Available online at www.dergipark.org.tr/en

e-ISSN: 2618-575X

INTERNATIONAL ADVANCED RESEARCHES
and
ENGINEERING JOURNAL

Journal homepage: www.dergipark.org.tr/en/pub/iarej

International Open Access

Volume 08
Issue 02

August, 2024

Review Article

Merger of internet of things and machine learning: The internet of everything sector projects, benefits, and future roles

Suheyla Uygur [a,*] **and *Mehmet Hilal Ozcanhan*** [b]

[a]*Dokuz Eylül University, Faculty of Science, Department of Computer Science, İzmir 35390, Turkey*
[b]*Dokuz Eylül University, Faculty of Engineering, Department of Computer Engineering, İzmir 35390, Turkey*

ARTICLE INFO

Article history:
Received 09 April 2024
Accepted 08 July 2024
Published 20 August 2024

Keywords:
Internet of everything
Internet of things
Machine Learning
Smart sectors

ABSTRACT

The convergence of the Internet of Things and Machine Learning shapes key developments in information technologies, such as the Internet of Everything environment. The Internet of Things' Machine-to-Machine connectivity advances, real-time Big Data storage, and data-driven Machine Learning synergize the scope of Internet of Everything innovations. As the Internet of Things and Machine Learning merger continues, the Internet of Everything reshapes the world sector map by providing unprecedented possibilities and efficiencies. The propelled Internet of Everything is ushering in a new era of transformative projects in various sectors such as Healthcare and Life Science, Manufacturing, Agriculture, Energy, Transportation, and Construction. The high-tech transformative projects offer many applications in process optimization, cost reduction, increased productivity, and efficiency. Our work examines the prominent joint Internet of Things and Machine Learning initiatives, projects and works to encourage new initiatives and multidisciplinary work worldwide. We also discuss the benefits of transformative projects in different sectors in detail and put forward a forecast for their future roles. Our study is supported by solid academic literature and project examples.

1. Introduction

The Internet of Things (IoT) is the network of physical objects such as sensor devices, appliances, vehicles, buildings, and other elements embedded with electronics and circuits. Every IoT device has software and network connectivity, enabling it to act as an object that exchanges data with other objects; hence, it is the definition of Machine-to-Machine (M2M) communication. Thus, IoT enables remote sensing and control of objects, opening up the possibility of rendering the physical world in computer-based systems. The trend towards greater IoT connectivity means collecting real-time data from more places, leading to real-time decisions and increased revenue, productivity, and efficiency [1].

The booming of smart devices due to miniaturization and the advances in technologies that connect everything from anywhere at any time has digitalized the world of human beings. The constant communication of humans with each other, as well as sensors and actuators, has brought a revolution focused on interconnection, automation, autonomy, and real-time data. Data grew so large that the name Big Data was given to describe the huge data from which useful additional information could be extracted. Artificial Intelligence (AI) and its child Machine Learning (ML) came to the rescue in data analysis to provide early warnings, forecasts, decision support systems, and even alarm generation. Hence, the IoT and ML collaboration opened the avenue for the Internet of Everything (IoE). IoE is beyond IoT as it involves people, data, things, and processes. In IoE, the data, processes, people, and things interact, thus facilitating transactions and information flow optimization for value creation. It is crucial to remember that ML is an AI discipline that learns from experiences and paradigms to augment IoT in delivering greater wisdom to humans. The number of devices and humans interconnected continues to increase incredibly, following the technology merger trend [2].

As shown in Figure 1, the latest IoT Analytics report shows that the number of global IoT connections grew by 18% in 2022 to 14.3 billion active IoT endpoints. In 2023, IoT Analytics expects the global number of connected IoT devices to grow another 16% to 16.7 billion active endpoints.

* Corresponding author. Tel.: +90-536-882-8412.
E-mail addresses: suheyla.uygur@deu.edu.tr *(S. Uygur)*, hozcanhan@cs.deu.edu.tr *(M.H.Ozcanhan)*
ORCID: 0009-0008-8613-729X *(S. Uygur)*, 0000-0002-5619-6724 *(M.H.Ozcanhan)*
DOI: 10.35860/iarej.1467110

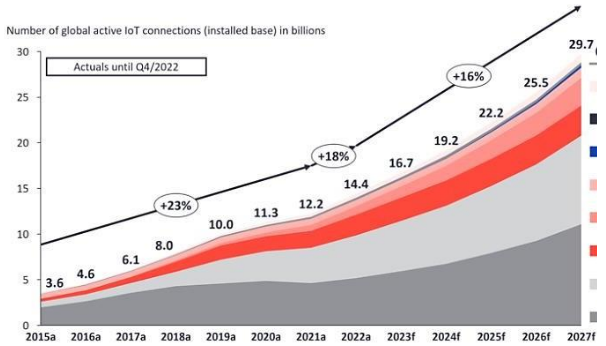

Figure 1. Global IoT devices forecast until 2027 [2].

While 2023 growth is forecasted to be slightly lower than in 2022, IoT device connections are expected to grow for many years. Propelled by the staggering number of IoT devices, M2M provides manufacturing companies with many new application opportunities. Hence, the progress in consumer applications improves our everyday lives. The remaining sections of our study are organized as follows:

- Section 2 discusses previous studies on the subject according to sectors.
- Section 3 provides information about the joint projects in which the three are involved by sector.
- Section 4 explains the results and discusses the future roles of joint IoT and ML projects that shape the IoE environment.
- In Section 5, we conclude.

With the above contents, our work attempts to make the following contributions:

- Provide a review and comparison of joint state-of-the-art IoT and ML research and applications that form the IoE environment.
- Focus on the collaboration, advantages, and future of IoT and ML technologies towards IoE in sectoral applications,
- Offer recommendations on how IoT and ML technologies towards IoE can be made more effective and efficient,
- Provide a perspective on future trends and their long-term impact on sectors.

The opportunities are shown by prominent examples of projects in important sectors and by highlighting the development and progress in the related fields. Briefly, our study aims to stimulate new studies by assisting researchers in identifying the effects of the merger between IoT and ML and, thus, the new IoE environment.

