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CONTENT

Assessing the Impact of Automation and AI on Supply Chain Resilience from Industry 4.0 to 5.0

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***Abstract*— The realm of supply chain management has significantly evolved with Industry 4.0 technologies and is poised for further transformation with Industry 5.0. This comprehensive survey examines the impact of these industrial revolutions on supply chain practices. Industry 4.0 introduced transformative technologies such as the Internet of Things (IoT), big data analytics, cyber-physical systems, and automation, fundamentally altering traditional processes by enhancing visibility, efficiency, and decision-making. These advancements enable real-time tracking, predictive insights, and better integration of physical and digital systems, leading to optimized operations and improved performance. As the field transitions to Industry 5.0, new paradigms are emerging that redefine supply chain management. Industry 5.0 emphasizes a human-centric approach, integrating technologies like artificial intelligence, augmented reality, and advanced manufacturing with a focus on human-technology collaboration. This shift aims to enhance customization, sustainability, and flexibility within supply chains. Key aspects of Industry 5.0 include human-robot collaboration, sustainable practices, and innovative technologies, reshaping global supply chains. This paper reviews current research on both Industry 4.0 and Industry 5.0, offering insights into technological impacts on supply chain management and highlighting the need for adaptation and innovation to maintain competitiveness in a dynamic industrial landscape.**

***Keywords*: Proactive Malware Detector, Data Integrity, Cybersecurity, Secure, Communications, Document Authentication, File Integrity Monitoring (FIM), Malware Detection, Random Forest Model, Data Preprocessing, Feature Extraction, Real-time Monitoring, Security Threat**

I. INTRODUCTION

The evolution of industrial practices has consistently influenced the dynamics of supply chain management (SCM). Historically, each industrial revolution has introduced new technologies and methodologies that have redefined supply chains, improving efficiency, productivity, and strategic capabilities. The current era, marked by Industry 4.0 and the emerging Industry 5.0, represents the latest phase in this transformative journey. Industry 4.0, often referred to as the Fourth Industrial Revolution, heralded a shift towards the digitization of manufacturing processes. Characterized by the convergence of digital technologies and manufacturing practices, it has brought forth advancements such as cyber-physical systems, the Internet of Things (IoT), big data analytics, and automation. These innovations have significantly altered the traditional supply chain landscape by enabling greater integration between physical operations and digital data, thus facilitating real-time monitoring, predictive analytics, and enhanced decision-making capabilities. The result has been supply chains that are more efficient, transparent, and responsive to dynamic market demands .As the industrial landscape continues to evolve, Industry 5.0 has emerged as the next frontier, emphasizing a human-centric approach to technological integration. Unlike its predecessor, which primarily focused on automation and digitalization, Industry 5.0 seeks to harmonize technological advancements with human needs and societal values. This paradigm shift advocates for the incorporation of artificial intelligence (AI), augmented reality (AR), and advanced manufacturing techniques, with an emphasis on enhancing human-technology collaboration. Industry 5.0 aims to address some of the limitations of Industry 4.0 by promoting sustainability, customization, and resilience within supply chains. The transition from Industry 4.0 to Industry 5.0 represents a fundamental shift in how supply chains are designed, managed, and optimized.

This evolution reflects broader changes in technological capabilities, organizational priorities, and societal expectations. As supply chains become increasingly complex and globalized, understanding these transformative processes becomes crucial for businesses aiming to maintain competitive advantage and adapt to evolving market conditions. This survey paper delves into the comprehensive impact of these industrial revolutions on supply chain practices. By exploring the advancements introduced by Industry 4.0 and the emerging trends of Industry 5.0, this study aims to provide a detailed analysis of how these changes have reshaped supply chain management. It examines the implications for efficiency, sustainability, and adaptability within modern supply chains, offering insights into the ongoing developments and future directions in this critical field.

II. OVERVIEW OF THE EVOLUTION OF SUPPLY CHAIN MANAGEMENT THROUGH INDUSTRY 4.0 AND INDUSTRY 5.0:

Supply chain management (SCM) has undergone substantial transformations with the adoption of Industry 4.0 technologies and is poised for even greater changes with the rise of Industry 5.0. Both of these industrial revolutions, powered by advanced technologies, have redefined how supply chains operate globally.

Industry 4.0 (2011–2020): Driving Efficiency with Automation and Digitalization

Launched in 2011 as part of Germany's high-tech initiative, Industry 4.0 transformed supply chains by integrating technologies like the Internet of Things (IoT), big data analytics, automation, and cyber-physical systems (CPS). These innovations enhanced visibility, efficiency, and decision-making capabilities within supply chains.

IoT enabled real-time monitoring of shipments and assets, providing unprecedented transparency across the supply chain. Big data analytics allowed companies to extract insights from large data sets, leading to improved demand forecasting, better inventory control, and more effective risk management. Automation and CPS seamlessly linked physical and digital systems, making supply chains more adaptive and able to handle disruptions efficiently.

Industry 4.0 revolutionized supply chains into dynamic, data-driven networks that could respond more rapidly to shifts in market demand. This era introduced real-time data collection and analysis, helping businesses optimize performance, reduce waste, and minimize downtime.

Industry 5.0 (2020–Present): Focusing on Human-Centric and Sustainable Supply Chains

Building on the advancements of Industry 4.0, Industry 5.0, which emerged around 2020, shifts its focus from sheer automation to a more human-centered model. This new phase emphasizes collaboration between humans and advanced technologies such as artificial intelligence (AI), augmented reality (AR), and collaborative robots (cobots). While Industry 4.0 concentrated on automation, Industry 5.0 fosters a partnership between human creativity and machine efficiency. In this phase, robots handle repetitive tasks, allowing humans to concentrate on creative, strategic, and complex functions. Additionally, Industry 5.0 advocates for more sustainable supply chain practices, focusing on minimizing environmental impact and promoting circular economies.

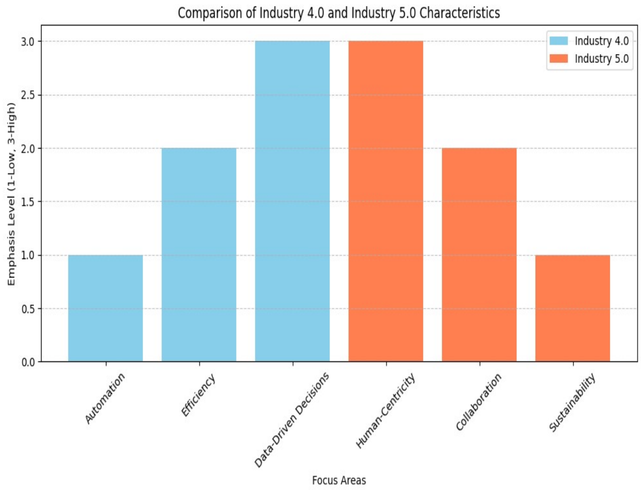


Fig. 2.1

Key Aspects of Industry 5.0 in Supply Chain Management

- **Human-Robot Collaboration**: Industry 5.0 emphasizes a closer partnership between humans and machines. Collaborative robots (cobots) are designed to work alongside human workers, improving efficiency while allowing humans to manage tasks that require judgment and creativity.
- **Sustainability**: A major theme of Industry 5.0 is sustainability. Supply chains are now being built with circular economy principles in mind, focusing on reducing carbon emissions, waste, and energy consumption to meet consumer and regulatory demands for more environmentally responsible operations.
- **Customization and Flexibility**: Industry 5.0 also promotes higher levels of customization in supply chains, enabling businesses to create personalized products tailored to consumer needs. AI and AR help companies adjust production processes quickly, allowing for more flexible operations that can respond to market changes.

Impact on Global Supply Chains

The move to Industry 5.0 signifies a new phase in global supply chain management, urging businesses to reassess their strategies to maintain their competitive edge.

- **Enhanced Decision-Making**: By utilizing AI and big data, supply chains can better process real-time information, enabling quicker, data-driven decisions that improve operational efficiency and adaptability.

- **Greater Resilience**: Industry 5.0 technologies, such as predictive analytics, make supply chains more resilient to disruptions like natural disasters or pandemics. These tools allow businesses to anticipate potential issues and adjust their operations proactively.
- **Maintaining Global Competitiveness**: As the focus shifts toward more sustainable and human-centric supply chains, companies must continually innovate. Adopting Industry 5.0 practices not only enhances performance but also builds trust with consumers, giving businesses a competitive edge
- **Enhanced Workforce Productivity**: Industry 5.0 promotes human-robot collaboration, which reduces the burden of repetitive tasks on workers, allowing them to focus on higher-value activities. This integration of human skills with advanced automation increases productivity, while also fostering a more skilled and engaged workforce.

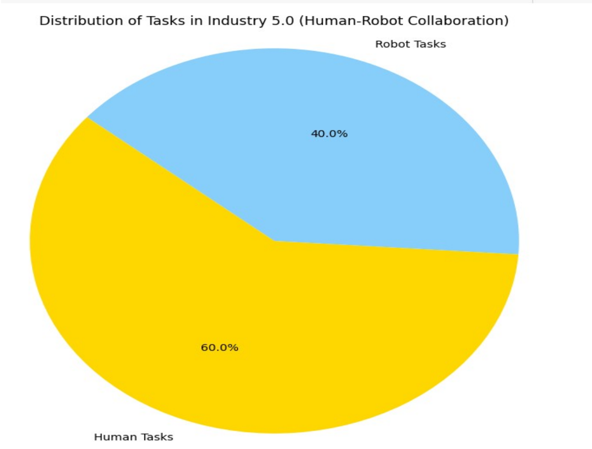
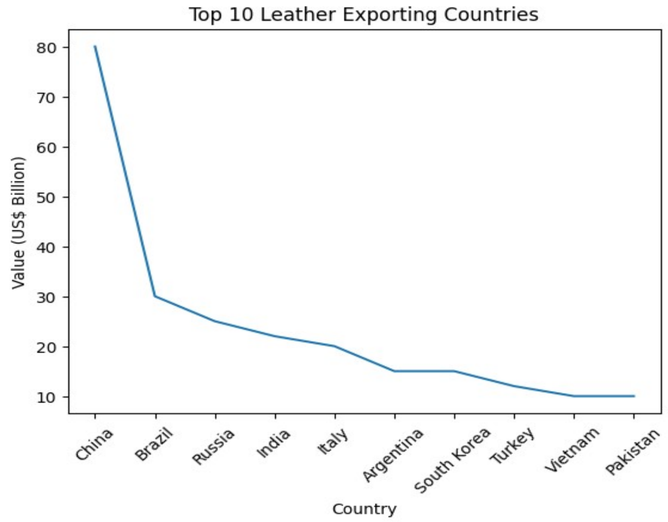


Fig. 2.2

Supply chains on leather industry in different countries:



The provided line graph, "Top 10 Leather Exporting Countries," offers a snapshot of the current global leather trade landscape. However, to gain a deeper understanding of the industry's dynamics, it's essential to examine the role of Industry 4.0 and Industry 5.0 technologies and their potential impact on future supply chains.

Industry 4.0 and its Influence on Leather Supply Chains

Industry 4.0, characterized by the convergence of technologies like the Internet of Things (IoT), artificial intelligence (AI), big data, and automation, is already transforming the leather industry. Here's how:

- **Smart Manufacturing:** Advanced manufacturing techniques, such as robotics and 3D printing, can improve production efficiency, reduce waste, and enable customization in leather goods.
- **Supply Chain Optimization:** IoT-enabled sensors can track raw materials, monitor production processes, and optimize logistics, leading to more efficient and transparent supply chains.
- **Quality Control:** AI-powered vision systems can automate quality inspection, ensuring consistent product quality and reducing defects.
- **Traceability:** Blockchain technology can provide end-to-end traceability of leather products, enhancing transparency and consumer confidence.

Industry 5.0: A Human-Centric Approach

As Industry 4.0 matures, the focus is shifting towards Industry 5.0, which emphasizes human-centric manufacturing and sustainable practices. In the context of leather, this means:

- **Ethical Sourcing:** Industry 5.0 promotes responsible sourcing of leather, ensuring animal welfare and environmental sustainability.
- **Circular Economy:** Technologies like bio-based tanning agents and leather recycling can contribute to a circular economy, reducing waste and environmental impact.
- **Collaborative Innovation:** Open innovation platforms can foster collaboration between industry players, researchers, and consumers to develop sustainable and innovative leather products.
- **Upskilling and Reskilling:** The transition to Industry 5.0 requires a skilled workforce. Investment in training and education will be crucial to ensure a smooth transition.

Implications for the Future

The integration of Industry 4.0 and Industry 5.0 technologies has the potential to revolutionize the leather industry. We can anticipate the following trends:

- **Increased Efficiency and Sustainability:** Advanced technologies will drive efficiency gains, reduce waste, and promote sustainable practices throughout the supply chain.
- **Regional Shifts:** As manufacturing becomes more automated and flexible, production may shift to regions with lower labour costs or specific skill sets.
- **Customization and Personalization:** Consumers will have greater access to customized and personalized leather products.
- **Ethical and Sustainable Consumption:** Growing consumer awareness of ethical and sustainable practices will drive demand for responsibly sourced leather products.

In conclusion, the leather industry is at a crossroads, poised to benefit from the transformative power of Industry 4.0 and Industry 5.0. By embracing these technologies and adopting a human-centric approach, the industry can create a more sustainable, efficient, and innovative future.

