH

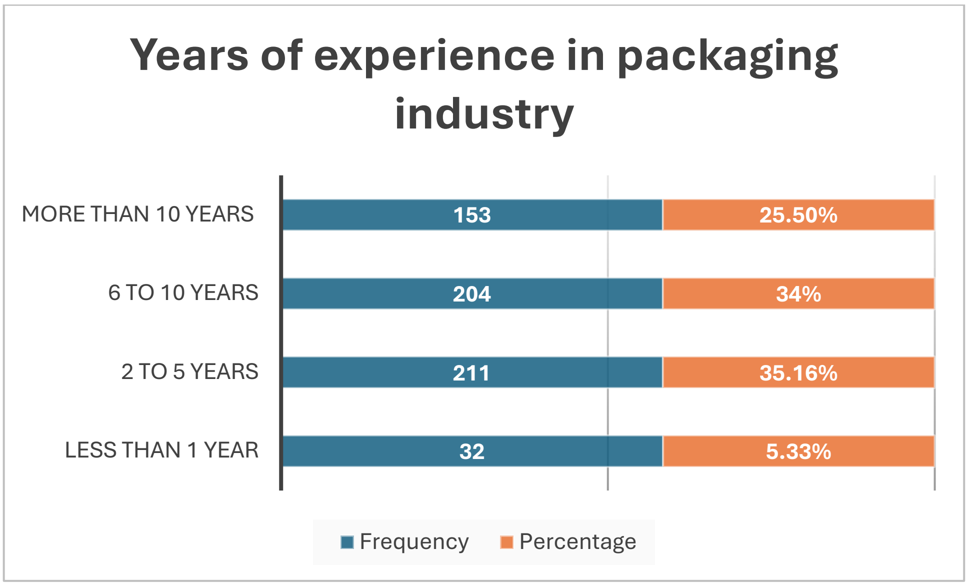


Table 4.6 assessed years of experience that respondents having in packaging industry. The findings of the study stated that majority of respondents having 2 to 5 years (N=211, 35.16%) of experience in packaging industry followed by 6 to 10 years (N=204, 34%). Less than 1 year of experience (N=32, 5.33%) found to be least in the study.

TYPE OF FAMILY TABLE

Type of Family	Frequency	Percentage
Nuclear Family	398	66.33%
Joint Family	202	33.67%

TYPE OF FAMILY BAR GRAPH

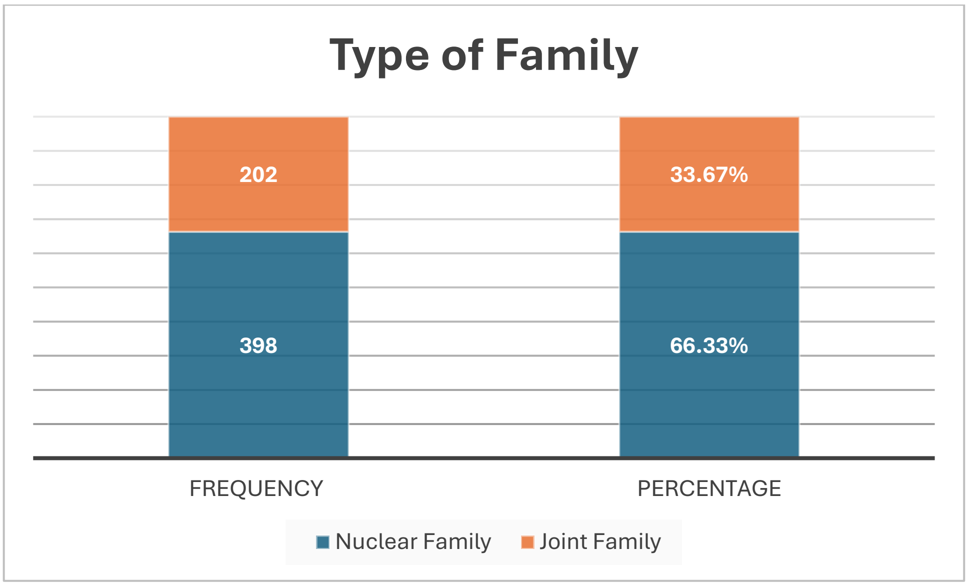


Table 4.7 analysed the type of family demographic factor in the existing study. The results of the study stated that majority of respondents in the study belongs to nuclear family (N=398, 66.33%). Only few belongs to joint family (N=202, 33.67%).

SIZE OF FAMILY TABLE

Size (no. of persons in your family)	Frequency	Percentage
2	313	52.16%
3 to 6	112	18.67%
6 to 9	99	16.50%
More than 9	76	12.67%

TYPE OF FAMILY BAR GRAPH

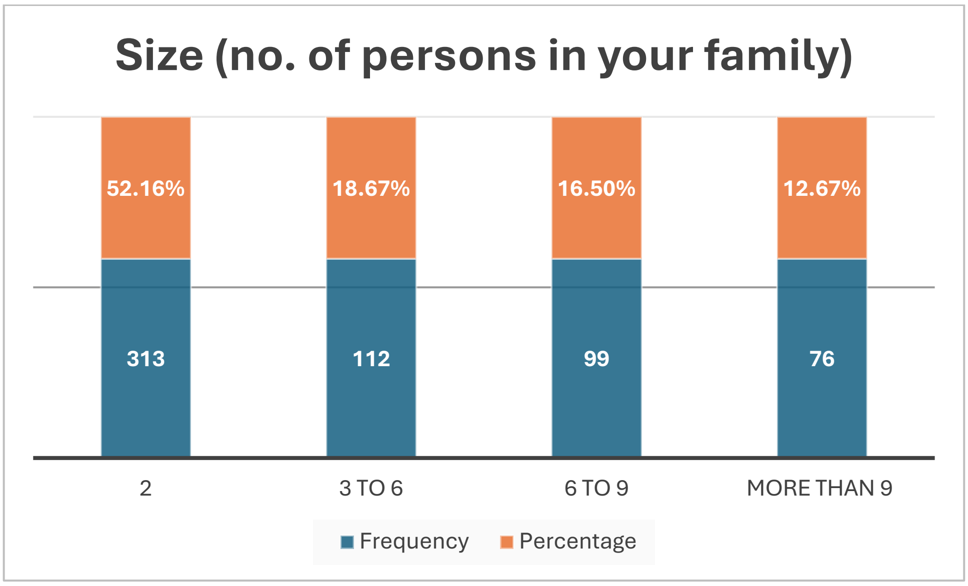


Table 4.8 analysed the size that is number of persons in respondents' family and stated that only 2 members (N=313, 52.16%) followed by 3 to 6 members (N=112, 18.67%) size found in the study. More than 9 members (N=76, 12.67%) found to be least in size in the study.

PART-II

RELIABILITY STATISTICS TABLE

Reliability Statistics	
Cronbach's Alpha	N of Items
0.765	3

Table 4.9 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.765 (N=3), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DESCRIPTIVE STATISTICS TEST TABLE

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Yes familiar	600	1	5	4.05	0.871
Moderate familiar	600	1	5	4.00	0.905
Not familiar	600	1	5	3.53	1.114
Valid N (listwise)	600				

Table 4.10 analysed the statistical test of descriptive analysis related to the use of industry 4.0 technologies and findings of the study stated that majority of respondents reply "Yes" (Mean=4.05 and Standard Deviation= 0.871) that they are familiar with the concept of use of industry 4.0 in their SMEs followed by "moderate familiar" (Mean=4.00 and Standard

Deviation=0.905). “Not familiar” (Mean=3.53 and Standard Deviation=1.114) found to be least in the study. Therefore, the results of the study related to the use of industry 4.0 technologies stated that majority of respondents are familiar with the use of industry 4.0.

ONE SAMPLE STATISTICS TEST TABLE

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Yes familiar	600	4.05	.871	.036
Moderate familiar	600	4.00	.905	.037
Not familiar	600	3.53	1.114	.045

Table 4.11 analysed the statistical test of one sample test related to the use of industry 4.0 technologies and findings of the study stated that majority of respondents reply “Yes” (Mean=4.05 and Standard Deviation= 0.871 and Standard error= .036) that they are familiar with the concept of use of industry 4.0 in their SMEs followed by “moderate familiar” (Mean=4.00 and Standard Deviation=0.905 and Standard error=.037). “Not familiar” (Mean=3.53 and Standard Deviation=1.114 and Standard error=.045) found to be least in the study. Therefore, the results of the study related to the use of industry 4.0 technologies stated that majority of respondents are familiar with the use of industry 4.0.

ONE SAMPLE TEST TABLE

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Yes familiar	114.007	599	.000	4.053	3.98	4.12
Moderate familiar	108.087	599	.000	3.995	3.92	4.07
Not familiar	77.693	599	.000	3.533	3.44	3.62

Table 4.12 analysed the statistical test of t test related to the use of industry 4.0 technologies and findings of the study stated that majority of respondents reply “Yes” (t=114.007) that they are familiar with the concept of use of industry 4.0 in their SMEs followed by “moderate familiar” (t=108.087). “Not familiar” (t=77.693) found to be least in the study. Therefore, the results of the study related to the use of industry 4.0 technologies stated that majority of respondents are familiar with the use of industry 4.0.

ANOVA TEST TABLE

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Yes familiar	Between Groups	28.711	4	7.178	10.023	.000
	Within Groups	424.682	593	.716		
	Total	453.393	597			
Moderate familiar	Between Groups	38.743	4	9.686	12.757	.000
	Within Groups	450.216	593	.759		
	Total	488.958	597			
Not familiar	Between Groups	44.063	4	11.016	9.402	.000
	Within Groups	694.768	593	1.172		
	Total	738.831	597			

Table 4.13 analysed the ANOVA analysis and results of the study stated that estimated value of ANOVA (N=0.000) found to be less than the acceptable threshold limit of 0.005. Hence, all the selected variables are significant in the study.

EXPOSURE TO AI TABLE

organisation used AI-based solutions in packaging operations	Frequency	Percentage
YES	438	73%
NO	162	27%

EXPOSURE TO AI BAR GRAPH

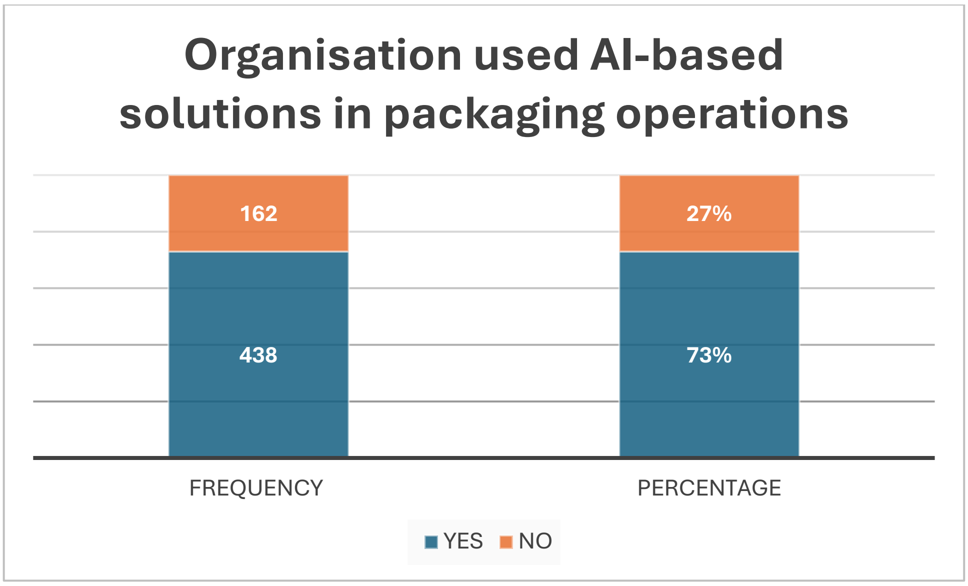


Table 4.14 analysed that whether the organisation of respondents use artificial intelligence-based solutions in packaging operations and the results of the study stated that majority of respondents replied “yes” (N=438, 73%). Only few replied “no” (N=162, 27%).

RELIABILITY STATISTIC TEST TABLE

Reliability Statistics	
Cronbach's Alpha	N of Items
0.782	6

Table 4.15 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.782 (N=6), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DESCRIPTIVE STASTICS TEST TABLE

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Quality management and fault detection	600	1	5	4.05	.871
Anticipated machine maintenance	600	1	5	4.00	.905
Individual design/customizing of packaging	600	1	5	3.53	1.114
Optimization of the supply chain and inventory	600	1	5	4.39	.727
Green and environmental conservation	600	1	5	4.25	.782

Experience with customers	600	1	5	3.90	.941
Valid N (listwise)	600				

Table 4.16 analysed the statistical test of descriptive analysis related to the areas where AI technologies currently applied in respondents' organization and findings of the study stated that "Optimization of the supply chain and inventory" (Mean=4.39 and Standard Deviation=.727) followed by "Green and environmental conservation" (Mean=4.25 and Standard Deviation=.782) are the areas where AI technologies currently applied in respondents' organization. "Individual design/customizing of packaging" (Mean=3.53 and Standard Deviation=1.114) found to be least area where AI technologies are currently applied. Therefore, the results of descriptive statistics related to the areas where AI technologies currently applied in respondents' organization stated that supply chain and inventory are the areas where AI is currently applied in respondents' organisation.

ONE SAMPLE STATITICS TABLE

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Quality management and fault detection	600	4.05	.871	.036
Anticipated machine maintenance	600	4.00	.905	.037
Individual design/customizing of packaging	600	3.53	1.114	.045
Optimization of the supply chain and inventory	600	4.39	.727	.030
Green and environmental conservation	600	4.25	.782	.032
Experience with customers	600	3.90	.941	.038

Table 4.17 analysed the statistical test of one sample analysis related to the areas where AI technologies currently applied in respondents' organization and findings of the study stated that "Optimization of the supply chain and inventory" (Mean=4.39 and Standard Deviation=.727 and Standard Error= .030) followed by "Green and environmental conservation" (Mean=4.25

and Standard Deviation=.782 Standard Error=.032) are the areas where AI technologies currently applied in respondents' organization. "Individual design/customizing of packaging" (Mean=3.53 and Standard Deviation=1.114 Standard Error=.045) found to be least area where AI technologies are currently applied. Therefore, the results of descriptive statistics related to the areas where AI technologies currently applied in respondents' organization stated that supply chain and inventory are the areas where AI is currently applied in respondents' organisation.