2. Related Background In Different Sectors

Figure 2 shows the map that embraces the IoT and different sectors [3]. The comprehensive map by Breecham Research divides the sectors into their scientific fields of expertise. Each sector's Application groups are given, and the application types of every group are listed. Finally, the devices and their use locations are listed at the outer rim of the circular map. Some of the most important sectors are discussed in detail below.

Figure 2 demonstrates that IoT technologies contribute to environmental sustainability efforts, energy optimization, efficiency in industrial production, and reduction of all sorts of consumptions. In the industrial sector, the IoT-ML partnership helps anticipate customer needs by analyzing large amounts of data. The same collaboration helps manage production planning and perform efficient supply chain management. Below, further typical examples are given in detail in some selected sectors.

Investigating research studies on joint IoT and ML initiatives forming the IoE reveals that their association or collaboration is overlooked in many works. Singular studies on IoT or ML only curb researchers' ability to identify research gaps. The research gap is depicted when sensor networks' live data from the environment is not augmented by ML-enabled smart machines that can perform diverse tasks. For example, collaborative work can easily help to detect insect damage in agriculture or help with irrigation planning [4].

In the manufacturing sector, it is possible to track the health of machines and the state of stored products using IoT devices and ML. When used together, it is possible to detect anomalies in machines and products [4]. Machines are now smart devices that can sense the environment and make decisions based on previous data, thus forming the IoE environment. Following production, products are inspected using IoT tags and tracked via cameras or sensors. The collected data of each product is fed to an ML or another AI set-up. Analyzing live data from machines through a well-designed ML algorithm can be used to monitor, detect potential production problems, and make the right corrections instantly.

Smart algorithms created using ML can reduce power consumption in the energy sector. Accurately tracking objects and applying computer vision and sensor networks with intelligent and well-chosen AI algorithms can also achieve quality control and assurance. Using live data across individual energy application groups (Figure 2) supported by an ML approach, a highly adaptable IoT-ML design is possible as an IoE example. AI-IoT integration produces supportive decision-making, predictive maintenance, and personalized user experiences, thus forming the IoE environment [4].

The impact of 4G and 5G communication on the IoT-ML merger is worth mentioning. 5G networks' faster and more reliable connectivity provides instantaneous IoT data to ML-based analyses, thus improving their performances. In an end-to-end IoT solution, continuous and instantaneous data from hundreds of sensors creates Big Data, the term of today's popular definition. By applying deep analysis through AI-based software, Big Data is transformed into new

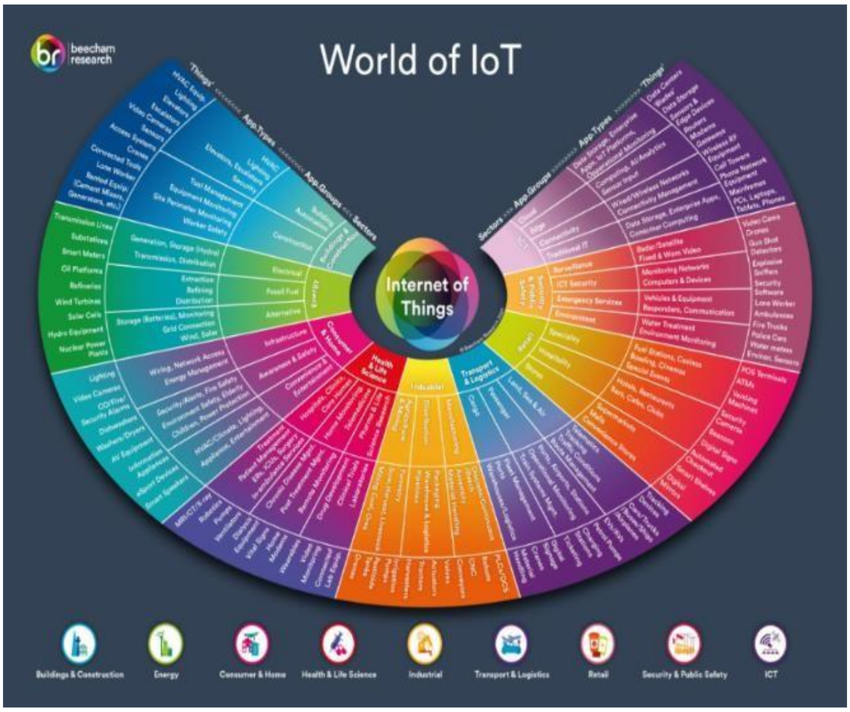

Figure 2. M2M and IoT Sector map according to Application Groups, location, and devices, by Beecham Research [3].

information that provides powerful new insight and intelligence. Considering the automotive industry, automotive connectivity to wearable body sensors, and autonomous cars, the magnitude of Big Data and the advantages gained from its AI analyses by the consumers and producers can be imagined.

The new hype of Digital Twins further magnifies the Big Data and its analyses. A Digital Twin replicates a physical model for remote monitoring, display, and control as a virtual representation on a computer. It is a real-time model of its physical system that adapts to changes. Based on the real-time data from various IoT sensors, a digital twin helps generate predictions using AI and ML [5]. Creating a Digital Twin in an IoE environment involves a lot of work. On top of making the virtual replica of the physical object, all the necessary sensors and actuators for tracking and controlling the physical object are needed. The virtual twin has to be prepared and trained for the new, real-time, instantaneous data to predict the possible feature outcomes related to the physical object. A Digital Twin can be created with a heart, car, production process, or whole system. In other words, Digital Twins will appear in the Health, Manufacturing, Agriculture, Energy, Transportation, and Construction Sectors.

2.1 Health and Life Science Sector

The healthcare sector is a data-rich environment. More data from more sources means better ML results in healthcare. Main medical IoT activities are:

- Creating automatic medical records,
- Predicting disease diagnoses,
- Monitoring patients in real-time,
- Dispensing medicine.

The reasons for the rapid adoption of IoT and ML towards an IoE environment in the healthcare sector are as follows.