III. LITERATURE SURVEY

Reddy, C, Kishor, Kumar., Nishitha, Pujala., Thandiwe, Sithole et al proposed a system for collaboration of humans and machines using advanced technology like big data analytics and internet of things. Future avenues for investigation within the context of Industry 5.0 Obstacles and concerns associated with the interactions stemming from the Covid-19 pandemic. Industry 5.0 underscores the significance of synergistic interactions between humans and machines to facilitate advancement. It augments consumer contentment, bolsters competitive benefits, and fosters economic development within manufacturing entities. Healthcare, logistical networks, industrial production, cloud-based manufacturing A multitude of domains encompassing healthcare, logistical networks, and industrial production [1]. Tingrui, Liu et al proposed a Literature review on international frameworks Engaged with pertinent resources via libraries and archival repositories. Insufficient empirical examination of the supply chain associated with China's industrial Internet. Requirement for comprehensive integration frameworks specifically designed to address the challenges present in the Chinese market. The industrial Internet sector in China demonstrates advancements notwithstanding the existing obstacles. The implementation of a cutting-edge supply chain paradigm is advocated for prospective development. Examining the implications of Industry 4.0 on supply chain management. Formulating an implementation framework that takes into account the facilitators and barriers associated with Industry 4.0 [2]. Muhammad, Saqib, Athar, et al. proposed a comprehensive literature review regarding the facilitators and impediments associated with the implementation of Industry 4.0. A system dynamics model was formulated to analyze supply chain dynamics. This review identifies deficiencies in the integration of Industry 4.0 within the supply chain context and constructs a theoretical framework addressing the challenges associated with its implementation. Additionally, an implementation framework is devised that considers both the facilitators and impediments of Industry 4.0. The review examines the obstacles encountered in adopting Industry 4.0 within the realm of supply chain management and investigates its implications on supply chain dynamics. Overall, it seeks to formulate an implementation framework that addresses the drivers and hindrances associated with Industry 4.0. [3]. Wai, Peng, Wong, Muhammad, Fahad, Anwar, K. Soh, et al. proposed a reductionist methodology derived from systems theory to conduct a comprehensive review of existing literature addressing deficiencies in Transportation 4.0. This review identifies research gaps, obstacles, and potential opportunities. It elucidates the evolving transportation landscape within the framework of the Industry 4.0 paradigm and proposes a Transportation 4.0 framework aimed at enhancing competitiveness and alleviating disparities. Additionally, the review specifies trajectories toward Industry 5.0 informed by research outcomes and emphasizes the integration of Industry 4.0 technologies within transportation systems. The proposed Transportation 4.0 framework aims to augment competitiveness and address existing disparities. [4]. Maciej Bielecki, Zbigniew Wiśniewski, Goran Dukic, Davor Dujak, et al. proposed analyses of the evolutionary patterns in logistics and production management through scenario analysis employing agent-based simulation modeling. Their work highlights the inadequacies inherent in contemporary management paradigms during recent crises and emphasizes the necessity for reconfiguring logistics frameworks and supply chains to effectively address these challenges.The reconfiguration of logistics frameworks and supply chains has the potential to mitigate crises, facilitating both a global and localized perspective of supply chains. Furthermore, advancements in logistics and supply chains within the context of Industry 4.0 are discussed, underscoring the importance of adapting frameworks to effectively respond to crises [5]. Hajar Fatorachian et al. proposed exploring technological innovations in artificial intelligence, automation, big data, and the Internet of Things, with a focus on harmonizing supply chain methodologies with principles of sustainability. Their work identifies research deficiencies in sustainable supply chain management within the context of Industry 5.0, emphasizing the need to align supply chain practices with sustainability principles amid rapid technological advancements.The integration of supply chain operations with sustainability principles in the context of Industry 5.0 is crucial for confronting challenges and leveraging opportunities presented by these innovations. Overall, the study underscores the importance of harmonizing supply chain methodologies with sustainability goals [6]. Amirhosseim Fateh, Josefa Mula, Manuel Díaz-Madroñero, et al. proposed a research methodology that encompasses modeling approaches, software instruments, digital technologies, and problem typology, with categorization based on diverse criteria. They articulated future research directives, emphasizing the importance of categorizing scholarly literature according to these criteria.The study also highlights the optimization of supply chain processes through the exploitation of extensive data analytics in supply chain management. [7]. Ajay Kumar Pandey, Saurabh Pratap, A. Dwivedi, Sharfuddin Ahmed Khan, et al. proposed a multi-method framework utilizing AHP, DEMATEL, and PROMETHEE-II for analytical assessment and validation. They highlight that the interrelationship among Industry 4.0 enablers, supply chain sustainability, and reliability remains insufficiently explored, indicating a need to identify and benchmark the facilitators of Industry 4.0 to enhance supply chain sustainability.Key enablers such as digitalization, decentralization, smart factory technologies, and data security are essential for achieving substantial ecological, economic, and social benefits within supply chains. The focus is on the digital transformation of the supply chain, emphasizing the importance of effective data management alongside these enablers [8]. Mona Mohamed, Karam M. Sallam, Ali Wagdy, et al. proposed the use of the Analytic Hierarchy Process (AHP) and Complex Proportional Assessment (COPRAS) for evaluating the integration of novel technologies within the framework of Industry 4.0. Their work focuses on mitigating concerns related to data security in the context of Industry 5.0.Industry 5.0 effectively addresses the challenges presented by Industry 4.0 through the development of an evaluator model for supply chain collaborators. This model aims to support producers within intelligent supply chain networks, emphasizing the technologies pertinent to both Industry 4.0 and Industry 5.0 [9]. Małgorzata Dendera-Gruszka, Ewa Kulińska, Julia Giera, et al. proposed the use of the Analytic Hierarchy Process (AHP) and Complex Proportional Assessment (COPRAS) for evaluating the integration of novel technologies within the context of Industry 4.0. Their work addresses concerns regarding data protection within the framework of Industry 5.0, highlighting how Industry 5.0 effectively mitigates the challenges posed by Industry 4.0. Additionally, they introduced an evaluator model for supply chain partners in Industry 5.0, focusing on the technologies associated with both Industry 4.0 and Industry 5.0. This model is designed to support manufacturers engaged in intelligent supply chain partnerships [10]. Shruti Agrawal, Rohit Agrawal, Anil Kumar, Sunil Luthra, Jose Arturo Garza-Reyes, et al. proposed a systematic literature review methodology that provides a comprehensive synthesis of 194 scholarly articles published between 2009 and 2022. Their work highlights the adoption of Industry 5.0 (I5.0) technology as a means to mitigate supply chain disruptions, pointing out that insufficient attention has been directed toward addressing these challenges. A pronounced deficiency exists in the adoption of I5.0 technologies to alleviate supply chain disruptions. The review identifies prospective research directions for this adoption, examining applications related to pandemics, warfare, and climate change-induced disruptions. Future research trajectories are suggested to enhance the integration of I5.0 technologies in supply chain management [11]. Herbert Sobotka, Reza Wolfgang Kurz Sattari, Sebastian Kickl Tiwari, et al. proposed a descriptive research methodology utilizing surveys for data acquisition. Their findings emphasize the continual allocation of resources toward research and development in innovative technologies and the enhancement of data analytical competencies to facilitate superior decision-making and optimization. Logistics Knapp AG achieved operational excellence through the implementation of Industry 4.0 principles, demonstrating how the advent of Industry 4.0 has fundamentally transformed supply chain management and contributed to organizational success. Key strategies include immediate data collection, predictive analytic methodologies, and streamlined automation. The integration of the Internet of Things (IoT), Artificial Intelligence (AI), and robotics further enhances operational efficiency [12]. Morteza Ghobakhloo, Mohammad Iranmanesh, Behzad Foroughi, Ming-Lang Tseng, Davoud Nikbin, Ahmad A. Khanfar, et al. proposed a content-centric literature review identifying a total of 16 functions of Industry 4.0 related to Supply Chain Resilience (SCR). The study delineates future research implications and significant research trajectories but fails to explicitly address the identified research deficiencies. Industry 4.0 enhances Supply Chain Resilience through the implementation of these 16 interconnected functions, which contribute to the overall resilience of the supply chain. Key functions include supply chain automation, process monitoring, and enhanced visibility, all of which play a crucial role in strengthening supply chain resilience [13]. Yağızalp Urgancı, Mehmet Çevik, et al. proposed a literature review focusing on the framework and advantages of digital supply chain systems, investigating the roles of IoT and cloud computing within supply chain operations. The review highlights insufficient illustrative examples regarding the execution of digital supply chains and inadequately explores the obstacles encountered during the process of digital transformation. The significance of business analysis in the context of Industry 4.0 digital supply chains is emphasized, noting that digitalization enhances the efficiency, competitiveness, and overall effectiveness of supply chains. Key elements discussed include the framework, attributes, and advantages of digital supply chains, as well as the critical roles of IoT and cloud computing in optimizing supply chain operations. [14]. Muchai Jemimah, M. Kuruvilla, Masato Gunji, P. Prasad, Dr. G. Jaspher, Associate W. Kathrine, Mr. S. Kirubakaran, Mercedes Evangelina, et al. proposed a centralized framework for the administration of purchase orders, oversight, and demand forecasting. This framework incorporates blockchain technology and the Industrial Internet of Things (IIoT) to monitor pharmaceutical products effectively.The proposed centralized framework facilitates the exchange of pharmaceuticals within healthcare facilities, employing blockchain technology to prevent the infiltration of counterfeit materials. By integrating blockchain and IIoT, the framework aims to enhance the management of pharmaceuticals and improve demand forecasting, ultimately mitigating the risks associated with counterfeit occurrences [15]. Parth H. Patel, Anil Kumar Angrish, Vipin Nadda, et al. proposed the employment of digital technologies in Industry 4.0 to enhance supply chain operations. In contrast, Industry 5.0 focuses on integrating human-centric digital technologies to promote sustainable supply chain management.The discussion identifies research deficiencies in the area of sustainable supply chain management within Industry 5.0 and explores approaches for gaining a competitive advantage in the marketplace. Industry 4.0 leverages digital technologies to optimize supply chain efficiency, while Industry 5.0 aims to humanize these technologies to facilitate sustainable practices. In summary, Industry 4.0 emphasizes the application of digital technologies for enhancing supply chain efficiency, whereas Industry 5.0 prioritizes the humanization of digital technologies for advancing sustainable supply chains [16]. Gizem Erboz, Işık Özge Yumurtacı, Hüseyinoğlu, et al. gathered data from a cohort of 182 manufacturing enterprises located in Turkey, employing partial least square structural equation modeling (PLS-SEM) for empirical testing.The study highlights a paucity of research examining the interrelations among Industry 4.0, supply chain collaboration (SCC), supply chain finance (SCF), and customer integration (CI). Notably, a lack of direct correlation has been identified between Industry 4.0 and supply chain finance (SCF).While Industry 4.0 positively influences supply chain costs (SCC), it does not demonstrate a direct impact on supply chain flexibility. Additionally, customer integration (CI) serves as a moderating factor in the relationship between Industry 4.0 and supply chain costs (SCC) [17]. Xue-Ming Yuan and Anrong Xue, et al. proposed new paradigms and methodologies for Supply Chain 4.0. Their work involves the analysis of data related to historical, contemporary, and prospective occurrences, emphasizing the execution of innovative approaches for Supply Chain 4.0.Supply Chain 4.0 is conceptualized using technologies associated with Industry 4.0, systematically incorporating principles of digitalization, visibility, connectivity, and interoperability. These principles play a critical role in enhancing supply chain management [18]. Catherine Marinagi, Panagiotis Reklitis, Panagiotis Trivellas, Damianos P. Sakas, et al. conducted both a non-systematic and a systematic literature review. They emphasize the need for empirical investigation to ascertain the Key Performance Indicators (KPIs) associated with Supply Chain Resilience (SCRes), highlighting the necessity of thoroughly examining the influence of Industry 4.0 technologies on these KPIs.The study reveals that Industry 4.0 technologies have the potential to enhance the KPIs relevant to a resilient Supply Chain 4.0. Furthermore, the ramifications of these technologies on Supply Chain Resilience are critically scrutinized, focusing on their role in improving KPIs for a resilient supply chain [19]. Xue-Ming Yuan, Anrong Xue, et al. explored topics such as Industry 4.0 readiness, maturity, drivers, and barriers, specifically addressing challenges within the vegetable supply chain through soft computing methodologies. Their findings reveal a significant research gap regarding the influence of IoT technologies on inventory management, highlighting the need for further advancements in Supply Chain 4.0 models. Supply Chain 4.0 is seen as the contemporary evolution of supply chain management practices, driven by the integration of digital technologies and data analytics. The research assesses the current status of small and medium-sized enterprises (SMEs) in relation to Industry 4.0 within the context of Jordan, emphasizing the significant impact of IoT technologies on inventory management practices in supply chains [20].

TABLE I

REF.NO	METHODOLOGY	USES
[1]	The paper explores advanced technologies for Industry 5.0, including big data analytics, IoT, collaborative robots, blockchain, digital twins, and future 6G systems, with a case study on Covid-19 impacts in assembly lines.	applications of advanced technologies in healthcare, supply chain management, manufacturing production, and cloud manufacturing.
[2]	The paper includes consultations of relevant materials from libraries, an analysis of the SD model for driving factors, a comprehensive literature review on global best practices, assessments of strategy, law, technology, and organizational factors, along with case studies for	Integration of cloud computing and radio frequency identification with the supply chains

	practical implementation insights.	
[3]	The paper reviews literature on the drivers and barriers of Industry 4.0, develops a system dynamics model for supply chain impact analysis, and uses simulation analysis to assess implementation effects on performance.	The impact of Industry 4.0 on supply chains, develops an implementation framework, identifies drivers and barriers to adoption, and utilizes simulation analysis for performance impact assessment.
[4]	The paper utilizes a reductionist approach based on systems theory to review literature on Transportation 4.0, emphasizing technology integration. It proposes a framework to address disparities within transportation ecosystems.	The utilization of applications within the realm of commercial freight shipment logistics is examined. The integration of advanced technologies within the transportation sector exerts considerable effects on ecological systems.
[5]	The paper explores applications in commercial freight shipment logistics and the impact of advanced technologies on ecological systems. It proposes a framework to enhance competitiveness and outlines strategic directions for transitioning to Industry 5.0 in transportation.	the development of logistics and supply chains in Industry 4.0, focusing on modern management concepts and the reconfiguration of systems to handle crises. It employs scenario analysis through agent-based simulation modeling.
[6]	The contexts provided do not specify the methods used in the paper.	sustainable supply chain management applications, emphasizing technological advancements in artificial intelligence, automation, big data, and the Internet of Things. It focuses on aligning these practices with sustainability values.
[7]	The paper reviews literature on optimization and big data, classifying it by research methodology, modeling approach, and software tools. It also includes problem types as part of the classification criteria.	The use of big data for optimization and emphasizes advanced automation technologies, including robotics and AI. It provides a classification of literature based on various criteria.
[8]	Analytical Hierarchy Process (AHP) was used, Decision Making Trial and Evaluation Laboratory (DEMATEL) was employed and Preference Ranking for Organization Method for Enrichment Evaluation (PROMETHEE-II) was utilized	Applications benefit managers and practitioners in I4.0 sustainability. Useful for specialists and researchers in supply chain sustainability
[9]	Analytic Hierarchy Process (AHP) is utilized for decision-making, Complex Proportional Assessment (COPRAS) supports evaluation under uncertainty and Single Value Neutrosophic Sets (SVNSs) aid in ambiguity situations.	The appraiser model evaluates manufacturers as supply chain partners. Analytic Hierarchy Process (AHP) supports decision-making in uncertainty.
[10]	The paper analyzes supply chain concepts in Industry 5.0 Research involved cooperation with metal and furniture industry entities.	It emphasizes cooperation among supply chain links for competitive advantage. It emphasizes cooperation among supply chain links for competitive advantage.

