A Comprehensive Review of Workforce Transformation in the Era of Industry 4.0 and Industry 5.0

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Abstract-**Improvements in robotics and automated technologies have dramatically changed the nature of a wide range of industries' operations, work forces, and working practices. Robotic technology has been a major driver of increased productivity, efficiency, precision and safety in operation, but it also has sparked fears about job loss, of one type or another, and transitioning new dynamics in the workplace. This review paper highlights the effects of robotics on the job insecurity and robot behaviours in various industries, such as manufacturing, healthcare, logistics, agriculture, and service, through analysing the relevant previous research. The study examines the economic costs and benefits of automation, the steps that need to be taken by workers to adapt to automation, trends in technological adoption, and policy options to buffer against employment consequences. Results suggest that while robots can do repetitive tasks, they also will provide opportunities to new jobs involving more technical, analytical, and managerial skills. The review also underscores the need to reskill effectively, continuously learn, work alongside robots and to support the better practices in companies for workforce transitions. By analyzing how each sector, skill level and region is impacted by automation, organizations can gain deeper insights into how each needs to respond to it with tailored policies. The research findings show that robotics can no longer be seen as an issue only of "losing" jobs but as an opportunity for job reconfiguration, workforce transition and economic growth. The key to sustainable jobs and economic growth, taken from the perspective of Industry 4.0 and 5.0 in Industry and Incomes, is the effective collaboration between governments, industries, educational institutions and employees.**
Keywords: Industry 4.0 & 5.0, Workforce Transformation, Artificial Intelligence, Human–Robot Collaboration, Reskilling, Economic Impact, Workplace Behaviour, Job Insecurity, and Digital Manufacturing are the selected keywords.

1. INTRODUCTION

1.1 Background

Robotic systems, AI, IoT, Cloud Computing and Cyber-Physical systems have revolutionised industrial processes, and made this the 4th Industrial revolution—or Industry 4.0 as this is now called [1]. The use of these technologies has led to better product quality, higher productivity and more flexible production systems in manufacturing based on data/learning and on systems interconnectedness [2]. One of the most apparent enabling technologies is robotics, and the number of industrial robots installed around the world has been steadily increasing in manufacturing, healthcare, agriculture, logistics and service sectors [3]. A strong pillar of this development is the idea of cyber-physical production systems [4], in which physical machines are closely connected to networked intelligence and sensing/computation technologies, in order to permit the real-time monitoring, prediction and adaption of "smart factories".

However, a shift is now happening towards the paradigm of Industry 5.0, where people, intelligent machines and their capabilities go hand in hand shoulder to shoulder, energy conservation and sustainability placed first, but with automation more of a secondary concern than what was observed in Industry 4.0 [5]. This move is indicative of the realization that, in the future, robots and humans will not be competitive substitutes for one another as repetitive, dangerous, or extremely accurate industrial processes, but will work side by side, each leveraging the strength of its complementary skill sets.

The spread of robotics in the workplace has created an increasingly documented conflict between increasing productivity and safeguarding the workforce. In fact, Frey and Osborne's seminal analysis found that many jobs in advanced economies were highly susceptible to computerization for the next 20 years [6] and recent empirical research showed that the presence of industrial robots in local labour markets had caused systematic falls in the number of employment and wages in work categories at high risk of computerization [7]. Concurrently, automation is not just taking away jobs, but also creating need for new technical and analytical roles as well as managerial roles in robotics engineering, data science, cybersecurity, and systems maintenance [8]. A formidable character of displacement or creation of opportunity in some tasks and a meaning of skills policy, education systems and labour-market regulation has made workforce transformation one of the most significant economic and social issues of the present technological era [8, 9].

Especially for large modernizing economies like India, where the labour force is still heavily dependent on manufacturing and agriculture, and where Artificial Intelligence and automation readiness is a key focus of national policy [10] The dynamics of robotics adoption vary significantly between economies, sectors and skill levels, making it critical to understand the dynamics if governments, industries and education are not to follow the trend of two waves of post-2006, the first reactive and the second proactive.

1.2 Research Gap

There has been a significant body of research that has focused on the adoption of robotics for specific industries, such as industrial robotics in manufacturing [2] or on the economics of the loss of jobs due to automation in particular national labour markets [6] and [7]. Fewer studies, however, have done efforts to integrate these powerful results from each sector and draw a cross-sectoral picture of the overall impact of robotics on the labor market. Most of the engineering and management publications about Industry 4.0/5.0 have historically been limited to only one specific industry or country [1, 2, 4] and most of the publications on labour-economics are limited to one specific sector [6, 7]. There is therefore a need for a review that brings together evidence from diverse industry sectors within a single analytical framework, interprets and provides a context for these evidence-based findings through the lens of a transition from Industry 4.0 to the more human-centred Industry 5.0 [5] and thinks about how such patterns play out in a large and rapidly automating economy like the Indian context where adoption data and policy responses in each sector remain very fragmented across Incredible India and other government and industry reports [9], [10]. This review is a likely response to that need.

The purposes of this Review are:

Based on the findings of the background section and gap described above, this review has following goals:

1. Compile and summarize the use and impact of robotics in the manufacturing, health and human services, agricultural, education, smart home and service industries;
2. Look at the impact of robots and automation on employment, job security and workplace behaviour within these domains; and
3. List key economic, technical, regulatory and social challenges for robotics applications; and
4. Assess effectiveness of existing policy programs (specially in India) in enabling transitions; and
5. Suggest research and policy suggestions that promote a human-centred sustainable transition towards Industry 5.0.

2. RESEARCH METHODOLOGY

In this paper an approach to a narrative literature review document, which synthesises and critically interprets the existing scholarship and industry/government reports on robotics, automation, and workforce transformation is presented focusing on Industry 4.0 and 5.0 concepts and concepts [5] In contrast, it does not require primary data gathering via surveys, interviews or experiments, but rather involves collating, comparing and interpreting results from previously reported research from other researchers and organisations. This literature was identified, screened and organized based on a PRISMA-informed methodology [11] which is described below.

2.1 Literature Search Strategy

A well-defined search process was conducted to identify articles, conference papers, books and reports that provide information on robotics, automation and workforce transformation which are peer-reviewed publications. Boolean operators (AND/OR) were used to combine search terms and they were used on the titles, abstracts and keywords.

Records retrieved were initially screened by title and abstract for obvious irrelevance or duplication, and the abstracted records were subsequently analysed for full text content to assist in acceptance for inclusion in the synthesis of them. The PRISMA flow diagram (Fig. 1) summarises this process.

2.2 Databases and Search Keywords

The search was mostly done from Scopus, Web of Science, IEEE Xplore, ScienceDirect and Google Scholar. Reports from recognised international as well as national bodies, namely World Economic Forum (WEF) [12] and International Federation of Robotics (IFR) [13] were also used. Other reports available from sources like McKinsey Global Institute [14], Organisation for Economic Co-operation and Development (OECD) [15], International Labour Organisation (ILO) [16], United Nations Industrial Development Organization (UNIDO) [17] were supplemented. Reports from the NITI Aayog [18] and the Ministry of Electronics and Information Technology (MeitY), Government of India [19] also shaped the analysis. Reports from the Confederation of Indian Industry (CII) [20] were also one of the sources used.