ONE SAMPLE TEST TABLE

One-Sample Test						
	Test Value = 0					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Quality management and fault detection	114.007	599	.000	4.053	3.98	4.12
Anticipated machine maintenance	108.087	599	.000	3.995	3.92	4.07
Individual design/customizing of packaging	77.693	599	.000	3.533	3.44	3.62
Optimization of the supply chain and inventory	147.878	599	.000	4.390	4.33	4.45
Green and environmental conservation	133.179	599	.000	4.254	4.19	4.32
Experience with customers	101.391	599	.000	3.895	3.82	3.97

Table 4.18 analysed the statistical test of t test analysis related to the areas where AI technologies currently applied in respondents' organization and findings of the study stated that "Optimization of the supply chain and inventory" (t=147.878) followed by "Green and environmental conservation" (t=133.179) are the areas where AI technologies currently applied in respondents' organization. "Individual design/customizing of packaging" (t=77.693) found to be least area where AI technologies are currently applied. Therefore, the results of descriptive statistics related to the areas where AI technologies currently applied in

respondents' organization stated that supply chain and inventory are the areas where AI is currently applied in respondents' organisation.

ANOVA TEST TABLE

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Quality management and fault detection	Between Groups	29.968	4	7.492	10.505	.000
	Within Groups	424.326	595	.713		
	Total	454.293	599			
Anticipated machine maintenance	Between Groups	18.606	4	4.652	5.859	.000
	Within Groups	472.379	595	.794		
	Total	490.985	599			
Individual design/customizing of packaging	Between Groups	15.871	4	3.968	3.245	.012
	Within Groups	727.462	595	1.223		
	Total	743.333	599			
Optimization of the supply chain and inventory	Between Groups	60.167	4	15.042	34.882	.000
	Within Groups	256.573	595	.431		
	Total	316.740	599			
Green and environmental conservation	Between Groups	65.908	4	16.477	32.676	.000
	Within Groups	299.521	594	.504		
	Total	365.429	598			
Experience with customers	Between Groups	81.097	4	20.274	26.849	.000
	Within Groups	449.288	595	.755		
	Total	530.385	599			

Table 4.19 analysed the ANOVA analysis and results of the study stated that estimated value of ANOVA (N=0.000) found to be less than the acceptable threshold limit of 0.005 in all cases except with the variable "Individual design/customizing of packaging" (N=0.012). Hence, all the selected variables are significant in the study except Individual design/customizing of packaging.

RELIABILITY STATITICS TEST TABLE

Reliability Statistics	
Cronbach's Alpha	N of Items
0.873	20

Table 4.20 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.873 (N=20), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DESCRIPTIVE STATISTICS TEST TABLE

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Large implementation and maintenance costs	600	1	5	4.55	.883
Access to talented labour in artificial intelligence and digital technologies	600	1	5	4.36	.783
Security and privacy issues with data	600	1	5	4.16	.814
Resistance to change in the organization	600	1	5	3.80	.974
Management support and leadership dedication	600	1	5	3.18	1.151

Uncertainty on Return on Investment (ROI)	600	1	5	4.51	.724
Infrastructure and technology preparedness	600	1	5	3.78	1.013
Coherence with already in place machines and systems	600	1	5	4.62	.619
Policies and regulatory structures of the government	600	1	5	4.50	.693
Commercial aid and subsidies	600	1	5	4.04	.965
Cooperation with technology suppliers	600	1	5	4.12	.807
The availability of industry-specific AI applications	600	1	5	4.09	.894
Demand of customized/smart packaging by consumers	600	1	5	4.12	.856
The demand to use eco-friendly and sustainable packaging	600	1	5	4.18	.743
Competitiveness in the market and international competitiveness	600	1	5	4.34	.632
Ethical issues of AI decision making	600	1	5	4.38	.655
Industry 4.0 and AI knowledge and awareness regarding their benefits	600	1	5	4.35	.720

Availability of high-quality big data to make AI-based decisions	600	1	5	4.42	.644
AI investments have a long payback period	600	1	5	4.18	.814
Cultural factors (employee attitude, fear of loss of job)	600	1	5	4.39	.619
Valid N (listwise)	600				

Table 4.21 analysed the descriptive statistics related to factors affecting AI adoption in the packaging industry "Coherence with already in place machines and systems" (Mean=4.62 and Standard Deviation=.619) followed by "Large implementation and maintenance costs" (Mean=4.55 and Standard Deviation=.883) are the key factors influencing AI adoption in packaging industry. "Management support and leadership dedication" (Mean=3.18 and Standard Deviation= 1.151) found be the least influencing factor influencing AI adoption in the packaging industry. Therefore, the results of descriptive analysis related to key factors influencing AI adoption in the packaging industry found to be consistency among machines and systems and implementation and maintenance costs.

ONE SAMPLE STATISTICS TEST TABLE

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Large implementation and maintenance costs	600	4.55	.883	.036
Access to talented labour in artificial intelligence and digital technologies	600	4.36	.783	.032
Security and privacy issues with data	600	4.16	.814	.033
Resistance to change in the organization	600	3.80	.974	.040

Management support and leadership dedication	600	3.18	1.151	.047
Uncertainty on Return on Investment (ROI)	600	4.51	.724	.030
Infrastructure and technology preparedness	600	3.79	1.013	.041
Coherence with already in place machines and systems	600	4.62	.619	.025
Policies and regulatory structures of the government	600	4.50	.693	.028
Commercial aid and subsidies	600	4.04	.965	.039
Cooperation with technology suppliers	600	4.12	.807	.033
The availability of industry-specific AI applications	600	4.09	.894	.036
Demand of customized/smart packaging by consumers	600	4.12	.856	.035
The demand to use eco-friendly and sustainable packaging	600	4.18	.743	.030
Competitiveness in the market and international competitiveness	600	4.34	.632	.026
Ethical issues of AI decision making	600	4.38	.655	.027

Industry 4.0 and AI knowledge and awareness regarding their benefits	600	4.35	.720	.029
Availability of high-quality big data to make AI-based decisions	600	4.42	.644	.026
AI investments have a long payback period	600	4.18	.814	.033
Cultural factors (employee attitude, fear of loss of job)	600	4.39	.619	.025

Table 4.22 assessed the one sample statistics related to factors affecting AI adoption in the packaging industry "Coherence with already in place machines and systems" (Mean=4.62 and Standard Deviation=.619 and Standard Error= .025) followed by "Large implementation and maintenance costs" (Mean=4.55 and Standard Deviation=.883 and Standard Error= .036) are the key factors influencing AI adoption in packaging industry. "Management support and leadership dedication" (Mean=3.18 and Standard Deviation= 1.151 and Standard Error=.047) found be the least influencing factor influencing AI adoption in the packaging industry. Therefore, the results of one sample analysis related to key factors influencing AI adoption in the packaging Industry found to be consistency among machines and systems and implementation and maintenance costs.

ONE SAMPLE TEST TABLE

One-Sample Test						
	Test Value = 0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Large implementation and maintenance costs	180.624	599	.000	4.133	4.06	4.20

Access to talented labour in artificial intelligence and digital technologies	136.583	599	.000	4.363	4.30	4.43
Security and privacy issues with data	125.023	599	.000	4.157	4.09	4.22
Resistance to change in the organization	95.479	599	.000	3.795	3.72	3.87
Management support and leadership dedication	67.734	599	.000	3.183	3.09	3.28
Uncertainty on Return on Investment (ROI)	152.596	599	.000	4.510	4.45	4.57
Infrastructure and technology preparedness	91.480	599	.000	3.785	3.70	3.87
Coherence with already in place machines and systems	182.562	599	.000	4.617	4.57	4.67
Policies and regulatory structures of the government	159.026	599	.000	4.502	4.45	4.56
Commercial aid and subsidies	102.477	599	.000	4.038	3.96	4.12
Cooperation with technology suppliers	124.996	599	.000	4.117	4.05	4.18
The availability of industry-specific AI applications	112.067	599	.000	4.088	4.02	4.16
Demand of customized/smart packaging by consumers	117.890	599	.000	4.118	4.05	4.19
The demand to use eco-friendly and sustainable packaging	137.829	599	.000	4.180	4.12	4.24

Competitiveness in the market and international competitiveness	168.378	599	.000	4.342	4.29	4.39
Ethical issues of AI decision making	163.693	599	.000	4.378	4.33	4.43
Industry 4.0 and AI knowledge and awareness regarding their benefits	147.981	599	.000	4.352	4.29	4.41
Availability of high-quality big data to make AI-based decisions	168.217	599	.000	4.422	4.37	4.47
AI investments have a long payback period	125.838	599	.000	4.180	4.11	4.25
Cultural factors (employee attitude, fear of loss of job)	173.966	599	.000	4.395	4.35	4.44

Table 4.23 analysed t test related to factors affecting AI adoption in the packaging industry "Coherence with already in place machines and systems" (t=182.562) followed by "Large implementation and maintenance costs" (t=180.624) are the key factors influencing AI adoption in packaging industry. "Management support and leadership dedication" (t=67.734) found be the least influencing factor influencing AI adoption in the packaging industry. Therefore, the results of t test analysis related to key factors influencing AI adoption in the packaging industry found to be consistency among machines and systems and implementation and maintenance costs.

ANOVA TEST TABLE

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Large implementation and maintenance costs	Between Groups	35.017	4	8.754	12.048	.000
	Within Groups	432.317	595	.727		
	Total	467.333	599			
Access to talented labour in artificial intelligence and digital technologies	Between Groups	12.350	4	3.088	5.183	.000
	Within Groups	354.443	595	.596		
	Total	366.793	599			
Security and privacy issues with data	Between Groups	26.654	4	6.663	10.698	.000
	Within Groups	370.620	595	.623		
	Total	397.273	599			
Resistance to change in the organization	Between Groups	30.942	4	7.735	8.573	.000
	Within Groups	536.843	595	.902		
	Total	567.785	599			
Management support and leadership dedication	Between Groups	24.254	4	6.064	4.688	.001
	Within Groups	769.579	595	1.293		
	Total	793.833	599			
Uncertainty on Return on Investment (ROI)	Between Groups	17.704	4	4.426	8.890	.000
	Within Groups	296.236	595	.498		
	Total	313.940	599			

Infrastructure and technology preparedness	Between Groups	50.232	4	12.558	13.224	.000
	Within Groups	565.033	595	.950		
	Total	615.265	599			
Coherence with already in place machines and systems	Between Groups	15.583	4	3.896	10.819	.000
	Within Groups	214.250	595	.360		
	Total	229.833	599			
Policies and regulatory structures of the government	Between Groups	15.707	4	3.927	8.581	.000
	Within Groups	272.291	595	.458		
	Total	287.998	599			
Commercial aid and subsidies	Between Groups	42.477	4	10.619	12.254	.000
	Within Groups	515.642	595	.867		
	Total	558.118	599			
Cooperation with technology suppliers	Between Groups	56.443	4	14.111	25.183	.000
	Within Groups	333.391	595	.560		
	Total	389.833	599			
The availability of industry-specific AI applications	Between Groups	67.484	4	16.871	24.434	.000
	Within Groups	410.834	595	.690		
	Total	478.318	599			
Demand of customized/smart packaging by consumers	Between Groups	49.613	4	12.403	18.972	.000
	Within Groups	388.985	595	.654		
	Total	438.598	599			
The demand to use eco-friendly and sustainable packaging	Between Groups	45.484	4	11.371	23.733	.000
	Within Groups	285.076	595	.479		
	Total	330.560	599			
Competitiveness in the market and international competitiveness	Between Groups	33.497	4	8.374	24.251	.000
	Within Groups	205.462	595	.345		
	Total	238.958	599			
Ethical issues of AI decision making	Between Groups	35.101	4	8.775	23.518	.000
	Within Groups	222.017	595	.373		
	Total	257.118	599			
Industry 4.0 and AI knowledge and	Between Groups	40.392	4	10.098	22.219	.000

awareness regarding their benefits	Within Groups	270.407	595	.454		
	Total	310.798	599			
Availability of high-quality big data to make AI-based decisions	Between Groups	37.246	4	9.312	26.249	.000
	Within Groups	211.072	595	.355		
	Total	248.318	599			
AI investments have a long payback period	Between Groups	69.255	4	17.314	31.474	.000
	Within Groups	327.305	595	.550		
	Total	396.560	599			
Cultural factors (employee attitude, fear of loss of job)	Between Groups	46.791	4	11.698	38.118	.000
	Within Groups	182.594	595	.307		
	Total	229.385	599			

Table 4.24 analysed the ANOVA analysis and results of the study stated that estimated value of ANOVA (N=0.000) found to be less than the acceptable threshold limit of 0.005. Hence, all the selected variables are significant in the study.