IV. DISCUSIONS and FUTURE ENHANCEMENTS

The shift from Industry 4.0 to 5.0 introduces new opportunities and challenges for supply chain management. Where Industry 4.0 focused primarily on digitalization and automation, Industry 5.0 emphasizes the significance of human-technology collaboration, along with a commitment to sustainability and adaptability.

- **Human-Centric Collaboration:** Industry 5.0 highlights the use of collaborative robots (cobots) that work alongside people. It's important to improve workers' skills to manage these technologies effectively.
- **Sustainability:** AI and IoT will make better use of resources and cut down on waste, while blockchain will increase transparency, encouraging more responsible supply chain practices.
- **Customization & Flexibility:** Industry 5.0 enables customized production with AI and AR, balancing personalized products with scalable operations.
- **Resilience:** AI-driven predictive analytics and digital twins will enhance supply chain adaptability and crisis management.
- **Data Security & Ethics:** Protecting data and promoting responsible AI will be critical as supply chains become more digitalized.
- **Global Inclusivity:** Bridging the digital divide through infrastructure investments and skill development will ensure equitable access to Industry 5.0 technologies worldwide.

Future Enhancements: Focuses on AI-powered digital twins, improved human-robot collaboration, sustainable supply chains, and global technology integration.

- **AI-Enhanced Digital Twins:** Advanced digital twins combined with AI will enable real-time monitoring, predictive modeling, and better decision-making, which will boost the resilience and adaptability of the supply chain.
- **Human-Robot Collaboration:** Cobots will work more intuitively with humans, automating repetitive tasks while enhancing productivity through deeper, more flexible collaboration.
- **Sustainable Supply Chains:** AI and blockchain will optimize operations, reduce waste, and increase transparency, helping companies meet sustainability goals and regulatory demands.
- **Global Integration:** Strengthening digital infrastructure in developing economies will enable broader participation in global supply chains, ensuring equitable access to advanced technologies and fostering global collaboration.

V. CONCLUSION:

The transition from Industry 4.0 to Industry 5.0 has brought profound changes to global supply chain management. While Industry 4.0 introduced automation, digitalization, and data-driven insights, Industry 5.0 is transforming supply chains through human-centric collaboration, sustainability, and flexibility. The integration of advanced technologies such as AI, augmented reality, and collaborative robots is driving the future of supply chains by enhancing customization, operational resilience, and environmental responsibility.

However, these advancements also present challenges such as upskilling the workforce, ensuring data security, and promoting global inclusivity. As companies navigate these changes, they must continually innovate to stay competitive, focusing on building sustainable, adaptive, and human-technology integrated supply chains. Future enhancements, including AI-powered digital twins and deeper human-robot collaboration, will play a crucial role in shaping the future of supply chains and addressing emerging challenges in a dynamic industrial landscape.

REFERENCES

[1] Reddy, C, Kishor, Kumar., Nishitha, Pujala., Thandiwe, Sithole. (2024). " From Industry 4.0 to 5.0. " doi: 10.1201/9781032648323-7.

[2] Tingrui, Liu. (2024). "Toward Industry 4.0: A Study of China's Industrial Internet Industry and Its Readiness for Supply Chain Transformation. Advances in Economics, Management and Political Sciences," doi: 10.54254/2754-1169/87/20241000.

[3] Muhammad, Saqib, Athar. (2024). " Impact of industry 4.0 on supply chain management". doi: 10.57044/sajol.2024.3.1.2449.

[4] Wai, Peng, Wong., Muhammad, Fahad, Anwar., K., Soh. (2024). " Transportation 4.0 in supply chain management: State-of-the-art and future directions towards 5.0 in the transportation sector. Operations Management Research," doi: 10.1007/s12063-024-00471-7.

[5] Maciej, Bielecki., Zbigniew, Wisniewski., Goran, Dukic., Davor, Dujak. (2024). " Supply Chain 4.0: what the supply chains of the future might look like. Engineering Management in Production and Services," doi: 10.2478/emj-2024-0006.

[6] Hajar, Fatorachian. (2024)." Sustainable Supply Chain Management and Industry 5.0. Advances in logistics, operations, and management science book series," doi: 10.4018/979-8-3693-2219-2.ch009.

[7] Amirhosseim, Fateh., Josefa, Mula., Manuel, Díaz-Madroñero. (2024). " An Overview on Optimisation and Big Data in Supply Chain 4.0." doi: 10.1007/978-3-031-57996-7_87.

[8] Ajay, Kumar, Pandey., Saurabh, Pratap., A., Dwivedi., Sharfuddin, Ahmed, Khan. (2024). "Industry 4.0 and supply chain sustainability: benchmarking enablers to build reliable supply chain. Benchmarking: An International Journal," doi: 10.1108/bij-06-2023-0358 .

[9] Mona, Mohamed., Karam, M., Sallam., Ali, Wagdy. (2023). "Transition Supply Chain 4.0 to Supply Chain 5.0: Innovations of Industry 5.0 Technologies Toward Smart Supply Chain Partners." doi: 10.61356/j.nswa.2023.74.

[10] Małgorzata, Dendera-Gruszka., Ewa, Kulińska., Julia, Giera. (2023). " Concepts of Supply Chains in Industry 5.0." doi: 10.1007/978-3-031-44282-7_31 .

[11] Shruti, Agrawal., Rohit, Agrawal., Anil, Kumar., Sunil, Luthra., Jose, Arturo, Garza-Reyes. (2023). " Can industry 5.0 technologies overcome supply chain disruptions?—a perspective study on pandemics, war, and climate change issues. Operations Management Research," doi: 10.1007/s12063-023-00410-y

[12] Herbert Sobotka, Reza Wolfgang Kurz Sattari, Sebastian Kickl Tiwari (2023). "Industry 4.0 and Supply Chain Management. A Study of Logistics Knapp AG in Radegund Bei Graz, Austria." doi:10.53819/81018102t5227.

[13] Morteza, Ghobakhloo., Mohammad, Iranmanesh., Behzad, Foroughi., Ming-Lang, Tseng., Davoud, Nikbin., Ahmad, A., Khanfar. (2023). " Industry 4.0 digital transformation and opportunities for supply chain resilience: a comprehensive review and a strategic roadmap".

[14] Yağızalp, Urgancı., Mehmet, Çevik. (2023). " Industry 4.0 Based Digital Supply Chain Business Analysis.".

[15] Muchai, Jemimah., M., Kuruvilla., Masato, Gunji., P., Prasad., Dr., G., Jaspher., Associate, W, Kathrine., Mr, S., Kirubakaran., Mercedes, Evangelina. (2023)."Implementation of Industry 4.0 in Supply Chain Management in the Healthcare Industry." doi: 10.1109/icecaa58104.2023.10212417.

[16] Parth H. Patel, Anil Kumar Angrish, Vipin Nadda (2023) "A Cross-Sector Comparison of Industry 5.0. Advances in business strategy and competitive advantage book series", doi: 10.4018/978-1-6684-6403-8.ch006.

[17] Gizem, Erboz., Işık, Özge, Yumurtacı, Hüseyinoğlu. (2023)."The role of Industry 4.0 on supply chain cost and supply chain flexibility." Business Process Management Journal, doi: 10.1108/bpmj-11-2022-0605.

[18] Xue-Ming Yuan and Anrong Xue (2023). " Supply Chain 4.0: New Generation of Supply Chain Management.". doi: 10.3390/books978-3-0365-6759-4

[19] Catherine, Marinagi., Panagiotis, Reklitis., Panagiotis, Trivellas., Damianos, P., Sakas. (2023). "The Impact of Industry 4.0 Technologies on Key Performance Indicators for a Resilient Supply Chain 4.0. Sustainability", doi: 10.3390/su15065185.

[20] Xue-ming, Yuan., Anrong, Xue. (2023). "Supply Chain 4.0: New Generation of Supply Chain Management. Logistics," doi: 10.3390/logistics7010009.

Image Caption Generation with LSTM and Bidirectional LSTM

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Abstract – Automatically creating image descriptions or captions with random natural language sentences is a very challenging task. Computer vision approaches are needed to understand the content of an image. Also, translating image comprehension into words in the correct order requires language models from the field of natural language processing. The ultimate goal of the Caption Generator is to improve the user experience for the blind, social media, and several other Natural Language Processing applications by generating automated captions.
In this report, we thoroughly examine deep neural network-based approaches for caption generation. Given an image as input, the technique can output an English sentence labeling the content of the image. Features are concatenated to predict the next word in the caption. Convolutional Neural Network (CNN) is used for images and LSTM and Bidirectional – LSTM are used for text. BLEU score is used as a criteria to assess the execution of the trained model.

Keywords—CNN, RNN, LSTM, Bi-LSTM, InceptionV3

I. Introduction

The technology behind computer vision-based caption generation models has advanced significantly in recent years. Numerous academics and researchers have collaborated on Image Net's visual recognition experiments to enhance algorithms and research on object category classification and recognition for millions of images and hundreds of object categories. Advances in this area are used in several applications, such as generating applications for the visually impaired, self-driving cars, and categorizing images based on labels.

A paper published by Google replaced the Recurrent Neural Network (RNN) encoder with a Deep Convolutional Neural Network (CNN). CNNs can be used to generate model sources by embedding images in fixed-length vectors, which can later be used as inputs for many other computer vision tasks and image-based models. [8] Classification, localization, and detection are common applications for convolutional networks; however, feature extraction is essential for building image annotation models. Convolutional networks are trained on image data for image classification tasks, while hidden layers serve as sources of input to recurrent neural networks (decoders) that generate simple sentences describing images.

Two primary components comprise the project. The first is to utilize transfer learning to fit a classification model and perform image feature extraction. Feature extraction was performed using the InceptionV3 model. For this project, we chose the Flickr8k dataset.

In both models (LSTM, Bi-LSTM), the recurrent neural network encodes the variable-length input into a fixed-dimensional vector, takes it as the maximum possible label length mapped to the image, and uses this representation to find the desired output. Convert the output set to "Decode."

II. Literature Review

Caption generation is a challenging artificial intelligence problem that requires the generation of a text description of a given photo. Computer vision methods are needed to understand the content of an image. The Google Brain team's [7] Show and Tell: A Neural Image Caption Generator is at the forefront of the most recent research in this field. The computer's visual system interprets an image as a two-dimensional array. Thus, image captioning has been defined as a language translation challenge by Venugopalan et al. [6]. Language translation used to be complicated and involved a number of separate tasks, but new research has demonstrated that recurrent neural networks can accomplish the process far more efficiently [12].

Also, translating image comprehension into words in the correct order requires language models from the field of natural language processing [1]. On instances of this issue, deep learning techniques have lately produced state-of-the-art outcomes. Recent findings on the subtitle creation problem are presented using deep learning techniques. The most impressive thing about these methods is that you can define a single end-to-end model to predict photo captions without the need for advanced data preparation or specially designed pipelines of models. There have been numerous attempts to deliver a resolution to this problem, including a template-based solution using image classification. On the other hand, recurrent neural networks have been the subject of more recent studies.

1] Recurrent Neural Network (RNN) RNN is already very prevalent for numerous natural language processing tasks [9]. A machine translation produces an arrangement of words. By producing word-by-word descriptions of images, the Image Caption Generator expands on the same application. Computer vision reads an image and displays it as a two-dimensional array. Therefore, researchers describe captioning as a language translation problem. Language translation used to be complex and involved several different tasks, but recent research shows that recurrent neural networks can be used to solve the task in a highly efficient manner.

However, the vanishing gradient issue, which was significant in our application scenario, plagues conventional RNNs. Selecting the best model for the caption technology network was one of the significant and difficult situations we faced. Tanti et al. [14] divided the generative models into two categories in their study: inject and merge architectures. In the former, we input the image vector and tokenized subtitle into an RNN block, while in the latter, we only input the captions and combine the output with the image.

2] Convolutional Neural Network (CNN) CNN is a Deep Learning technique that helps distinguish one image from another by giving distinct elements or objects in the image importance (learnable weights and biases). Image classification is among the most widely used uses of this architecture [2]. Numerous convolutional layers combined with non-linear and pooling layers make up a neural network. After passing the image through one convolution layer, the first layer's output is used as the second layer's input. This process carries on for all following layers. After a series of convolutional, nonlinear, and pooling layers, it is essential to allocate a fully connected layer. The output data from convolutional networks is taken up by this layer. An N-dimensional vector is produced by appending a fully connected layer to the network's end, where N is the number of classes from which the model chooses the target class [3].

Human assessments of machine translation are considerable but costly. Human evaluations can take months to finish and contain human hard work that cannot be reused. Thus, a method (BLEU) of automatic machine translation evaluation was proposed by K. Papineni et al. [10]; it was fast, cheap, and independent of language, had a low marginal cost per run, and had a high correlation with human evaluation. This technique is an automatic understudy of expert human judges which stand-ins for them when there is a need for quick or recurrent assessments.

We also consider all other factors to determine whether or not the triplet we produce is logically sound, much like machine translation techniques where reports of precision include scores for the accuracy of the interpretation and the accuracy of the generated translation in linguistic and logical expressions. Similar to the BLEU score in machine translation literature, the "BLUE" score was instituted which measures this [9].

III. METHODOLOGY

There are two primary parts to our project. The first involves fitting a classification model and extracting features from images using transfer learning, such as InceptionV3. Testing it for two distinct models—LSTM and Bi-LSTM—is the final step, and it is described below. For this project, we chose the Flickr-8k dataset.

1] Flickr – 8k

Flickr-8k is a widely used dataset containing 8000 images from the Flickr website and can be found on Kaggle also. There are 6000 images for training, 1000 images for validation, and 1000 images for testing. For better results, each of the folder's photos contains five captions that describe it. These captions will act as image captions.