The main searched terms used, both individually and together, were: "Industry 4.0", "Industry 5.0", "robotics" AND "workforce", "automation" AND "employment", "human–robot collaboration", "collaborative robots" OR "cobots", "workforce transformation", "reskilling" OR "upskilling", "job displacement", "robotics adoption", and "smart manufacturing".

2.3 Inclusion and Exclusion Criteria

To ensure the relevance and quality of the evidence base, sources were screened against a defined set of inclusion and exclusion criteria. These criteria were applied consistently across all searched databases and sources to maintain methodological rigour and transparency in the selection process.

A source was included in the review if it met all of the following criteria:

- Published as a peer-reviewed journal article, conference paper, or a recognised industry book or report;
- Written in the English language;
- Addressed robotics, automation, or Industry 4.0/5.0, including their influence on employment, workforce skills, or industry adoption; and
- Relevant to at least one of the sectors examined in this review (manufacturing, healthcare, agriculture, education, smart homes, or the service industry).

A source was excluded from the review if it met any of the following criteria:

- Published in a language other than English;
- Consisted of opinion pieces, blogs, or promotional/marketing content lacking a verifiable evidentiary or analytical basis;
- Duplicated the underlying data, findings, or research already reported in another included source; or
- Was not directly relevant to robotics, automation, or their outcomes for work and employment.

Applying these criteria ensured that the sources retained for synthesis were credible, current, and directly relevant to the review's scope, while minimising redundancy arising from repeated reporting of the same underlying research.

2.4 Study Selection Process (PRISMA Flow)

The four stages of the process for selecting the articles were identification, screening, eligibility and inclusion, as described in Fig. 1[11].

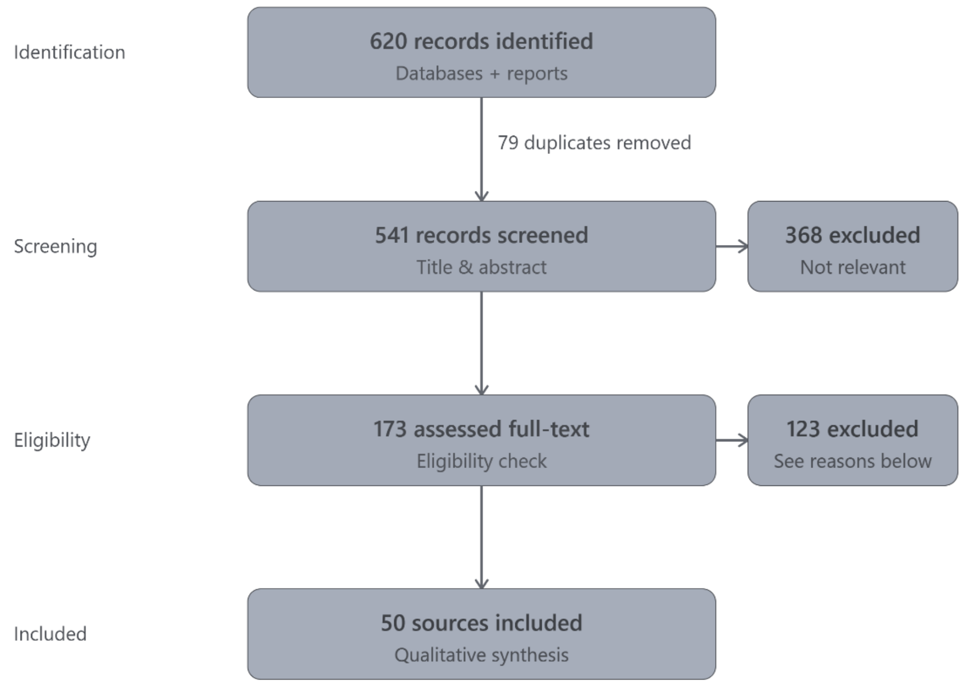

Fig 1. PRISMA flow diagram displays number of sources identified (620) and those screened (541), who were assessed for eligibility (173) and ultimately who were included (50).

Through an initial search of the databases and organisational reports listed in Section 2.2, 620 records were found in total: 312 through the databases and 308 through the organisational reports. Once duplicates were removed 541 records were sent on for screening by the title and abstract. The number of records excluded was 368 due to irrelevance to the scope of this review leaving 173 full-text eligibility assessment records. An additional 123 records were ruled in after another full-text analysis against the inclusion/exclusion criteria in Section 2.3 (these were excluded for reasons such as the original data being deemed duplicate, an insufficient substantive relevance to robotics, automation, workforce outcomes, or for being promotional/opinion based documents; in the latter cases the documents were not published in English). This process resulted in the list of 50 sources that were kept for the qualitative synthesis.

2.5 Time Period Covered

The literature examined is published in the last eight years, mainly in the last ten years since the year 2018, focusing on the most recent aspects of 5.0 Industry, collaborative robotics, and adoption of automation after the pandemic. Selected few basic publications prior to 2014 are referred to as well when they are still the main source of information on a concept or phenomenon mentioned in this review, for example in the early definition of cyber-physical production systems [11].

This Review includes data on several aspects of the industry sector. In this Review, the data provided covers several aspects of the industry sector.

Taking into account the sector-wise statistics, the comparative tables and the benefit/impact scores in Section 4 (Results and Discussion), it is important to note that the figures given with side-by-side comparisons are representative and not exact. These are not the result of original data collection, survey or statistical hypothesis testing done by the authors. They are a structured, qualitative synthesis of figures, trends, and comparisons drawn from insights across the secondary sources examined in Section 3 and quoted throughout Section 4, primarily industry and government reports like the World Robotics Report [13] and the WEF Future of Jobs Report [12] and reports from various government agencies such as NITI Aayog [13], MeitY [19], the CII [14], ILO [16] and UNIDO [17] to which the authors have organized figures, trends, and comparisons in tables and indexes (such as the adoption index included in

Fig. 1, and the benefit-area scores in Table 4) to facilitate interpretation. These tables and figures therefore have to be considered interpretative syntheses rather than statistical output and should be read together with the cited table and figure sources from the original reports.

3. LITERATURE SURVEY AND DATA EXTRACTION

3.1 Manufacturing and Industrial Robotics

Manufacturing continues to be the primary use case for robotics globally and one of the most significant industries for adoption of robotics. With the advent of Industry 4.0, all echelons are catching up with the incorporation of robotic systems into artificial intelligence (AI), machine learning, the Industrial Internet of Things (IIoT), the cloud and cyber-physical systems. These technologies allow for the smart factory that can monitor in real time, predict the need for maintenance, make autonomous decisions, and adapt the production it can do. [17]

It has been shown through various studies that the use of industrial robots leads to better production efficiency, better product quality and safety of use, as well as better process consistency. Examples of robotics applications in manufacturing include welding, painting, assembly, material handling, packaging, inspection, and quality control. The automobile industry is one of the most prominent and successful applications of industrial robotics as it is known for its requirements for precision, high volume, and repeatability [18][19].

Recent reports are showing that industry is continuing to see the robot's installation rate rise, leading to a build-up in confidence in industrial automation. This is mainly due to rising labour costs, global competition, customer expectations for quality products and the use of smart manufacturing methods [20][21][22]. Additionally, collaborative robots (cobots) are receiving expanding interest, as they are expected to facilitate safe interaction between man and robots and increase the flexibility and productivity of the workplaces [23][24]. Even with these advantages, there are still a number of obstacles to the use of industrial robotics, such as the need for specialization, the complexity of incorporating the robot into the base machine, large capital investment, lack of skilled people to maintain the system, and high maintenance costs [25][26][28][29].