CORRELATION TEST TABLE

Correlations																					
		Large implementation and maintenance costs	Access to talented labour in artificial intelligence and digital technologies	Security and privacy issues with data	Resistance to change in the organization	Management support and leadership dedication	Uncertainty on Return on Investment (ROI)	Infrastructure and technology preparedness	Coherence with already in place machines and systems	Policies and regulatory structures of the government	Commercial aid and subsidies	Cooperation with technology suppliers	The availability of industry-specific AI applications	Demand of customized/smart packaging by consumers	The demand to use eco-friendly and sustainable packaging	Competitiveness in the market and international competitiveness	Ethical issues of AI decision making	Industry 4.0 and AI knowledge and awareness regarding their benefits	Availability of high-quality big data to make AI-based decisions	AI investments have a long payback period	Cultural factors (employee attitude, fear of loss of job)

Large implementation and maintenance costs	Pearson Correlation	1	.251**	.259**	.218**	.176**	.319**	.138**	.179**	.253**	.194**	.222**	.216**	.222**	.258**	.220**	.242**	.202**	.203**	.157**	.184**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Access to talented labour in artificial intelligence and digital technologies	Pearson Correlation	.251**	1	.398**	.201**	.109**	.274**	.132**	.353**	.239**	.167**	.134**	.124**	.098*	.094*	.140**	.165**	.158**	.275**	.112**	.155**
	Sig. (2-tailed)	0.000		0.000	0.000	0.007	0.000	0.001	0.000	0.000	0.000	0.001	0.002	0.017	0.021	0.001	0.000	0.000	0.000	0.006	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Security and privacy issues with data	Pearson Correlation	.259**	.398**	1	.297**	.242**	.343**	.286**	.222**	.316**	.298**	.346**	.229**	.280**	.160**	.220**	.202**	.185**	.211**	.202**	.152**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Resistance to change in the organization	Pearson Correlation	.218**	.201**	.297**	1	.308**	.229**	.277**	.188**	.197**	.307**	.266**	.270**	.272**	.185**	.144**	.122**	.196**	.175**	.226**	.171**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Management support and leadership dedication	Pearson Correlation	.176**	.109**	.242**	.308**	1	.130**	.293**	.101*	.146**	.246**	.223**	.260**	.236**	.160**	.127**	.105*	.101*	0.073	.212**	.137**
	Sig. (2-tailed)	0.000	0.007	0.000	0.000		0.001	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.010	0.013	0.072	0.000	0.001
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Uncertainty on Return on Investment (ROI)	Pearson Correlation	.319**	.274**	.343**	.229**	.130**	1	.286**	.385**	.391**	.206**	.224**	.204**	.226**	.146**	.202**	.240**	.206**	.226**	.178**	.202**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600

Infrastructure and technology preparedness	Pearson Correlation	.138**	.132**	.286**	.277**	.293**	.286**	1	.246**	.353**	.351**	.380**	.312**	.357**	.231**	.253**	.226**	.191**	.213**	.221**	.221**
	Sig. (2-tailed)	0.001	0.001	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Coherence with already in place machines and systems	Pearson Correlation	.179**	.353**	.222**	.188**	.101*	.385**	.246**	1	.402**	.195**	.213**	.182**	.183**	.139**	.220**	.267**	.213**	.331**	.160**	.287**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.013	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Policies and regulatory structures of the government	Pearson Correlation	.253**	.239**	.316**	.197**	.146**	.391**	.353**	.402**	1	.353**	.370**	.284**	.299**	.200**	.199**	.214**	.218**	.210**	.153**	.203**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600

Commercial aid and subsidies	Pearson Correlation	.194**	.167**	.298**	.307**	.246**	.206**	.351**	.195**	.353**	1	.530**	.410**	.383**	.305**	.233**	.233**	.221**	.267**	.251**	.212**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Cooperation with technology suppliers	Pearson Correlation	.222**	.134**	.346**	.266**	.223**	.224**	.380**	.213**	.370**	.530**	1	.537**	.447**	.352**	.325**	.381**	.326**	.336**	.337**	.312**
	Sig. (2-tailed)	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
The availability of industry-specific AI applications	Pearson Correlation	.216**	.124**	.229**	.270**	.260**	.204**	.312**	.182**	.284**	.410**	.537**	1	.550**	.361**	.340**	.382**	.387**	.324**	.350**	.369**
	Sig. (2-tailed)	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Demand of customized/smart	Pearson Correlation	.222**	.098*	.280**	.272**	.236**	.226**	.357**	.183**	.299**	.383**	.447**	.550**	1	.408**	.354**	.352**	.374**	.273**	.343**	.353**

packaging by consumers																					
	Sig. (2-tailed)	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
The demand to use eco-friendly and sustainable packaging	Pearson Correlation	.258**	.094*	.160**	.185**	.160**	.146**	.231**	.139**	.200**	.305**	.352**	.361**	.408**	1	.513**	.402**	.368**	.344**	.344**	.339**
	Sig. (2-tailed)	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Competitiveness in the market and international competitiveness	Pearson Correlation	.220**	.140**	.220**	.144**	.127**	.202**	.253**	.220**	.199**	.233**	.325**	.340**	.354**	.513**	1	.482**	.396**	.462**	.387**	.427**
	Sig. (2-tailed)	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000

	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Ethical issues of AI decision making	Pearson Correlation	.242**	.165**	.202**	.122**	.105*	.240**	.226**	.267**	.214**	.233**	.381**	.382**	.352**	.402**	.482**	1	.567**	.476**	.527**	.454**
	Sig. (2-tailed)	0.000	0.000	0.000	0.003	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Industry 4.0 and AI knowledge and awareness regarding their benefits	Pearson Correlation	.202**	.158**	.185**	.196**	.101*	.206**	.191**	.213**	.218**	.221**	.326**	.387**	.374**	.368**	.396**	.567**	1	.410**	.484**	.407**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Availability of high-quality big data to make AI-based decisions	Pearson Correlation	.203**	.275**	.211**	.175**	0.073	.226**	.213**	.331**	.210**	.267**	.336**	.324**	.273**	.344**	.462**	.476**	.410**	1	.425**	.478**

	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
AI investments have a long payback period	Pearson Correlation	.157**	.112**	.202**	.226**	.212**	.178**	.221**	.160**	.153**	.251**	.337**	.350**	.343**	.344**	.387**	.527**	.484**	.425**	1	.462**
	Sig. (2-tailed)	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Cultural factors (employee attitude, fear of loss of job)	Pearson Correlation	.184**	.155**	.152**	.171**	.137**	.202**	.221**	.287**	.203**	.212**	.312**	.369**	.353**	.339**	.427**	.454**	.407**	.478**	.462**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

In table 4.25 correlation analysis is applied. All the selected variables in the study are having positive degree of association among each other. For Instance, "Large implementation and maintenance costs is positively correlated with Access to talented labour in artificial intelligence and digital technologies, Security and privacy issues with data, Resistance to change in the organization, Management support and leadership dedication, Uncertainty on Return on Investment (ROI), Infrastructure and technology preparedness, Coherence with already in place machines and systems, Policies and regulatory structures of the government, Commercial aid and subsidies, Cooperation with technology suppliers, The availability of industry-specific AI applications, Demand of customized/smart packaging by consumers, The demand to use eco-friendly and sustainable packaging, Competitiveness in the market and international competitiveness, Ethical issues of AI decision making, Industry 4.0 and AI knowledge and awareness regarding their benefits, Availability of high-quality big data to make AI-based decisions, AI investments have a long payback period and Cultural factors (employee attitude, fear of loss of job).” Like-wise, all other factors are also positively correlated in the current research.

MODEL SUMMARY TABLE

Model Summary									
Model	R		Adjusted R Square	Std. Error of the Estimate	Change Statistics				
		R Square			R Square Change	F Change	df1	df2	Sig. F Change
1	.354[a]	0.307	0.383	0.648	0.307	12.842	20	579	0.000
a. Predictors: (Constant), Cultural factors (employee attitude, fear of loss of job), Management support and leadership dedication, Access to talented labour in artificial intelligence and digital technologies, Policies and regulatory structures of the government, Large implementation and maintenance costs, Resistance to change in the organization, The demand to use eco-friendly and sustainable packaging, Infrastructure and technology preparedness, Industry 4.0 and AI knowledge and awareness regarding their benefits, Uncertainty on Return on Investment (ROI), Commercial aid and subsidies, Coherence with already in place machines and systems, Security and privacy issues with data, The availability of industry-specific AI applications, AI investments have a long payback period, Availability of high-quality big data to make AI-based decisions, Competitiveness in the market and international competitiveness, Demand of customized/smart packaging by consumers, Cooperation with technology suppliers, Ethical issues of AI decision making									

In table 4.26, first step of regression analysis that is Model Summary is applied. Two things that r square (n=0.307) and adjusted r square (n=0.383) is close to each other and r square value is greater than 30%. Moreover, calculated F significance value (0.000) is also less than 0.005 which is the acceptable threshold limit. Therefore, dependent variable which is factors affecting AI adoption in the packaging industry are significantly influenced by independent variables which are "Cultural factors (employee attitude, fear of loss of job), Management support and leadership dedication, Access to talented labour in artificial intelligence and digital technologies, Policies and regulatory structures of the government, Large implementation and maintenance costs, Resistance to change in the organization, The demand to use eco-friendly and sustainable packaging, Infrastructure and technology preparedness, Industry 4.0 and AI knowledge and awareness regarding their benefits, Uncertainty on Return on Investment (ROI), Commercial aid and subsidies, Coherence with already in place machines and systems, Security and privacy issues with data, The availability of industry-specific AI applications, AI investments have a long payback period, Availability of high-quality big data to make AI-based decisions, Competitiveness in the market and international competitiveness, Demand of customized/smart packaging by consumers, Cooperation with technology suppliers, Ethical issues of AI decision making."

ANOVA TEST TABLE

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	107.694	20	5.385	12.842	.000[b]
	Residual	242.771	579	.419		
	Total	350.465	599			
a. Dependent Variable: Factors Affecting AI Adoption in the Packaging Industry						

b. Predictors: (Constant), Cultural factors (employee attitude, fear of loss of job), Management support and leadership dedication, Access to talented labour in artificial intelligence and digital technologies, Policies and regulatory structures of the government, Large implementation and maintenance costs, Resistance to change in the organization, The demand to use eco-friendly and sustainable packaging, Infrastructure and technology preparedness, Industry 4.0 and AI knowledge and awareness regarding their benefits, Uncertainty on Return on Investment (ROI), Commercial aid and subsidies, Coherence with already in place machines and systems, Security and privacy issues with data, The availability of industry-specific AI applications, AI investments have a long payback period, Availability of high-quality big data to make AI-based decisions, Competitiveness in the market and international competitiveness, Demand of customized/smart packaging by consumers, Cooperation with technology suppliers, Ethical issues of AI decision making

In table 4.27, second step of regression analysis that is ANOVA is applied. The calculated significance value found to be 0.000 with degree of freedom 599 and fisher's value 12.842. Therefore, dependent variable which is factors affecting AI adoption in the packaging industry are significantly influenced by independent variables which are "Cultural factors (employee attitude, fear of loss of job), Management support and leadership dedication, Access to talented labour in artificial intelligence and digital technologies, Policies and regulatory structures of the government, Large implementation and maintenance costs, Resistance to change in the organization, The demand to use eco-friendly and sustainable packaging, Infrastructure and technology preparedness, Industry 4.0 and AI knowledge and awareness regarding their benefits, Uncertainty on Return on Investment (ROI), Commercial aid and subsidies, Coherence with already in place machines and systems, Security and privacy issues with data, The availability of industry-specific AI applications, AI investments have a long payback period, Availability of high-quality big data to make AI-based decisions, Competitiveness in the market and international competitiveness, Demand of customized/smart packaging by consumers, Cooperation with technology suppliers, Ethical issues of AI decision making."

RELIABILITY STASTISTIC TEST TABLE

Reliability Statistics	
Cronbach's Alpha	N of Items
0.903	25

Table 4.28 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.903 (N=25), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DESCRIPTIVE STATISTICS TEST TABLE

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation

The initial investment costs are very high and it deter firms to embrace AI technologies	600	1	5	4.36	.783
Most packaging companies cannot afford the cost of AI system maintenance and upgrades	600	1	5	4.16	.814
The access to financial resources is limited and prevents the use of AI solutions by SMEs	600	1	5	3.80	.974
Absence of AI-qualified practitioners does not allow turning out a successful implementation in packing processes	600	1	5	3.18	1.151
The need to train continuously puts added pressure on the employees and organizations	600	1	5	4.51	.724
The adoption is hampered by the lack of interdisciplinary knowledge (AI + packaging processes)	600	1	5	3.78	1.013
Poor IT infrastructural support delays the use of AI in the packaging plants	600	1	5	4.62	.619
Combination of AI and the current machines and systems is not easy	600	1	5	4.50	.693

High frequency of system upgrades and interoperability problems bring about operational hitches	600	1	5	4.04	.965
There is not much access to AI tools specific to the industry used in packaging, which limits the practice	600	1	5	4.12	.807
The privacy of data is one of the obstacles to the use of AI in packaging	600	1	5	4.09	.894
The absence of standardized data collection practices complicates the use of AI	600	1	5	4.12	.856
The threat of cybersecurity is enhanced with the digitalization of the packaging system based on AI	600	1	5	4.18	.743
Employee resistance to change is a barrier to AI	600	1	5	4.34	.632
The unwillingness to invest is lowered because of management doubtfulness regarding the advantage of AI	600	1	5	4.38	.655
The absence of leadership commitment slows an AI-driven change	600	1	5	4.35	.720

Resistance is caused by workers fearing loss of work to AI-based automation	600	1	5	4.42	.644
AI in packaging ROI has no certainty	600	1	5	4.18	.814
Hard work in quantifying tangible results makes decision-makers shy	600	1	5	4.39	.619
The payback periods are long and this would make companies not adopt AI	600	1	5	4.19	.765
Inability to support or subsidize AI by the government undermines its adoption in the industry	600	1	5	4.26	.710
Lack of regulatory guidelines cripples AI-based innovation in packaging	600	1	5	4.39	.644
There is a lack of cooperation between the technology suppliers and packaging companies, minimizing the use of AI	600	1	5	4.36	.678
The issues of AI usage relating to ethics influence adoption	600	1	5	4.23	.748
The AI systems might not be compatible with the sustainability and the elimination of a circular economy	600	1	5	4.23	.698
Valid N (listwise)	600				

Table 4.29 examined the descriptive statistics related to challenges in AI integration in respondents' organisation and stated that "Poor IT infrastructural support delays the use of AI in the packaging plants" (Mean=4.62 and Standard Deviation= .619) followed by "The need to train continuously puts added pressure on the employees and organizations" (Mean=4.51 and Standard Deviation=.724) are the key challenges in AI integration in packaging industry. "Absence of AI-qualified practitioners does not allow turning out a successful implementation in packing processes" (Mean=3.18 and Standard Deviation= 1.151) is the least challenge faced by packaging industry in AI integration. Therefore, the results of descriptive analysis investigated that poor IT infrastructural support delays the use of AI in the packaging plants.