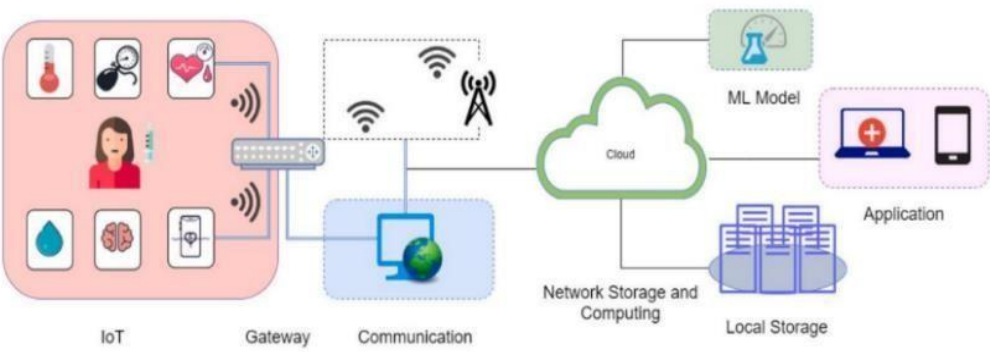

Figure 3. The architecture of a typical joint ML and IoT model, as a IoE-based healthcare application [6].

A typical IoE environment in healthcare is shown in Figure 3. Sensors are widely used in hospital applications to collect data from the environment. For example, medical sensors can monitor a patient's heart rate, oximetry, pressure, glucose, temperature, ECG, EEG, EMG, etc. In some set-ups, a Raspberry Pi board harbors blood pressure, temperature, and heart rate sensors. The accelerometer, gyroscope, proximity, GPS, and smartphone camera sensors are also used in healthcare applications. Radiofrequency identification (RFID), chemical and Infrared (IR) sensors, and wearable IoT devices are the other tools used in expert hospital systems [6]. Additionally, custom-made software organizes sensor data recording, storing to Cloud Computing Servers, and analysis of the stored information to determine health abnormalities. For example, continuous patient monitoring using a Pulse Sensor can predict the presence of a coronary disease. An example work on the subject uses the Support Vector Machine (SVM), Naive Bayes, Decision Tree, K-NN, and Random Forest algorithms [7]. Another example is the monitoring of patients by sensors placed in the room. Furthermore, wearable fall or bedside carpet sensors can detect a patient's fall and issue an alarm for assistance [8, 9].

Hence, IoT has enabled professionals to connect with patients proactively. For example, RFID-based systems help professionals to apply the right dose to the right patient at the right time [10, 11]. The proposed system integrated base stations to remotely regulate patients' pulse and body temperature. The patient data is also transferred to the doctor's phone [11]. Expert IoT systems can send SMS to patient relatives and medical experts during emergencies.

ML comes into play for formal evaluation of the patient's health status. For example, ML is used in various cancer classification applications to diagnose cancer types correctly. ML algorithms, widely used in healthcare applications, are also applied to many clinical decision support systems to create advanced ML models. ML finds further application in medical imaging in the processes used for creating body-part images to help with treatment and diagnosis. ML is also applied to studying environmental and physiological factors to diagnose diseases effectively. In other words, ML is used to identify signs, symptoms, and risk factors associated with a particular disease to increase diagnostic efficiency and accuracy. The most popular supervised ML algorithms used in healthcare are the K-Nearest Neighbor, Naive Bayes, Decision Trees, SVM, Neural Networks, Gradient Boosting, Regression Tree, and Random Forest [11].

In the health and life science sector, ambulance services can be improved by tracking personnel and assets in the ambulance with automatic data collection technology. The technique includes automatic tracking of mobile assets in the ambulance with RF technology supported by a database [12]. In an ambulance automation system, an IoE control center can organize the hospitals in a smart city to arrange the correct hospital with the appropriate capacity to send the nearest available ambulance to an emergency[8].

"Networked contact lenses" are also a type of wearable device in health technology. In 2014, Google and Novartis began developing a connected contact lens to monitor blood sugar levels by analyzing a patient's tear fluid [8].

Further examples in the literature that synergize innovation in healthcare are listed in work [8], as below:

- The EU I-PROGNOSIS project is a smartphone application that enables early detection of Parkinson's disease.
- Projects in the treatment of acutely ill patients.
- The "Artificial Intelligence in Pathology" project (November 2018 – October 2020) is an AI tool that supports diagnosing and treating colon cancer.
- A computerized project to detect skin tumors, 136 accurately diagnosed cases.
- A project in Boston, an autonomously operating AI robotic catheter in humans and animals.
- Optical touch sensors and image processing algorithms for determining the exact location in the human body.
- AI projects to diagnose and treat psychological problems at an early stage.
- An AI model that can recognize depressive changes based on speech patterns.
- Automated medical chatbots, emotion recognition, cognitive and baby health monitoring systems [13].
- Computer-based wheezing sound detection model for improved diagnosis of respiratory disorders [14]

Many other studies have been carried out on the diagnosis of heart diseases, nutritional monitoring, clinical decision support systems, dementia monitoring, diabetes-related eye problems, children with Autism Spectrum Disorder, etc. The long list has helped the term Internet of Medical Things (IoMT) emerge from networking sensor-based medical devices to improve healthcare services. In summary, the background of IoMT includes a significant amount of IoT research and ML work in healthcare that makes the healthcare IoE environment.

2.2 Manufacturing Sector

Figure 4 includes various use cases for smart manufacturing 4.0, such as Digital Twins, quality sensing, augmented workforce, etc. [15].

IoT and ML towards IoE are used together to automate the production process, optimize products, reduce cost and energy waste, and provide useful information by analyzing data collected from different aspects of the manufacturing business, including production equipment.