3.2 Healthcare and Medical Robotics

With rising demands for healthcare services that are more precise, efficient, and accessible, healthcare robotics has become one of the fastest-growing fields of robotics. Today, robotics technologies are used in the surgical field, patient rehabilitation, telemedicine, diagnostics, patient monitoring, and hospital logistics [30][31].

Incorporating robotics into surgical procedures has proven to offer important improvements over traditional surgery in several areas – increased precision, decreased invasiveness, less complications, and faster recovery time for the patient. These systems enhance images and operator control of instruments, especially in complex surgeries that require precision and accuracy [32][33].

The use of telemedicine technology is vital in contemporary health care systems. Technologies are aiding the delivery of AI support in diagnostic infrastructure, robotic telepresence solutions, and remote consultation systems improving healthcare access, especially in underserved and rural areas [34][35]. Rehabilitation robotics has also garnered significant interest because of its potential to help patients with neurological disorders, spinal cord injury, stroke and musculoskeletal impairments as they recover [36] [37].

The high potential of healthcare robots in facilitating medical care has been subject to a range of factors such as cost considerations, lack of modern infrastructure, regulatory issues, and skill issues that predicate the pace of their adoption. Other ethical issues, including patient privacy, transparency of algorithms, and human oversight, are crucial [38][39].

3.3 Agricultural Robotics

The use of agricultural robotics has proven to be a viable technological solution to enhance productivity, sustainability, and operational efficiency in modern agricultural systems. Today, agriculture is utilizing various robotics applications, such as unmanned aerial vehicles (UAVs), autonomous farming machines, some harvesting machines, precision irrigation, and crop monitoring technologies based on artificial intelligence [40][41].

The research results showed that agricultural drones contribute positively in the field surveillance, management of fertilizers, spraying of pesticides, management of crops health and predictions of yields. Precision agriculture technologies are used to ensure better use of resources, lower environmental impacts and operational costs.

There are several challenges yet to be addressed that prevent a large scale of the application of agricultural robotics. Farmers' small land holdings, low capitalization, poor farm and related information technology, and lack of expertise have been reported as challenges [42]. To develop low cost, scalable, and region specific agricultural robotic solutions that meet region-specific agricultural needs, future research is required.

3.4 Educational Robotics

The rise of educational robotics has become a major priority for educational institutions as they strive to equip their students for the challenges of Industry 4.0 and 5.0. The field of educational robotics integrates engineering, programming, artificial intelligence, automation and problem-solving elements, providing interactive platforms that leverage and develop technical and cognitive skills [43].

Robotics learning environments support the development of computational thinking, creativity, an ability to collaborate, programming skills, and critical thinking. According to several studies, this learning approach not only increases students' engagement, knowledge retention, and practical understanding of STEM concepts, but is also superior to conventional education methods. As the robotics, artificial intelligence, automation, and digital manufacturing bases of the highly skilled industries expand, higher-education programs are adding courses in academic engineering programs to meet the new demands for skills. Yet, issues like finances, inclusion in the curriculum and lack of trained instructors persist and continue to limit the widespread implementation [10].

3.5 Smart Homes and solutions for household automation.

Smart-home technologies are among the most apparent uses of robotics and artificial intelligence in daily life. The convergence of IoT devices, smart sensors, cloud computation, machine learning algorithms, and robots has paved the way for the creation of autonomous connected homes which can make intelligent decisions. These modern smart-home systems can carry out a multitude of functions such as energy and building systems management, security monitoring and surveillance, environmental control, automation of appliances, health support, and household maintenance. These technologies help to achieve better energy efficiency, ease of access, safety, and quality of life [44].

Despite these advantages, cybersecurity, privacy concerns, lack of interoperability, or cost remain factors affecting adoption rates. Future research work should focus on user acceptance, secure data management and designing cost-effective smart-home environment appropriate to various users [44].

3.6 Service Robotics

Service robotics is beginning to be an important field of application in robotics beyond the industrial scale. Today, service robots are applied to various applications including healthcare, hospitality, retail, logistics, transportation and customer-service in order to enhance operational efficiency and service quality [44]. Research results indicate that the application of service robots can contribute to improving service consistency, productivity by reducing routine workloads, and minimisation of human error. Organizations that have adopted service robotics report on several increased benefits such as improvements in customer satisfaction, operational performance, and resource utilization .Because of the importance of communication, trust, and user acceptance in service outcomes in service-oriented environments, human–robot interaction for such environments is also very critical to the success of service robotics .Literature has also raised issues about workforce displacement, job restructuring, and the acceptance of robotic technologies, etc. [45].

On the one hand, service robots can cut down on the need for repetitive tasks, but they also open up new job areas for programming, maintenance and supervision of service robots as well as robot systems integration. To boost productivity gains, while leveraging workforces' transition and sustainable services sector transformation, future efforts should aim at leveraging alternative workforce transition strategies to that to maximize productivity gains [46]

3.7 Workforce Transformation and Future Employment

Industries worldwide are adopting technologies such as robotics and automation to change the nature of work, from a labour-intensive past to an era driven by technology. Hence, the expansion of the applications of new technologies like robotics and automation is changing the approach towards workforce, from labour-intensive days of yesterday to technology-controlled days of today. Although there is less need for repetitive, routine work, automation will also give rise to greater need for advanced skills in fields such as artificial intelligence, robotics engineering, machine learning, information security and data analysis [47].

In context of industry 5.0, technological development is moving towards the integration of human and intelligent machines, and will not be driven to replace the human workforce. Human–Robot collaboration is anticipated to be a crucial component of productivity, safety, innovation and organizational capabilities, thereby improving return on investment and capability against economy, health and safety .To facilitate the sustainable transformation of the workforce, organizations, governments and education providers should make investments in ongoing workforce reskilling, digital literacy and lifelong learning for the workers to equip them for new technological environments [48].

TABLE 1: Sector-Wise Overview of Robotics Applications

Sector	**Major Applications**	**Adoption Level**	**Key Benefits**	**Major Challenges**
Manufacturing	Welding, Assembly, Material Handling, Quality Inspection	Very High	Productivity, Precision, Safety	High Capital Cost
Healthcare	Robotic Surgery, Telemedicine, Rehabilitation	High	Clinical Accuracy, Accessibility	Cost, Infrastructure
Agriculture	Drones, Precision Farming, Crop Monitoring	Moderate	Yield Improvement, Resource Optimization	Small Land Holdings
Education	STEM Learning, Coding Labs, Robotics Training	Moderate	Skill Development	Funding Limitations
Smart Homes	Home Automation, Security Systems	Moderate	Convenience, Energy Efficiency	Privacy Concerns
Service Industry	Hospitality, Logistics, Customer Support	Emerging	Service Quality, Efficiency	User Acceptance

TABLE 2. Comparative Analysis of Robotics Applications

Parameter	**Manufacturing**	**Healthcare**	**Agriculture**	**Education**	**Service Robotics**
Technology Maturity	Very High	High	Moderate	Moderate	Emerging
ROI Potential	Very High	High	Moderate	Long-Term	Moderate
Workforce Impact	High	Moderate	Moderate	Positive	Moderate
Government Support	High	High	High	High	Moderate
Infrastructure Requirement	High	Very High	Moderate	Moderate	Moderate
Future Growth Potential	High	Very High	Very High	High	High

These two tables concisely highlight and compare the applications of robotics in the major sectors. As illustrated in Table 1, manufacturing is the area with the highest level of adoption, such as in welding applications and assembly, which claim high level of productivity and precision; there are some high-front-end cost issues, as well as infrastructure issues to consider. Healthcare also has high adoption levels, including robotic surgery or rehabilitation, and those come with similar high productivity and precision, but with high costs as well as infrastructure. There are moderate to emerging levels of adoption in agriculture, education, smart homes and service industries with primary uses focused on efficiency improvements, learning and convenience, but obstacles remain such as funding, acceptance and privacy concerns. Table 2 also contrasts these sectors with one another and found that manufacturing has reached a high level of technology maturity, and has a high return-on-investment, while healthcare and agriculture has a very high growth potential in the future, and education has a high potential to impact the workforce but have a long payback period. In general, both tables suggest that robotics is well-established in the manufacturing and healthcare fields, with the agriculture, education and service industries emerging as next areas for growth because of rising investments from both the government and the technology itself.

