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Safejack- An AR/VR Integrated Protector and Display

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Abstract
The project goal is to revolutionize construction project. management by leveraging IoT devices and backend AI/ML tools development to create an industry-standard dashboard for real-time monitoring. In addition to providing live reports on progress, the dashboard will supply stakeholders with updates on resource usage, safety, and quality-performance metrics, allowing them to make more data-driven decisions and optimize their production flow. Safety standards will be dramatically improved due to real-time hazard detection and accident prevention. Quality assurance will be strengthened through AI-enabled defect recognition and management. Resource usage will be maximized through real-time monitoring of equipment and human hours, allowing stakeholders to reduce waste and operating costs through dashboard. This project also creates a 3D model by comparing an original model with a photograph and displays the 3D model in the dashboard for easy viewing and analyzing. Therefore, using IoT and AI technologies will deliver successful construction project outcomes by ensuring safety and quality while increasing resource usage.

Keywords: *Iot Device, AR/VR Application, Dashboard, AI/ML Tools, Image Processing Tools*

1. Introduction
In recent years, the construction industry has undergone a significant change, moving towards incorporating advanced technologies such as Internet of Things (IoT) devices and Artificial Intelligence/Machine Learning (AI/ML) tools to improve project management and monitoring capabilities. Real-time monitoring of construction projects has become essential for ensuring efficient resource utilization, improving safety measures, and optimizing project outcomes. This paper examines the development and deployment of dashboards for real-time monitoring of construction projects using IoT devices and backend AI/ML systems. The conventional method of managing construction projects often encounters difficulties in effectively monitoring resources like machinery and manpower, and in ensuring their top performance and safety under different operational circumstances. Implementing IoT devices can convert construction sites into intelligent spaces where different elements of project implementation are constantly observed and evaluated. A vest integrated with these devices allow for the real-time gathering of data related to equipment usage, workforce efficiency, environmental conditions, and safety measures. Here [1] Next to the slow performance growth of the construction sector, organizations initiate investigations into the adoption of AI to optimize procedures and drive productivity. These benefits provide relief in cost overruns, enhance site safety, increase management efficiency in planning projects, and support productivity growth at construction sites. AI plays a very fundamental role because it forms the cornerstone in implementing authentic digital strategies within these fields: engineering, construction, and management. As a discipline of computer science, AI allows computers to act like human beings in perceiving and learning inputs. Here [2], The Development of the haptic vest is designed to increase virtual reality experience and make it as if a person is there. This is done through a number of concrete vibrotactile stimuli, including impact

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effects, thermal effects and touch-based communication among the members of one and the same training team. The primary aim of the project is to design a vest that can deliver multiple types of haptic feedback, thereby leading to positive outcomes such as increased realism and the experience of being fully engaged in the virtual world. [3] Personal protective equipment (PPE) is created with a view to decreasing the rate of accidents and, consequently, saving the worker from injury. The PPE should be capable enough to shield workers from any sort of physical impacts and to reduce the workforces exposure to them.There are safety vests, safety helmets, goggles, gloves, and safety shoes that are the most popular PPEs used in different industries. Consistently, PPE is appreciated as mostly the key to saving the lives of workers, especially in construction sites, port and terminals, warehouses, and other places where the accident happens. In truth of the matter, almost all businesses have given their employees rules on wearing protective gear to be followed before they go inside the forbidden place. [4] Together with the development of the newest technologies, virtual reality (VR) has become the most popular tool in construction for the purpose of training the workers on safety due to its great effect on such programs . And so, VR has been referred to as the best solution for the said problems.VR can be a transforming agent of learning by allowing the workers to go through the safety scenarios in 3-D and learn multiple times which leads to people's heightened interest, stronger involvement and the higher retention of the acquired knowledge. Active inquiry-based pedagogical techniques such as the implementation of critical thinking, exploration, and discourse on the safety regulations have been established to ameliorate the safety in construction [5].

2. Implementation Framework and Data Flow for Safejack

2.1. Sensor Data Collection

The Safejack system begins with the deployment of multiple sensors integrated into the safety jacket. These sensors include a BMP pressure sensor for measuring atmospheric pressure changes, gas sensors for detecting hazardous gases such as CO, CH4, and H2S, temperature sensors, fall detection sensors, and GPS for location tracking. Each sensor continuously monitors its respective parameter, ensuring that real-time data on environmental conditions and worker status is collected. This data is crucial for assessing safety conditions at construction sites, especially those with varying elevations and potential exposure to toxic gases.