In the manufacturing sector, joint IoT and ML projects provide important transformation by combining the power of automation and data analysis. Today, machines connect and collaborate to make better decisions without human intervention. AI improves and automates decision-making in complex manufacturing environments, increasing production efficiency and reducing human error. Combining these technologies enables the creation of smarter and more efficient production processes in the manufacturing sector. Therefore, ML is one of the key elements of smart manufacturing. ML algorithms are used in many areas, such as making predictions by analyzing data flow in production processes, increasing quality control, predicting failures, and optimizing maintenance processes. These technologies give manufacturers a competitive advantage by enabling more efficient and flexible production processes and effectively utilizing the abundance of data in their production facilities. Example applications include monitoring, fault prediction, and bearing models in electricalmachines [16].

Advancements in IoE technology are promising improved sustainable smart production. Some examples of the benefits provided to smart production by big data and applications are as follows. For example, fault detection is a critical component of predictive maintenance. ML helps to detect errors at a very early stage. Hence, ML applications reduce maintenance costs, repair stoppages, machine failure, and inventory, increasing spare parts life span, operator safety, production,and overall profit [17].

2.3 Agriculture Sector

One of the focuses of smart agriculture is increasing crop productivity and reducing irrigation waste. Large crop production is a critical issue as it is a basic human need. Therefore, more products are obtained by field-based sensors, drones, and advanced technologies. A future water scarcity forecast is also provided [18].

Crops must be constantly monitored for moisture, temperature, soil, light, etc. Figure 5 shows a smart agriculture IoT architecture for monitoring the factors supported by IoT technology. The farmer gets data for analysis from sensors such as Ultra Violet, Temperature, Air Humidity, Soil Moisture, Soil Ingredient, Color, etc. Drones also take part in data collection. Hence, abundant data is collected to extract information and obtain smart agriculture applications [19]. ML is the tool for making sense of the collected IoTdata.

Drone-supported IoT technology and ML jointly play an important role in the agricultural sector's productivity, sustainability, and decision-making. ML algorithms help farmers detect plant diseases, increase crop productivity, and optimize irrigation. Moreover, farmers can use more efficient and effective farming methods with the automation of agricultural machinery, drones, and the integration of forward-thinking technologies. AI uses weather forecasts, harvest timing, and market demands to help farmers make decisions. The combined use of the technologies enables a significant transformation in agricultural production. A simple example is the smart irrigation system that predicts crop water needs. The results obtained with an ML algorithm are sent to farmers via e-mail to make in advance water supply decisions [18].

Figure 4. Smart Manufacturing 4.0 use-case diagram [15].

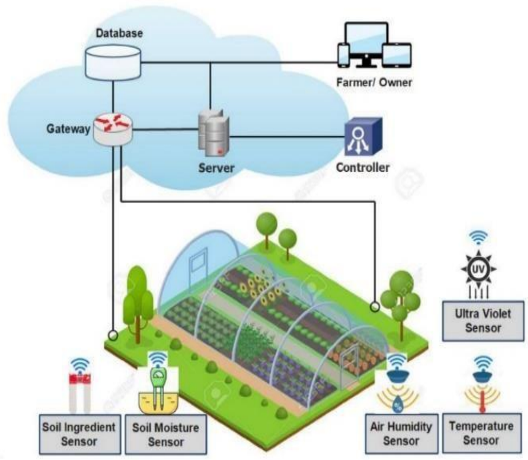

Figure 5. The architecture of a smart agriculture application [19].

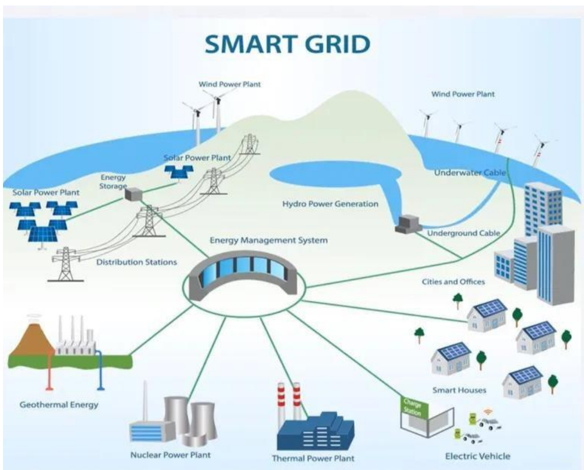

Figure 6. The diagram of a smart grid [20].

2.4 Energy Sector

Smart grid is a term used to describe various new data-based services in the supply, marketing, storage, and use of renewable energy. The smart grid that provides transmission and distribution of power in smart cities is shown in Figure 6. Smart grids are considered as the future of electrical energy management systems [20]. Smart grids emerged due to the digitalization of energy systems, making processing and interpreting digital data possible. Merged IoT and ML models play an important role in the fast and efficient processing of energy distribution data. ML models perform data storage, visualization, analysis, capture, and update tasks.

Smart grid systems play a key role in power line load forecasting. The ML techniques use to forecast power line loads helped design load balancing in power grids. Predictive maintenance (PM), supply on demand, and energy source discovery are all possible with the IoT-ML merged applications. PM is indispensable not only for the vitality and longevity of machines but also for reducing human error in energy distribution. Condition-based maintenance often saves costs and optimizes production. There are also multi-level neural ML networks that learn consumption patterns by analyzing large amounts of data from different energy sources, devices, and power system infrastructure [21,22]. Many companies were able to implement Industry 4.0 and Society 5.0 due to the IoE environment. Examples of IoE environment technologies include the following subjects:

- energy distribution and storage systems,
- advanced energy materials,
- response to energy demand and efficiency,
- strategic energy planning under uncertainty,
- large-scale integration of renewable energy,
- Big data analytics in a smart grid environment.

AI also plays an important role in complex issues such as estimating renewable energy sources used in power generation, managing energy storage systems, and predicting energy market prices. Thus, AI contributes to creating more efficient, reliable, and sustainable energy systems. In summary, the IoE environment of merged IoT and ML is widely used in smart energy production, power grid management, optimum power flow, voltage, and reactive power control [23].

2.5 Transportation Sector

The use of IoE environments in smart transportation has attracted the attention of many researchers. The IoT-ML merged projects have been used in areas such as traffic management, route optimization, parking, street light illumination, accident prevention/detection, road and infrastructure anomaly detection, telematics, and autonomous driving services [24]. Some examples of IoT-ML projects in the transportation sector are [25]:

• forecasting travel demand,
• smart card data analysis,
• smart route,
• sustainable urban mobility practices and development.