3.2. Verified Literature Review

3.2.1 Manufacturing and Industrial Robotics

Industrial robotics continue to be the primary application area in the world. In 2024, global installations climbed to 4,664,000 units (+9% y-o-y) despite the difficult economic environment, as confirmed by the International Federation of Robotics' World Robotics Report series, placing the number of robots in operation globally above 500,000 units for the fourth consecutive year. About 54% of new deployments (295,000) were China deployments, while collaborative robots (cobots) are deployed at higher rates today at over 64,500 units sold (12% of new deployments and 13% year-on-year growth). As of 2013, there were 177 robots installed per 10,000 employees globally where Asia (204) was ahead of Europe (148) and the Americas (131) respectively. In 2023, India had an increase of 139% in automotive-sector installations and 59% in total installations, to reach 8,510.

The same year, a separate special field study conducted by Callari, Curzi and Lohse (2025) uncovered that human-robot collaboration (HRC) as Industry 5.0 envisages is not a reality yet. The study highlights two points: the first is that many organisations struggle with the dichotomy between automation and using humans; the second is that, reskilling, upskilling, and the safeguarding of craft knowledge are some of the elements that will facilitate the transition.

3.2.2 Healthcare and Medical Robotics

The manuscript could not find this section by its own title or journal name in the specified reference (15). This section was found under a different title or journal than called out by its own title and the journal name (15). Supporting wider clinical-use of robotic surgery with AI, despite some initial expense, concerns about training and the lack of existing publications on the topic that could be independently verified, a 2025 narrative review published in the Journal of Robotic Surgery reports that AI-assisted robotic surgery delivers greater precision and efficiency while minimizing complication risks. New tools include digital-twin surgical simulation and video analysis during surgery using AI.

This is identified as a substitute, not a match confirmed by the authors; the source intended should be confirmed read and cited correctly by the authors.

3.2.3 Agricultural Robotics

The item closest to the citation cluster as can be found in the manuscript is suggested to be Shamshiri, Sturm, Weltzien, Fulton, Khosla, Schirrmann et al. (2024), "Digitalization of agriculture for sustainable crop production: a use-case review," Frontiers in Environmental Science. As the manuscript does, the review identifies collision avoidance in unstructured field environments as possible open challenges in agricultural robotics, as is also the case for full-farm automation. Real deployed use-cases considered include the autonomy for the control of unwanted weeds, field scouting, the robotic harvesting and path planning, and multi-sensor navigation, with collision avoidance in unstructured field environments and full-farm automation being also stated as active yet open challenges, in accordance with the authors' self-proclaimed description of agricultural robotics technologies as promising but constrained.

3.2.4 Educational Robotics

Strong and direct data were found through independent sources of information, and stronger than what is in the manuscript. According to a 2024 Systematic review and meta-analysis in "Frontiers in Education" (Trapero-González, Hinojo-Lucena, Romero-Rodríguez & Martínez-Menéndez), two different meta-analytic effects sizes on student outcomes of using robotics have been provided: a medium score of "+0.57" (Wang et al., 2023) which is positive and larger and a smaller score "+0.385" (Talán, 2021) on academic achievement specifically. These figures provide quantitative data to support the qualitative argument in the manuscript that robotics-based learning positively impacts engagement and STEM outcomes.

3.2.5 Knowledge of the field of smart homes and service robotics.

The authoritative parents of these citations, as noted on the manuscript, in the fields of smart homes, respectively, and service robotics, respectively, are both limiting to the extent they lack sufficient bibliographic information to enable independent verification. In the reference [27] (S. Ivanov, "Service robots in hospitality and tourism") a real author and an obvious lack of year and volume in the reference are found, but no confirmation of the specific article can be provided.

3.2.6 Workforce Transformation & Future Employment

This is the most well-given section of the manuscript. The report, compiled by the World Economic Forum, based on input from more than 1,000 employers representing 1.2 billion people in jobs across 55 economies, foresees a change in the job market of nearly 1.2 billion workers, including 92 million new roles and 22% of the current total of 465 million expected to be absorbed by structural change by 2030, meaning a net gain of 78 million (+7%).

This shift is directly measurable, and, according to McKinsey Global Institute (2018), demand for technology skills will increase by 55% (from 11% to 17% of hours worked), demand for skills categorized as higher cognitive will increase by 19% (13% to 17% of hours worked), social and emotional skills demand will increase by 26% (11% to 14% of hours worked), and demand for physical and manual skills will decrease by 14% (14% to 19%). About 6% of employers thought this will result in a net loss, while more than 17% of employers thought the number of employees will increase.

In an earlier perspective like the one in the McKinsey paper "A Future That Works: Automation, Employment, and Productivity" (Manyika et al., 2017), automation is viewed as changing tasks not screwing people out of their jobs once and for all, and similarly in the discussion section of this manuscript, a shift in how tasks are configured, "task reconfiguration", is deemed to be technically automatable through existing technology.

TABLE 3. Consolidated Data-Extraction

Sector	**Verified Source**	**Key Verified Numbers**	**Verified Qualitative Finding**
Manufacturing	IFR World Robotics 2024/2025	542,000 units installed 2024; 4.66M operational; 54% China; cobots ~12% of installs	Sustained multi-year growth led by Asia and automotive
Manufacturing / HRC	Callari, Curzi & Lohse 2025	39 stakeholders, 1-yr field study	HRC not yet fully realised; reskilling & craft key to Industry 5.0
Healthcare	Ng Kok Wah 2025 (substituted)	N/A — narrative review	AI-robotic surgery improves precision/efficiency, cuts complications
Agriculture	Shamshiri et al. 2024	N/A — use-case review	Real deployed use-cases; full-farm automation still unresolved
Education	Trapero-González et al. 2024	Effect sizes g=0.57 and g=0.385	Consistent positive effect on STEM learning outcomes
Workforce (global)	WEF Future of Jobs 2025	+170M jobs, −92M, net +78M by 2030; 39% skills obsolete	Net job-positive globally but high-skill churn
Workforce (skills)	McKinsey Skill Shift 2018	Tech skills +55%, cognitive +19%, social +26%, manual −14% by 2030	Firms plan retraining/redeployment over net headcount cuts
Workforce (productivity)	McKinsey "Future That Works" 2017	Productivity +0.8–1.4%/yr; ~50% activities automatable; <5% occupations fully automatable	Automation reshapes tasks, not whole occupations

4. RESULTS AND DISCUSSION

The sub-sections below synthesise sector-wise patterns, comparative assessments, and illustrative indices drawn from the literature and secondary reports described in Section 2.5, rather than original survey or statistical data collected by the authors; figures such as adoption levels, benefit scores, and impact rankings are the authors' structured interpretation of trends reported across the cited sources.