KMO AND BARLETT'S TEST TABLE

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.925
Bartlett's Test of Sphericity	Approx. Chi-Square	5496.050
	df	300
	Sig.	.000

In table 4.30, to check the sampling adequacy and to ensure further implementation of factor analysis, KMO and Bartlett's test of Sphericity is conducted. The estimated value of KMO is .925 which is close to 1 and significance value of Bartlett's test of Sphericity is also 0.000 which is less than .005 (permissible limit). Therefore, sampling adequacy is present and further exploratory factor analysis can be performe

COMUNALITIES TABLE

Communalities		
	Initial	Extraction
The initial investment costs are very high and it deter firms to embrace AI technologies	1.000	.595

Most packaging companies cannot afford the cost of AI system maintenance and upgrades	1.000	.505
The access to financial resources is limited and prevents the use of AI solutions by SMEs	1.000	.512
Absence of AI-qualified practitioners does not allow turning out a successful implementation in packing processes	1.000	.585
The need to train continuously puts added pressure on the employees and organizations	1.000	.491
The adoption is hampered by the lack of interdisciplinary knowledge (AI + packaging processes)	1.000	.439
Poor IT infrastructural support delays the use of AI in the packaging plants	1.000	.579
Combination of AI and the current machines and systems is not easy	1.000	.637
High frequency of system upgrades and interoperability problems bring about operational hitches	1.000	.538
There is not much access to AI tools specific to the industry used in packaging, which limits the practice	1.000	.601

The privacy of data is one of the obstacles to the use of AI in packaging	1.000	.582
The absence of standardized data collection practices complicates the use of AI	1.000	.551
The threat of cybersecurity is enhanced with the digitalization of the packaging system based on AI	1.000	.452
Employee resistance to change is a barrier to AI	1.000	.498
The unwillingness to invest is lowered because of management doubtfulness regarding the advantage of AI	1.000	.648
The absence of leadership commitment slows an AI-driven change	1.000	.570
Resistance is caused by workers fearing loss of work to AI-based automation	1.000	.549
AI in packaging ROI has no certainty	1.000	.578
Hard work in quantifying tangible results makes decision-makers shy	1.000	.508
The payback periods are long and this would make companies not adopt AI	1.000	.551

Inability to support or subsidize AI by the government undermines its adoption in the industry	1.000	.641
Lack of regulatory guidelines cripples AI-based innovation in packaging	1.000	.637
There is a lack of cooperation between the technology suppliers and packaging companies, minimizing the use of AI	1.000	.619
The issues of AI usage relating to ethics influence adoption	1.000	.632
The AI systems might not be compatible with the sustainability and the elimination of a circular economy	1.000	.544
Extraction Method: Principal Component Analysis.		

Table 4.31 analysed the communalities in exploratory factor analysis. The results examined and stated that all the selected factor having value greater than 0.40, which is the required permissible limit to cross in order to be considered for further examined and tested. Therefore, now total variance explained can be applied.

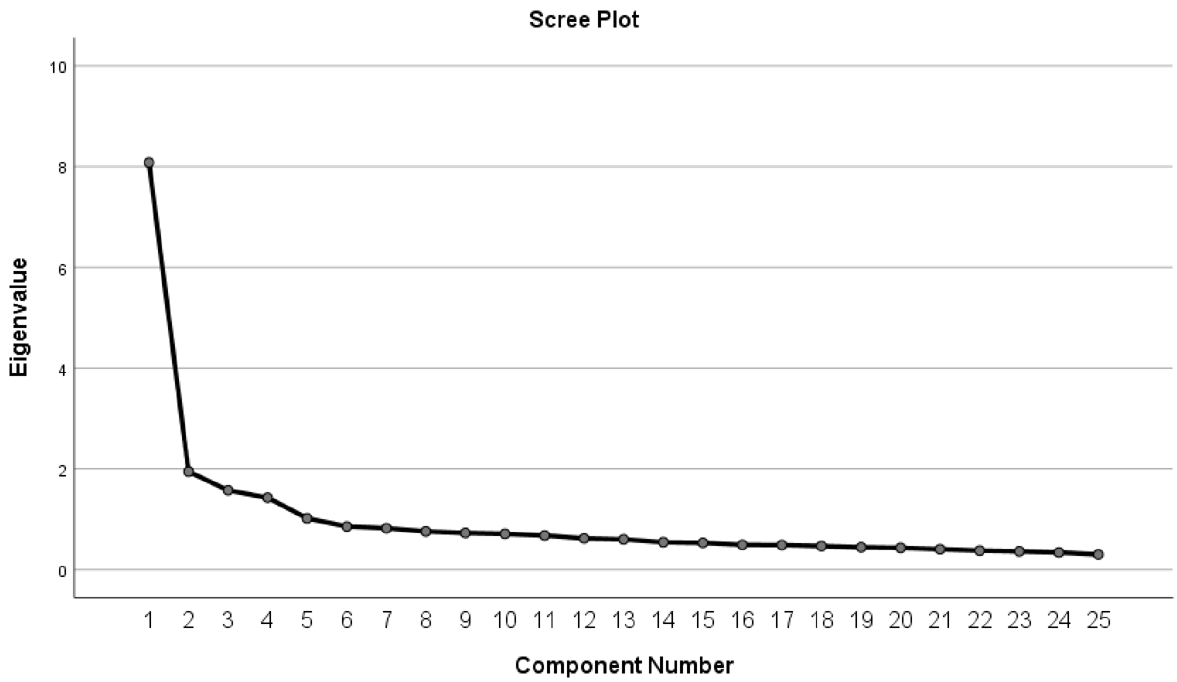
TOTAL VARIANCE TEST TABLE

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %

1	8.080	32.320	32.320	8.080	32.320	32.320	3.691	14.765	14.765
2	1.945	7.779	40.099	1.945	7.779	40.099	3.632	14.529	29.294
3	1.574	6.296	46.394	1.574	6.296	46.394	2.870	11.478	40.772
4	1.427	5.707	52.101	1.427	5.707	52.101	2.258	9.032	49.805
5	1.018	16.071	66.172	1.018	16.071	66.172	1.592	16.367	66.172
6	0.856	3.424	59.596						
7	0.821	3.285	62.880						
8	0.758	3.031	65.911						
9	0.728	2.910	68.822						
10	0.711	2.843	71.664						
11	0.678	2.711	74.376						
12	0.620	2.482	76.857						
13	0.600	2.402	79.259						
14	0.544	2.177	81.436						
15	0.531	2.124	83.560						
16	0.491	1.966	85.526						
17	0.487	1.950	87.475						
18	0.468	1.870	89.346						
19	0.444	1.776	91.122						
20	0.431	1.725	92.847						
21	0.404	1.617	94.464						
22	0.378	1.513	95.977						
23	0.363	1.452	97.429						
24	0.341	1.366	98.795						

25	0.301	1.205	100.000						
Extraction Method: Principal Component Analysis.									

In table 4.32, total variance explained is conducted. The cumulative value of total variance explained is 66.172% which is greater than 60% (permissible limit). Hence, further rotated component matrix need to perform.



In figure 4.10 scree plot is displayed. X axis shows the eigen values and Y axis shows the component number. 2-25 component number showed the strong factor retention. Hence, variables are positively close to each other.

ROTATED COMPONENT MATRIX TEST TABLE

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
The initial investment costs are very high and it deter firms to embrace AI technologies	.659				
Most packaging companies cannot afford the cost of AI system maintenance and upgrades	.454				
The access to financial resources is limited and prevents the use of AI solutions by SMEs	.477				
Absence of AI-qualified practitioners does not allow turning out a successful implementation in packing processes	.642				
The need to train continuously puts added pressure on the employees and organizations		.724			
The adoption is hampered by the lack of interdisciplinary knowledge (AI + packaging processes)		.644			
Poor IT infrastructural support delays the use of AI in the packaging plants		.714			
Combination of AI and the current machines and systems is not easy			.539		

High frequency of system upgrades and interoperability problems bring about operational hitches			.671		
There is not much access to AI tools specific to the industry used in packaging, which limits the practice			.669		
The privacy of data is one of the obstacles to the use of AI in packaging			.617		
The absence of standardized data collection practices complicates the use of AI			.606		
The threat of cybersecurity is enhanced with the digitalization of the packaging system based on AI				.492	
Employee resistance to change is a barrier to AI				.619	
The unwillingness to invest is lowered because of management doubtfulness regarding the advantage of AI				.754	
The absence of leadership commitment slows an AI-driven change				.717	
Resistance is caused by workers fearing loss of work to AI-based automation				.602	
AI in packaging ROI has no certainty				.680	

Hard work in quantifying tangible results makes decision-makers shy				.607	
The payback periods are long and this would make companies not adopt AI					.662
Inability to support or subsidize AI by the government undermines its adoption in the industry					.721
Lack of regulatory guidelines cripples AI-based innovation in packaging					.690
There is a lack of cooperation between the technology suppliers and packaging companies, minimizing the use of AI					.730
The issues of AI usage relating to ethics influence adoption					.738
The AI systems might not be compatible with the sustainability and the elimination of a circular economy					.661
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.					
a. Rotation converged in 7 iterations.					

In table 4.33, rotated component matrix is examined. All variables the estimated value is greater than 0.40 (permissible limit). Hence 25 factors reduced to 5 variables.

RELIABILITY STATISTICS TEST

Reliability Statistics	
Cronbach's Alpha	N of Items
0.900	20

Table 4.34 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.900 (N=20), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DECRIPTIVE STATISTICS TEST

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation

AI increases the speed and efficiency of production during packaging	600	1	5	4.40	.720
AI-based predictive maintenance minimizes packaging-machinery downtimes	600	1	5	4.42	.644
AI streamlines supply chain and inventory in packaging companies	600	1	5	4.18	.814
AI helps increase the quality control by minimizing packaging defects and mistakes	600	1	5	4.39	.619
Machine learning and computer vision enhance the quality of real-time inspection	600	1	5	4.19	.765
AI allows uniform packaging when there is high volume of production	600	1	5	4.26	.710
AI promotes different types of packaging design and materials	600	1	5	4.39	.644
AI-based insights are useful in developing customer-focused and individual packaging decisions	600	1	5	4.36	.678
AI improves flexibility in the packaging adjustment to the evolving needs of the market	600	1	5	4.23	.748
AI assists in creating an environmentally friendly and recyclable packaging	600	1	5	4.23	.698

Machine learning minimises the wastage of materials used in packaging	600	1	5	4.19	.825
The use of AI will lead to the fulfilment of the objectives of the circular economy in the context of the packaging industry	600	1	5	3.97	.942
The use of AI enhances the competitiveness of packaging companies in the world	600	1	5	3.75	1.065
AI helps companies to be responsive to changing consumer needs	600	1	5	4.19	.818
AI helps to cut costs, hence enhancing profitability	600	1	5	3.89	.907
AI facilitates intelligent packaging	600	1	5	4.05	.871
AI provides greater satisfaction to consumers with innovative packaging solutions	600	1	5	4.00	.905
AI-based packaging enhances brand loyalty and the interest of the customers	600	1	5	3.53	1.114
AI gives useful data points in enhanced decision-making in packaging activities	600	1	5	4.39	.728
The implementation of AI creates the possibilities of partnerships and cooperation within the packaging ecosystem	600	1	5	4.25	.782
Valid N (listwise)	600				

Table 4.35 examined the descriptive analysis related to opportunities in AI integration in respondents' organisation. The results stated that "AI-based predictive maintenance minimizes packaging-machinery downtimes" (Mean= 4.42 and Standard Deviation= .644) followed by "AI increases the speed and efficiency of production during packaging" (Mean= 4.40 and Standard Deviation= .720) are the key opportunities in AI integration in packaging industry. "AI-based packaging enhances brand loyalty and the interest of the customers" (Mean= 3.53 and Standard Deviation= 1.114) is the least important opportunity in AI integration in packaging industry. Therefore, the results of descriptive analysis related to opportunities in AI integration in respondents' organisation stated that AI-based predictive maintenance minimizes packaging-machinery downtimes is the opportunity the packaging industry look for.

KMO AND BARLETT'S TEST TABLE

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.914
Bartlett's Test of Sphericity	Approx. Chi-Square	4610.871
	Df	190
	Sig.	.000

In table 4.36, to check the sampling adequacy and to ensure further implementation of factor analysis, KMO and Bartlett's test of Sphericity is conducted. The estimated value of KMO is .914 which is close to 1 and significance value of Bartlett's test of Sphericity is also 0.000 which is less than .005 (permissible limit). Therefore, sampling adequacy is present and further exploratory factor analysis can be performed.

COMMUNALITIE TABLE

Communalities		
	Initial	Extraction

AI increases the speed and efficiency of production during packaging	1.000	.588
AI-based predictive maintenance minimizes packaging-machinery downtimes	1.000	.548
AI streamlines supply chain and inventory in packaging companies	1.000	.624
AI helps increase the quality control by minimizing packaging defects and mistakes	1.000	.558
Machine learning and computer vision enhance the quality of real-time inspection	1.000	.529
AI allows uniform packaging when there is high volume of production	1.000	.605
AI promotes different types of packaging design and materials	1.000	.609
AI-based insights are useful in developing customer-focused and individual packaging decisions	1.000	.615
AI improves flexibility in the packaging adjustment to the evolving needs of the market	1.000	.625
AI assists in creating an environmentally friendly and recyclable packaging	1.000	.567

Machine learning minimises the wastage of materials used in packaging	1.000	.457
The use of AI will lead to the fulfilment of the objectives of the circular economy in the context of the packaging industry	1.000	.478
The use of AI enhances the competitiveness of packaging companies in the world	1.000	.521
AI helps companies to be responsive to changing consumer needs	1.000	.404
AI helps to cut costs, hence enhancing profitability	1.000	.544
AI facilitates intelligent packaging	1.000	.614
AI provides greater satisfaction to consumers with innovative packaging solutions	1.000	.617
AI-based packaging enhances brand loyalty and the interest of the customers	1.000	.419
AI gives useful data points in enhanced decision-making in packaging activities	1.000	.718
The implementation of AI creates the possibilities of partnerships and cooperation within the packaging ecosystem	1.000	.699

Extraction Method: Principal Component Analysis.