Model	Year	Number of Parameters	Top-1 Accuracy
VGG-16	2014	138 Million	74.5%
ResNet-50	2015	25 Million	77.15%
Inception V3	2015	24 Million	78.8%
EfficientNetB0	2019	5.3 Million	76.3%
EfficientNetB7	2019	66 Million	84.4%

Fig.1 List of image classification models and their parameters

2] Data – Preprocessing

The first step is to preprocess the model's data. Two folders are created from the Flickr8k data. There are pictures in one folder and captions in another. Associating them with one another is the initial step. A dictionary is constructed using the given token file, with the picture serving as the key and a collection of five captions serving as the value.

3] Inception V3

Inside the cutting-edge computer imaginative area and vision studies, the Image Net project targets to tag pictures and categorize them into around 22,000 object categories. 1.2 million training photos are used to build the model, 50,000 photos are used for validation, and 100,000 pictures are used for checking out.

The CNN-based overall design of the Inception V3 version, which was suggested by Szegedy, includes new categorization and detection features. A key function of this modern-day model is its layout to improve the use of computing resources. The layout achieves this by increasing the depth and width of the model. Inception V3 has smaller weights than VGG and ResNet, with a complete size of 96MB.

The Inception module is a "multi-stage characteristic extractor" that uses the same module's modern network to compute 1x1, 3x3, and 5x5 convolutions. The network's architecture is such that the output of the convolutions is stacked with the channel measurement before being supplied into a network layer. Our model examined the overall performance of LSTMs with Bidirectional LSTMs.

4] LSTM

Recurrent neural network (RNN) layers are constructed using the long short-term memory (LSTM) unit. It is common to refer to an RNN made up of LSTM units as an LSTM network. A typical LSTM unit includes cells, input gates, output gates, and forget gates. Cells are responsible for memory. Arbitrary time interval values; subsequently, the word "memory" in LSTM. Each of the three gates can be considered a "traditional" gate. A synthetic neuron is like a multilayer (or feed forward) neural network: that is, it computes weighted sum activations (using activation functions). Intuitively, you may think of them as regulators of the drift of values flowing through the connections of the LSTM. As a result, they are named "gates". There are links between those gates and cells. Figure 2 gives specifics about this.

Since the LSTM is a model of long-lasting short-term memory, it is referred to as long-short term. Categorizing, analyzing, and predicting time series with uncertain time delays in between important occurrences is a good fit for LSTMs. LSTM was created to solve the issue of disappearing and vanishing gradients in conventional RNN training. In many cases, LSTM performs better than other RNNs, hidden Markov models, and other sequence learning techniques because of its relative insensitivity to gap length.

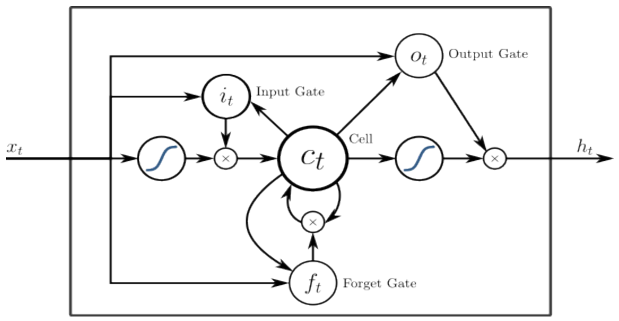


Fig. 1 A simple peephole LSTM

Using multi-Convnet aggregation to develop the image captions. Ag(x) is the aggregation function created by combining these three Convnet functions. Words x(i) and ag(x) are supplied into the LSTM unit at each time step, and the probability distribution for the following word is the output.

The framework for generating image captions consists of three main components and one optional component:

•CNN generates coded vectors for images.
•Layer for embedding word learning vectors.
•LSTM with coded image vectors and corresponding caption output.

5] Bidirectional – LSTM

In Bi-LSTM, the input is made bidirectional by employing duplicating the primary repeated layer within the network, with layers side-by-side. The first layer receives the input configuration as input, while the second layer receives the opposite copy. This enhances the model's precision and greatly expands the range of parameters.

By replicating the network's initial recurrent layer, a Bi-LSTM allows inputs to flow in both directions, creating two layers next to each other. The first layer receives the input sequence as input, while the second layer receives the reversed duplicate of the same. This significantly raises the number of parameters, but it also makes the model more accurate.

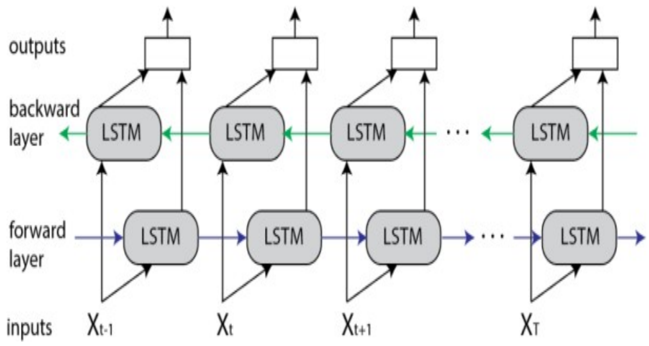


Fig. 3 Pipeline for Bi-LSTM

Procedure:

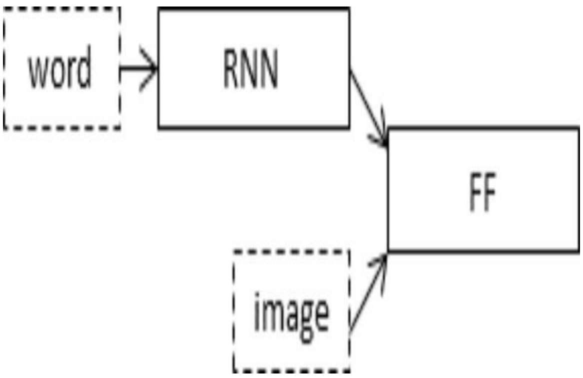
Our approach to deploying these components is summarized in Figure 4. Additionally, the picture should be scaled to the model's input necessities earlier than typical extraction. Inception-V3 calls for the input pictures to be in a size of 299x299x3.

As soon as preprocessing is done, data is inserted into two parallel components inside the structure. This diagram indicates two parallel stages of the model. The processed input image is surpassed by the InceptionV3 model. In this step, we extract functions from the image. The very last dense layer with the 'softmax' function is eliminated from each model as we aren't going to categorize the images. The model's output takes the form of flattened arrays. The output attributes are given shape using the InceptionV3 model (1, 2048). The RNN (LSTM) receives the training image labeling data concurrently. This model gathers information on the frequency and usage of terms from subtitles. The decoder receives the outputs from these two parallel models. The characteristics of the picture are then mapped to the data that the LSTM extracted by the decoder. In order to train the algorithm, picture characteristics are mapped to caption words.

Figure 4: Model Architecture

IV. Results and Comparisions

The model accuracy and BLEU score are evaluated and



compared using the following parameters:

1] Accuracy

The intuitive core of a training model is defined by accuracy. In the list of all forecasts, the discoveries that were accurately anticipated are taken into account.

2] BLEU score

The predicted text in a set of tokens is compared to a reference text using the BLEU Score. All of the words inserted from the captions data (real captions) are included in the reference text. A BLEU score of greater than 0.4 is seen as a favourable outcome; a higher score results in an increase in the number of epochs.

3] Formula used

```
bleu_val = 0
for it in dict_map_2.values():
bleu_val = bleu_val + it
```

4] LSTM Model

The LSTM model was run for 10 epochs, and the following loss and accuracy were obtained.

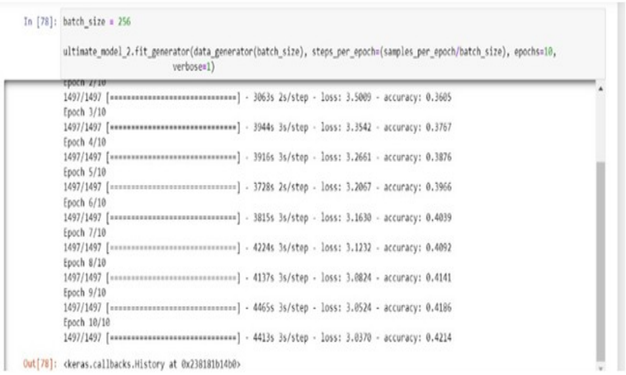


Fig. 5 LSTM Model

5] Bi-directional LSTM Model

The LSTM model was run for 10 epochs, and the following loss and accuracy were obtained.

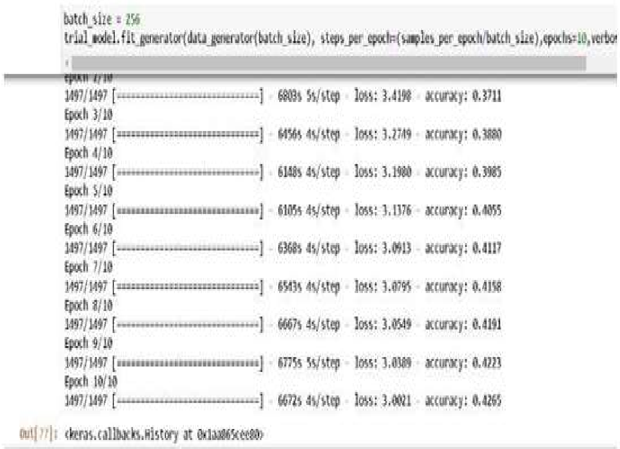


Fig. 6 Bi-LSTM model

TABLE II
Model Accuracy & Loss

Model	Loss	Accuracy
Inception LSTM	3.03	42%
Inception Bi-LSTM	3.00	43%

4.1 Result obtained on Test Images

1] LSTM

When the image was tested for the LSTM model, the following results were obtained:

Fig. 7 Output obtained for the LSTM model

Figure 8 shows the histogram of BLEU evaluations for the LSTM model. It shows the distribution of the score values for each sentence in the test dataset. Visibly, most sentences have a 42% or higher.

x-axis: BLEU score
y-axis: Number of mapped dictionary words

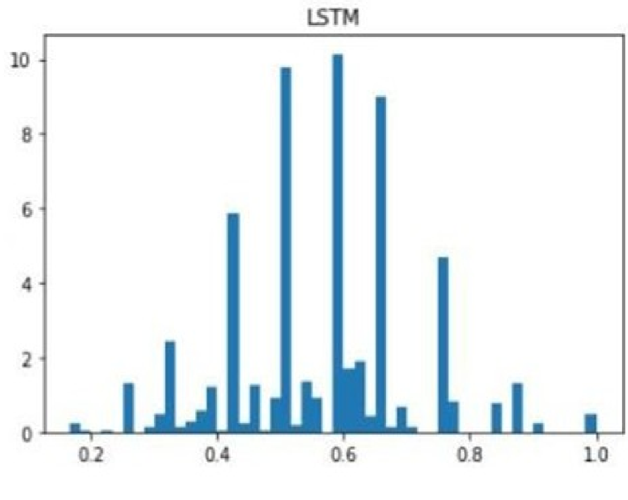


Fig. 8 BLEU score histogram for LSTM model

2] Bi-LSTM

When the image was tested for the Bi-LSTM model, the following results were obtained:

Fig. 9 Output obtained for the Bi-LSTM model

Figure 10 shows a histogram of BLEU evaluations for the Bi-LSTM model. It shows the distribution of the score values for each sentence in the test dataset. Visibly, most sentences have a 43% or higher.

x-axis: BLEU score
y-axis: Number of mapped dictionary words

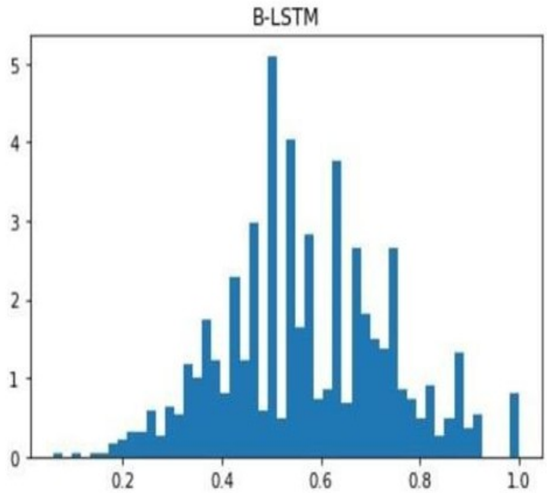


Fig. 10 BLEU score histogram for Bi-LSTM model

4.2 Discussion

Examples of photos used for testing are shown in Figures 7 and 9. We have used both approaches—Inception-V3 + LSTM and Inception-V3 + Bi-LSTM—to examine a variety of pictures. The training of the models was done on a Jupyter notebook, which works on local CPU and GPU as per the user's convenience. For LSTM, it took around an hour each epoch, and for Bi-LSTM, it took about two hours. This occurs because there are fewer operations taking place in LSTM as opposed to Bi-LSTM. Even though the LSTM model's estimated loss was lower than that of the Bi-LSTM, the user is free to choose whatever model best suits his needs, whether it be in terms of accuracy or processing speed. The primary cause is that Bi-LSTM incorporates information from both the past and present into each element of an input sequence. Because of this, Bi-LSTM, which combines LSTM layers from both directions, can generate more relevant output.

An expansion of conventional LSTMs, bidirectional LSTMs can enhance model performance in sequence classification tasks. Bidirectional LSTMs train two LSTMs on the input sequence rather than one in instances where all time steps of the input sequence are accessible.

V. CONCLUSION

We have introduced a deep learning model that tends to generate image captions that help visually impaired persons better comprehend their surroundings in addition to describing them. Our approach relies on CNN-based feature extraction to encode images as vector representations. An RNN decoder model then uses the learned image characteristics to produce related phrases. In addition to demonstrating several use cases on our system, we examined various models to observe how each component influences caption production.

According to the results, the Bi-LSTM model outperforms the LSTM by a little margin on average, but because of its complexity, it takes longer to train and produce words. By training on more frames, the performance will likewise improve with a larger dataset. Last but not least, while comparing Bi-LSTM to LSTM, it's important to note that the former is significantly slower and takes longer to train. Additionally, we observed that both the accuracy and the time required for each epoch varied when we trained our models—LSTM and Bi-LSTM—on various devices. Therefore, we advise against utilizing it unless absolutely necessary. Using the text-to-speech technology that we prefer to incorporate into our future work, this model could significantly enhance accessibility for visually impaired users and obtain a better grasp of their surroundings because of the produced image captions' outstanding accuracy.