The Canadian Intelligent Transportation System (ITS) is a warning system that prevents traffic accidents and congestion by offering a smart route and controlling traffic lights. Therefore, ITS plays a vital role in improving road safety. A typical ITS system can be seen in Figure 7. Technically, an ITS forms a network to provide commuters with all the functions and information they need to get safely from their starting point to their destination [26].

IoE projects help the transportation sector by providing environmental-aware vehicles. ML algorithms help cars to perceive the environment and move safely. Learning drivers' preferences offer a more personalized driving experience through ML analysis. The creation of driverless vehicles has also facilitated our lives in some cities. In summary, AI has helped us to predict traffic density, optimize travel times, prevent traffic accidents, and create safer, more efficient, and environmentally friendly smart cities.

2.6 Construction Sector

The hype of the construction sector is the smart house. Figure 8 presents the layered architecture, modules, and their interrelationships of the smart house design. The smart house application design comprises presentation, security, control, communication, data, and device layers. Various remotely controlled and monitored IoT devices, such as motion/presence detectors, temperature sensors, and air conditioner-TV-oven consoles, serve in a smart house. The smart house automation system that provides control and communication is obtained by analyzing the collected Big Data from the IoT devices [27].

As a result of the widespread smart house applications, AI is now capable of managing assets, implementing energy-efficient automation, ensuring security, and monitoring (e.g., Building Information Management). Various automation systems can automate a house's security, energy management (e.g., Home Energy Management System), and well-being. Integrated AI and smart IoT home systems optimize energy consumption, improve security systems, and increase occupant comfort [28].

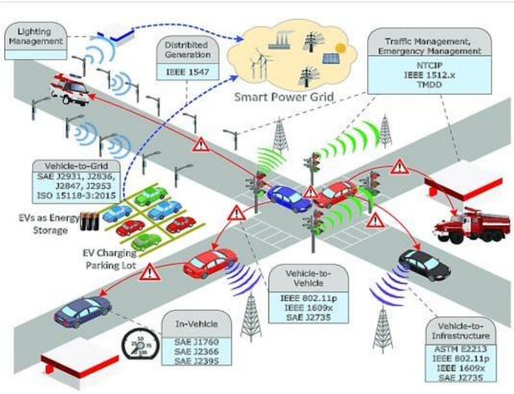

Figure 7. The schema of the Canadian ITS system [26].

Furthermore, ML and AI are jointly used in many areas, such as building design, construction process, and management (e.g., Home Management System). ML algorithms enable innovation in civil engineering and architecture in complex tasks such as building materials selection, structural analysis, and project planning. AI-powered design software offers architects and designers faster and more efficient design processes. Meanwhile, AI-controlled robots automate construction processes and increase efficiency.

3. Related Transformative Projects

The related work merging IoT and ML has been studied. Sectors in Table 1 present examples of the joint IoT and ML projects that propel IoE technologies. As a fast-progressing area, new literature comes out every day.

Table 1. Example joint ML and IoT projects in various sectors.

Health	***Manufacturing***	***Agriculture***	***Energy***	***Transportation***	***Construction***	***Others***
[29] AI-Based Drug Diagnosis	[37] Smart Manufacturing	[46] Device to Prevent False Spring in Apricot Agriculture	[51] Fault Detection in Wind Turbine	[55] Smart Parking	[61] Smarthome	[66] Fire Detection Using UAV
[30] Gait Disorder Detection	[38] Supply Chain Management	[47] Smart Garden Irrigation	[52] ML for Modeling of Energy Consumption	[56] Parking Lot Finder	[62] Smart Building Evacuation System	[67] Robotic Systems and AI App in Livestock
[31] AI-Based Diagnosis of Skin Diseases	[39] PM Decision-Making in Smart Manufacturing	[48] Detecting animals damaging fields	[53] Short-Term Solar Power Forecasting	[57] AI Issues Fines for Honking Ban	[63] Energy Management in Buildings	[68] Stray Animal Control System with AI
[32] Diagnosis of Skeletal Malocclusion with ML	[40] Trends in Predictive Manufacturing Systems in Big Data Environment	[49] Agricultural Crop Monitoring	[54] Smart Grids Energy Management	[58] DL-based Multi-Functional Recognition for Autonomous Vehicles	[64] Smart mirror with image processing support	[69] Attendance System with Face Recognition
[33] Image Captioning Supported System	[41] Digital twins of manufacturing equipment	[50] Giyilebilir duyargalar		[59] Smart Cities for Traffic Management	[65] Data Mining Techniques in Smart Home	[70] Detection of Harmful Fishing Nets in Surface Waters
[34] Stuttering individual development tracking	[42] Supply Chain Optimization			[60] Foreign Object Detection on the Track		[71] Live Bomb Detection
[35] Classification of brain waves	[43] Smart Factories					[72] Smart Water Dispenser
[36] Patient Monitoring (Philips Healthcare)	[44] Connected Supply Chain (Industry 4.0)					[73] Fire Smoke Detection
	[45] Digital Twins for Equipment Simulation					[74-79] Works on Real-Time Human Tracking, Image Generation, Resume Classification, HydroFlow, and Emotion Analyses.

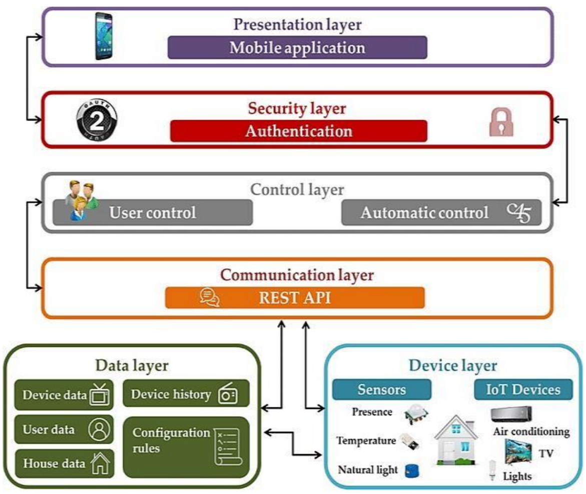

Figure 8. The architecture of a smart house application [27].