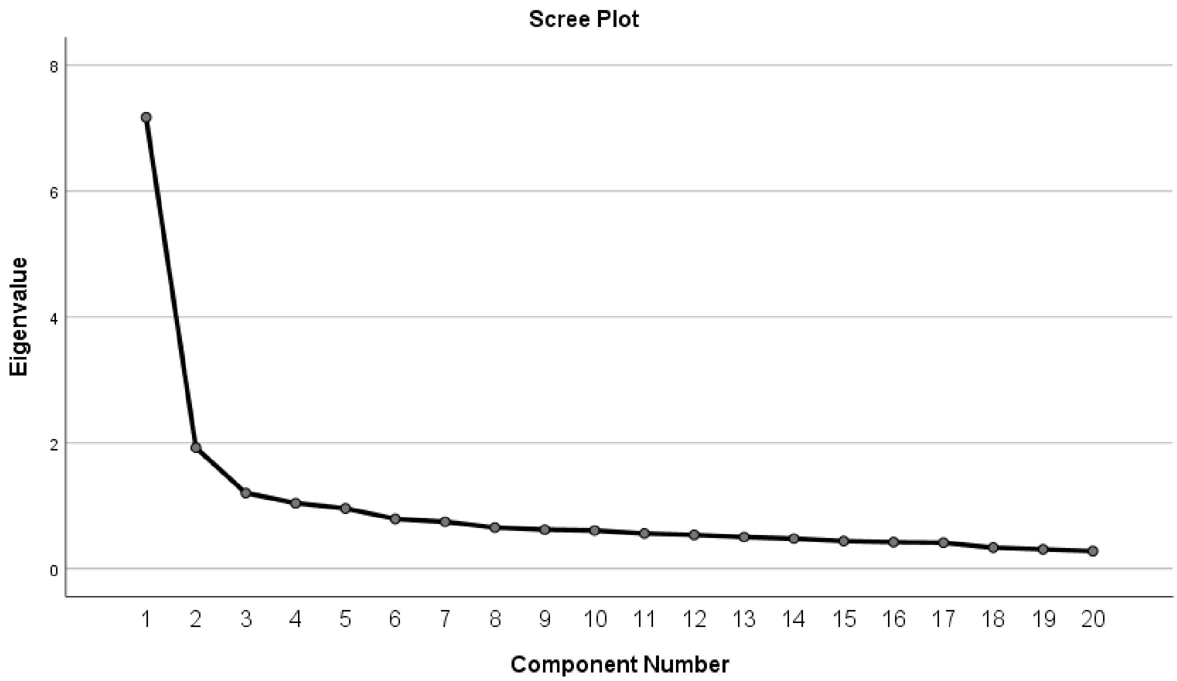
Table 4.37 analysed the communalities in exploratory factor analysis. The results examined and stated that all the selected factor having value greater than 0.40, which is the required permissible limit to cross in order to be considered for further examined and tested. Therefore, now total variance explained can be applied.

TOTAL VARIANCE TEST TABLE

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.171	35.857	35.857	7.171	35.857	35.857	3.826	19.131	19.131
2	1.923	9.614	45.471	1.923	9.614	45.471	3.558	17.788	36.919
3	1.204	6.019	51.490	1.204	6.019	51.490	2.439	12.197	49.116
4	1.042	17.211	66.701	1.042	17.211	66.701	1.517	17.585	66.701
5	0.958	4.791	61.492						
6	0.792	3.959	65.451						
7	0.746	3.730	69.181						
8	0.655	3.275	72.456						
9	0.622	3.110	75.566						
10	0.609	3.043	78.610						
11	0.560	2.800	81.410						
12	0.538	2.691	84.101						
13	0.505	2.524	86.624						

14	0.479	2.393	89.017						
15	0.439	2.194	91.211						
16	0.422	2.109	93.320						
17	0.414	2.068	95.387						
18	0.334	1.671	97.058						
19	0.308	1.538	98.596						
20	0.281	1.404	100.000						
Extraction Method: Principal Component Analysis.									

In table 4.38, total variance explained is conducted. The cumulative value of total variance explained is 66.701% which is greater than 60% (permissible limit). Hence, further rotated component matrix need to perform.



In figure 4.10 scree plot is displayed. X axis shows the eigen values and Y axis shows the component number. 2-20 component number showed the strong factor retention. Hence, variables are positively close to each other.

ROTATED COMPONENT MATRIX TEST TABLE

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
AI increases the speed and efficiency of production during packaging			.733	
AI-based predictive maintenance minimizes packaging-machinery downtimes			.639	
AI streamlines supply chain and inventory in packaging companies			.726	
AI helps increase the quality control by minimizing packaging defects and mistakes			.644	

Machine learning and computer vision enhance the quality of real-time inspection		.650		
AI allows uniform packaging when there is high volume of production		.695		
AI promotes different types of packaging design and materials		.666		
AI-based insights are useful in developing customer-focused and individual packaging decisions		.719		
AI improves flexibility in the packaging adjustment to the evolving needs of the market		.738		
AI assists in creating an environmentally friendly and recyclable packaging		.674		
Machine learning minimises the wastage of materials used in packaging	.523			
The use of AI will lead to the fulfilment of the objectives of the circular economy in the context of the packaging industry	.645			
The use of AI enhances the competitiveness of packaging companies in the world	.675			
AI helps companies to be responsive to changing consumer needs	.526			

AI helps to cut costs, hence enhancing profitability	.700			
AI facilitates intelligent packaging	.743			
AI provides greater satisfaction to consumers with innovative packaging solutions	.736			
AI-based packaging enhances brand loyalty and the interest of the customers	.601			
AI gives useful data points in enhanced decision-making in packaging activities				.794
The implementation of AI creates the possibilities of partnerships and cooperation within the packaging ecosystem				.743
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 6 iterations.				

In table 4.39, rotated component matrix is examined. All variables the estimated value is greater than 0.40 (permissible limit). Hence 20 factors reduced to 4 variables.

RELIABILITY STATISTIC TABLE

Reliability Statistics

Cronbach's Alpha	N of Items
0.827	14

Table 4.40 analysed the internal consistency status among the variables in the study. To check whether internal consistency is present among selected variables in the study or not, the reliability test is conducted. The calculated value of Cronbach's Alpha found to be 0.827 (N=14), which stated that the presence of internal consistency among variables as the value of estimated reliability statistics is greater than 0.60 which is required permissible limit. Therefore, the study can go ahead and can apply other statistical tools in the study.

DESCRIPTIVE STATISTICS TEST TABLE

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Give incentives, subsidies, or tax breaks to promote the use of AI by the government.	600	1	5	4.35	.736
Design educational courses to develop AI-related skills in professionals of the packaging industry	600	1	5	4.14	.830
Promote the partnerships of the packaging companies and AI technology	600	1	5	4.13	.883
Develop effective regulatory frameworks and ethics of AI use	600	1	5	4.36	.783
Make investments in the modernization of the digital infrastructure (IoT, cloud systems, connectivity) to facilitate the integration of AI	600	1	5	4.16	.814

Promote the use of AI towards sustainability (environmentally friendly materials, reduction of waste)	600	1	5	3.80	.974
Encourage the best practice sharing sites on AI-based packaging	600	1	5	3.18	1.151
Enhance protection of AI-enabled systems by enhancing cybersecurity	600	1	5	4.51	.724
Offer incentives programs to encourage small and medium business organizations (SMEs) to embrace AI	600	1	5	3.78	1.013
Implement pilot projects to receive the advantages of AI in practice during packaging	600	1	5	4.62	.619
Promote leadership devotion and change management in order to minimize resistance	600	1	5	4.50	.693
Normalize AI tools and technologies so as to integrate them across the industry	600	1	5	4.04	.965
Fund interdisciplinary studies between AI, packaging design and circular economy	600	1	5	4.12	.807
Create consumer awareness of smart packaging products using AI	600	1	5	4.09	.894
Valid N (listwise)	600				

Table 4.41 examined the descriptive analysis related to recommendations for making AI adoption easy in respondents' packaging organisation. The results of the study stated that "Implement pilot projects to receive the advantages of AI in practice during packaging" (Mean=4.62 and Standard Deviation=.619) followed by "Enhance protection of AI-enabled systems by enhancing cybersecurity" (Mean=4.51 and Standard Deviation=.724) are the key recommendations for making AI adoption easy in packaging industry. "Encourage the best practice sharing sites on AI-based packaging" (Mean=3.18 and Standard Deviation=1.151) is the least recommendation for making AI adoption easy in packaging industry. Therefore, conducting pilot study to implement AI in packaging industry is the key recommendation in the study.

ONE SAMPLE STATISTIC TABLE

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Give incentives, subsidies, or tax breaks to promote the use of AI by the government.	600	4.35	.736	.030
Design educational courses to develop AI-related skills in professionals of the packaging industry	599	4.14	.830	.034
Promote the partnerships of the packaging companies and AI technology	600	4.13	.883	.036
Develop effective regulatory frameworks and ethics of AI use	600	4.36	.783	.032
Make investments in the modernization of the digital infrastructure (IoT, cloud systems, connectivity) to facilitate the integration of AI	600	4.16	.814	.033

Promote the use of AI towards sustainability (environmentally friendly materials, reduction of waste)	600	3.80	.974	.040
Encourage the best practice sharing sites on AI-based packaging	600	3.18	1.151	.047
Enhance protection of AI-enabled systems by enhancing cybersecurity	599	4.51	.724	.030
Offer incentives programs to encourage small and medium business organizations (SMEs) to embrace AI	600	3.79	1.013	.041
Implement pilot projects to receive the advantages of AI in practice during packaging	600	4.62	.619	.025
Promote leadership devotion and change management in order to minimize resistance	600	4.50	.693	.028
Normalize AI tools and technologies so as to integrate them across the industry	600	4.04	.965	.039
Fund interdisciplinary studies between AI, packaging design and circular economy	600	4.12	.807	.033
Create consumer awareness of smart packaging products using AI	600	4.09	.894	.036

Table 4.42 examined the one sample analysis related to recommendations for making AI adoption easy in respondents' packaging organisation. The results of the study stated that "Implement pilot projects to receive the advantages of AI in practice during packaging" (Mean=4.62 and Standard Deviation=.619 and Standard Error= .025) followed by "Enhance protection of AI-enabled systems by enhancing cybersecurity" (Mean=4.51 and Standard Deviation=.724 and Standard Error= .030) are the key recommendations for making AI adoption easy in packaging industry. "Encourage the best practice sharing sites on AI-based packaging" (Mean=3.18 and Standard Deviation=1.151 and Standard Error= .047) is the least recommendation for making AI adoption easy in packaging industry. Therefore, conducting pilot study to implement AI in packaging industry is the key recommendation in the study.

ONE SAMPLE TEST TABLE

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Give incentives, subsidies, or tax breaks to promote the use of AI by the government.	144.767	599	.000	4.350	4.29	4.41
Design educational courses to develop AI-related skills in professionals of the packaging industry	122.046	598	.000	4.140	4.07	4.21
Promote the partnerships of the packaging companies and AI technology	114.624	599	.000	4.133	4.06	4.20
Develop effective regulatory frameworks and ethics of AI use	136.583	599	.000	4.363	4.30	4.43

Make investments in the modernization of the digital infrastructure (IoT, cloud systems, connectivity) to facilitate the integration of AI	125.023	599	.000	4.157	4.09	4.22
Promote the use of AI towards sustainability (environmentally friendly materials, reduction of waste)	95.479	599	.000	3.795	3.72	3.87
Encourage the best practice sharing sites on AI-based packaging	67.734	599	.000	3.183	3.09	3.28
Enhance protection of AI-enabled systems by enhancing cybersecurity	152.433	598	.000	4.511	4.45	4.57
Offer incentives programs to encourage small and medium business organizations (SMEs) to embrace AI	91.480	599	.000	3.785	3.70	3.87
Implement pilot projects to receive the advantages of AI in practice during packaging	182.562	599	.000	4.617	4.57	4.67
Promote leadership devotion and change management in order to minimize resistance	159.026	599	.000	4.502	4.45	4.56
Normalize AI tools and technologies so as to integrate them across the industry	102.477	599	.000	4.038	3.96	4.12

Fund interdisciplinary studies between AI, packaging design and circular economy	124.996	599	.000	4.117	4.05	4.18
Create consumer awareness of smart packaging products using AI	112.067	599	.000	4.088	4.02	4.16

Table 4.43 examined t test analysis related to recommendations for making AI adoption easy in respondents' packaging organisation. The results of the study stated that "Implement pilot projects to receive the advantages of AI in practice during packaging" (t=182.562) followed by "Enhance protection of AI-enabled systems by enhancing cybersecurity" (t=152.433) are the key recommendations for making AI adoption easy in packaging industry. "Encourage the best practice sharing sites on AI-based packaging" (t=67.734) is the least recommendation for making AI adoption easy in packaging industry. Therefore, conducting pilot study to implement AI in packaging industry is the key recommendation in the study.