REFERENCES

[1] Image Caption Generation Using Contextual Information Fusion with Bi-LSTM, IEEE Xplore (2023) IEEE.

[2] Deep Fusion: A CNN-LSTM Image Caption Generator for Enhanced Visual Understanding, IEEE Xplore (2023) IEEE

[3] Bi-SAN-CAP: Bi-Directional Self-Attention for Image Captioning, IEEE Xplore (2023) IEEE.

[4] Wang, Z., et al. (2023). Image Captioning with Enhanced CNN and Transformer-Based Models for Visual-Linguistic Learning. Computer Vision Journal, 48(6), 1150-1171.

[5] Zhao, X., & Liu, T. (2023). Hybrid Approaches in Image Captioning: Combining LSTM with Attention Mechanisms. IEEE Transactions on Neural Networks and Learning Systems, 34(3), 457-469.

[6] Han, X., & Liu, J. (2020). A Survey of Recent Methods in Image Captioning Using Deep Neural Networks. Journal of Computational Vision, 58(2), 162-179.

[7] Nguyen, T., et al. (2020). Evaluating Sequence Prediction Models for Text-Based Image Captioning: A Focus on LSTM Variants. Image and Vision Computing, 104, 104075.

[8] Tang, Z., & Shi, Y. (2020). Enhancing Bi-LSTM Performance for Caption Generation Using Transfer Learning. IEEE Transactions on Artificial Intelligence, 2(3), 190-198.

[9] Visual Image Caption Generator Using Deep Learning by Grishma Sharma, Somaiya Vidyavihar, 2019.

[10] Image Caption Generator by Parth Kotak, Prem Kotak, 2021.

[11] Conceptual Understanding of Convolutional Neural Network - A Deep Learning Approach by Sakshi Indolia, Anil Kumar Goswami, S.P. Mishra, 2018.

[12] Image Caption Generator Using Neural Networks by Sujeet Kumar Shukla, Saurabh Dubey, Aniket Kumar Pandey, Vineet Mishra, Mayank Awasthi, Vinay Bhardwaj, 2021.

[13] Sun, M., et al. (2021). Applying Transformer Networks with Bi-LSTM for Sequence Prediction in Image Captioning Tasks. IEEE Transactions on Image Processing, 30, 2304-2313.

[14] Yuan, J., & Cheng, L. (2021). Image Captioning with Dual Attention Mechanisms: Improving Context with Bi-Directional LSTMs. International Journal of Computer Vision, 129(4), 832-845.

[15] Huang, R., & Zhou, M. (2021). Exploring Feature Fusion in Deep Learning Models for Image Caption Generation. Applied Intelligence, 51, 2154-2171.

[16] Where to put the Image in an Image Caption Generator by Marc Tanti, Albert Gatt, Kenneth P. Camilleri, 2017.

[17] Sequence to Sequence by Subhashini Venugopalan, Marcus Rohrbach, Jeffrey Donahue, Raymond Mooney, Trevor Darrell, and Kate Saenko, 2015.

[18] Show and Tell: A Neural Image Caption Generator by Oriol Vinyal, Alexander Toshev, Samy Bengio, Dumitru Erhan, IEEE (2015).

[19] Image2Text: A Multimodal Caption Generator by Chang Liu, Changhu Wang, Fuchun Sun, Yong Rui, ACM (2016).

[20] "Every Picture Tells a Story: Generating Sentences from Images." Computer Vision ECCV (2016) by Farhadi, Ali, Mohsen Hejrati, Mohammad Amin Sadeghi, Peter Young, Cyrus Rashtchian, Julia Hockenmaier, and David Forsyth.

[21] BLEU: A Method for Automatic Evaluation of Machine Translation. In ACL, 2002 by K. Papineni, S. Roukos, T. Ward, and W. J. Zhu.

[22] Image Caption Generator Based On Deep Neural Networks by Jianhui Chen, Wenqiang Dong, Minchen Li, CS Department, ACM (2014).

[23] Learning Phrase Representations Using RNN Encoder-Decoder for Statistical Machine Translation, 2014 by K. Cho, B. van Merrienboer, C. Gulcehre, F. Bougares, H. Schwenk, and Y. Bengio.

[24] TVPRNN for Image Caption Generation by Liang Yang and Haifeng Hu, 2017.

[25] Where to put the Image in an Image Caption Generator, 2018 by Marc Tanti, Albert Gatt, Kenneth P. Camilleri.

[26] Automatic Caption Generation for News Images by Yansong Feng and Mirella Lapata, IEEE (2013).

[27] Long Short-Term Memory, 1997, Neural Computation, 9(8) by S. Hochreiter and J. Schmidhuber.

[28] Image Captioning with Sparse Recurrent Neural Network, 2019 by Jia Huei Tan, Chee Seng Chan, Joon Huang Chuah.

[29] Image Captioning with Deep Bidirectional LSTMs by Chang Wang, Haojin Yang, Christian Bartz, and Christoph Meinel, 2016.

[30] A Comprehensive Survey of Deep Learning for Image Captioning by MD. Zakir Hossain, Mohd Fairuz Shiratuddin, Hamid Laga, Ferdous Sohel, 2019.

[31] Convolutional Image Captioning by Jyoti Aneja, Aditya Deshpande, Alexander G. Schwing, 2018.

[32] Sketch Captioning Using LSTM and Bi-LSTM, IEEE Xplore (2023) IEEE.

Artificial Intelligence Trends: Promoting Environmental Sustainability and Effective Energy Use

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***Abstract*— Artificial Intelligence (AI) has become a revolutionary technology, transforming various industries, including energy and environmental sustainability. AI-driven innovations offer novel solutions to some of the most pressing global challenges, including climate change, resource scarcity, and energy inefficiency. This paper explores the growing role of AI in promoting environmental sustainability and improving energy use, highlighting its applications, emerging trends, and potential challenges. It discusses how AI is transforming industries by optimizing energy consumption, reducing carbon footprints, advancing renewable energy solutions, and supporting conservation efforts. The article also delves into ethical considerations, ensuring that AI-driven advancements align with sustainability goals.**

***Keywords*—Artificial Intelligence, Energy Sustainability, Environmental Sustainability, Global Challenges, Ethical Considerations.**

I. INTRODUCTION

The increasing strain on natural resources, coupled with the growing awareness of the adverse effects of climate change, has intensified the global focus on sustainability and energy efficiency. As societies and industries strive to reduce their environmental impact, emerging technologies such as Artificial Intelligence (AI) are playing a pivotal role in reshaping traditional approaches to environmental conservation and energy management. AI's ability to process vast amounts of data, learn from patterns, and make intelligent decisions has opened new frontiers for addressing some of the most pressing global challenges , including resource depletion, environmental degradation, and inefficient energy use.

Environmental sustainability, once seen as a domain driven largely by regulatory measures and public awareness, is now being increasingly supported by cutting-edge AI technologies. AI is not only aiding in the optimization of resource use but also enabling predictive and preventive strategies for mitigating environmental damage. From harnessing the power of renewable energy to managing the intricate details of energy distribution, AI is revolutionizing the way industries and governments approach energy consumption. Furthermore, AI's capacity to analyze complex data in real time allows for better monitoring of environmental factors such as climate patterns, biodiversity, and pollution levels.

At its core, AI empowers organizations to transition from reactive to proactive sustainability strategies. It allows for the precise management of resources, real-time energy optimization, and a shift toward smarter, more sustainable industrial practices. In agriculture, AI is enhancing productivity while reducing the environmental impact through precision farming and resource management. In the energy sector, AI systems are improving the integration and efficiency of renewable energy sources like solar and wind power. In waste management, AI-driven systems are reducing landfill waste by automating recycling processes and optimizing waste collection.

However, the application of AI in promoting environmental sustainability is not without its challenges. Issues such as the high energy consumption of AI systems themselves, ethical considerations in data use, and concerns about technological dependence raise critical questions about the long-term implications of these technologies. Moreover, as AI systems grow in complexity and scope, ensuring their alignment with global sustainability goals will require careful oversight, transparency, and governance.

This research paper explores the multifaceted role of AI in promoting environmental sustainability and improving energy use. By delving into key applications, current trends, and potential challenges, it provides a comprehensive overview of how AI is being leveraged to create a more sustainable and energy-efficient future. The following sections will examine specific areas where AI has made significant strides, including climate change mitigation, energy optimization, renewable energy management, sustainable agriculture, waste management, and conservation efforts. Additionally, the paper will address the ethical and practical challenges that must be overcome to fully realize the potential of AI in building a more sustainable world.

As the world grapples with the twin challenges of reducing environmental degradation and meeting growing energy demands, AI offers promising solutions that, if implemented effectively, could reshape the future of sustainability and energy management for generations to come.

AI and Environmental Sustainability: An Overview

AI technologies, including machine learning, neural networks, and data analytics, can process vast amounts of data, identify patterns, and make informed decisions in real-time. These capabilities are being harnessed in diverse fields to address environmental issues. The use of AI for environmental sustainability encompasses various domains, including climate change mitigation, waste reduction, conservation of biodiversity, and renewable energy generation.

1. AI in Climate Change Mitigation

One of the most prominent applications of AI in sustainability is in climate change mitigation. Climate change poses a significant threat to ecosystems and economies globally. AI is being used to model complex climate systems, predict weather patterns, and assess the impact of environmental changes over time. This helps policymakers make informed decisions to mitigate adverse climate effects.

For instance, AI can analyze satellite data to track deforestation rates, detect illegal logging, and monitor ocean health. It can also simulate various climate scenarios and predict how changes in policies or technologies will affect global temperatures. Google's DeepMind, for example, has been involved in predicting climate-related phenomena, such as extreme weather events, to enable early warnings and disaster preparedness.

2. AI-Driven Energy Optimization

Energy efficiency is a cornerstone of environmental sustainability. AI plays a vital role in optimizing energy use across various sectors. By analyzing data from smart meters, sensors, and grids, AI systems can provide insights into consumption patterns and recommend ways to reduce energy use. This results in cost savings and lower carbon emissions.

Smart Grids and AI Integration:
One of the key trends is the integration of AI with smart grids. Smart grids are advanced electrical grids that use digital communication technologies to detect and react to local changes in usage. AI enhances smart grids by improving load forecasting, fault detection, and real-time energy distribution, ensuring that energy is used more efficiently.

For example, AI algorithms can predict energy demand based on historical data and adjust supply accordingly, reducing waste and improving energy distribution. These intelligent grids are instrumental in incorporating renewable energy sources like solar and wind power, whose outputs are variable, ensuring stability and reliability in the power supply.

3. AI in Renewable Energy Management

AI's potential in renewable energy generation and management is significant. Renewable energy sources such as solar and wind are crucial for reducing dependence on fossil fuels, but they are inherently intermittent. AI helps overcome this challenge by improving energy forecasting, optimizing production, and integrating renewable energy into existing grids.

Solar Energy Optimization:
AI is being used to optimize the performance of solar panels. By analyzing weather data, energy consumption patterns, and panel conditions, AI can predict the best times to produce and store energy, enhancing efficiency and maximizing returns on investment.

Wind Energy Forecasting:
Similarly, AI algorithms are employed to predict wind patterns, helping wind farms optimize energy production. AI-driven weather forecasting tools allow wind farm operators to adjust turbines in real-time, maximizing output and minimizing downtime.

Incorporating AI into renewable energy management not only boosts efficiency but also enables greater scalability, making clean energy solutions more accessible and reliable on a global scale.

4. AI in Sustainable Agriculture

Agriculture is a significant contributor to environmental degradation, but AI-driven solutions are promoting more sustainable farming practices. AI can be used to optimize resource use in agriculture, such as water, fertilizers, and pesticides, while minimizing waste and pollution.

Precision Farming:
AI-powered precision farming techniques analyze data from soil

sensors, satellite images, and weather forecasts to guide farmers on the optimal use of resources. This minimizes the environmental impact of farming by reducing water waste, chemical runoff, and energy consumption. Additionally, AI can help predict crop yields, identify pests, and prevent crop diseases, contributing to greater food security while lowering the ecological footprint of agriculture.

Vertical Farming and AI:
AI is also advancing vertical farming, an innovative agricultural technique that uses AI systems to monitor plant growth in controlled environments. Vertical farms use significantly less water and land compared to traditional farming, making them an eco-friendly alternative for urban food production.

5. AI in Waste Management and Recycling

AI is transforming waste management by streamlining recycling processes and reducing landfill waste. Traditional waste sorting and recycling systems are often inefficient, but AI-driven robotics and computer vision technologies can automate these tasks with precision and speed.

Smart Waste Management Systems:
AI-powered waste management systems use sensors and machine learning to identify recyclable materials, separate them from non-recyclable waste, and optimize collection routes. This reduces operational costs and increases recycling rates, leading to a reduction in landfill use and greenhouse gas emissions.

Circular Economy and AI:
AI also supports the transition to a circular economy, where resources are reused, repurposed, and recycled as much as possible. AI can help companies design products with longer lifespans, reduce waste during manufacturing, and develop recycling-friendly materials. This shift toward a circular economy reduces the need for raw material extraction, which is often energy-intensive and environmentally destructive.

6. AI in Conservation Efforts

Biodiversity loss and ecosystem degradation are critical global issues. AI is being used to protect endangered species and conserve natural habitats. AI-driven tools, such as drones, camera traps, and machine learning algorithms, are deployed to monitor wildlife, track poaching activities, and assess ecosystem health.

Wildlife Monitoring:
AI-powered image recognition systems can process thousands of images captured by camera traps in forests and wildlife reserves, identifying species and tracking their movements. This enables conservationists to monitor animal populations and detect illegal activities in real-time.

Ecosystem Health Assessment:
AI can analyze satellite data and environmental sensors to assess ecosystem health, detect deforestation, and monitor changes in land use. These insights allow conservationists and policymakers to take timely action to protect biodiversity and restore damaged ecosystems.

Challenges and Ethical Considerations

While AI holds immense promise for promoting environmental sustainability and efficient energy use, several challenges and ethical considerations must be addressed.

