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Wi-Fi Poles in Johor Bahru for Wearable Sensors in Construction Sites and Digital Cities

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ABSTRACT

This study explores the potential integration of wearable sensors with existing Wi-Fi poles in Johor Bahru to enhance safety monitoring on construction sites and contribute to the development of digital cities. In this study, the assessment of the capabilities and limitations of the existing Wi-Fi infrastructure, interpretation of survey data on the effectiveness of Wi-Fi, identification of challenges in monitoring construction sites, and development of a heat map for wearable sensor usage were undertaken. Focused on Hutan Bandar, Johor Bahru, with a specific emphasis on two Wi-Fi poles, the research employs a methodology that includes literature review, surveys, statistical data analysis, and visualization of findings. The significance of this study lies in its potential to improve safety practices, reduce accidents, and contribute to the development of smarter and safer construction sites and digital cities in Johor Bahru. The evaluation of the Wi-Fi infrastructure in Hutan Bandar, Kulai, Johor, highlights the need for improvement to accommodate wearable sensors and support digital city initiatives. In conclusion, the construction industry in Johor underutilizes wearable sensors, presenting an opportunity for enhancement. The integration of IoT sensors not only enhances safety but also has the potential to boost productivity.

1.0 INTRODUCTION

Wireless connectivity, particularly through Wi-Fi infrastructure in cities, has become integral in our daily lives, fostering effortless communication and the integration of smart technologies. This expansion in urban Wi-Fi accessibility has positioned it as a crucial component of city infrastructure, supporting connectivity and digital service access (Zhang & Cheng, 2017). This infrastructure also enables the effective implementation of the Internet of Things (IoT), which involves physical objects embedded with sensors and software that connect and exchange data over the internet (Lee et al., 2022). IoT offers significant advantages in the construction industry by improving the management of resources such as workers, materials, and equipment (Yian et la., 2023; Lee et al., 2025). In smart cities, IoT enhances urban infrastructure by optimizing resource management and providing real-time data for informed decision-making (Mylonas et al., 2021).

This paper explores the intersection of IoT technologies and the construction industry, focusing on the potential benefits of wearable sensors for efficiency and safety monitoring on construction sites. By attaching these sensors to workers, real-time monitoring of vital signs and environmental conditions becomes possible, contributing to improved safety protocols and resource optimization (Sathvik et la., 2022). This capability is crucial, as it allows for the immediate detection of potential safety risks or hazardous conditions, enabling swift interventions to prevent accidents and protect worker well-being. The integration of wearable sensors with existing Wi-Fi infrastructure in Johor Bahru presents an opportunity to transform construction sites into connected environments, fostering the development of digital cities. Johor Bahru, as a city committed to expanding free Wi-Fi access for its residents, provides an ideal setting for these advancements (BERNAMA, 2020).

The study aims to address the potential improvement construction sites by leveraging IoT and wearable sensor technologies, ultimately enhancing safety practices, improving efficiency, and contributing to the advancement of smarter and safer construction sites and digital cities in Johor Bahru. The investigation focuses on Wi-Fi poles nearby the targeted construction site, which provide free internet access, as an accessible and scalable starting point for integrating these technologies into the urban environment (Ang & Seng, 2016).

1.1. Problem Statement

The global trend towards smart cities has yet to fully integrate crucial infrastructure like Wi-Fi poles in regions such as Johor (BERNAMA, 2020). Despite their potential, the underutilization of Wi-Fi poles limits the development of interconnected urban systems, essential for the implementation of smart city initiatives (Utusan Borneo Online, 2014). This gap in infrastructure integration impedes the widespread adoption of IoT technologies, including wearable sensors, which rely on robust and pervasive wireless connectivity. Without fully leveraging Wi-Fi poles, cities risk falling behind in the smart city transformation, missing opportunities to enhance safety, efficiency, and sustainability in construction and beyond (Utusan Borneo Online, 2014).