ANOVA TEST TABLE

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Give incentives, subsidies, or tax breaks to promote the use of AI by the government.	Between Groups	18.897	4	4.724	9.198	.000
	Within Groups	305.603	595	.514		
	Total	324.500	599			
Design educational courses to develop AI-related skills in professionals of the packaging industry	Between Groups	35.226	4	8.807	13.876	.000
	Within Groups	376.994	594	.635		
	Total	412.220	598			
Promote the partnerships of the packaging companies and AI technology	Between Groups	34.270	4	8.568	11.771	.000
	Within Groups	433.063	595	.728		
	Total	467.333	599			
Develop effective regulatory frameworks and ethics of AI use	Between Groups	8.014	4	2.003	3.322	.010
	Within Groups	358.780	595	.603		
	Total	366.793	599			
	Between Groups	34.465	4	8.616	14.131	.000

Make investments in the modernization of the digital infrastructure (IoT, cloud systems, connectivity) to facilitate the integration of AI	Within Groups	362.808	595	.610		
	Total	397.273	599			
Promote the use of AI towards sustainability (environmentally friendly materials, reduction of waste)	Between Groups	47.161	4	11.790	13.474	.000
	Within Groups	520.624	595	.875		
	Total	567.785	599			
Encourage the best practice sharing sites on AI-based packaging	Between Groups	58.792	4	14.698	11.898	.000
	Within Groups	735.042	595	1.235		
	Total	793.833	599			
Enhance protection of AI-enabled systems by enhancing cybersecurity	Between Groups	23.618	4	5.905	12.092	.000
	Within Groups	290.061	594	.488		
	Total	313.679	598			
Offer incentives programs to encourage small and medium business organizations (SMEs) to embrace AI	Between Groups	84.226	4	21.056	23.593	.000
	Within Groups	531.039	595	.893		
	Total	615.265	599			
Implement pilot projects to receive the advantages of AI in practice during packaging	Between Groups	13.891	4	3.473	9.569	.000
	Within Groups	215.942	595	.363		
	Total	229.833	599			
Promote leadership devotion and change management in order to minimize resistance	Between Groups	32.387	4	8.097	18.847	.000
	Within Groups	255.612	595	.430		
	Total	287.998	599			
Normalize AI tools and technologies so as to integrate them across the industry	Between Groups	92.378	4	23.094	29.504	.000
	Within Groups	465.741	595	.783		
	Total	558.118	599			
Fund interdisciplinary studies between AI, packaging design and circular economy	Between Groups	88.950	4	22.237	43.975	.000
	Within Groups	300.883	595	.506		
	Total	389.833	599			
Create consumer awareness of smart	Between Groups	153.851	4	38.463	70.532	.000
	Within Groups	324.467	595	.545		

packaging products using AI	Total	478.318	599			

Table 4.44 analysed the ANOVA analysis and results of the study stated that estimated value of ANOVA (N=0.000) found to be less than the acceptable threshold limit of 0.005 in all cases except with the variable "Develop effective regulatory frameworks and ethics of AI use" (N=0.010). Hence, all the selected variables are significant in the study except Develop effective regulatory frameworks and ethics of AI use.

CHI SQUARE TEST TABLE

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	103.513[a]	16	.000
Likelihood Ratio	65.349	16	.000
Linear-by-Linear Association	34.204	1	.000
N of Valid Cases	600		
a. 14 cells (56.0%) have expected count less than 5. The minimum expected count is .03.			

Table 4.44 examined the Chi-square test and the findings of the study stated that the computed Pearson Chi-Square value is 0.000 which is less than 0.005. Therefore, all the recommendations given for making AI adoption easy in packaging industry.

Hypothesis Testing Results

HYPOYTHESIS RESULT TABLE

S.No.	Hypothesis Statements	Decision
H01	There are no significant key factors affecting artificial intelligence adoption in the packaging industry in India.	**Rejected**
Ha1	There are significant key factors affecting artificial intelligence adoption in the packaging industry in India.	**Accepted**
H02	There are no significant challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India.	**Rejected**
Ha2	There are significant challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India.	**Accepted**
H03	There are no significant opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India.	**Rejected**
Ha3	There are significant opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India.	**Accepted**
H04	There are no significant recommendations to ensure effective adoption and integration of	**Rejected**

	artificial intelligence into industry 4.0 in the packaging industry.	
Ha4	There are significant recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry.	**Accepted**

Summary and Conclusion

The existing study aims to explore integration of AI into industry 4.0 to address challenges and opportunities in the packaging industry. The goals of the study is to identify and analyse factors affecting artificial intelligence adoption in the packaging industry in India; to examine the challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India; to examine the opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India and to provide suitable recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry. The findings of the demographic statistics factor of age distribution stated that majority of respondents comes under the age range of 25 to 35 years; the study assessed gender distribution and stated that majority of respondents in the study are male; the findings of marital status stated that majority of respondents in the study are married; the results of educational qualification assessed that majority of respondents in the study are post graduate; the majority of respondents in the study found to be having monthly income of Rs. 55001 to 65000; the findings of the study stated that majority of respondents having 2 to 5 years of experience in the packaging industry; the results of the study stated that majority of respondents in the study belongs to nuclear family and lastly analysed the size that is number of persons in respondents' family and stated that only 2 members.

The second part of analysis deals with first factors that influence AI adoption in packaging industry and stated that consistency among machines and systems and implementation and maintenance costs are the key factors that influence AI adoption in packaging industry. Secondly, challenges in AI integration in respondents' organisation assessed and stated that poor IT infrastructural support delays the use of AI in the packaging plants is the key challenge. the results related to opportunities in AI integration in respondents' organisation stated that AI-based predictive maintenance minimizes packaging-machinery downtimes is the opportunity the packaging industry look for. Lastly, recommendations for making AI adoption easy in respondents' packaging organisation is assessed. The results of the study stated that implement pilot projects to receive the advantages of AI in practice during packaging is the key recommendation of the study.

CHAPTER-V

Discussion of the Study

The study demonstrates that the implementation of the Artificial Intelligence (AI) into Industry 4.0 could revolutionize the packaging industry as it may be efficient, sustainable, and innovative. This argument consists of the literature review, the theoretical knowledge and the created research gaps to emphasize the revolutionary nature of AI in the area as well as considering the complexity that necessitates the restraint of the extensive application.

It is one of the most significant elements that become apparent that AI can help improve the efficiency of operational processes in the packaging area on a significant level. In most cases, the conventional methods of packaging are time consuming and can be easily damaged by the absence of automation since it may require manual monitoring. Using AI mechanisms as an industry 4.0 structure, the packaging companies will be able to experience predictive maintenance and real-time monitoring of the processes, as well as more autonomous working of the processes. This not only reduces the amount of time utilized during the production facet, but ensuring a higher degree of quality and accuracy in the package creation routine. One of the direct advantages of such developments as pointed out by the research is enhanced competitiveness in a globalized market where time to market and quality invariance has so far been identified to play a critical role in the differentiation process.

The other area of interest on the controversy is the question of AI in streamlining sustainability on packaging. The pressure of the packaging industry is the ability to reduce the environmental impact, monitor and comply with the regulations and meet the consumer needs of the environmentally-friendly products. With the application of the AI and the Industry 4.0 technologies, life-cycle assessment becomes possible, and it is possible to optimize the exploitation of the raw material and develop the packaging solution that would be recycled. The machine learning algorithm can be applied, as an example, in simulating the array of materials compositions to decide what sustainable alternative to use without decreasing the durability. This is in accordance with the escalation of the global movement (circular economy) movement, that is, the AI-Industry 4.0 nexus can be not only an economic catalyst but also an obligatory factor of the environment.

The study also provides the prospects of AI to transform the consumer behavior whereby smart packaging and personalized packaging can be observed. Industry 4.0 revolves around systems that are linked to each other and is digitized in nature as compared to AI that applies data analytics in order to decipher consumer preferences. Under this kind of synergy, the packaging companies can develop specific and interactive packaging experience that can deliver consumers with all the product information and traceability as well as immersive experiences with QR and AR. Not only do these innovations make the brands stronger, but packaging becomes a strategic marketing tool that is not limited to the traditional protecting poses.

However, the issue of AI implementation in packaging cannot be disregarded in the packaging of the Indian market whereby the industry is typified by small and medium-sized enterprises (SMEs). The cost of high implementation, lack of skilled labour force, lack of proper infrastructure and resistance to change are major challenges as demonstrated by the study. Compared to big business, the SMEs are capable of carrying out their activities using minimal resources, and even find it difficult to adopt advanced AI applications. This renders critical problems with inclusivity and access to technological transformation. Therefore, despite the massive opportunities of AI and Industry 4.0, they should be treated differently in their approach to implementation because various companies in the packaging industry have different capacities.

The other point of discussion of importance is the point of collaboration and policy support. The study suggests that adoption of AI in Industry 4.0 cannot be adopted on its own. The connection of the packaging companies with the technology suppliers, government agencies, and academic institutions is necessary to acquire knowledge, reduce costs, and develop proliferation. The government offering incentives and tax breaks, and grants of innovation may be key in convincing smaller companies to utilize AI. Similarly, even the democratization of access to high-technologies that are created by establishing industry clusters or shared innovation hubs can also be implemented in such a way that the small corporations will not reap the rewards.

There is one broader socio-economic implication of AI implementation in the packaging industry, which is mentioned in the discussion. Industry 4.0 systems being AI-based will be able to enhance the economic growth of the countries and environmental protection by enhancing efficiency and making the practice sustainable. The Indian market that is currently experiencing the boom of the packaging sector due to increasing e-commerce, retail, and export operations, the creation of AI might not only enable the provision of jobs and high-technological jobs to increasingly operate, but also reduce the number of manual operations over which managers are currently relying on. However, the change requires reskilling services which would ensure that they displace their employees but rather enable them work even better in the new digital employment opportunities.

Finally, but most certainly not least, the study has demonstrated the strategic importance of aligning the process of implementing AI and Industry 4.0 with the long-term business goals. Though it may seem that the introduction of these technologies will result in an additional expense in the short term, the long-term benefits in the form of saving of operations and adherence to sustainability, connection with the consumers, competitiveness will significantly outweigh the investments. This is due to the fact that the companies that take a long time to adopt them may fall behind their competitors in the global arena who are already operating using AI and Industry 4.0 to simplify their processes. It is a problem that makes implementation of AI not only decision of technology, but also survival and growth is a must in the modern packaging world.

In conclusion, it is possible to mention that the discussion above demonstrates that AI and Industry 4.0 can merge into an opportunity the packaging industry can utilize to transform its progress to cause its growth. Some of these challenges such as cost, skills deficiency, and infrastructural vulnerabilities still remain to be crucial, but the possibilities of such integration concerning efficiency, sustainability, customization, and competitiveness pose this integration as extremely timely. These findings suggest a collaborative and gradual and policy-implemented strategy or approach that would bring both of the major companies and SMEs to enjoy the advantages of the digital transformation. Lastly, the study puts the practice of Industry 4.0, driven by AI as the key driver that can remedy the current issues in both packaging and related prospects to consumer-oriented and climate-driven innovation in the future.

Factors Influencing AI in Industry 4.0 in the Packaging Industry

The Artificial Intelligence concept implementation under the industry 4.0 in the packaging industry is predetermined by the multifarious interdependent factors. One of those factors is the technological preparedness, as these are the most significant in this equation, and such a level is the one, to which the companies and other industries became ready to use and apply the recent technological methods (Palanivelu and Vasanthi, 2020). Military digital infrastructure such as sensors, automation, and data analytics platforms is also needed by the packaging companies to achieve the AI solutions success. In the absence of trusted connection, embedded data systems and compatible equipment, the most progressive AI solutions are never improved to a level that they were supposed to work. Technological preparedness would also entail the presence of knowledgeable human resource that has the prowess to operate, fix and continually upgrade AI-enabled processes. The lack of such preparedness will leave companies with no choice than to wrestle with high barriers to the implementation of AI, leading to inhomogeneous use of the technology throughout the industry.

The other important AI determinant in the packaging is the economic conditions and cost factors. The costs required to initiate AI-based Industry 4.0 technologies in the case of most companies particularly the small and medium-sized companies (SMEs) may be a disadvantage. Other forms of investment like AI-driven robotics, predictive maintenance or smart packaging technologies might be numerous high-upfront capital-intensive investments and this might not be well accessible to companies with resources limitations (Florido, Adame and Tagle, 2015). In the meantime, the long-term economic outcomes, such as reduction of waste, the improvement of efficiency, and high quality of the products, will be able to offset the original investments, in case the firms use the right strategies and receive adequate funding. Hence, low expenses of technology, financial resources, and apparent profits are major influences that define the degree and pace of AI adoption in the packaging sector.

Influence on AI introduction into Industry 4.0 also is strong, through regulatory and policy frameworks. Governments and other regulatory bodies usually build standards to determine how AI-based solutions can be used by the packaging companies particularly in markets that are sensitive such as food, pharmaceuticals, and healthcare. Laws that limit data protection, the ethical use of AI, environmental compliance, and, consumer safety establish the potential applications of AI in the packing procedures (Liu, 2010). Also, as an example, one has to have strict health and safety provisions to support intelligent packaging technologies that track the freshness of food or authenticity of pharmaceuticals. The application of AI should accelerate through government schemes, tax exemptions and innovation-supporting policies and strict / vague legislations will most probably slow it down. This technology-government interrelation drives the impact of external institutional circumstances on the digitalization of the packaging industries.

The other significant issue which is adversely affecting the packaging of AI is the demand and expectations of the consumers in the market. The existing consumers do not only require practical packaging, but recyclable, tailored and fulfilling. The introduction of online shopping and the direct-to-consumer-delivery designs have increased the requirement of effective and smart packaging systems. The transformed needs can be guided by the AI technologies of the predictive demand analysis, smart labelling and personalization tools. Take the replica as an example, depending on the taste of a particular customer, it is possible to design a package, with the help of AI-based design systems that will increase the rates of customer satisfaction and brand loyalty. In addition to that, the increasing environmental consciousness of the tourists makes the companies use AI to regulate the use of materials more effectively, generate less waste, and find alternatives that can be more environmentally friendly in terms of packaging. As such, transformation in consumer behaviour is a strong competitive driver of AI innovation in the industry 4.0 packaging systems (Hirschi, 2018).