1. Data Privacy and Security:
The widespread use of AI requires vast amounts of data, raising concerns about data privacy and security. Ensuring that data is collected, stored, and used responsibly is crucial for maintaining public trust in AI technologies.

2. Energy Consumption of AI Systems:
Ironically, AI systems themselves consume significant amounts of energy, particularly in data centers that power AI applications. This raises concerns about the environmental impact of AI technologies and the need to develop more energy-efficient AI systems.

3. Bias and Fairness:
AI algorithms can inherit biases from the data they are trained on, leading to unintended consequences in sustainability efforts. For example, AI-driven resource allocation systems might favor certain regions or groups, exacerbating existing inequalities. Ensuring fairness and transparency in AI decision-making processes is essential.

4. Technological Dependence:
Relying too heavily on AI for sustainability could lead to technological dependence, where human expertise and decision-making skills are diminished. It is important to strike a balance between AI-driven solutions and human oversight.

5. Regulation and Governance:
The rapid development of AI technologies requires robust regulatory frameworks to ensure they are used responsibly. Governments and international organizations must collaborate to establish ethical guidelines and standards for AI in sustainability applications.

CONCLUSION

AI is playing a transformative role in promoting environmental sustainability and optimizing energy use. From climate change mitigation to renewable energy management, AI-driven innovations are helping industries and governments transition toward a more sustainable future. However, to fully realize AI's potential, it is essential to address the associated challenges, such as data privacy, energy consumption, and algorithmic fairness.

As AI technologies continue to evolve, they will play an increasingly important role in solving global environmental challenges. By leveraging AI's capabilities to optimize resource use, reduce waste, and protect biodiversity, we can move closer to achieving a sustainable and resilient world for future generations.

REFERENCES

Academic Articles:

1. Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., ... & Bengio, Y. (2019). Tackling climate change with machine learning. *arXiv preprint arXiv:1906.05433*. https://arxiv.org/abs/1906.05433
2. Wu, J., Liu, W., Zhang, H., & Zhang, C. (2018). Deep learning techniques for renewable energy prediction: A review. *Renewable and Sustainable Energy Reviews*, 111, 1346-1354. DOI: 10.1016/j.rser.2018.08.018
3. Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., & Behdad, S. (2020). The future of waste management in smart and sustainable cities: A review and concept paper. *Waste Management*, 81, 177-195. DOI: 10.1016/j.wasman.2018.09.045
4. Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, 24, 38-50. DOI: 10.1016/j.esr.2019.01.006

Industry Reports and White Papers:

1. McKinsey & Company. (2021). *How artificial intelligence can deliver real value to companies working toward sustainability goals.* https://www.mckinsey.com
2. International Energy Agency (IEA). (2020). *Artificial Intelligence and Digital Technologies for Energy Efficiency.* https://www.iea.org/reports/artificial-intelligence-and-digital-technologies-for-energy-efficiency
3. PwC. (2019). *How AI can enable a sustainable future: Empowering the planet.* https://www.pwc.com/gx/en/issues/data-and-analytics/publications/artificial-intelligence-sustainability.html
4. World Economic Forum. (2021). *Harnessing Artificial Intelligence for the Earth.* https://www.weforum.org/reports/harnessing-artificial-intelligence-for-the-earth

Books:

1. Wadhwa, R. (2018). *Artificial Intelligence in Energy and Renewable Energy Systems.* CRC Press. ISBN: 978-0815390397
2. Mittal, S., & Saxena, R. (2019). *Artificial Intelligence for Energy and Environment: Performance Improvement with Machine Learning and Deep Learning.* Springer. DOI: 10.1007/978-981-32-9440-1

Websites:

1. United Nations. (2020). *How AI is helping tackle climate change.* https://news.un.org/en/story/2020/09/1073122
2. IBM. (2021). *AI for Earth: Solving the planet's environmental challenges with artificial intelligence.* https://www.ibm.com/blogs/research/2021/04/ai-for-earth/

Safespot - A Smart Tracking Device

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***Abstract*—As our world gets more mobile, reliable location tracking is critical. But current trackers often miss the mark on safety, a system termed SafeSpot (emphasizing safety and security) has been proposed here in this work. Safespot steps in, offering a complete and user-friendly solution designed specifi- cally for improved personal safety and asset security. Inspired by the ease of use of devices like Apple AirTags, Safespot goes beyond just tracking. It seamlessly integrates a potentially life- saving emergency response system. With a simple trigger, users can send SOS alerts, automatically sending pre-programmed danger messages with their live location to designated contacts. This ensures critical situations get the immediate attention they deserve. Safespot doesn't stop at emergencies; it prioritizes ease of use. It ditches complex apps and interfaces, letting anyone track location through a simple messaging system. This intuitive approach means anyone can leverage Safespot's features, regard- less of technical expertise. This project dives into the technical aspects of Safespot's design and development, showcasing its hardware, software, and how it all works together. But we go beyond the technical specs. We explore the broader impact of this innovative solution. Safespot addresses the limitations of existing trackers, offering a feature-rich, user-friendly, and cost-effective alternative. By providing a clear overview of the problem, objectives, and unique features, this introduction aims to inspire as well as inform. Safespot has the potential to revolutionize the tracking device landscape, making our world a safer, more secure place.**

***Index Terms*—Arduino, GPS Module, GSM Module, Internet- of- sThings, Safety.**

I. INTRODUCTION

The world we live in is constantly on the move, demanding an ever-increasing reliance on mobile technology and location-based services. Whether navigating bustling city streets, ven- turing into the great outdoors, or simply ensuring the safety of loved ones, the need for reliable and accessible real-time location tracking has become paramount. However, existing solutions often fall short, lacking crucial features that could prove invaluable in critical moments.

Safespot emerges as a revolutionary force in the tracking device landscape, transcending basic functionalities to offer a comprehensive and user-friendly solution specifically designed for enhanced personal safety and asset security. Inspired by the convenience of devices like the Apple AirTag, Safespot goes beyond passive tracking by seamlessly integrating an intuitive and potentially life-saving emergency response system. This unique feature empowers users with the ability to instantly trigger an SOS alert in critical situations, automatically sending pre-configured danger messages containing the device's live location to designated contacts. This ensures prompt assistance and potentially saves lives when immediate action is most needed [1].

Beyond emergency response, Safespot prioritizes accessibility and simplicity. The device eliminates the need for complex applications or dedicated interfaces by offering effortless lo- cation retrieval through a simple message-based communica- tion system [2]. This intuitive approach ensures that anyone, regardless of their technical background, can easily access and utilize the device's functionalities.

In this project, we delve into the technical aspects of Safespot's design and development, showcasing its hardware and soft- ware components, functionalities, and operational principles. However, our focus extends beyond the technical specifi- cations. We explore the broader significance and potential impact of this innovative solution, highlighting its ability to address the limitations of existing tracking devices and offer a feature-rich, user-friendly, and cost-effective alternative. By providing a comprehensive overview of the problem statement, objectives, and unique features, this introduction aims to not only inform but also inspire, showcasing Safespot's potential to revolutionize the tracking device landscape and contribute to a safer, more secure future for all.

While tracking devices have become increasingly common, they often fall short in key areas, especially when per- sonal safety is at stake. Many lack integrated emergency response systems, leaving users without crucial help in crit- ical moments. Additionally, complex user interfaces reliant on dedicated apps or web platforms can create barriers for less tech-savvy users, hindering accessibility. Furthermore, bulky designs and power-hungry components often translate to higher costs and shorter battery life, limiting practicality and portability. Finally, the lack of customization options restricts users from tailoring the device to their specific needs and preferences, compromising optimal functionality.

This project aims to bridge this gap by developing Safespot, a smart tracking device meticulously designed to address these issues and revolutionize the tracking landscape. At its core, Safespot prioritizes user safety and accessibility. It integrates an intuitive SOS alert system that triggers immediate action upon button press, automatically sending pre-configured danger messages with the device's live location to designated contacts. This ensures a prompt response in emergencies, potentially saving lives in critical situations.

Beyond safety, Safespot emphasizes user-friendliness. It eliminates the need for complex applications by offering effortless location retrieval through a simple message-based communication system. This intuitive approach guarantees that anyone, regardless of their technical background, can easily utilize the device's functionalities.

By meticulously addressing the limitations of existing solutions, Safespot sets itself apart as a feature-rich, user-friendly, and cost-effective alternative. It caters to a diverse range of use cases, offering enhanced personal safety, asset security, and peace of mind for individuals and organizations alike. Whether navigating unfamiliar environments, ensuring the safety of loved ones, or safeguarding valuable assets, Safespot serves as a reliable and adaptable companion, empowering users with real-time location awareness, immediate emergency response, and the invaluable knowledge that help is always just a message away.

Concept for a battery-powered, GPS-based tracking system with continuous tracking and an SOS function that is based on IoT. The device when triggered uses a micro-controller and a GPS module to extract location data and send it to a group of registered users and a central server using a GSM module via SMS and AT commands [3].

The main problem tackled is the kidnaping and other problem which are increasing day by day in India. So as to address the above issue, an app called "BeSafe" is created, which contains a mixture of all kinds of features in one app which overcomes all the problems and issues which were not addressed in many research works since they lack in most of the functionality [4].

The major objectives of this work can be listed as follows:

1) Develop a compact and portable tracking device: Enable easy attachment to personal belongings, pets, or assets for diverse use cases.
2) Integrate an intuitive SOS alert system: Trigger immediate emergency response upon button press, sending pre-configured danger messages with live location to designated contacts.
3) Offer user-friendly message-based location access: Simplify location retrieval through SMS communication, eliminating the need for dedicated applications.
4) Optimize for low power consumption: Implement hardware and software optimizations to maximize battery life for extended operation.
5) Provide customization options: Empower users to configure alert recipients, message content, operational set- tings, and notification preferences for personalized functionality.
6) Ensure data security and privacy: Implement robust security measures to protect user data and location information.
7) Maintain affordability: Develop a cost-effective solution accessible to a wide range of users.
8) Explore potential for integration with existing platforms: Investigate seamless integration with relevant platforms for enhanced functionality and user experience.
9) Conduct thorough testing and validation: Ensure device reliability, performance, and user-friendliness through rigorous testing procedures.

The entire contribution has been documented in three subsequent sections. Section II explains the methodology adopted; section III discusses the various outcomes of the system along with model developed. Section IV concludes the work by stating the future extension of the same.

II. Models and Components

1) *Arduino Uno Micro controller:* The Arduino Uno **(Fig. 1)** is an open-source micro controller board. The board has 14 digital I/O pins (six capable of PWN output), 6 analog I/O pins, and is programmable with the Arduino IDE. This micro-controller is ideal for the development of this model.

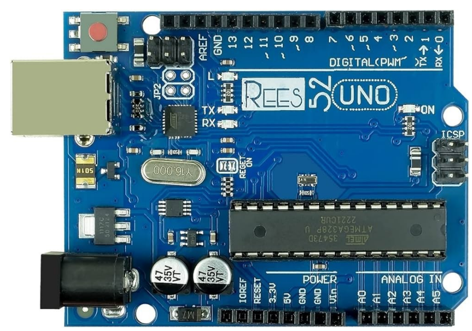


Fig. 1. Arduino Uno R3

2) *Neo6M GPS Module:* The Neo GPS module **(Fig. 2)** is a GPS receiver that is used for location-based applications, tracking, and navigation. For portable devices and Internet of Things applications, it provides accurate location data while consuming the least amount of power possible.

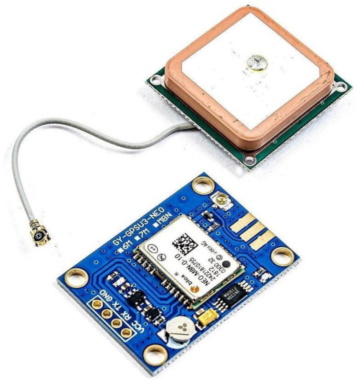


Fig. 2. Neo6M GPS Module

3) *SIM800L GSM Module:* The SIM800L **(Fig. 3)** is a small GSM/GPRS modem module supporting quad-band functionality. External antenna connection is required for network operation. The module operates within a 3.4V to 4.4V DC voltage range. Utilizing the SIM800L, developers can integrate quad-band GSM/GPRS connectivity into their projects. This compact module necessitates an external antenna and operates with a DC voltage between 3.4V and 4.4V.

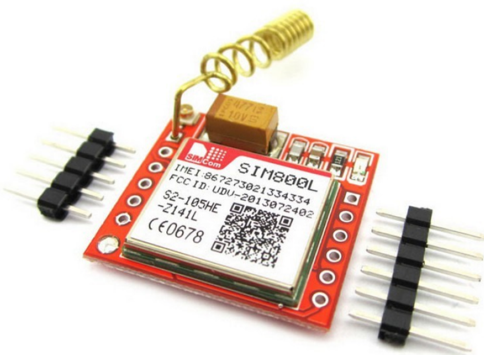


Fig. 3. SIM800L GSM Module

4) *3.7vLi-Po1200mAH battery:* These 3.7V Lithium-Ion polymer batteries **(Fig. 4)** provide a high-power capacity in a very small lightweight package, making them ideal to power the GSM module which operates on voltage between 3.4V to 4.4V.

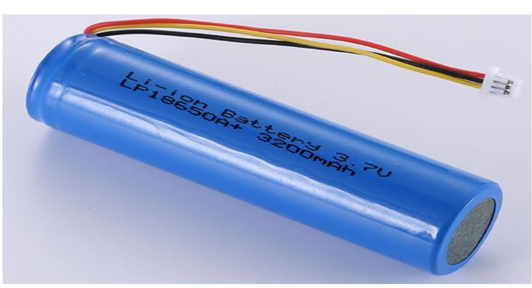


Fig. 4. LIPO Battery with Holder and charging module

5) *5V Step Up Power Module:* A 5V step-up power module **(Fig. 5)** is an electrical device that raises a low input voltage to a higher output voltage. It is also known as a boost converter or step-up converter. When you require a higher voltage than what your power supply can provide, this might be helpful in a number of situations.

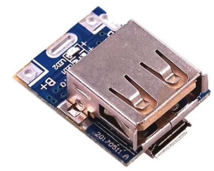


Fig. 5. 5V Step UpPower Module

6) *LM2596 Buck Converter:* The LM2596 **(Fig. 6)** is a popular buck converter integrated circuit (IC) for ramping down voltage levels in electronic circuits is the LM2596. It is extensively utilized in numerous applications that call for a regulated and steady DC voltage.