Despite ongoing efforts to prevent injuries in the construction industry, persistent high accident rates worldwide underscore the need for innovative safety measures. Traditional strategies have plateaued, as evidenced by stagnating injury statistics over the past decade. Based on Yoon et al. (2024), around 10,000 construction workers working in the United States lost their lives due to injuries onsite from 2011 to 2021.Wearable sensors offer a promising solution for enhancing safety in construction by integrating into personal protective equipment (PPE) or worn by workers, thus addressing the industry's safety challenges and contributing to improved performance (Sathvik et al., 2022).

To effectively implement wearable sensors for safety monitoring on construction sites, robust internet connectivity is essential. In Johor Bahru, the government’s initiative to provide free internet through Wi-Fi poles offers a valuable opportunity to utilize this existing infrastructure. Consequently, this study investigates how the connectivity and coverage of these Wi-Fi poles—assessed through a heat map—can be leveraged to support real-time safety monitoring on construction sites.

1.2. Objectives

This study aims to explore the use of wearable sensors and IoT technologies with existing WiFi infrastructure in Johor Bahru to improve safety monitoring on construction sites and advance the development of digital cities. The objectives are as follows:

i. To identify the capabilities and limitations of the existing Wi-Fi infrastructure in Johor for supporting efficient and real-time safety monitoring on construction sites.

ii. To interpret survey data collected from respondents regarding the effectiveness of the free Wi-Fi in the area.
iii. To discover the challenges and issues faced in monitoring construction sites and managing connectivity using the current Wi-Fi poles.
iv. To create a heat map utilizing data collected manually on the effectiveness of the Wi-Fi poles.

1.3. Scope of Study

This research examines the capabilities and limitations of existing WiFi poles in Hutan Bandar, Johor Bahru, Malaysia, specifically focusing on their potential to enhance real-time safety monitoring on construction sites. The study aims to improve worker safety by addressing challenges in promptly detecting and responding to potential hazards.

The Spot-r system by Triax Technologies is the primary technology considered for future use as a wearable sensor. The geographical scope is limited to two Wi-Fi poles in Johor Bahru with coordinates (1.482942,103.745978) & (1.480589,103.746500). The research involves surveys and interviews with individuals in the construction industry to gather insights on pole usage, safety monitoring, and existing sensor utilization. Methodologies include manual readings, surveys, and data analysis to assess the effectiveness of wearable sensors and IoT integration in the construction industry.

2.0 LITERATURE REVIEW

The growing significance of wireless connectivity, coupled with the expansion of Wi-Fi infrastructures in cities, presents an opportunity to integrate wireless technologies into construction sites. This study explores the potential of using wearable sensors and IoT technologies with existing Wi-Fi poles in Johor Bahru, Malaysia, aiming to enhance safety monitoring and improve construction site management. The research assesses the capabilities of free Wi-Fi services, identifies challenges in monitoring construction sites, and develops a heat map to guide the implementation of these technologies. The findings contribute to advancements in construction practices and the development of connected cities, fostering safer construction sites and the realization of digital cities.

The ProQuest database search yielded 1,349 articles, indicating a growing interest in sensors and the Internet of Things (IoT) in the construction industry. Figure 1 displays the cumulative number of publications from 2012 to 2022, showing a consistent annual increase. This surge in publications since 2020 suggests a growing demand for sensors in IoT applications within construction. Overall, the data indicates a significant rise in scholarly exploration and attention towards sensors and IoT in construction, with expectations of further advancements and increased publications in the future.