The position of the organizational culture and leadership cannot be disregarded as well in the analysis of conditions that can influence AI in the packaging industry. Good implementation of AI not only involves the technological equipment but also good attitude within the organization. The dedication of the leaders, the numerous attempts at innovation, willingness to invest in digitalization assumes the leading position in the determination of the successful implementation of AI technologies (Taylor and Conexxus, 2018). Firms with a high hierarchical organizational culture or slow and slow to adapt to may not embrace AI in their operations. On the other hand, the likelihood of cashing in on the full potential of Industry 4.0 technologies is relatively high in organisations with the organisational culture of experimentation, training, and continuous improvement. Thus, vision leadership and organizational flexibility can be considered to be highly important in the packaging AI adoption.

Another factor that influences the level of collaboration is the system of packaging. The principle of the connection is the cornerstone of Industry 4.0, in other words, individual companies will not be capable of deploying AI solution individually. The packaging companies must collaborate with other technology suppliers, supply chain partners, the research institutes, and the government agencies in order to make the implementation successful. Expertise is also provided through sharing knowledge and also through joint ventures and alliances in the industry, risk reduction has also been facilitated and more innovation has been encouraged. A good example is that collaboration with AI solutions developers may help the packaging SMEs receive access to the newest technologies without being required to develop all of them by themselves. In this respect, networked partnerships are the motifs that determine the AI diffusion in the packaging industry.

Finally, the demand to be sustainable and international competition contribute to the use of AI in Industry 4.0 packaging. The threat of environmental concerns is reshaping the packaging exercise in every corner of the world and compelling businesses to identify new approaches, which would reduce their consumption of resources, improve on recycling and implementation of green policies. Artificial intelligence provides potent bases of streamlining material, carbon index, and creation of environment-friendly substitutes. Meanwhile, the world is becoming increasingly competitive and it is compelling companies to implement AI to enhance their performance besides cutting down on costs to help them stay afloat in the rapidly changing market. The said dual sustainability and competitiveness threat, in its turn, introduces a need and an opportunity of the packaging companies to consider the concept of artificial intelligence as a part of their Industry 4.0 policy.

To sum up, AI implementation in Industry 4.0 in the packaging sector is conditional upon the quantity of the factors, which are interdependent and comprises technological preparedness, economic limits, regulatory framework, consumer priorities, organizational culture, alliances and sustainability demands. All these will go towards the adoption rate of AI and the degree to which it will revolutionize the practices of packaging. These impacts would be appreciated by the firms, the policy makers, and stakeholders planning to use AI to modernize the packaging sector in regard to efficiency, sustainability, and innovation.

Challenges of AI in Industry 4.0 in the Packaging Industry

On the one hand, the implementation of Artificial Intelligence in the Industry 4.0 within the packaging industry possesses a revolutionary potential, and it is not a VUCA flow. It is among the highest obstacles as it is very costly to incorporate and implement. Small and medium sized enterprises (SMEs) and the packaging companies generally face economic pressure to invest and use AI enabled machines, predictive machines and other advanced data analytics systems. These technologies involve high capital investments at their inception, continued capital investments in upgrades and integration (Teitel, 2000). Unlike the larger multinational corporations that may find it possible to absorb such costs, the smaller players are faced with the issue of finding a balance between the two costs and low chances of returning on the investment. In turn, the barriers to the economy continue to have a fire branding effect on the rampant use of AI in the packaging arena.

The second issue is of importance is the technological preparedness and the digital infrastructure. IBM 4.0 based on Artificial Intelligence are highly reliant on the interconnective apparatus and appropriate data collection and the existence of a steady connection. However, such demands cannot be facilitated by most firms in the packaging sector particularly in the emerging economies due to their lack of the necessary infrastructure. Bad digital ecosystems, outdated machines, and fragmented information (systems) reduce performance and reliability of artificial intelligence implementations. In addition, redesign would be needed in the traditional systems, which are switching to the smart factories in most of the cases, and it can further interfere with business, leading to resistance by the company. Without taking into account such infrastructural issues, disproportional and piecemeal implementation of AI by the packaging industry is possible (Tay *et al.*, 2018).

More significant issues also include data management and cybersecurity. The application of AI systems works on the mega real time processes which take place in the production processes, customer interactions and supply chain. This data should be accurate, consistent, and available in order to stabilize an AI functioning. However, some of the problems that are encountered by the packaging companies include data silos, lack of information, and uneven patterns all of which reduce the performance of AI applications. In addition, greater dependency on interconnection system creates vulnerability to information assault and cyber-attacks. Fragile information concerning the level of consumer behaviour, the design of its products, and chain supply logistics are beckoning hackers who will lead to a loss of funds and a varied detriment. Therefore, lack of information control and cybersecurity have become serious problems in AI-controlled packaging.

The shortage of skills and willingness to work force also complicates the problem of handling AI to Industry 4.0. The processes within packaging organizations traditionally consume labour and adaption to AI-based automation demands labour that is competent of adapting to the new technical competencies such as acquisition of data analysis skills, knows about robotics programming and the capacity to integrate systems. However, the entire workforce is not well-informed enough to use AI systems and automatize them. This leads to two problems, the first one is that firms are now facing the problem of the shortage of proficiency skills and second, existing workers fear being automated out of the job. The socio-technical nature of the packaging operations not only serves as the guarantee to the investment approach through the purchase of new technologies but also in terms of upskilling and reskilling programs that help the workers gain new employment. The failure to consider human factor will make companies susceptible to the resistance of change, productivity, and cultural-artificial intelligence mismatch (Machado, Winroth and Ribeiro da Silva, 2020).

The virtual uncertainty of the regulation is also an issue in the AI implementation of the packaging. By the fact that packaging business is more likely to intersect with other continuously high demanding industries such as food, drugs, and healthcare, the companies are required to abide by high safety, labelling standards as well as sustainability standards. However, the legislations that cover the use of AI and digital technologies are at a transitional stage and the compliance requirements are thus ambiguous at the present. One such example would be using an AI-driven smart package to monitor the freshness of the food or the traceability which may contradict the existing labelling laws or the privacy policy of consumers. Moreover, the world is not uniform in its policies and this only adds to the plight of a company with more than one market. Absence of a dependable or clear regulatory system then creates a time out of nowhere in the process of implementing AI based solutions in packaging.

The question of sustainability provides the second dimension. Although, the AI can help maintain a greener attitude to the surrounding, better use of the material resources and fewer wastes, the development of AI systems, in its turn, most of the time concerns energy-consuming networks and electronic devices. The companies need to balance the utilisation of AI within the company to be able to survive and the environmental cost of digital transformation. In addition, the increasing pressure of biodegradable and recyclable packaging in the globe burdens the companies with an obligation to be creative in a responsible manner without undermining the issues of environmental awareness. Attaining sustainability to embrace the implementation of energy consuming AI systems is a delicate and tricky game to play.

And the last point is that the bigger supply chain may become one of the pitfalls towards the implementation of AI in packaging. The 4.0 Industry dwells on integrating the entire chain where packaging must correlate well with production, logistics and distribution. Supply chains are though generally non-linear and different players will be in diverse technology levels. The introduction of AI-driven systems to a packaging company may result in difficulties concerning the integration with other suppliers or distributors without similar functions. It decreases the efficacy of the end-to-end digitalization, as well as harms the chance of collaboration among Industry 4.0. The interoperability at the various stakeholder levels is however a major challenge to realize.

In conclusion, despite the fact that the AI can lead to tremendous opportunities in transforming packaging based on the industry 4.0 paradigm, firms are faced with various challenges that include loss of money in implementing the technology, absence of infrastructures, threats to data management and cybersecurity, skill shortage among the workforce, regulatory ambiguity, and supply chain integration. Such problems worsen the clumsy process of restructuring the traditional approach to packaging operations to AI-based ones. Their hostile bargaining would be a concerted action by the firms, governments, technology vendors, and employees to ensure that the AI integration is sustainable, inclusive and also, strategically profitable to the packaging industry (Castagnoli *et al.*, 2022).

Opportunities of AI in Industry 4.0 in the Packaging Industry

The introduction of the Artificial Intelligence (AI) into Industry 4.0 introduces opportunities that the packaging industry has never enjoyed before, thus it is the most dominant player in the technological transformation. The second chance is the attainment of efficiency in its operations. Automation of processes and predictive analytics can allow packaging companies promote the improvement of the production cycle, reduce the time of production, and optimize the utilization of the available resources due to AI (De Propris and Bailey, 2020)To give an example, AI-based predictive maintenance can be used to monitor the state of the equipment operation continuously and detect abnormalities before they lead to failures in the machine. This precaution will save time, declare life of machines and lower the maintenance cost. Companies have not only increased speed and accuracy by automating the process of sorting, labelling or inspection of quality, but also set the human resource free, allowing them to be put on more productive creative and strategic processes.

The second chance that AI can offer the industry 4.0 is the possibility of enhancing the quality of a product and its safety. Packaging is an essential factor in preservation of the product integrity in industries like food, beverage and pharmaceutical industry. Computer vision systems with the assistance of AI are capable of inspecting labelling line with high accuracy and identify them as having defects, including mislabelling, broken seals, or misprint in real-time. This enhances consumer security, reduces the likelihood of the recall of the product, and ensures that the rules in the industry are adhered to the latter. Similar to inspection, AI can also predict and prevent the quality issues according to the past trends of the historical data. Such degree of accuracy boosts the trust of the products and develops the image of packaging companies under the most competitive business conditions (Matt, Modrák and Zsifkovits, 2020).

AI can also be used in spacious innovation of intelligent packaging solutions. The more the necessity to raise the level of interaction, smartness and personalisation of packaging, the more AI will bring the chance to design and introduce the level of packaging that goes beyond the traditional design and functionality. Combining AI analytics and sensors and QR codes on smart labels can provide the consumers with the information regarding the authenticity of the products, their shelf life, or sustainability certificates. These inventions do not just enhance the customer experience, but also create brand loyalty in relation to fulfilling the consumer transparency and traceability needs. In addition to this, AI-powered design systems will allow corporations to make customized packaging, which will be tailored to the preference of the consumer and it will be able to tailor it in large productions. This type of interaction is a new dimension of communication between brand and consumer.

Sustainability is another area that AI can provide the packaging industry with revolutionary opportunities. With the growing concern of the environmental care issue, packaging firm have been under pressure to reduce material wastes, cut carbon emission and shift towards environmentally friendly solutions. Artificial intelligence-driven analytics enable the companies to justify the use of materials to make their packaging more cheap and even sustainable. Algorithms will be in a position to sample and simulate different packaging designs as a computer simulation before they are physically made without the influence of trial and error. Bio degradable materials can also be developed using AI by evaluating the great mass of data on performances and sustainability of materials (Stankovic, Gupta and Figueroa, 2017). These innovations are able to not only meet the regulatory pressure, but also to meet the need of the environmentally friendly consumers and thus assist the firms to put themselves at the forefront of the sustainable practices.

This is because AI enhances the integration of the supply chain within the packaging process and opens a new potential of integration and responsiveness. The industry 4.0 puts much focus on the interconnected systems, and AI is in the middle of harmonizing the activities of packaging processes with production, logistics, and distribution networks. AI-based real-time data analytics can enable packaging companies to identify changes in demand, match production timelines, and deliver products at the right time. The indicatives in the e-commerce sector are that AI can be applied to streamline the packaging design and quantities based on the purchasing pattern of the consumers and reduce overproduction and inventory holding. This responsiveness and agility enhance resiliency to the supply chain as well as provide businesses with competitive edge in unstable markets.

The other opportunity is a possibility to use AI-based analytics to boost the consumer insights and responsiveness to changes in the market. Packaging is not always a container but can be a major point of contact during the process of dealing with the consumers. By relying on AI, businesses can access consumer behaviour, preferences, and purchase patterns data, which they can use to develop the packaging that attracts specific segments. AI makes it possible to promote the individual packaging, make marketing through packaging tasteful, and instantly adapt to client trends. This increases the responsiveness of the market besides offering more channels through which the brands can differentiate themselves in the crowded markets through the consumer-led innovation.

On the one hand, the opportunities of the introduction of small and medium-sized packaging enterprises (SMEs) into the competitive realm of Industry 4.0 are opened through the introduction of AI. SMEs tend to be challenged in adopting new technologies and with the aid of AI, they will be able to have solutions that are scalable and can be customized to their specific requirements. The fact that advanced analytics and automation can be accessible to smaller companies through the reduction and elimination of the need to invest heavily in infrastructure is an example of cloud-based AI platforms. Through the introduction of AI, the SME will be able to be more productive and enhance quality and provide new packaging options to compete with larger businesses. This democratization in technology creates the prospects of increased people and expansions in packaging industry (Samans, 2019).

In conclusion of the existing situation in the AI integration in Industry 4.0, various opportunities are posed to the packaging industry and can be further extended to general efficiency of operation, quality enhancement, intelligent packaging, sustainability, collaboration of supply chain, communication with consumers, and competitiveness of SME. With these opportunities, the packaging firms are not only able to improve their operations in the internal environment but also redefine its place in the global chain of supply and the consumer market. As the Industry 4.0 continues to assume a new form, AI will continue playing a leading role in bringing change and will elevate the packaging industry to the same level both as an industrial growth agent and as an agent of sustainable development.

Suggestions for Integrating AI into Industry 4.0 in the Packaging Industry

The implementation of an Artificial Intelligence (AI) in Industry 4.0 is a paradigm shift of the packaging industry, and the migration should be carefully planned and implemented strategically. An important recommendation is to start with the capacity building and the training of the workforce. Small and medium-sized enterprise (SME) in the packaging companies in many cases have no ready talents to run AI-enabled technologies. Resistance to adoption can be greatly mitigated by investing in training programs that help equip the employees with knowledge about machine learning, robotics and smart sensors. Also, developing relationships with universities and research centres will provide a permanent update on skills as well as staying in touch with new technologies on the part of employees. Even the most powerful AI systems will not be fully exploited without an educated and intelligent labour force (Sadiku, Fagbohungbe and Musa, 2020).