2.2. Data Transmission via MQTT Protocol

Once collected, the sensor data is transmitted to the central system using the MQTT protocol. MQTT, a lightweight implementer of a publish-and- subscribe network is ideal for transmitting data from IoT devices due to its efficiency and low bandwidth usage. The protocol ensures that data from the sensors is sent reliably and in real-time to a local IoT gateway or directly to the cloud. This step is critical for maintaining the flow of real-time information necessary for immediate safety monitoring and response.

2.3. Data Aggregation and Pre-Processing

At the IoT gateway or cloud service, the sensor data from multiple jackets is aggregated and pre-processed. This involves filtering out any noise or irrelevant data and ensuring the integrity and accuracy of the collected data. Initial analytics might also be performed at this stage, such as averaging sensor readings or detecting anomalies. This pre-processed data serves as the foundation for more in-depth analysis and visualization, ensuring that only relevant and accurate information is forwarded to the next stages [6-10].

2.4. Cloud Storage for Sensor Data

The pre-processed data is then stored in a cloud database or data lake. Cloud Storage Solutions like AWS, Azure or Google Cloud provide easy and secure storage options for large amounts of data. Store data in the cloud for fast processing and historical analysis. This centralized storage approach allows for seamless integration with analytics and visualization tools, providing a robust platform for further data utilization.

2.5. Data Analysis through AI/ML Systems

Perform advanced data analytics using AI and ML systems. This system analyzes archived data for archived data to extract insightful content and

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perform predictive analytics. For example, machine learning algorithms can predict security risks based on historical data patterns. These steps improve prevention risk reduction and ensure that potential issues are detected and resolved before they escalate, improving overall security and performance efforts in the field.

2.6. Real-Time Data Visualization with Power BI

Power BI is utilized for the real-time visualization of sensor data. By integrating with the cloud-stored data, Power BI creates interactive dashboards, charts, and maps that display key metrics such as atmospheric pressure, gas levels, temperature, fall events, and worker locations. These visualizations enable stakeholders to monitor construction site conditions in real-time, facilitating quick and informed decision-making. The clear and interactive nature of Power BI dashboards ensures that complex data is presented in an easily understandable format.

2.7. Integration of AR / VR

The integration of AR and VR technology can enhance the user experience and improve safety and training. AR transfers real-time sensor data into the physical environment, providing workers with instant updates on equipment, safety alerts, and operations. VR offers a fully immersive experience for training and project planning, allowing workers to navigate and interact with virtual models of the construction site. These technologies enhance spatial understanding, reduce errors, and provide effective training solutions.

2.8. Stakeholder Monitoring and Decision-Making

The final step in the Safejack system involves monitoring and decision-making by stakeholders using the Power BI dashboards. Stakeholders, including project managers, safety officers, and other relevant personnel, can access real-time data visualizations to monitor construction site conditions, worker activities, and safety metrics. The dashboards provide critical insights that support proactive risk management and optimized resource allocation. This comprehensive monitoring capability enhances decision-making processes, ensuring that safety and productivity are continuously improved on the construction site.

3. Development of Safejack Vest

The project focuses on developing a safety jacket for construction workers, integrating IoT devices and AI/ML systems for real-time monitoring and safety enhancement. In the construction sector, where efficiency and safety are paramount, this technology aims to revolutionize traditional project management practices. The safety jacket incorporates various sensors such as temperature, pressure, gas, fall detection, and GPS, all connected to an Arduino board. These sensors continuously gather data related to environmental conditions, worker safety, equipment usage, and location, shown in Figure 1.