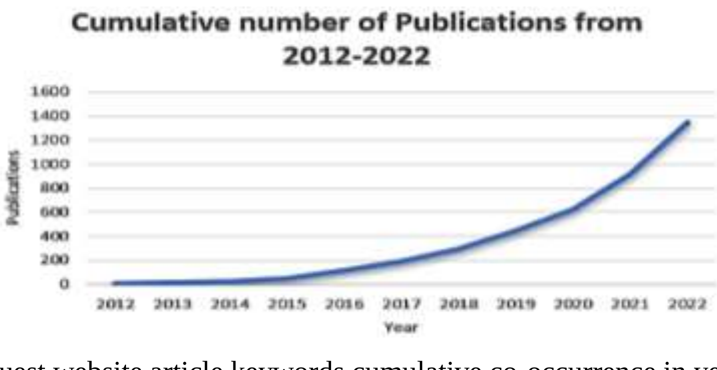

Figure 1. ProQuest website article keywords cumulative co-occurrence in year 2012 to 2022.

The objective was to identify patterns of keyword connections within the bibliographic network, specifically focusing on ScienceDirect website articles between 2012 and 2022. Out of 5,697 keywords assessed, 680 met the threshold criteria. Notable keywords with strong connections included "Internet of Things," "sensors," "artificial intelligence," "computer science," and "automation." VOS Viewer was used to process bibliographic data and visualize the keyword patterns. The analysis revealed a focus on topics related to the Internet of Things, sensors, and computer science. The most frequent keyword was "Internet of Things," appearing 429 times with a total link strength of 5,606. Overall, this research provides insights into prevailing trends and topics within the field from 2012 to 2022, based on data available as of 23/2/2024.

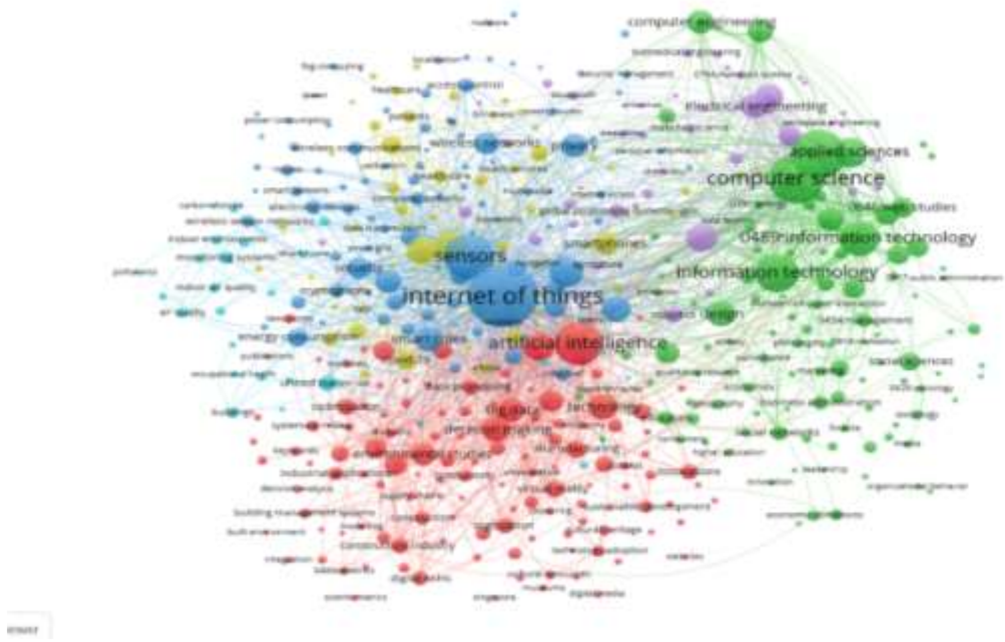

Figure 2. Network Visualization for ProQuest website article keywords co-occurrence from 2012 to 2022.

The concept of digital cities leverages technology and data to enhance urban services and address community challenges. Using information and communication technologies, smart sensors, and video cameras, digital cities aim to improve residents' quality of life and optimize urban functioning. These technologies, including IoT sensors and video cameras strategically placed throughout the city, collect data on aspects such as traffic patterns and air quality, providing valuable insights. The use of sensor data can drive the development of applications and systems that positively impact urban areas, promoting sustainable development, enhanced efficiency, improved quality of life, cost reduction, and citizen engagement (Ang and Seng, 2016).