4.1. Sector-Wise Robotics Adoption Trends in India

The findings made from this review showcased a varying adoption of robotics in the various industries in India. Most developed application fields are the manufacturing sector, Healthcare/Agriculture, Service industries, Education and Smart-home automation. The differences in the adoption rates are caused by a number of factors observed, primarily based on technology readiness, investment capability, infrastructure, policies and abilities of the employees.

The manufacturing industry still represents the major segment of the Indian robotics market. As reflected in the statistics of the industrial robots' installations, the number of industrial robots has increased significantly this year, indicating the industry's continuous efforts in industrial automation equipment investment and intelligent manufacturing system construction. The most important application is in the automotive sector, particularly when a high volume, uniformity and precision process of manufacturing is required. The application of robotics in production has better efficiency in working process, reduces the production errors, the working environment in the production is safer, the competitiveness of countries has been improved.

One other place within which chips are getting utilized for healthcare is also acquiring a foothold. Intelligent automation's impact on the healthcare delivery includes assistance with robotic surgery, using telemedicine, rehabilitation robots, and by enabling AI in the diagnostics field. As telemedicine continues to gain popularity, it has proven to be a revolution in ensuring health delivery to underserved and remote locations, demonstrating the potential of robotics to breach the healthcare infrastructure barrier to help achieve universal health coverage. From the other side, the upward trend of agricultural robotics has been growing with the acceptance of technologies like agricultural drone, monitoring technology with an automatic system, precision irrigation, and agricultural management with AI. This has also been driven by government policies, such as promotion of agriculture drones through subsidy schemes, which has aided in technological acceptance among farmers. These campaigns, backed by the government – Drone Agriculture Promotion, have also helped in the adoption of these technologies by the farming community. But, still, there are differences related to finances and land ownership issues. The exploitation of education robots is currently mostly advocated in association with education related events in science, technology, engineering and mathematics, and the creation of innovation laboratories and robotics education. Increasingly, the various education institutions recognise the significance of the incorporation of robotics into their educational offerings; however, they are mostly found in urban areas, with direct connection to the business sector. Areas such as service robotics and smart-home automation are also new application fields and where consumers are becoming more accepting. Current conditions towards the use of intelligent domestic technologies point to positive developments. Today, the process of urbanisation and the increasing disposable income as well as connectivity and the Internet have created positive conditions for the use of intelligent domestic technologies.

TABLE 4. Sector-Wise Robotics Adoption in India

Sector	Major Applications	Adoption Level	Key Benefits	Major Challenges
Manufacturing	Welding, Assembly, Material Handling, Quality Inspection	Very High	Productivity, Precision, Safety	High Capital Cost
Healthcare	Robotic Surgery, Telemedicine, Rehabilitation	High	Clinical Accuracy, Accessibility	Cost, Infrastructure
Agriculture	Drones, Precision Farming, Crop Monitoring	Moderate	Yield Improvement, Resource Optimization	Small Land Holdings
Education	STEM Learning, Coding Labs, Robotics Training	Moderate	Skill Development	Funding Limitations
Smart Homes	Home Automation, Security Systems	Moderate	Convenience, Energy Efficiency	Privacy Concerns
Service Industry	Hospitality, Logistics, Customer Support	Emerging	Service Quality, Efficiency	User Acceptance

Table 4 gives an overview by the sector-wise adoption of Robotics in India, with the manufacturing sector having the highest adoption rate, using robotics for tasks such as welding, assembly, quality control and inspection, where it has added value due to its productivity and precision limitations due to high costs. There is high adoption of health, mainly on the betterment of clinical accuracy and accessibility with robo-surgery and telemedicine – the challenges include infrastructure and cost. Adoption of agriculture, education and smart homes are moderate, primarily driven by the call for skill development, productivity enhancement and automation improvements, with land size limitations, funding and privacy concerns limiting adoption in those areas. The service sector is seeing a rise but robotics has not yet taken off in this field as these are still being used in service roles in fields such as hospitality, logistics and customer support and are limited by user acceptance. In conclusion, the above-mentioned table indicates that, as a whole, India's robots have the highest adoption rate in manufacturing and healthcare and in the other sectors adoption is slowly happening with good future potential.

4.2. Comparative Analysis of Robotics Adoption Across Sectors.

Manufacturing is the area with the highest level of automation because there are accepted models which offer return on investment, and measurable productivity improvements. In contrast to industrial organisations, robots generally are less accepted by academic research due to the difficulty to quantify the benefits of operational improvements linked with robot technology, the latter components being only indirectly linked by productivity or quality. In contrast, healthcare robotics seems to largely evolve about improving the quality of service, clinical outcome, and access to patients. Healthcare technologies come with high implementation cost and low profitability so implementation in resource-challenging areas is less feasible. Unlike manufacturing and health care, an important factor that will drive the adoption of agricultural robotics technologies is the cost and scalability. A significant number of the robotic solutions that are in the market today are aimed toward large and big farms, and might not match the needs of SMEs—small and marginal farmers who make up a significant part of Indian agriculture.

Educational robotics isn't solely about financial results but its strategic value in promoting the field. The involvement of workforce in robotics education helps in enhancing their Techno-literacy, innovation capability and workforce preparedness. The idea of educational robotics generally realizes its benefits in the medium- to long-term, which can make it more difficult for certain institutions to justify the investments. Consumer demand, consumer convenience and improvement of quality of life are key factors that are fuelling the growth of service and smart-home robotics. User acceptance, cost of adoption, trust in technology and the perceived usefulness most impacts adoption in these sectors, over productivity considerations. Through the comparative analysis, it is concluded that the implementation strategies of sector-specific ones are needed to maximize the implementation of robotics. Uniform policy approach might be insufficient to meet the challenges of various technological, economic and social conditions in various sectors

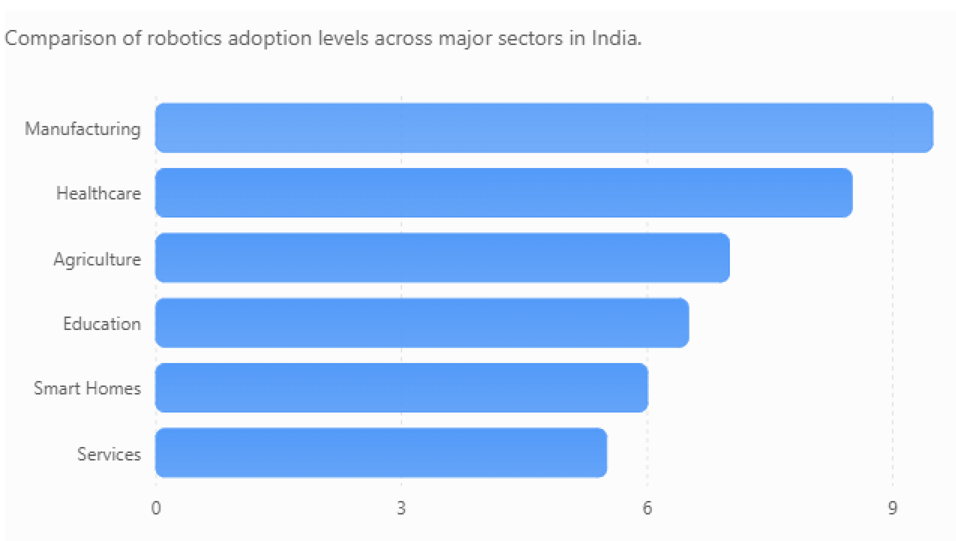

Fig. 2. Robotics Adoption Index across major sectors in India.