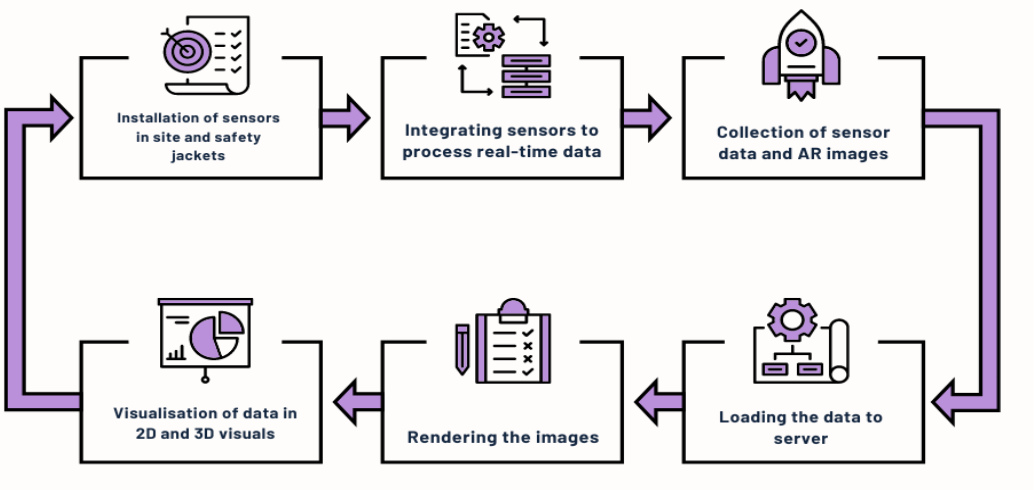

Figure 1 System Architecture

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The implementation of IoT devices transforms construction sites into smart environments where every aspect of the project is monitored in real time. This includes tracking machinery performance, assessing workforce efficiency, ensuring adherence to safety protocols, and optimizing resource utilization. Artificial intelligence algorithms play an important role in analyzing the large amount of data collected by sensors.They enable predictive maintenance of machinery, early detection of potential hazards, personalized safety alerts for workers, and optimization of workflow based on historical data and real-time insights. DHT11 temperature sensor in the jacket to accurately measure temperature using a thermistor and capacitive humidity sensor. It provides real-time data on the environmental temperature conditions surrounding the construction worker. This data is crucial for ensuring worker comfort and safety, especially in extreme weather conditions. The sensor's reliability, cost-effectiveness, and stability make it an ideal choice for continuous monitoring of temperature variations. The gyroscope sensor integrated into the safety jacket detects sudden changes in orientation and movement, which are indicative of a potential fall. By constantly monitoring the wearer's posture and movement patterns, the gyroscope sensor can trigger immediate alerts in case of a fall or loss of balance. This proactive approach to fall detection enhances worker safety by enabling swift response and assistance during emergencies, shown in Figure 2.

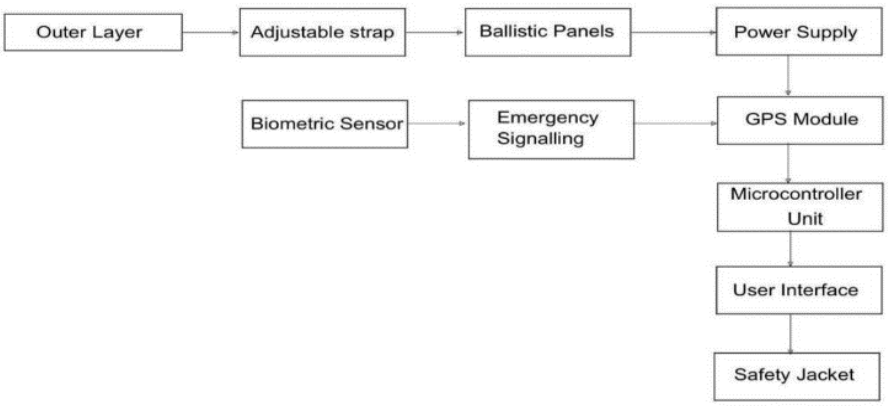

Figure 2 System Specification

The BMP pressure sensor embedded in the safety jacket measures atmospheric pressure changes, providing valuable insights into altitude variations and environmental pressure fluctuations. This data is crucial for assessing the working conditions at different construction sites, especially those at varying elevations. The pressure sensor's accuracy and responsiveness contribute to enhanced safety measures, particularly in environments where pressure differentials can impact worker well-being.
The gas sensor integrated into the safety jacket is designed to detect and monitor the presence of hazardous gasses in the surrounding environment. It uses semiconductor-based gas sensing elements to detect specific gases such as carbon monoxide (CO), methane (CH4), and hydrogen sulfide (H2S), among others. The sensor continuously monitors air quality and provides real-time data on gas concentration. Power BI serves as a powerful tool for data visualization and analysis in this construction project incorporating IoT devices and AI/ML systems. By integrating data from various sensors such as temperature, pressure, gas, fall detection, and GPS, Power BI enables real-time monitoring and comprehensive insights into project management and worker safety. Visualizations such as interactive dashboards, charts, and maps provide stakeholders with a clear understanding of construction site

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conditions, equipment performance, worker activities, and safety metrics. This enhances decision-making processes, facilitates proactive measures for risk mitigation, optimizes resource allocation, and ultimately contributes to improved project outcomes and enhanced safety measures for construction workers.