4. Results and Discussion

Integrating IoT and ML towards forming a strong IoE environment is poised to play an increasingly important role in shaping the future of various sectors. As the technologies evolve, their collective impact is expected to unlock new possibilities and opportunities. As industries become increasingly dependent on real-time data for critical decision-making processes, the future roles of IoT and ML are going to be instrumental in driving innovation, process optimization, and smart systems design. The future role of the IoT and ML merger will likely extend beyond current applications to delve deeper into more complex decision-making and prediction systems. The advances in wireless technologies will further strengthen the capabilities of IoE applications by providing faster and more reliable connections across all expanding sectors. Thus, faster and more reliable wireless communications will contribute to advanced automation, personalized user experiences, and sustainable applications. As a solid IoE example, the Scientific and Technological Research Council of Turkey (TÜBİTAK, Türkiye Bilimsel ve Teknolojik Araştırma Kurumu) includes Big Data, IoT, Embedded Systems, Semiconductor, Broadband and display technologies among its top innovative research and development project topics. Meanwhile, the AI technology roadmap is in the works [80].

At this point, there are certain issues when open and transparent dialogues are required among sector leaders, academics, and regulators. First, a multidisciplinary approach is needed to evaluate the joint project's social and economic impact and the principles of sustainability and equity. In this context, in-depth discussions and cooperation are inevitable in determining the ethical framework of future technological developments and social benefits.

It is true that the bridge between IoT and ML that forms the IoE world is changing the business world and daily life radically. But, the ethical concerns of rapid technological advances should not be ignored. Also, the encountered security and privacy challenges of the growing complex IoE networks, where billions of M2M communications take place daily, should be met by regularly updated equivalent rules, regulations and laws.

5. Conclusions

This study focuses on the innovative merger of IoT and ML resulting in the present IoE world. The interaction among the people, processes, data, and things of the IoE world is making a big bang. The effect of the IoT-ML merger on the world sector map has been studied through state-of-the-art transformative technologies. Our study shows that the transformation of our world by rapidly evolving sectors is enormous. Our study provides abundant solid project examples and academic works. According to our future role analyses, the transformative technologies have huge opportunities in all sectors.

Our work encourages new initiatives and multidisciplinary work on the world sector map by identifying the benefits of the joint IoT and ML initiatives. We clearly present the potential of the evolving IoE environment to create a strong incentive for a technology-driven future, in all sectors.

Declaration

The author(s) declared no potential conflicts of interest concerning this article's research, authorship, and publication. The author(s) also stated that this article is original and was prepared by international publication and research ethics, and ethical committee permission or any special permission is not required.

Author Contributions

Author Uygur performed the literature search, and prepared the manuscript. Author Özcanhan supervised and improved the study, proofread the article.

References

1. Munirathinam, S., *Industry 4.0: Industrial Internet of Things (IIOT)*. Advances in Computers, 2020, **117**(1): p. 129-164.
2. Sinha, S., *State of IoT 2023: Number of connected IoT devices growing 16% to 16.7 billion globally*. IoT Analytics, 2023.
3. Beecham Research Limited Company, *World of IoT Sector Map*. Beecham Research, 2008.
4. Rahman, M. S., Ghosh, T., Aurna, N. F., Kaiser, M. S., Anannya, M., Hosen, ASMS, *Machine Learning and Internet of things in industry 4.0: A review.* Measurement: Sensors, 2023, **28**: p. 100822.
5. Kaur, M. J., Mishra, V. P., & Maheshwari, P., *The Convergence of Digital Twin, IoT, and Machine Learning: Transforming Data into Action.* Digital Twin Technologies and Smart Cities, *2019,* p. 3-17.
6. Sworna, N. S., Islam, A. K. M. M., Shatabda, S., & Islam, S., *Towards the development of IoT-ML driven healthcare systems: A survey.* Journal of Network and Computer

Applications. *2021*, **196**(15): p. 103244.