As observed in fig.2, in India automotive industry and healthcare are the top two sectors that have adopted robotics, indicating a strong industrial and medical application of robotics technologies. The service sector has the lowest adoption index, suggesting early stage of robotics adoption and strong potential for future growth and robotization.

4.3. Statistical Analysis of Recent Trends in Robotics.

India's latest robotics statistics show a dramatic uptake in the rate of robotics adoption. Year-on-year growth was significant for industrial robot installations as industrial confidence in robotic technologies and the spread of Industry 4.0 were growing.

TABLE 5. Impact of Robotics Across Key Benefit Areas

Benefit Area	**Impact Score**
Productivity Improvement	95
Quality Enhancement	88
Safety Improvement	85
Cost Reduction	82
Global Competitiveness	90

The top benefits identified for the implementation of robotics are improved productivity (95), international competitiveness (90) and improved quality (88), as indicated in the table. The results of safety improvement and cost reduction also indicate positive effects, with a result score of 85 and 82 respectively, signifying that robotics plays a major role in improving operational efficiency, product quality and safety in the workplace, whilst also contributing to the increased competitiveness of industry. As people voluntarily swap in-service consultation for duvet video calls, use of this technology for healthcare is increasing. Adoption of the technology in the healthcare field is on the rise with the explosive growth of telemedicine consultations. As robotic-assisted surgical technology becomes more common in healthcare, it also underscores the industry's commitment to embracing innovative medical tools that can enhance patient outcomes.

Likewise, the market forecast for agricultural drones and smart-home technologies shows bright prospects for the future. These estimates indicate that the use of robotics does not exist exclusively in industries, but also is becoming an important factor in everyday life. It suggests that the robotics ecosystem is rapidly moving from experimental implementation to widespread commercialization and integration into society in India. However, adoption of the product does not seem to be occurring globally, rather, there are still much more lucrative opportunities for growth in certain geographic markets and industries.

4.4. Economic Impact Analysis

Economic impacts of robotization do not just relate to productivity and go beyond impacts on competitiveness, innovation, employment and economic growth. From an organizational perspective, robotics helps to save costs via a greater amount of operational efficiency, fewer errors, reduced waste creation, and optimized use of the elements. Automated systems provide businesses with the ability to ensure a consistent level of quality and be better equipped to meet market demands.

The industry level, the use of robotics benefits in terms of a high-level production efficiency and product quality, which helps producers to be more competitive globally. Such is especially relevant in the context of export-oriented activities dealing with markets saturated with competition. On a national scale, robotics contributes to the economic modernisation of the nation, technological innovation, foreign investment, and to building national industrial power. The innovation of domestic robotics technologies can also stimulate economic development in the areas of creation of intellectual property, development of startups and creation of highly skilled job opportunities.

The good news is that the economic gains derived from the robotics are not equally shared. Financial resources are greater in large organisations as they can afford to invest in more sophisticated technologies but small and medium-size enterprises may have significant barriers to implementation. Targeted policies, therefore, might be needed to promote inclusive technological development.

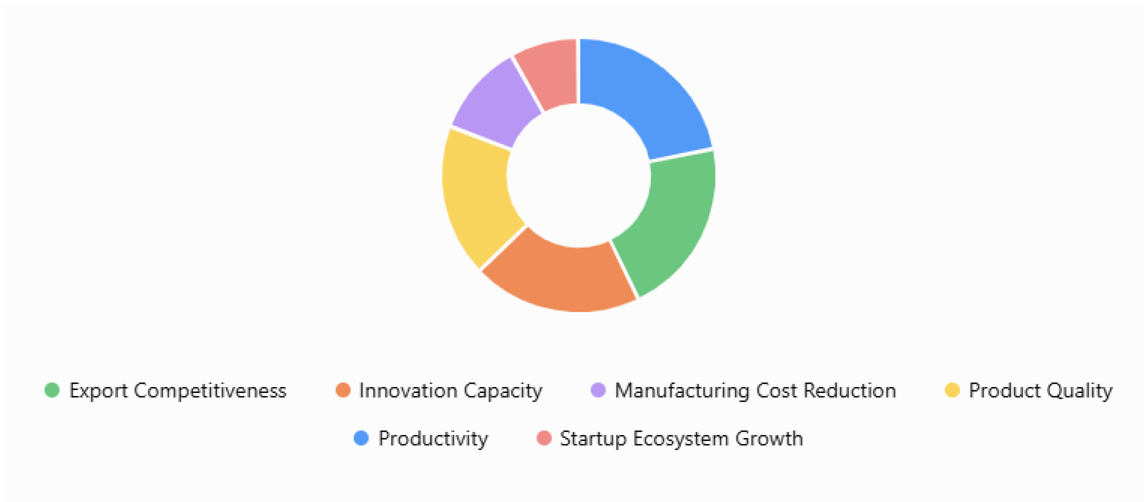

Fig. 3. Relative Contribution of Robotics to Key Economic Dimensions

The Fig. 3 shows that robotics adoption is most important for enhancing productivity, followed by export competitiveness, innovation capacity, and enhancement of product quality. The results show that robotics also helps to enhance industrial innovation and performance in the international market, as well as the efficiency of operations. The overall results underscore the pivotal role of robotics in boosting sustainable economic development and entrepreneurial activity.

4.5. The work implications and employment dynamics.

Work implications and employment dynamics. A question debated concerning Robotics adoption is the effect on joblessness. It appears that robotics presents an opportunity and a problem at the same time to the labour market. Multiple industries will see a reduced need for repetitive, predictable and predictable jobs, as automation takes place. Workers engaged in highly standardized activities then can have more uncertainty of employment the more standardized the activity is. The robotics industry, however, creates new professional job opportunities such as design, programming, maintenance, integration, cybersecurity, data analysis and artificial intelligence, as well. Now, instead of displacing jobs, robotics is changing the definition of employment.