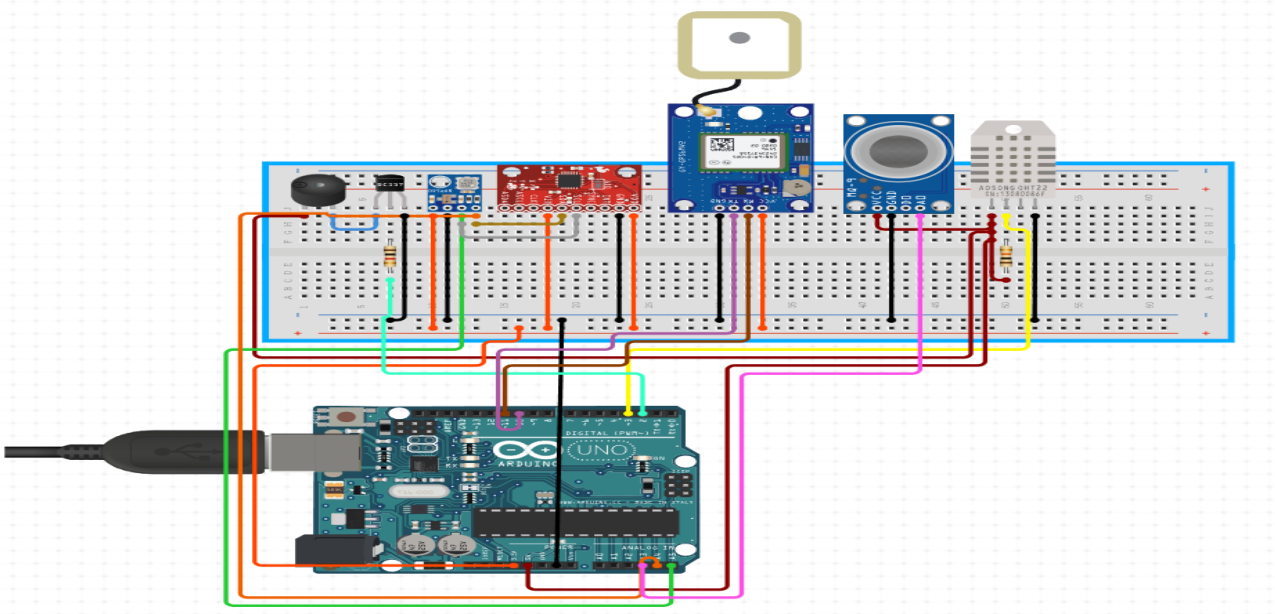

Figure 3 Circuit Diagram

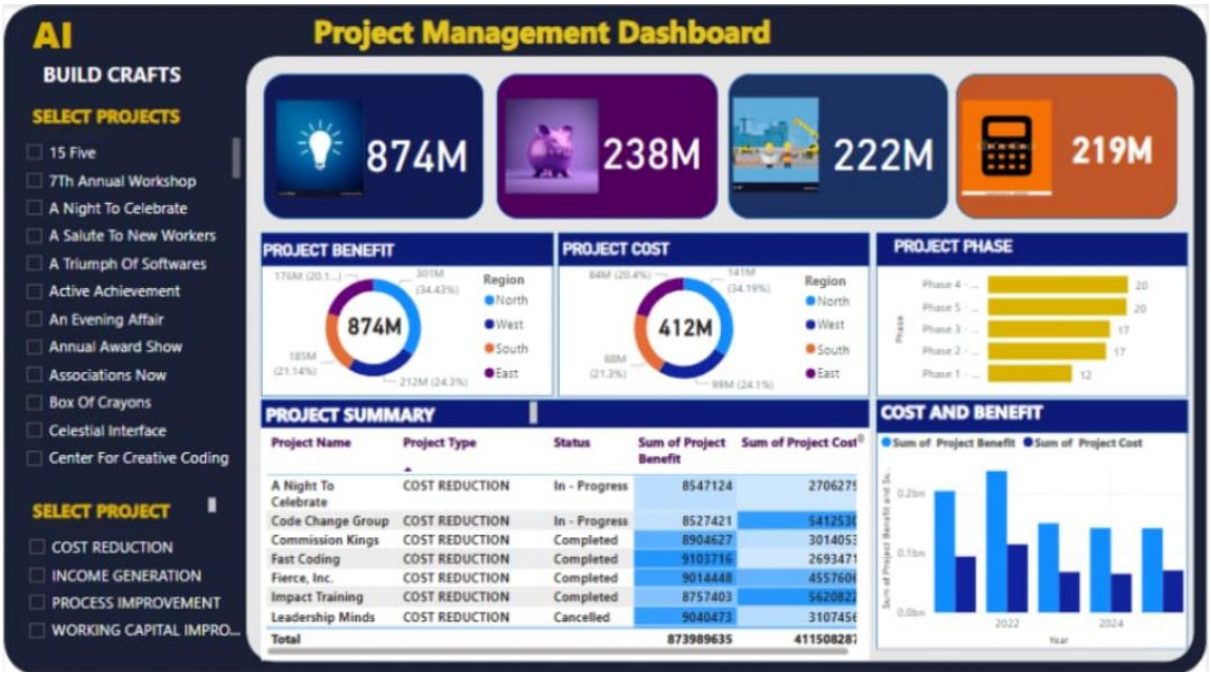

Figure 4 Dashboard

The construction project uses augmented reality (AR) and virtual reality (VR) technology to enhance 3D visualization and provide a better view of the construction site and project details. AR overlays digital information into the physical environment, allowing workers to access real-time information

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such as equipment and safety alerts and work directly from their perspective. VR is an experience where users can walk through a real-life virtual environment, interact with virtual models, simulate scenarios and conduct training. These technologies not only improve spatial understanding and project planning but also enable remote collaboration, training simulations, and safety drills, thereby enhancing efficiency, reducing errors, and ensuring a safer working environment for construction workers. The haptic vest development within the project enhances worker immersion and interaction in virtual environments, providing realistic feedback through vibrotactile stimuli. This technology aids in training simulations, improving safety awareness, and refining emergency response strategies. Overall, the integration of IoT devices, AI/ML systems, and haptic technology in safety jackets for construction workers represents a significant advancement towards ensuring worker safety, optimizing project management, and fostering productivity growth in the construction industry, shown in Figure 3 & 4.

3.1. Sensor Technology

3.1.1. BMP Pressure Sensor