In Brazil, Vinhedo and Pedreira implemented digital city projects focusing on municipal management, telecommunications, and public service accessibility. These projects utilized action-research case studies to enhance communication, improve services, and increase city efficiency through digital inclusion. In Sheffield, UK, smart streetlights were implemented as part of a smart city initiative, offering automation, remote monitoring, fault detection, and energy performance tracking. Similar projects were initiated in Edinburgh, projecting significant energy savings over time. Digital cities employ various technologies tailored to their objectives, including geographic information systems, building information modelling, blockchain-based identity systems, and digital teaching-learning technologies (Rezende, 2013).

The utilization of the Internet of Things (IoT) in various sectors in Malaysia is rapidly growing. The IoT industry in Malaysia was valued at RM9.7 billion in 2019 and is projected to reach RM37.1 billion by 2025 (Reddy & Kone, 2019). While the construction sector is just beginning to adopt IoT technology, its use is expected to increase significantly due to the potential for cost reduction, increased productivity, and market differentiation (Liu et al., 2021).

Wearable devices, such as smartwatches, fitness trackers, and smart clothing, have gained attention in construction for enhancing safety and health by addressing concerns like falls, injuries, postures, and fatigue monitoring. Some are commercially available, while others are in development. Researchers have explored wearable device applications in construction safety, studying factors influencing adoption, reviewing applications and sensors, and proposing recommendations like sensor fusion and risk assessment [12-14].

Wearable sensing devices have the potential to address construction industry challenges. In terms of functions and applications, wearable smart devices (WSDs) with computer and electronic technologies can monitor physiological indicators, sense the environment, detect hazards, and track vital signs. They analyse data like heart rate and posture to monitor fatigue levels, prevent injuries, and sense hazardous gases for early warnings about potential hazards. Research highlights the potential benefits of wearable sensors and IoT technologies in detecting hazards, providing real-time alerts, and improving safety outcomes in construction (Rao et al., 2022).

3.0 METHODOLOGY

This research consisted of the following key activities; thorough literature review and bibliometric analysis (Choi et al., 2021), Survey and manual data collection, analysing survey data through SPSS and the generation of a heatmap from the manually collected Wi-Fi data.