7. Pandey, H., & Prabha, S., *Smart Health Monitoring System using IoT and Machine Learning Techniques.* 2020 Sixth International Conference on Bio Signals, Images, and Instrumentation(ICBSII), 2020 , p.1-6.
8. Ghazal, T. M., Hasan, M. K., Alshurideh, M. T., Alzoubi, H. M., Ahmad, M., Akbar, S. S., Al Kurdi, B., & Akour, I. A., *IoT for Smart Cities: Machine Learning Approaches in Smart Heathcare—A Review.* Future Internet. *2021*, **13**(8): p. 218.
9. Dalkılıç, H., Özcanhan, M. H., & Özdemir, H., *Wireless data transfer with the use of Internet of things (IoT) technologies in smart textiles.* Textile Research Journal, 2021, **91**(15-16): p. 1568-1575.
10. Özcanhan, M. H., *Improvement of a Weak RFID Authentication Protocol Making Drug Administration Insecure.* Life Science Journal, 2014, **11**(10): p. 269-276.
11. Aldahiri A., Alrashed, B., Hussain W., *Trends in Using IoT with Machine Learning in Health Prediction System.* Forecasting, 2021, **3**(1): p.181-206.
12. Özcanhan, M. H., Dalkılıç, G., Utku, S., Alkım, E., & Akis, S., *Akıllı Ambulans Araçlarına Doğru İlk Adımlar: RFID Ambulans Varlıkları Takibi.* 19. "Türkiye'de İnternet" Konferansı Bildiriler Kitabı, 2014.
13. Bharadwaj, H. K., Agarwal, A., Chamola, V., Lakkaniga, N., Hassija, V., Guizani, M., & Sikdar, B., *A Review on the Role of Machine Learning in Enabling IoT Based Healthcare Applications*. IEEE Access, 2021, **9**: p. 38859-38890.
14. Hakki, L., Serbes, G., *Detection of wheeze sounds in respiratory disorders: a deep Learning approach.* Internatıonal Advanced Researches and Engineering Journal, 2024, **8**(1): p. 20-32.
15. Deloitte Touche Tohmatsu Limited, *Imoroving return on smart manufacturing investments*. 2020.
16. Kotsiopoulos, T., Sarigiannidis, P., Ioannidis, D., Tzovaras, D., *Machine Learning and Deep Learning in smart manufacturing: The Smart Grid paradigm.* Computer Science Review, 2021, **40**: p. 100341.
17. Çınar, Z. M., Nuhu, A. A., Zeeshan, Q., Korhan, O., Asmael, M., & Safaei, B., *Machine Learning in Predictive Maintenance towards Sustainable Smart Manufacturing in Industry 4.0.* Sustainability, 2020, **12**(19): p. 8211.
18. Reddy, K. S. P., Roopa, Y. M., Kovvada, R. L. N., & Nandan, N. S., *IoT based Smart Agriculture using Machine Learning.* 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), 2020, p. 130-134.
19. Quy, V. K., Hau, N. V., Anh, D. V., Quy, N. M., Ban, N. T., Lanza, S., Randazzo, G. and Muzirafuti, A., *IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges.* Applied Sciences, 2022, **12**(7): p. 3396.
20. Joy, P., *Smart grid enables quantum improvement in energy management efficiency*. Virtual PowerUP Conference 2022.
21. Ahmad, T., Madonski, R., Zhang, D., Huang, C., Mujeeb, A., *Data-driven probabilistic machine Learning in sustainable smart energy/smart energy systems: Key developments, challenges, and future research opportunities in the context of smart grid paradigm,* Renewable and Sustainable Energy Reviews, 2022, **160**: p. 112128.
22. Rahman, A., Pasaribu, E., Nugraha, Y., Khair, F., Soebandrija, K. E. N., & Wijaya, D. I., *Industry 4.0 and Society 5.0 through Lens of Condition Based Maintenance(CBM) and Machine Learning of Artificial Intelligence (MLAI).* IOP Conference Series: Materials Science and Engineering, 2020, **852**: p. 012022.
23. Cheng, L., & Yu, T., *A new generation of AI: A review and perspective on machine Learning technologies applied to smart energy and electric power systems.*International Journal of Energy Research, 2019, **43**(6): p. 1928-1973.
24. Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D., *A Review of Machine Learning and IoT in Smart Transportation*. Future Internet, 2019, **11**(4): p. 94.
25. Badii, C., Bellini, P., Difino, A. & Nesi, P., *Sii-Mobility: An IoT/IoE Architecture to Enhance Smart City Mobility and Transportation Services*, Sensors, 2018, **19**(1): p. 1.
26. Haponik, A., *AI, big data, and machine Learning in transportation*. Addepto, 2021.
27. Reyes-Campos, J., Alor-Hernández, G., Machorro-Cano, I., Olmedo-Aguirre, J.O., Sánchez-Cervantes, J.L., & Rodríguez-Mazahua, L., *Discovery of Resident Behavior Patterns Using Machine Learning Techniques and IoT Paradigm*, Mathematics, 2021, **9**(3): p. 219.
28. Alzoubi, A., *Machine Learning For Intelligent Energy Consumption In Smart Homes*, International Journal of Computations, Information and Manufacturing(IJCIM), 2022, **2**(1): p. 62-75.
29. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Alzheimer Hastalari İçin Yapay Zekâ Temelli İlaç Tanı Uygulaması.* Project Number:26136, 2023.
30. Öztürk, Z., Uygur, S., *Ai Supported Ms Patients Gait Disorder Detection*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220571, 2023.
31. Yıldız, R., *Yapay Zeka Tabanlı Egzema, Gül Hastalığı, Melanom, Keratoz Pilaris Cilt Hastalıklarının Ön Teşhisi İçin Bir Mobil Uygulama*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220812, 2023.
32. Coşkun, E., Marangoz, A., *Ortodontik Hasta Videolarından Makine Öğrenmesi İle İskeletsel Sınıf Maloklüzyonunun Erken Yaşta Teşhisi İçin Bir Mobil Uygulama Geliştirilmesi*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220819, 2023.
33. Tatar, M. S., *Turistler İçin Engelli Bireylere Yönelik Ekler de İçeren Görüntü Altyazılama Destekli Bilgilendirme ve Öneri Sistemi*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220674, 2023.
34. Gören, B. N., Özgür B., Akbaba, Y., *Break Your Blocks*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220698, 2023.
35. Serin, B., *Beyin dalgalarının sınıflandırılması*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220805, 2023.
36. Houten, H. v., *The rise of the digital twin: How healthcare can benefit*. Philips. 2018.
37. Smith, J., & Johnson, A., *Integrating Machine Learning into Smart Manufacturing Systems*, Journal of Smart Manufacturing, 2021, **32**(4), 567-580.
38. Chen, L., Wang, J., & Smith, K., *IoT and Analytics for Supply Chain Management: A Review*. IEEE Transactions on Industrial Informatics, 2019, **15**(6): p.3246-3257.
39. Zhang, Y., Li, L., & Wang, L., *A Predictive Maintenance Decision-Making System in Smart Manufacturing Based on IoT and Edge Computing.* Journal of Manufacturing Systems, 2020, **54**: p.239-249.
40. Lee, J., Lapira, E., Bagheri, B., & Kao, H. A., *Recent Advances and Trends in Predictive Manufacturing Systems*

in Big Data Environment. Manufacturing Letters, 2013, **1**(1): p.38-41.