The BMP Pressure Sensor is designed to measure atmospheric pressure, providing critical data on altitude variations and environmental pressure fluctuations. This sensor continuously collects pressure data, which is crucial for understanding and assessing working conditions at different elevations on construction sites. The collected data is transmitted via the MQTT protocol over Wi-Fi to an IoT gateway or cloud server. After initial aggregation and pre-processing, the data is stored in a cloud platform where AI/ML systems analyze it for insights. Finally, the processed data is visualized on Power BI dashboards, allowing stakeholders to monitor and ensure safe working conditions related to atmospheric pressure.

3.1.2. ii) Gas Sensor

The role of gas sensors is to detect pollutants such as carbon monoxide (CO), methane (CH4) and hydrogen sulfide (H2S). It samples the air quality in real-time, providing continuous data on gas concentration levels. This data is transmitted using the MQTT protocol over Wi-Fi to the IoT gateway or cloud. After aggregation and pre-processing, it is stored in the cloud. AI/ML systems analyze the data for trends and anomalies, which is then visualized on Power BI dashboards. This process ensures real-time monitoring and alerts to maintain worker safety in environments where toxic gases may be present.

3.1.3. Temperature Sensor:

The temperature sensor monitors the ambient temperature around the worker, continuously collecting data to ensure that workers operate within safe temperature ranges. The collected temperature data is sent via the MQTT protocol over Wi-Fi to the IoT gateway or cloud. It undergoes aggregation and pre-processing before being stored in a cloud platform. AI/ML systems then analyze this data to identify any potential hazards due to temperature fluctuations. The insights are visualized on Power BI dashboards, providing real-time updates to stakeholders to help maintain safe working conditions.