Fig. 6. Buck Converter

7) *Breadboard:* All the connections are made through the breadboard **(Fig. 7)**. Ground of the Arduino Uno is connected to the "+" of the breadboard and the 5v of the Arduino Uno is connected to the "-" of the breadboard.

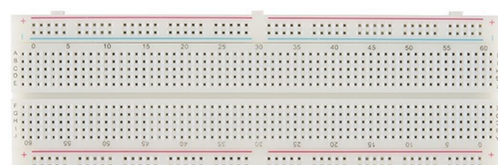


Fig. 7. Breadboard

III. PRODUCT DESCRIPTION

It is critical to have a dependable fire alarm system in place to identify and inform inhabitants to a potential fire risk. In the proposed model, we design and build a fire alarm system that can detect smoke and sound an alarm in the form of a message and pop-up text to inform the owner to a potential fire hazard. The working of the proposed system is described algorithmically as follows:

A. Algorithm

Input:

- GPS Coordinates
- Temperature sensor readings
- Phone number for SMS alerts
- Custom message for SMS alert

Output:

- SMS alert with custom message

1) BEGIN
2) Initialize the Safespot device.
3) Continuously monitor for user interaction.
4) If the user presses the SOS button:
   a. Trigger the emergency response.
5) The emergency response
6) involves:
   a. Getting the current location using GPS or other location services.
   b. Constructing an SOS message with the current location.
   c. Sending the SOS message to designated contacts.
7) Repeat steps 2-4 indefinitely.
8) END

The same has also been represented pictorially in the following flowchart.

B. Flowchart

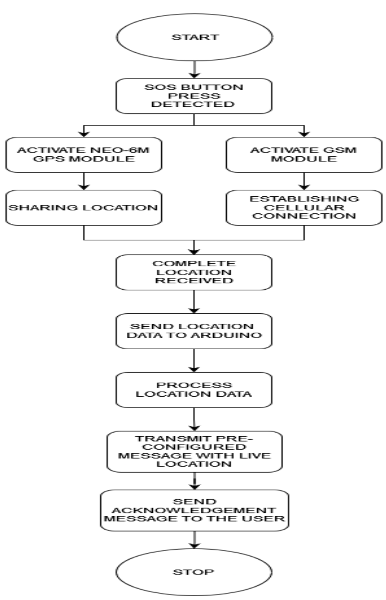


Fig. 8. SafeSpot-Flowchart

C. IGNIS- The Hardware

We have assembled the model around 2 breadboards to clearly demonstrate the connections and wiring of this system.

After successfully completing various simulations on *circuito.io*, the actual hardware for SafeSpot has been developed. Due to involvement of multiple sensors, power distribution in SafeSpot is a little complex as the GSM requires 3.7v of power, and the Neo6M GPS module needs just 3.4v to work which cannot be supplied from the Arduino UNO Board [5].

To tackle this situation, we installed a **LM2596 Buck**

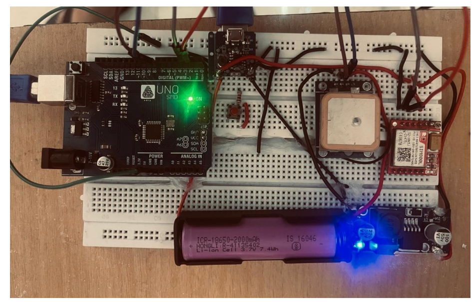
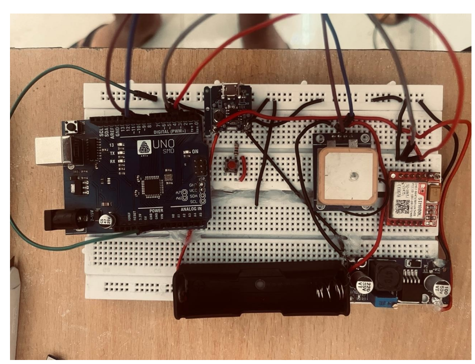


Fig. 9. Working Prototype - SafeSpot

Converter which is a Step-down motor to convert the voltage from 3.7v to 3.4v which is ideal for the Neo6m GPS Module. We imagined Safespot to be a environment friendly and not

depend on that 1 use batteries, which is why we installed a 3.7v lithium-ion rechargeable battery to power the entire model. But to power the micro-controller directly from the Li-Po battery can be dangerous as it might heat-up the Li-Po battery or short the micro-controller. To prevent this, we used a 5V Step-Up Module Battery Charging Protection Board with USB Port. Through this USB port we can directly connect the Arduino micro-controller with the Li-Po Battery as the module will provide stable 5v of current which would surpass the risks as well as recharge it by



connecting it using a micro-USB cable into the 5v Step-Up power module [6].

Fig. 10. Working Prototype - SafeSpot

IV. RESULTS AND DISCUSSIONS

A. Working:

The System activates when any of the of 2 conditions happen:

- The SOS Button is Pressed
- A specific code **"GETLOC"** is shared through a text message by a number.

If the first condition occurs, The GSM and GPS module will activate only when the SOS button is pressed on the system. As soon as the button is pressed, A Google Maps link will generate along with an emergency text, the generated location and message will be shared to a contact number which will be predefined.

In case of the latter, when a specific command which is "GETLOC" is messaged to a specific number, A Google Maps link will generate along with an emergency text, the generated location and message will be shared to a contact number from which the message was originally sent [7].

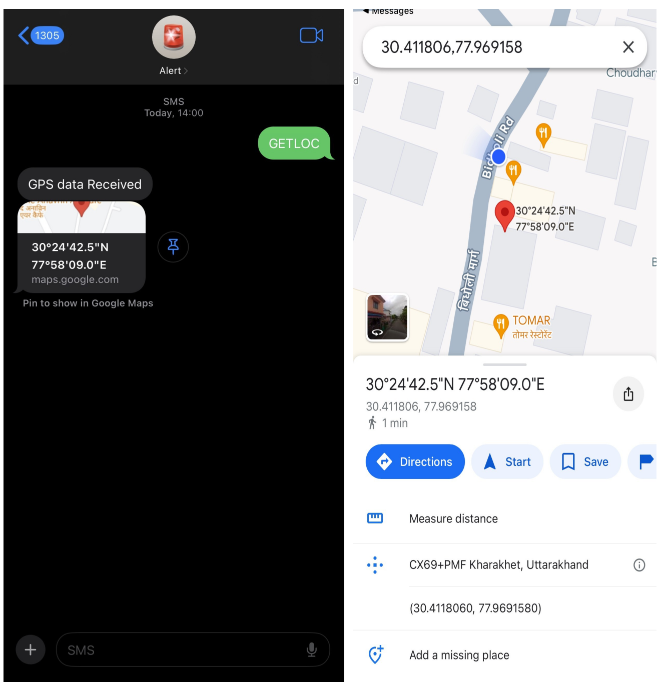


Fig. 11. Alert upon system activation

V. CONCLUSION & FUTURE WORK

Safespot represents a significant leap forward in the domain of tracking devices, particularly in the realm of personal safety and asset security. By seamlessly integrating an intuitive emergency response system with real-time location tracking capabilities, Safespot transcends the limitations of traditional tracking devices, offering users a comprehensive and user- friendly solution for addressing critical situations. Through the implementation of features inspired by successful devices like the Apple AirTag, Safespot not only enhances user safety but also prioritizes accessibility and simplicity, ensuring that individuals of all technical backgrounds can effectively utilize its functionalities.

As demonstrated in this exploration of Safespot's design and development, its innovative approach not only addresses existing limitations within the tracking device landscape but also sets a new standard for future advancements in this field. By providing a comprehensive overview of its technical specifications, operational principles, and broader significance, this project highlights Safespot's potential to revolutionize personal safety and security measures, ultimately contributing to a safer and more secure future for all.

As an extension of Safespot, Ai-Thinker A9G development board can be used which is integrated with GPS and GSM Capabilities, though it is expensive compared to the current model, however, in time help reduce the size and need of connections.

REFERENCES

[1] Explore existing research on wearables, tracking devices, and emergency response systems focused on personal safety. Analyze their functionalities, limitations, and user adoption patterns.

[2] Examine academic literature on the development and usage of location based services, focusing on privacy concerns, ethical considerations, and data security.

[3] R. O. Jacob, S. M. Alyaan, K. Nikitha and H. S. Niranjana Murthy, "IoT Based GPS tracking system with SOS Capabilities," 2022 International Mobile and Embedded Technology Conference (MECON), Noida, India, 2022, pp. 72-75, doi: 10.1109/MECON53876.2022.9752019.

[4] K. Vasudevan, V. V. Joliya, L. Aashry and N. C. Brintha, "Intel- ligent SoS Application with GPS Tracking and Hidden Camera De- tection," 2022 6th International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, 2022, pp. 964-969, doi: 10.1109/ICOEI53556.2022.9777167.

[5] Bujang, S. H., H. Suhaimi, and Pg E. Abas. "Performance of low cost Global Positioning System (GPS) module in location tracking device." IOP Conference Series: Materials Science and Engineering. Vol. 991. No. 1. IOP Publishing, 2020.

[6] P. Kanani and M. Padole, "Real-time Location Tracker for Critical Health Patient using Arduino, GPS Neo6m and GSM Sim800L in Health Care," 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2020, pp. 242-249, doi: 10.1109/ICI- CCS48265.2020.9121128.

[7] Kharisma, Oktaf B., et al. "Development of location tracking system via short message service (SMS) based on GPS unblox neo-6m and sim 800l module." Journal of Physics: Conference Series. Vol. 1363. No. 1. IOP Publishing, 2019.

Sustainable Street-Light Control System

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***Abstract*—The Sustainable Street Light Control System is a cutting-edge system that presents a comprehensive and sustain- able solution for street lighting. This system aims to optimize energy usage, reduce operational costs, and contribute to environmental sustainability by incorporating advanced technologies and intelligent control mechanisms. The system utilizes a Light Dependent Resistor (LDR) to monitor Real-Time ambient light levels and change the intensity of the streetlights according to it. This real-time adjustment ensures that the lights are only operating at their full capacity when required, thereby conserving energy during periods of low activity.**

To further enhance the system's sustainability, a solar panel is integrated to harness clean and renewable solar energy. This provides an independent power source, reducing reliance on the conventional electrical grid and minimizing carbon footprint.

In order to improve safety and efficiency, the ultrasonic sensor is employed to find the presence of objects or individuals within the vicinity of the light. When an object is detected, the system intelligently increases the light intensity, ensuring better visibility and enhancing overall safety for pedestrians and drivers alike.

Overall, the Smart Street Light Control System demonstrates the potential to revolutionize traditional street lighting infrastructure by integrating smart technologies. By optimizing energy usage, utilizing renewable energy sources, and implementing intelligent control mechanisms, this system contributes to sustainability efforts, reduces operational costs, and enhances safety in urban environments. This system sets the stage for smarter and greener cities, ensuring a brighter and more efficient future for street lighting.

***Keywords*—Arduino, IoT, LDR, Street Light, Sustainability.**

I. INTRODUCTION

The evolution of smart technologies has paved the way for innovative solutions to enhance the efficiency and sustain- ability of various systems, and street lighting is no exception. Traditional street lighting and monitoring systems often operate at a fixed intensity throughout the night, leading to unnecessary energy consumption and increased operational costs. To address these challenges, this system introduces a Smart Street Light Control System that leverages advanced technologies to optimize the use of streetlights, reduce energy wastage, and contribute to environmental sustainability.

Safety being one of the major concerns on roads has been taken into account as well. There are only few who take into consideration both sustainability and security into account. Sustainability and controlled energy consumption are few of the major factors that we looked upon when considering building this system. We have added a sensor which upon detecting motion increases the light intensity for a limited time span so that anyone walking by can see clearly which makes it very useful for everyone's safety [1].

It is a sustainable and efficient approach to street lighting by leveraging advanced technologies to optimize energy usage, reduce operational costs, and contribute to environmental sustainability. By integrating LDR-based intensity control, solar power utilization, object detection, and a user-friendly application, this system showcases the potential for smarter and greener cities. The implementation of this system has the potential to transform traditional street lighting infrastructure, ensuring a brighter, safer, and more sustainable future. There have been various implementations to manage the streetlights like an individual control system for street luminaries that turns them on and off based on the speed of change of natural light in the evening and by calendars in the morning is more complex, but can provide valuable insights [2]. The modern street lighting system that uses network protocols like Zigbee protocol to control the intensity of streetlights based on vehicle movements and atmospheric conditions is considered much more accurate [3]. An intelligent lighting control system for street lighting, using sensors to adjust brightness based on presence of vehicles and pedestrians, saving energy and improving safety [1]. Automatic controlling of street light systems according to seasonal variations, which includes an auto loop system with its respective time dependent, while vehicle crossing the road which might give large impact of saving electricity [4]. Traditional street lighting systems are often inefficient and consume excessive amounts of energy, resulting in high operational costs and a significant environ- mental impact. Fixed-intensity lighting throughout the night leads to unnecessary energy wastage. Additionally, the lack of adaptive control mechanisms poses safety concerns as it fails to address variations in pedestrian and vehicular activity. Therefore, there is a pressing need for a sustainable street light control system that optimizes energy usage, reduces operational costs, enhances safety, and contributes to environmental sustainability [6].

A comprehensive solution that incorporates advanced technologies, such as a Light Dependent Resistor (LDR), a so- lar panel, an ultrasonic sensor, and a control application, is required to address these challenges effectively [5]. The proposed Smart Street Light Control System aims to tackle these issues by adjusting the intensity of streetlights based on ambient light levels, leveraging solar energy to power the system, and enhancing safety through object detection. The integration of these components will revolutionize streetlighting infrastructure, making it more sustainable, cost-effective, and responsive to the needs of urban environments [6].
The major objectives of this work can be listed as follows:

- Develop a sustainable street light control system that utilizes a LDR to regulate the intensity of the streetlights based on natural light levels.
- Evaluate the performance of the system through compre- hensive testing and data analysis to validate its effective- ness in optimizing energy usage and improving safety.
- Showcase the feasibility and scalability of the proposed system by implementing a pilot system in a real-world urban environment and gathering feedback from users and stakeholders.
- Use only renewable, sustainable and energy efficient components.
- Power the system using only renewable energy.