Another important recommendation is to implement a gradual and step by step policy. The high expenses and judgment on novel technologies make many firms not fully adopt AI. Pilot projects in certain domains such as predictive maintenance, automated quality inspection or supply chain forecasting should be introduced to the company instead of enforcing large-scale changes. The smaller applications are obtainable with some quantifiable benefits, and also the firms are able to gradually transition to digital operations. In the long run, with increasing levels of confidence and returns on investment, businesses will be able to ramp up and increase the use of AI in a variety of functions. The approach minimizes risks, makes the operations financially viable, and develops lower transitions.

A powerful data management framework is also necessary in order to utilize AI effectively. The industry 4.0 relies on the real time data on the production line, logistics and consumer behaviour. The companies should invest in the digital infrastructure that will be most active in collecting, storing, and analysing the data to give AI tools an amazing performance. To give an example, the process of integration will be realized without issues and lower the level of errors because uniform data collection systems will be used in all the operations. At the same time, organizations must have effective cybersecurity initiatives that will improve the security of the valuable data and protect against the attacks of their systems. Having effective data governance will not only result in high degree of efficiency in its operations but will also instil trust to the customers, regulators or other stakeholders.

The idea of AI needs to be shaped by environmental objectives as sustainability is among the most topical demands of a modern packaging enterprise. The artificial intelligence-based solution can automatize consumption of raw materials, reduce the amount of energy consumed, and develop environmentally conscious packaging solutions that would be able to meet the needs of the market. The move to make AI sustainable is also capable of enabling packaging companies to align itself to the global environmental expectations besides fulfilling the rising consumer demands in more eco-friendly products. The goals of the circular economy can be also achieved with the help of smart recycling solutions and AI-based waste management solutions that can not only make the packaging companies more competitive but also form their reputation (Soni *et al.*, 2020).

Collaboration is another important tip that can be considered. Since most SMEs may not have the financial and technical resources to purchase and install such technologies personally, it can be defeated by forming a partnership with technology vendors, larger businesses, and industry organizations. The more AI technologies are distributed in the innovation hubs or on shared digital platforms, the more accessible and less expensive they will be. To provide an example of how SMEs can be helped, AI-based logistics systems created within the sector can reduce the expenditures; simultaneously, promoting the effectiveness. Sharing of knowledge and innovation on a group level is also encouraged by this model of teamwork.

On a higher scale, the development of AI-based Industry 4.0 in the packaging industry depends on policy support and the role of the government. The policymakers should provide certain incentives, such as subsidies, credit schemes, and tax incentives on the firms making investments in AI-based solutions. In the meantime, the legislation must ensure that it is morally sound, privacy of information, and cyber strength. With appropriate policy frameworks, the business nature will be friendly and, in this way, the businesses will be motivated to adopt AI. The government-led innovation centres focusing on the technologies of packaging can be created as well that will motivate the startups and SMEs to experiment with the AI-driven solutions without the prohibitive costs.

And finally, the packaging sector will need to implement AI using a customer-oriented innovation. The artificial intelligence technologies will be capable of telling them what they want, thereby providing them with personal solutions of packaging and developing a stronger brand loyalty. The use of AI to forecast the customer needs will enable the firms to design intelligent packaging that is not only functional, but also incorporates other functionalities such as QR codes, interactive design, real-time product details, etc. This does not only improve consumer experience, but also creates new sources of revenues. The companies that apply AI to be customized and innovative will gain more benefits of creating a competitive edge in the saturated markets.

Lastly, AI should undergo a holistic approach to transformation into Industry 4.0 in the packaging industry, which will rely on the formation of the workforce, incremental deployment, sound data management, sustainability, collaboration, enabling policies, and customer-centred innovations. Under the influence of such recommendations, the packaging firms will be capable of overcoming the current problems and harnessing the opportunities of competitive advantage and growth in the long-term. It not only should be concerned with the transformation of technology but should also strive towards establishing an ecosystem where the individuals, processes, and policies are aligned so that the benefits of AI become self-fulfilling.

Chapter-VI

Implications, Recommendations and Conclusion

This research findings have a major implication on the theory, practice and policy particularly in the dynamic packaging industry. The Artificial Intelligence (AI) implementation on the industry 4.0 does not only provide the tips on how the technology may be used in the packages processes, but also demonstrates how the technology may influence the socio-economic and environmental outcomes of its use.

Theoretical Implications

The study, in theory, fits into the growing body of literature on Industry 4.0 since the author prioritizes the problem of packaging as one of the key areas to introduce AI. Even though many researches have been done in AI in manufacturing industry, logistics and supply chain, findings in the packaging sphere have not received a significant scholarly focus because it is a leading field of focus that connects manufacturers with consumers. In this study, the gap will be bridged by showing that AI can enhance the efficiency of packaging, sustainability, and personalization. It describes the fact that it is necessary to enlarge the present Industry 4.0 models to refer to the processes connected with packaging, such as the selection of materials, the innovative design, and engagement with customers.

In addition, the study adds to the set of theories about the circular economy and sustainability since it demonstrates the way the AI-based packaging methods can help to optimize the use of resources and reduce the waste volume. The relationship between AI application and environmental performance makes a contribution to the interdisciplinary prospects of digital transformation and sustainable business model integration. Such theoretical contribution provides a challenge to the future researchers to dig deeper into the intersection, technology, sustainability, and consumer engagement considering the packaging.

Practical Implications

The study provides various insights that may be implemented by players in the industry. The companies that specialize in packaging might use the AI-based Systems of industry 4.0 in order to have a smoother functioning with the purpose of reducing the expenses and enhancing the quality of the products. One such example is the use of predictive maintenance that is AI based and will save down time and smart quality-control systems will reduce defects and wastage. The practices can help the companies to be more competitive in the global markets where speed, precision and reliability are highly demanded.

The second practical implication is on the sustainability practices. With the help of artificial intelligence, firms are able to justify the consumption of raw materials, design in a more environment-friendly manner, and develop smart recycling mechanisms as part of doing business. This is not only fulfilling the rising demands of the customer regarding green packaging but also ensures that environmental rules are both keen and tough. As the study explains, in the long run, the companies that will package products with AI-based sustainability policies will enjoy such benefits as a better reputation, customer loyalty, and brand differentiation.

In addition to this, the investigation mentions the potential of consumer-oriented innovation. Smart packaging can be developed with the help of artificial intelligence and provide interactive and personalized design, as well as traceability of the product. These technologies improve the ties between customers and brands and generate packaging as the means of marketing strategy and not as a need. Businesses that supported themselves on such opportunities would have a simpler time acquiring some of these markets within competitive and dynamic industries such as e-commerce and fast-moving consumer goods (FMCG).

Policy Implications

The research has significant implications to the policymakers and regulators of the industry. The Indian packaging industry is largely dominated by SMEs and thus the policy assistance is burning so much needed in the situation of AI adoption. The SMEs can utilize the high cost of implementation of AI by subsidies, tax benefits, and low-interest loans among others. Moreover, to ensure the companies within the different regions have access to reliable data networks and smart manufacturing systems, policies, which help in the creation of digital infrastructure, are necessary.

The other implication of the policy involves the need to develop a talented workforce. The governments in question, along with the industry agencies and educational institutions should pursue the idea of reskilling to turn around their employees into those capable of working in the new AI-inspired Industry 4.0 environments. Such programs will not only comfort the toddlers towards adopting technology, but would also eliminate the issue of job displacement when new jobs in technical and analytical profession are developed.

Finally, challenges of data governance, privacy and cybersecurity in the package industry should be addressed by the policymakers. The AI systems rely on real-time information a lot, thus there is the necessity to have clear directions that ensure protection of sensitive information and enhance innovation. Indicating the rules of applying AI will also ensure that the benefits of implementing AI will not be lost along with the trust of the consumers or their safety.

Conclusion

The existing study aims to explore integration of AI into industry 4.0 to address challenges and opportunities in the packaging industry. The goals of the study is to identify and analyse factors affecting artificial intelligence adoption in the packaging industry in India; to examine the challenges of integrating artificial intelligence into industry 4.0 in the packaging industry in India; to examine the opportunities of integrating artificial intelligence into industry 4.0 in the packaging industry in India and to provide suitable recommendations to ensure effective adoption and integration of artificial intelligence into industry 4.0 in the packaging industry. The findings of the demographic statistics factor of age distribution stated that majority of respondents comes under the age range of 25 to 35 years; the study assessed gender distribution and stated that majority of respondents in the study are male; the findings of marital status stated that majority of respondents in the study are married; the results of educational qualification assessed that majority of respondents in the study are post graduate; the majority of respondents in the study found to be having monthly income of Rs. 55001 to 65000; the findings of the study stated that majority of respondents having 2 to 5 years of experience in the packaging industry; the results of the study stated that majority of respondents in the study belongs to nuclear family and lastly analysed the size that is number of persons in respondents' family and stated that only 2 members.

The second part of analysis deals with first factors that influence AI adoption in packaging industry and stated that consistency among machines and systems and implementation and maintenance costs are the key factors that influence AI adoption in packaging industry. Secondly, challenges in AI integration in respondents' organisation assessed and stated that poor IT infrastructural support delays the use of AI in the packaging plants is the key challenge.

the results related to opportunities in AI integration in respondents' organisation stated that AI-based predictive maintenance minimizes packaging-machinery downtimes is the opportunity the packaging industry look for. Lastly, recommendations for making AI adoption easy in respondents' packaging organisation is assessed. The results of the study stated that implement pilot projects to receive the advantages of AI in practice during packaging is the key recommendation of the study.

Recommendations of the Study

Based on the findings and discussion, it is possible to make several recommendation statements to ensure that the Artificial Intelligence (AI)-based and Industry 4.0-based technologies could be successfully introduced into the packaging industry. The practitioners, policymakers, and researchers will be the target audience of these suggestions as they are interested in the same goal the competitiveness of the sector and its sustainability as well as its ability to be innovative.

Enhancing Expertise and abilities in the Workforce

One of the most highly needed requirements is the creation of effective staff capable of collaborating with AI-based Industry 4.0. Lack of skills in the area of digital and analytical skills is also acute when it comes to the packaging industry particularly in India. In a manner of managing this, businesses should consider investing in continuous training and reskilling of its employees across all ranks. Partnerships with higher institutions, technical colleges, and research institutions could be adopted to come up with specialized courses according to the activities of packaging. The lack of resistance to change is also linked to the inability of companies to embrace new technologies with unproblematic ease and effort, with the encouragement of the trend in promoting the levels of digital literacy and AI competency of employees.

Advanced and Progressive Implementation of AI

As the process of AI adoption is expensive and complicated, especially to small and medium-sized enterprises (SMEs), the recommended practice would be to take it step by step rather than attempting to change the entire operation of the company simultaneously. The initial pilot projects should be carried out on specific functions e.g. on predictive maintenance or quality inspection or demand forecasting. Such projects, which were successful previously, can be extended to the production, logistics and supply chain networks. The approach will reduce the risk and facilitate investments as well as create trust in the organizations about the feasible benefits of integrating AI.

The focus on Sustainability and Circular Economy

Another valuable recommendation that must be made is the fact that the implementation of AI in the packaging business must be accompanied by sustainability principles. Firms should adopt solutions based on AI where optimization of the materials shall be implemented, recyclable packages shall be developed, and the carbon footprint tracked. Through undertaking sustainability within AI projects and Industry 4.0 projects, businesses can not only meet the regulatory requirements, but they will also gain some confidence with customers in a market where the significance of eco-friendly products is continuously increasing. The AI initiatives that governments and other industry agencies should pursue should make a direct contribution to the sustainability and must lead to win-win scenario regarding the environmental stewardship and performance of the businesses.

Increasing Data Infrastructure and Data Governance

Determining one of the pillars of successful integration is data infrastructure since AI systems need extensive volumes of information that is correct and timely. Firms within the packaging industries must find a way of developing quality data collection, data storage and data analysis systems in both the production and supply chain processes. High-investments in cloud computing, IoT sensors, and combined platforms will improve the viability of AI. Besides infrastructure, the firms are also supposed to introduce efficient policy measures to handle data governance in order to enable transparency, safety and compliance to the regulations on privacy. This will gain organizations the goodwill of the stakeholders and protect organizations against cyber risks that are increasingly on the increase; during the digital transformation era.

Creating Teamwork and Ecosystem Building

The close types of integration can be extremely beneficial in the packaging world in reducing the costs load, and enhancing accessibility of modern technologies. The SMEs in particular are compelled to establish alliances with the bigger businesses, suppliers of technological resources and even trade associations to share resources, knowledge and best practice. That can be achieved by establishing innovation centres or common digital packaging space and thereby establish collaborative development to the game. The type of collaboration is not only used to accelerate adoption but also to facilitate co-creation of solutions addressing common problems in the industry.

Government incentives and Policy support

Policies must be closely working hand in hand to be able to introduce AI to the Industry 4.0 successfully. In order to encourage the use of AI technologies, governments should come up with certain policies such as subsidies, tax benefits and low-interest innovations. It must as well entail policies on the digital advancement on regions where the cluster of the packaging industries is vast and the companies need to have access to efficient internet connections and modern facilities. At the same time, such issues as cybersecurity, the ethical application of AI and environmental compliance should be included into the regulatory framework. The policies will provide a ground levelled and conducive environment that could help businesses use AI without apprehension.

Consumer-Centric Innovation

Finally, it may be recommended that the companies involved in the packaging should approach the consumer-centric perspective when thinking about the AI strategies. The artificial intelligence analytics enables businesses to study more about the likes of customers, and come up with personal and interactive and traceable packaging. These features, such as the use of QR codes, smart labels, and AR, could enhance the experience with the consumer and add some new values to the product. Those companies will integrate consumer insights into the package design that will increase the brand-loyalty and differentiate among increasingly competitive markets Innovation.

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