3.1.4. Fall Detection Sensor:

The fall detection sensor identifies and alerts about fall incidents by detecting sudden movements or impacts indicative of a fall. It sends immediate alerts to the system, ensuring prompt response to potential accidents. The sensor data is transmitted using the MQTT protocol over Wi-Fi to the IoT gateway or cloud. Aggregated and pre-processed data is stored in the cloud, where AI/ML systems analyze it to identify patterns and improve fall detection accuracy. The processed data and alerts are displayed on Power BI dashboards, allowing stakeholders to monitor and respond quickly to fall incidents, enhancing worker safety.

3.1.5. GPS

The GPS sensor tracks the real-time location of the worker, providing essential data for monitoring worker movement and ensuring safety across different areas of the construction site. GPS data is transmitted via the MQTT protocol over Wi-Fi to the IoT gateway or cloud. After aggregation and pre-processing, the data is stored in a cloud platform. AI/ML systems analyze the location data for insights into worker movement patterns and potential safety risks. The visualized data on Power BI dashboards helps stakeholders track worker locations in real-

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time, ensuring effective monitoring and quick response to any safety concerns.

3.1.6. MQTT Protocol

The MQTT protocol plays a crucial role in efficiently transmitting sensor data to the IoT gateway or cloud service. This lightweight protocol, designed for constrained environments, employs a publish-subscribe architecture that ensures real-time data transmission. Each sensor, such as the BMP Pressure Sensor, Gas Sensor, Temperature Sensor, Fall Detection Sensor, and GPS, continuously collects data and publishes it to an MQTT broker. The broker acts as an intermediary, forwarding the data to subscribers, which can be IoT gateways or cloud services. Once the data reaches the IoT gateway, it undergoes initial aggregation and pre-processing to ensure data integrity. The pre-processed data is then transmitted to cloud storage platforms where it is further analyzed by AI/ML systems. Finally, the analyzed data is visualized on Power BI dashboards, providing stakeholders with real-time insights into various metrics such as atmospheric pressure, gas concentration levels, temperature, fall incidents, and worker locations, thereby enabling continuous monitoring and informed decision-making. By employing the MQTT protocol, the Safejack system ensures efficient, real-time data transmission from sensors to the cloud and ultimately to stakeholders, enhancing the overall safety and effectiveness of construction site management [11-13].

3.1.7. Wi-Fi Technology

Wi-Fi technology is pivotal in enabling wireless data transmission from sensors to the IoT gateway and cloud, ensuring connectivity and accessibility without the need for wired connections. The process begins with the various sensors, including the BMP Pressure Sensor, Gas Sensor, Temperature Sensor, Fall Detection Sensor, and GPS, continuously collecting data relevant to their specific functions. These sensors are equipped with Wi-Fi modules that facilitate the wireless transfer of collected data. The data is transmitted over the Wi-Fi network to a local IoT gateway, which serves as an aggregation point. The IoT gateway performs initial processing, such as filtering out noise and validating data integrity, before forwarding the pre-processed data to the cloud. Alternatively, in some configurations, sensors may directly transmit data to cloud servers via Wi-Fi, bypassing the IoT gateway. This seamless data transfer ensures that all collected information is readily accessible for further analysis. Once in the cloud, AI/ML systems analyze the data, detecting patterns, performing predictive analytics, and generating insights crucial for worker safety and project management. Finally, the analyzed data is visualized on Power BI dashboards, providing stakeholders with real-time, interactive insights into various metrics, such as atmospheric pressure, gas concentration levels, temperature readings, fall incidents, and worker locations. This comprehensive, end-to-end process facilitated by Wi-Fi technology ensures continuous monitoring and informed decision-making, enhancing the overall efficiency and safety of construction site management.

4. Result and Discussion

This safe jack is developed to provide all the necessary health statistics for the site workers in the construction arena. In addition to this, the oxygen level and blood pressure are the parameters that are being monitored. This project is thus concluded with an efficient use of VR and electronics with sensors. Today's construction projects are not properly managed, and workers are not preserved or protected from danger in construction projects; however, there is much to be gained if the construction industry transforms digitally. The solution to the ending of wearable devices in this sector as the cure for a lot of the diseases of the labor off Virtual job sites; the establishment of digitized cooperation, and the achievement of more productive, timely, efficient and safe production are some of the critical roles of wearable gadgets.The desired effect is to have a connection to live jobsite operations which will be management's goal to get to this level by making appropriate real-time decisions. Worker safety is monitored through the tracking of their current location. The convenience of live information such as location and status makes work faster and ensures safety.

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