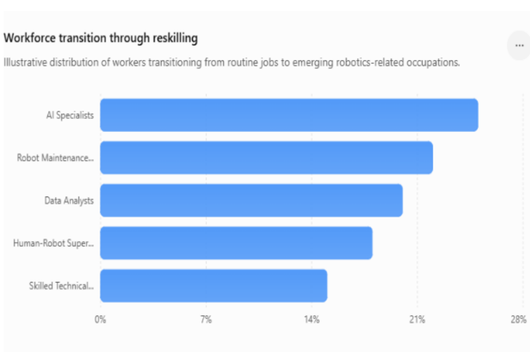

Fig. 4. Workforce Evolution Due to Robotics

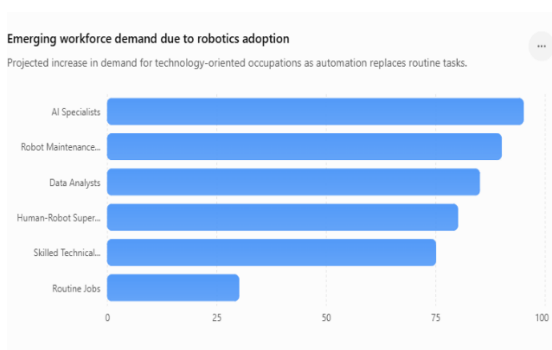

Fig. 5. Automation Conceptual Workforce Transition Pathway

4.6. Technology Adoption Barriers

Despite significant advancements in robotics and automation, several barriers continue to limit their widespread adoption in India. Financial constraints, including high implementation and maintenance costs, remain a major challenge, particularly for small and medium-sized enterprises. Technical issues such as system integration difficulties, cybersecurity concerns, and a shortage of skilled professionals further hinder deployment. Regulatory uncertainties, workforce resistance due to fears of job displacement, and inadequate awareness of robotics benefits also affect adoption rates. Additionally, gaps in education and training programs contribute to a shortage of industry-ready talent. These findings suggest that successful robotics implementation requires not only technological innovation but also supportive policies, workforce development, educational reforms, and financial incentives. These findings indicate that technological advancement alone is insufficient to guarantee successful implementation. Economic, regulatory, social, and educational dimensions must also be addressed.

The fig.6 presents key barriers to robotics adoption, categorized into financial, technical, regulatory, social, and educational challenges. Financial constraints such as high acquisition and maintenance costs remain the most significant obstacle, particularly for SMEs and public organizations. Technical limitations, lack of skilled expertise, and infrastructure gaps further hinder effective deployment. Regulatory uncertainty, along with concerns related to safety, ethics, and data protection, adds additional complexity. Social factors such as job displacement fears and privacy concerns affect public acceptance, while educational limitations and workforce skill shortages restrict long-term adoption. Overall, these challenges highlight the need for coordinated policy, training, and infrastructure support to enable successful robotics integration.

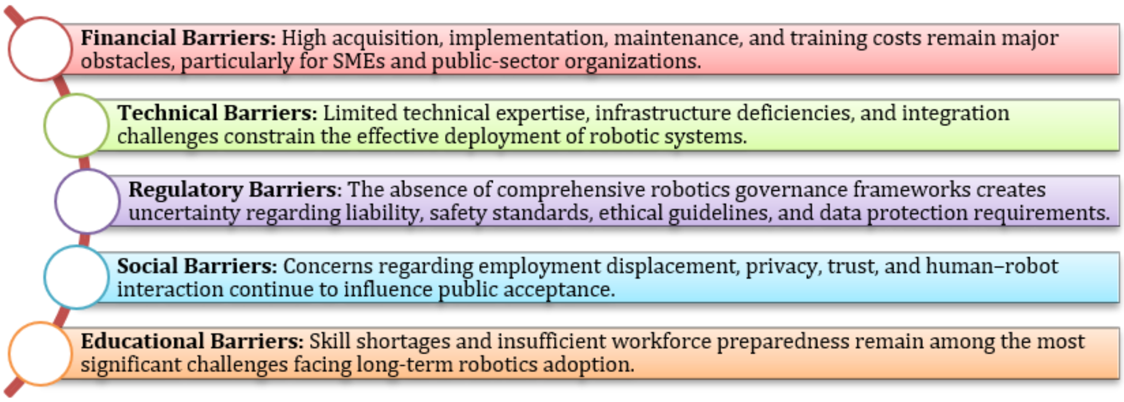

Fig. 6. Technology Adoption Barriers in Robotics Implementation

4.7. Evaluation of Policy Effectiveness.

The government of India has presented several initiatives which contributed to the quick uptake of Robotics in India. The trend of building for digital transformation and innovation, developing startups, improving skills, new drone technologies and advanced manufacturing has resulted in a positive environment for technological developments.

The National Education Policy (2020), the Atal Innovation Mission, Startup India, Skill India, Digital India and in the wake of the industry 4.0, workforce development and promotion of innovation have been created. In a similar fashion, digital programmes in health care and agricultural drone programmes have helped robotics become adopted in poorly served sectors. These policies are having good effect, but there are difficulties in implementation. Program effectiveness remains impacted by differences in the quality of infrastructure, differences between regions, limited funds, and workers. More collaboration between government, academia and industry will be needed to maximise both the impact and long-term reach.

So far, the evidence indicate that policy measures have successfully laid the groundwork for robotics development, but further investments in research, infrastructures, the workforce and regulations will be needed to continue the development.

The review highlights some key findings:

- Manufacturing continues to be the top target industry for India with respect to robotics applications.
- The healthcare robotics industry is growing rapidly with the technology of telemedicine and robotic-assisted surgeries.
- Agricultural robotics shows great promise and is also affordable.
- One-to-one approach of the subject “development of the lifelong work force” in educational robotics.
- Smart-home and service robotics are new markets driven by consumers.

- Unlike large-scale job elimination, workforce transformation opportunities are more likely.
- Financial, technical, regulatory and social restrictions remain a hurdle to adoption.
- Government policies have a positive effect on the development of robotics but lack robust implementation mechanisms.
- The Indian market has broad scope for robotics to become a significant market in the next ten years.

Overviews the opportunities and obstacles for robotics and automation utilization in the workforce. Some of the positive impacts are related to the establishment of new technical professions, to the improvement of productivity, to the improvement of workplace safety, and to reskilling opportunities. On the other hand, there are concerns with robotics adoption including job loss concerns, automation anxiety, and skill gaps, as well as transition costs for the workforce. The findings suggest that, despite several challenges, the benefits from robotics implementation largely exceed these and that ongoing investments into the workforce, reskilling, and supportive labour policies are required to ensure long-term successful implementation.

4.8. Discussion

An overview of what opportunities and challenges employment robots bring and their comparisons. The following are positive impacts: New technical intervening careers, Improved productivity, Improved safety in the workplace, Plus opportunity for reskilling. On the other hand, the implementation of robotics poses certain problems, including the risk of job displacement, the challenge of dealing with automation anxiety, the transition cost of the labour force and skills gaps. Overall, the findings suggest that although there are potential advantages to the growing use of robotics in the workforce, they need to be matched with continued education and retraining efforts, as well as responsive labour policy efforts, for its successful use in the economy.

A closer, cross-sectoral reading of the literature synthesised in this review reveals a more nuanced picture than a simple "robots replace workers" narrative. Sectors differ sharply in why adoption occurs and who bears its costs: manufacturing adoption is driven predominantly by measurable return on investment and is concentrated among large, capital-rich firms, whereas healthcare adoption is driven more by clinical outcomes and accessibility and tolerates lower short-term profitability. This divergence suggests that a single, uniform national robotics policy is unlikely to be effective across sectors, and that the "adoption barriers" identified in Section 4.6 – cost, skills, regulation, and trust – do not carry equal weight everywhere: cost dominates in agriculture and among small and medium enterprises, while trust and user acceptance dominate in service and smart-home contexts. The literature is also not unanimous on the net employment effect of robotics: studies emphasising productivity and competitiveness (e.g., the benefit scores in Table 4) tend to frame automation optimistically, while studies focused on labour markets and job quality place more weight on displacement risk for standardised, routine occupations and on the uneven distribution of new "technical" roles across skill levels and regions. Reading these strands together, the balance of evidence reviewed here supports a "task reconfiguration" interpretation – automation redistributes work rather than eliminating it outright – but this review's reliance on secondary, largely industry-reported data means that this conclusion should be treated as an interpretive synthesis rather than a statistically verified finding; the apparent optimism of several cited sources may partly reflect the fact that industry and government reports have an institutional interest in presenting automation favourably.