41. GE Digital, *Digital twin applications*. 2022.
42. DHL, *Digital twins have come alive in the supply chain*. 2024.
43. Siemens AG, *Siemens showcases smart solutions and industry-specific implementation for Industrie 4.0. 2019.*
44. World Economic Forum, *COVID-19: A globally connected supply chain system – Interoperability white paper*. 2020.
45. ABB Group, *Digital twin applications*.2024.
46. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Kayısı Tarımında Yalancı Bahar Olayının Önlenmesi İçin Özgün Yapay Zeka Destekli Peltier Otonom Yönlendirme Cihazı*. Project Number: 26228, 2023.
47. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Yapay Zeka Kontrollü Akıllı Bahçe Sulama Sistemi*. Project Number: 25920, 2023.
48. Derbent, Z., Taşdemir, R., *Tarlam Güvende*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220678, 2023.
49. IBM & Yara, *Helping smallholder farmers: Predicting the weather can transform the global food system*.2020.
50. Özcanhan, M. H., *Giyilebilir duyargaların kesin besicilikte büyükbaş hayvanlara uygulanması: Basit bir yöntemle yemlemenin geviş aktivitesinden ayrıştırılması.* Bilgi Teknolojileri Dergisi, 2016, **9**(3): p. 255.
51. Calderon, A. A. R., *Rüzgâr Türbinlerinde Uç Yapay Zekâ Temelli Hata Tespiti Yapılması*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220601, 2023.
52. Torabzadeh-Tari, M., Golestaneh, F., & Tolabi, H. B., *A Review of Machine Learning Approaches for Predictive Modeling of Energy Consumption in Buildings,* Energy and Buildings, 2016, **117**: p. 103-115.
53. Inman, R. H., & Pedro, J. O., *Short-Term Solar Power Forecasting for Energy Management in Buildings,* IEEE Transactions on Industrial Informatics, 2016, **12**(4): p. 1566-1575.
54. GE Digital, *Data analytics: Do more with what you already have.* 2024.
55. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Akıllı Park Ve Otopark Sistemi.* Project Number: 26969, 2023.
56. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Otopark Yeri Bulucu*. Project Number: 26902, 2023.
57. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Korna Çalınması Yasak Olan Yerlerde Otomatik Ceza Kesen Yapay Zeka Sistemi*. Project Number: 21717, 2023.
58. Çeçen, M., *Otonom Taşıtlar İçin Derin Öğrenme Destekli Çok Fonksiyonlu Tanıma Sistemi.* Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220652, 2023.
59. Siemens AG, *Siemens and IBM collaborate to accelerate sustainable product development and operations.*2021.
60. Demirel, O., Seçilmiş, Ö., *YABDEF*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220787, 2023.
61. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Smarthome*. Project Number: 25834, 2023.
62. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Yapay Zekâ Destekli Akıllı Bina Tahliye Sistemi*. Project Number: 21642, 2023.
63. Schneider Electric, *Schneider Electric launches digital twin software solution.* 2022.
64. Sarhangi, M. M., Öğrü, O., *Görüntü İşleme Destekli Akıllı Ayna*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220788, 2023.
65. Behl, A., & Kaur, I., *A Survey of Data Mining Techniques in Smart Home,* Journal of King Saud University-Computer and Information Sciences. 2017.
66. Aksoy, B., Korucu, K., Çalışkan, Ö., Osmanbey, Ş., Halis, D. H., *İnsansız Hava Aracı İle Görüntü İşleme ve Yapay Zekâ Teknikleri Kullanılarak Yangın Tespiti: Örnek Bir Uygulama*, Araştırma Makalesi, Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 2021, p.112-122.
67. Işık, H. A. Alakus, F., Eskicioğlu, C. Ö., *Hayvancılıkta Robotik Sistemler ve Yapay Zekâ Uygulamaları,* Derleme, Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 2021,p. 370-382.
68. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Yapay Zekâ İle Başıboş Hayvan Kontrol Sistemi*. Project Number: 26943, 2023.
69. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Yüz Tanıma İle Otomatik Yoklama Sistemi.* Project Number: 26906, 2023.
70. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *İha, Yapay Zeka Ve Görüntü İşleme Teknolojisi Destekli Özgün Veri Seti İle Yüzey Sulardaki Zararlı Balık Ağlarının Tespiti İle Balık Ekosisteminin Korunması*. Project Number: 26336, 2023.
71. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Yapay Zekâ Yardımıyla Canlı Bomba Tespiti.* Project Number:21605, 2023.
72. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *Nesnelerin İnterneti Bağlamında Yapay Zeka Destekli Bir Akıllı Su Sebili Çalışması: Su Kalitesi, Siparişi Ve Su İçme Yardımı*. Project Number: 21524, 2023.
73. Başaran, B., Kır, G., *Fire Smoke Detection*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220566, 2023.
74. Argüç, D., Akdemir, M., Açıkgöz, M. C., *Görüntü İşleme ile Gerçek Zamanlı İnsan Tespit ve Takibi Yapabilen Kamera Sistemi*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi, Project Id: 20220679, 2023.
75. Arcas, H., *Derin Öğrenme ile Metin Tabanlı Görüntü İçeriği Oluşturma Mobil Uygulaması*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi. Project Id: 20220778, 2023.
76. Bilbaşar, O., *Özgeçmiş Okuyup Sınıflandıran Sistem*. Genç Beyinler Yeni Fikirler Proje Pazarı ve Bitirme Projeleri Sergisi. Project Id: 20220741, 2023.
77. Leblebicioğlu, T., Deniz, E. İ., Şahin, A. N., *HydroFlow: Development of a Multi-User Hydrological Model and Flow Prediction System*. Genç Beyinler Yeni Fikirler – Proje Pazarı ve Bitirme Projeleri Sergisi. Project Id: 20220565, 2023.
78. İlman, A., Ortadal, G. E., Furat, T., *Görüntü İşleme İle Toplantılar İçin Yüz İfadelerinden Duygu Analizi*. Genç Beyinler Yeni Fikirler – Proje Pazarı ve Bitirme Projeleri Sergisi. Project Id: 20220636, 2023.
79. Şengül, F., Akkaya, S., *A Modified MFCC-based deep Learning method for emotion classification from speech*. Internatıonal Advanced Researches and Engineering Journal, 2024, **8**(1): p. 33-42.
80. Türkiye Bilimsel Ve Teknolojik Araştırma Kurumu, *TÜBİTAK 2020*. 2019.