The entire contribution has been documented in three subsequent sections. Section II explains the methodology adopted; section III discusses the various outcomes of the system along with model developed. Section IV concludes the work by stating the future extension of the same.

II. OUTCOME & DISCUSSION

For improved security, the Smart Street Light Control Sys- tem utilises solar power, adjusts the level of illumination based on the surrounding environment, and features object detection. With the aid of an intuitive software, thereby this integrated system aims to transform street lighting to become more affordable, eco-friendly, and responsive to urban requirements.

A. MODELS AND COMPONENTS

1) Arduino Uno Microcontroller: A microcontroller board is called an Arduino Uno **(Fig. 1)**. The board can be programmed using the Arduino IDE and features 14 digital I/O pins, including 6 PWM output pins. This microcontroller is an integral part of the system.

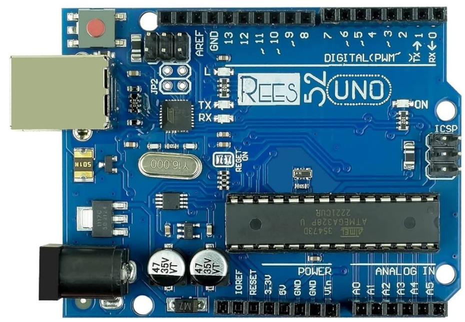

Fig. 1. Arduino UNO R3

2) LDR (Light Dependent Resistor): An LDR **(Fig. 2)** is a unique kind of resistor that operates on the principle of photoconductivity, which asserts that resistance varies with light intensity. The more intense the light, the lower its resistance becomes.

Fig. 2. Light Dependent Resistor

3) Solar Panel: A solar panel **(Fig. 3)** is a device which is an arrangement of multiple solar cells, which are connected in parallel or series alignment to observe sunlight and then generate direct current (DC).

Fig. 3. Solar Panel

4) Ultrasonic Sensor: An apparatus that uses ultrasonic sound waves to gauge an object's distance is called an ultrasonic sensor **(Fig. 4)**. An ultrasonic sensor transmits and receives ultrasonic pulses using a transducer to determine the proximity of an item.

Fig. 4. Ultrasonic Sensor

5) *03962a Module:* This 03962a module **(Fig. 5)** is designed to be used with the constant-current/constant-voltage (CC/CV) charging method for rechargeable lithium batteries. The module not only allows a lithium battery to be charged securely, but it also offers the safety that lithium batteries need.

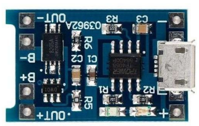

Fig. 5. 03962a Module

6) *3.7v 2600mAH Li-Po Battery:* These 3.7V Polymer Lithium-Ion polymer batteries **(Fig. 6)** provide a high-power capacity in a very small lightweight package. The 2 batteries are charged using the solar panels.

Fig. 6. 3.7v 2600mAH Li-Po Battery

7) *LM2596 Buck Converter:* A 3-A load can be driven by the DC-DC Buck Converter Step Down Module LM2596 Power Supply **(Fig. 7)**, a step-down (buck) switching regulator with superior line and load control.

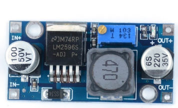

Fig. 7. LM2596 Buck Converter

III. METHODOLOGY

The proposed smart street light control system integrates safety and sustainability challenges. It uses an approach that includes motion detection, solar panel for sustainability, and sensor-based light intensity management. The working of the proposed system is described algorithmically as follows:

A. Algorithm

Input:

- LDR sensor reading (ambient light level).
- Ultrasonic sensor reading (pedestrian detection).
- Threshold light level for activation.
- Base LED intensity (60

Output:

- LED light intensity (variable).

1) BEGIN
2) Initialize the LDR (Light Dependent Resistor) pin to detect ambient light levels.
3) Initialize the LED pin to control the LED light intensity.
4) Initialize the ultrasonic sensor to detect pedestrian prox- imity.
5) Set the threshold level for the LDR to determine when the ambient light is below the desired level.
6) Set the initial LED light intensity to 60
7) Continuously monitor the ambient light level using the LDR.
8) If the ambient light level is below the threshold:
9) Calculate the proportion of surrounding light based on the LDR reading. b. Adjust the LED light intensity accordingly, considering the proportion and the 60% baseline intensity.
10) Continuously monitor the ultrasonic sensor for pedes- trian proximity.
11) If a pedestrian is detected in close proximity: a. Tem- porarily increase the brightness of the LED light to aid the pedestrian while walking. b. After a certain duration or when the pedestrian moves away, restore the LED light intensity to the previous level.
12) END

The same is represented pictorially in the following flowchart:

B. Flowchart

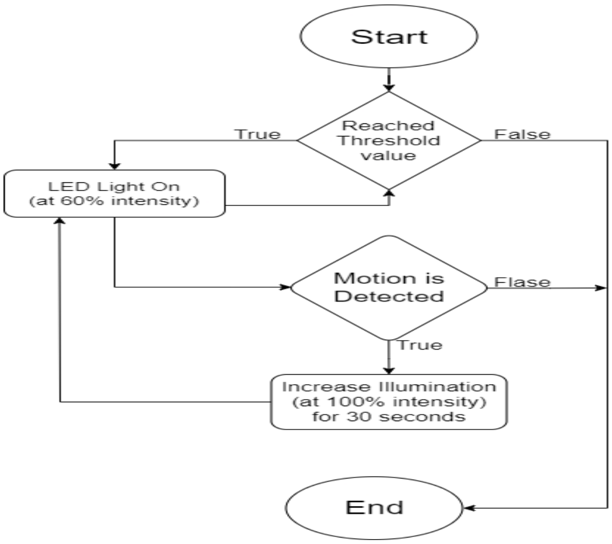

Fig. 8. Flowchart- Sustainable Street-Light System

C. Working:

The proposed system will activate once the LDR detects that the ambient light is below the threshold level. As soon as this condition is met, the LED light will switch on in proportion to the surrounding light. They will work completely on clean and renewable energy which will be provided by the solar panels installed. The Light works on 60% intensity, irrespective of the ambient light in order to save energy. An Ultrasonic sensor is placed in such a way that, when a pedestrian is in close proximity of the light, it will temporarily increase the brightness of the light, so that the illumination aids the pedestrian while walking across. The whole system is powered by Two 3.7v Li-Po battery, which is powered by 4 solar panels, which are connected in Parallel to provide maximum energy, which ultimately powers the Arduino. Arduino can run on a fixed voltage of 5v. If powered by variable current, it might cause a short circuit in the Arduino.

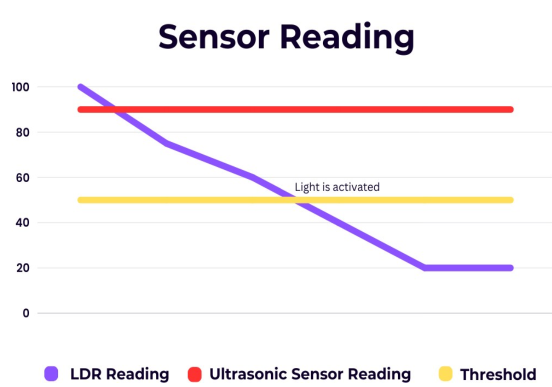

Fig. 9. Sensor Readings

To prevent that we are using LM2596 Buck Converter to step down the voltage to exactly 5v. We can clearly see the sensor readings in **Fig 8,** which indicate, as the ambient light diminishes below the threshold the light is activated. The readings are actual sensor readings, and the threshold is set at 50, crossing which would lead to system activation.

D. Street Light Control System - The Hardware

The four solar panels are connected in parallel configuration as demonstrated in **Fig. 10**. The negative of the solar panel goes to the -input of the 03962a module and the positive goes to the +input of the 03962a module.

Fig. 10. Working Prototype

The B+ and B- of the 03962a are connected to the positive and negative of the 2 Li-Po batteries connected in series. The power from the solar panels power the batteries directly. The

-out Pin and +out Pin of the 03962a module are connected to the -Input and +Input of the LM2596 Buck Converter. Finally, the -output Pin and +output pin of the LM2596 Buck Converter are soldered to the Ground Pin and Vin Pin of the Arduino Uno. Once the battery is charged at a sufficient capacity, the Arduino Uno powers up.

After the system is switched on, the LDR detected the LOW ambient Light and set the intensity of the LED accordingly. An object (i.e. Fevicol tube) is places in front of the Ultrasonic sensor to demonstrate the full intensity light function of the system in **Fig. 11**.

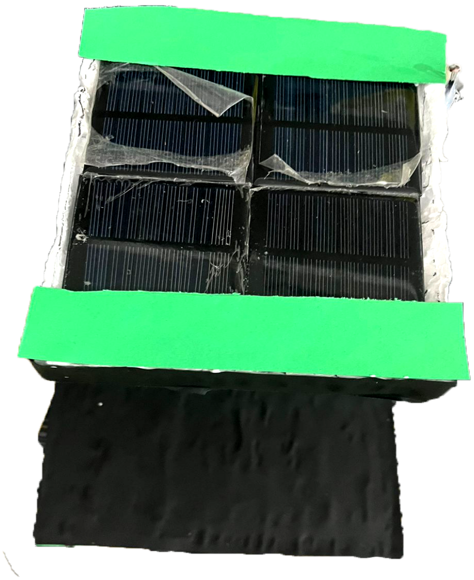

Fig. 11. Solar Panels placed on the Top

E. Serial monitor Output

As soon as the readings from LDR falls under 500, The LED is activated according to the value. The lower the value, higher the intensity of the LED. But to save energy the LED will **not run at an intensity higher than 60% capacity**. These are Serial Monitor screenshots taken in the Arduino IDE. The Distance refers to the space from the Ultrasonic sensor. If it is **less than 12 the LED activates at 100% capacity**.

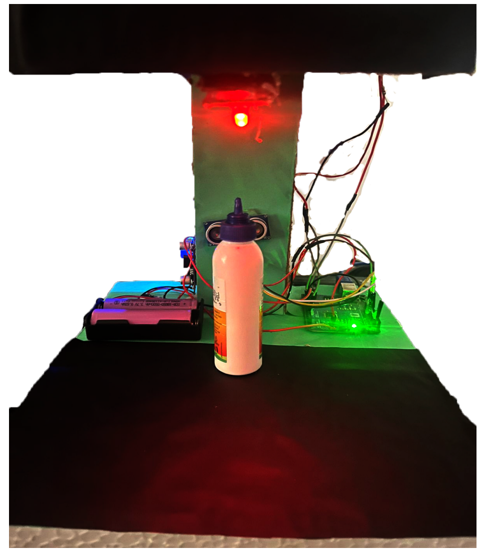

Fig. 12. System with object detection (Switched on)

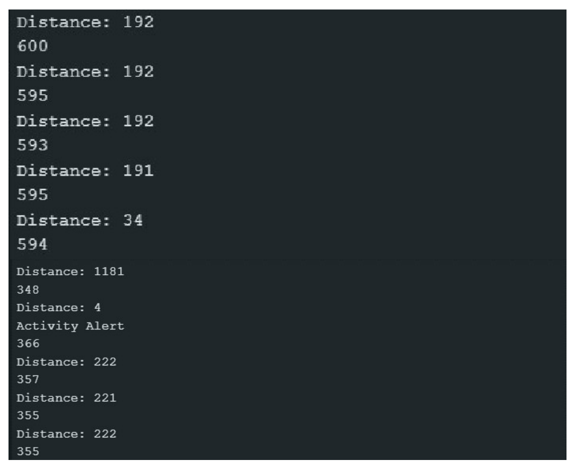

Fig. 13. Serial Monitor Screenshots

IV. CONCLUSION & FUTURE WORK

This system delivers an intelligent and sustainable lighting solution, seamlessly integrating automation, energy efficiency, and user convenience. By leveraging ambient light detection and ultrasonic sensors, it adapts to its surroundings, providing optimal illumination only when needed.

Operating at a baseline 60% intensity and powered by renewable solar energy, the system minimizes energy consumption while ensuring sufficient lighting. Furthermore, the ultrasonic sensor detects nearby pedestrians, automatically increasing brightness for enhanced visibility and safety.

This combination of adaptability, sustainability, and user-centric design makes the proposed IoT program a compelling solution for smart cities, public spaces, and even residential settings. As smart technologies continue to evolve, this innovative approach to lighting promises a brighter and more sustainable future.

As an extension of this system, some remote data monitoring and fault detection capabilities will be incorporated in future.

REFERENCES

[1] R. Lohote, T. Bhogle, V. Patel and V. Shelke, "Smart Street Light Lamps," 2018 International Conference on Smart City and Emerging Technology (ICSCET), Mumbai, India, 2018, pp. 1-5, doi: 10.1109/IC- SCET.2018.8537304.

[2] S. A. Bhosale and T. Ankalkote, "Modern Street Lighting System with Intensity Control based on Vehicle Movements and Atmospheric Con- ditions using Zigbee," 2018 International Conference on Information, Communication, Engineering and Technology (ICICET), Pune, India, 2018, pp. 1-4, doi: 10.1109/ICICET.2018.8533817.

[3] T. P. Nam and N. Van Doai, "Application of Intelligent Lighting Control for Street Lighting System," 2019 International Conference on System Science and Engineering (ICSSE), Dong Hoi, Vietnam, 2019, pp. 53-56, doi: 10.1109/ICSSE.2019.8823357

[4] A. Pachamanov, D. Pavlov, K. Kassev and K. Nikolova, "Individual Control of Street Luminaries by Speed of Change of Natural Light in the Evening and by Calendars in the Morning," 2021 Sixth Junior Conference on Lighting (Lighting), Gabrovo, Bulgaria, 2021, pp. 1-4, doi: 10.1109/Lighting49406.2021.9599034.

[5] U. Khayam and A. Zaeni, "Review of Smart Street Lighting Research in Indonesia," 2022 5th International Conference on Power Engineering and Renewable Energy (ICPERE), Bandung, Indonesia, 2022, pp. 1-4, doi: 10.1109/ICPERE56870.2022.10037440.

[6] R. Prasad, "Energy Efficient Smart Street Lighting System in Nagpur Smart City using IoT-A Case Study," 2020 Fifth International Confer- ence on Fog and Mobile Edge Computing (FMEC), Paris, France, 2020, pp. 100-103, doi: 10.1109/FMEC49853.2020.9144848.