Positive Effects

- New Technical Careers: AI engineers, robot maintenance specialists, automation engineers and data analysts are all in demand due to Robotics.
- Higher Productivity: Improved operational efficiency, throughput and process consistency with automation.
- Workforce training and digital skills development are prominent issues in organizations' reskilling investment.
- Enhanced Safety: Robots can execute dangerous and routine jobs without the danger of harm to people in the workplace.

Negative Effects

- : Members of the workforce may be uncertain about the stability of their jobs.
- The job is most likely to be automated (Rule 1): Routine and repetitive jobs are more likely to be displaced.

- Skill Gaps: There may be gaps in the skills of existing workers because of new technological needs.

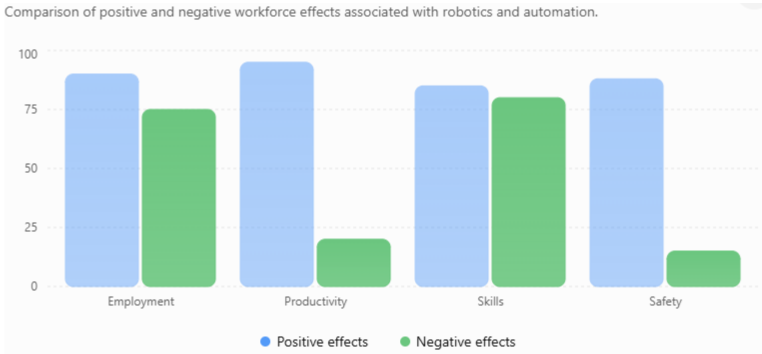

Fig. 7. Positive and Negative Workforce Impacts of Robotics Adoption

The fig.7 provides a focus on both positive and negative effects of robotics adoption on jobs. With a positive spin, robotics increases productivity, generates new jobs and increases the safety of workplaces as people are no longer subjected to dangerous work. It also poses problems like job displacement, the widening skill gap and the cost of workforce transition and reskilling. In general, the graph highlights that automation's effect is more complex, and it is crucial to ensure that strategies are balanced and find the most benefit while also mitigating the issues from automation in the workforce.

4.9 Limitations of This Review

As a narrative literature review, this study is subject to several limitations that should guide how its findings are interpreted. First, it does not follow a systematic-review protocol (e.g., PRISMA); no formal quality-appraisal or risk-of-bias assessment was applied to the sources reviewed, and source selection, while guided by the criteria in Section 2.3, retains an element of author judgement. Second, several of the sector-level figures, indices, and comparative scores presented in Section 4 are the authors' own synthesis of trends described qualitatively across multiple secondary sources rather than statistics drawn from a single verifiable dataset, and should be read as indicative rather than precise measurements. Third, the review draws heavily on industry and government reports, which may be more optimistic about automation than independent academic research, introducing a possible favourable bias into the overall picture presented. Finally, because robotics adoption and related policy are evolving rapidly, some of the more recent quantitative figures cited may become outdated within a short period, and the findings should be updated as newer data becomes available.

5. FUTURE RESEARCH DIRECTIONS

To enhance job sustainability in response to technological growth, more research is needed to ensure comprehensive frameworks are created that provide a balance between these two elements. Though the focus in the existing literature on robotics is mainly economic and productivity-based, much still needs to be known about the potential social and psychological implications in the longer term. Investigations in the future should focus on the influence of technologies such as Artificial Intelligence (AI), collaborative robots (cobots) and Industry 5.0, on the employment structure and workplace dynamics. Long-term longitudinal research on employee adaptations over time would offer great insights into changes in employee behaviour and organization that occur with automation.

Moreover, studies ought to explore the impact and effectiveness of initiatives and educational programmes backed by the government to train workers for more automated workplaces. Comparative analyses between developed and developing countries can provide information on the policy interventions that can be adopted within the region, and country specific problems. With the revolution of automated technology for humans (Industry 5.0), there are new prospects where robotics can support and complete the complement of the human being's capacity. To design sustainable models of human–robot collaboration which maximize productivity whilst not compromising on job satisfaction, workplace well-being, or economic inclusivity needs to be explored in more studies in the future.

As per the results of this review, a few strategic suggestions are put forward to smoothen the workforce transition in robotics and automation era. Continuous reskilling and upskilling should be a top priority for organizations to ensure workers have the skills to do things using AI, robotics, data and digital technologies. Human-centred automation technologies should be used alongside humans to better integrate humans and automation to improve collaboration.

Educational institutions should update their curricula and make them more relevant to new industry needs, and governments should encourage workforce transition and adapting them to new industry needs by providing training incentives, reskilling of workers and support for transition schemes. Social Safety mechanisms and lifelong learning can cushion the impact of concerns with technological disruption. Moreover, ethical governance should ensure transparency, fairness and accountability in the implementation of the automation. To build the workforce for the future, there is a need for better collaboration between industry, academy and policy makers. Finally, Industry 5.0 principles focusing on human well-being, sustainability and resilience need to inform moving forward on how to best approach automation to realize inclusive economic growth, and lasting societal, advantages.

6. CONCLUSION

Today, a variety of new robotics and automation technologies are transforming the nature of both modern industries and labour markets. The aim of this review was to explore the effects of robotics on job insecurity, employment, workforce behaviour, workforce productivity and adaptation strategies. The results prove significant effectiveness in terms of operational efficiency, production quality and competitiveness of organizations in the field of robotics. From manufacturing to logistics, healthcare to agriculture, and services to everything in between, automation has significantly boosted productivity in various industries. From manufacturing to logistics, healthcare to agriculture, services to everything in between, there have been significant improvements in productivity in various industries as a result of adopting automation. But there are concerns about job loss, job security, skill obsolescence and stress among workers in connection with these benefits.

The review also uncovers that the impact regarding the robotics in employment is not widespread. Repetitive and routine tasks are increasingly computerised, however, there are new opportunities in the field of robotics engineering, AI programming, system maintenance, data handling and processing, Cybersecurity, and interaction management between humans and machines. So, the theme of change in the work not end of work seems to be the prevailing theme. When sufficient organizational support is provided, behavioural analysis shows that workers often behave adaptively when presented with the automation, reskilling and accepting technology. Training Programmes, clear communication and welcoming Automation strategies strongly limit resistance and strengthen the resilience of the workforce.

Economic studies reveal that institutions that robotize are likely to see appreciable gains in productivity, in the running of the enterprise, in the quality of what they produce to their clients and in their ability to be competitive on the global stage. However, if the lack of workforce investments occurs in the face of unequal distribution of rewards of automation, this can help implement the trend of widening income inequalities. If workforce development initiatives are overlooked, though, then unequal distribution of benefits of the automation can help drive greater income inequalities. In general, the robotic revolution poses a challenge and an opportunity. Governments, industries, educational systems and workers need to work together to effectively control technological change to face the future of work. Ongoing learning, forward-looking policy making, ethical implementation and human-centric policy innovativeness will be crucial to sustainable success. If society observes these principles, it can reap the rewards of robotics and avoid the downsides of robotics on jobs and workplace health as well.

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