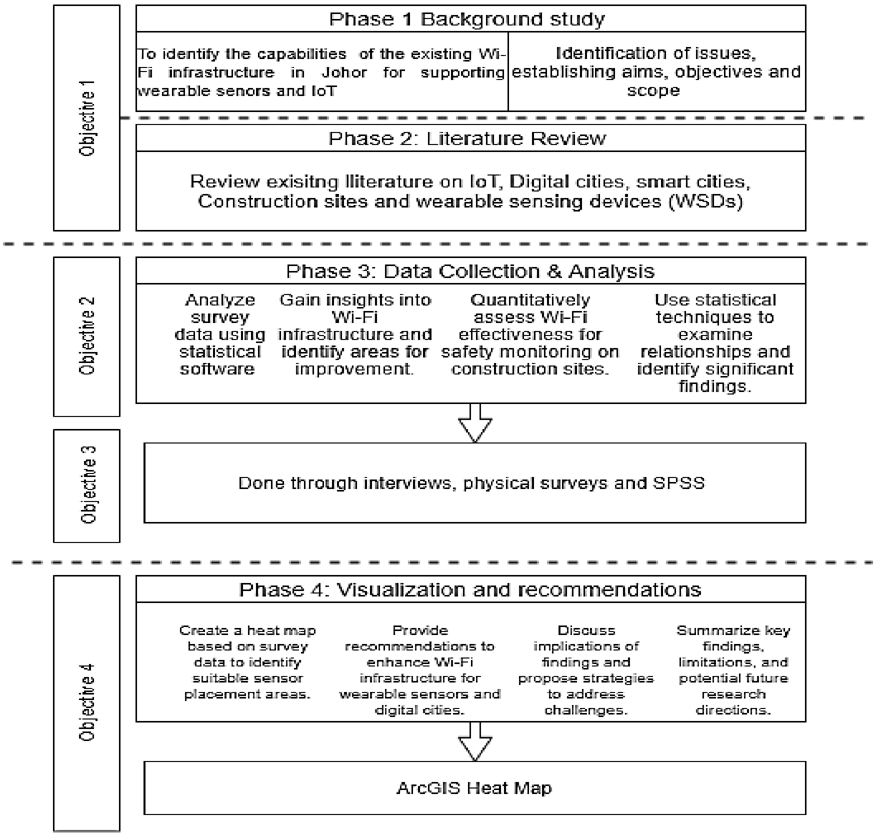

Figure 3. Flowchart of study.

3.1. Study Area

Figure 4. Wi-Fi Poles and the surrounding Construction Site at Hutan Bandar

3.2. Questionnaire Survey

Questionnaire surveys, the primary data collection method, targeted people construction industry that use Johor Free WIFI such as project managers and engineers. The study, included 19 engineering staff from targeted construction companies near Hutan Bandar. With a small population, the sample size (n= 15) was determined using Taro Yamane's formula, encompassing all staff (engineers and managers) in the target group as study samples, potential users of wearable sensors (Yamane, 1967).

The questionnaire covered demographic details, the effectiveness of Wi-Fi at Construction Sites and the need for wearable sensors for construction worker monitoring on-site. systems. A five-point Likert scale was applied to gauge respondents' opinions, with ratings ranging from 1 to 5, where 1 represents "Strongly Disagree" and 5 represents "Strongly Agree" (Likert, 1932). This scale allows for the measurement of varying degrees of agreement or importance, enabling a more nuanced understanding of respondent perceptions (Chua, 2009). The responses obtained formed the foundation for the subsequent analysis. SPSS Version 27.0.1.0 was employed to conduct the statistical analysis for the questionnaire survey.

The study of consistency and stability is referred to as reliability analysis. The aim of reliability analysis is to assure that test or measurement results are accurate, consistent, and reliable. The reliability value in this study is obtained using Cronbach's alpha, as shown in Table 1. The acceptability of each variable will be determined and justified using a reliability test with Cronbach's alpha. Internal reliability is measured by Cronbach's alpha which is recognized as a scale reliability indicator. Cronbach’s alpha is a reliability coefficient, not any kind of statistical test.

Table 1. The general ranges and consistency of Cronbach's alpha (Lee, 1951).

Internal Consistency	Cronbach’s Alpha Range
Excellent	$\alpha \geq 0.9$
Good	$0.8 \leq \alpha < 0.9$
Acceptable	$0.7 \leq \alpha < 0.8$
Questionable	$0.6 \leq \alpha < 0.7$
Poor	$0.5 \leq \alpha < 0.6$
Unacceptable	$\alpha < 0.5$

Relative Importance Index (RII) is an analysis used in this study to evaluate the criteria of respondents' questionnaire answers according to their relative importance regarding the study's objective. RII refers to a statistical measure commonly used to rank or prioritize factors based on their relative importance as perceived by respondents. This study adopted the RII formula as cited in Yosvani's study (Nourbakhsh et al., 2012) from the University of Holguin as the following:

$$RII = \Sigma W / (N*A)$$

W = Assigned Likert scale weights
A = Higher weight
N = Total number of samples

Table 2. RII scale (Nourbakhsh et al., 2012)

Relative Importance Index (RII) range	Importance level
0.8 < RII	High importance
0.5 < RII < 0.8	Medium importance
0.5 < RII < 0	Low importance

This reveals trends, preferences, and opinions on Wi-Fi infrastructure and construction site monitoring challenges. These analyses yield quantitative summaries and statistical characteristics, offering valuable insights into the current state of Wi-Fi infrastructure and construction site monitoring practices (Kemp et al., 2018).

3.3. Google Earth Pro

In this investigation, Google Earth Pro was used for methodically exploring and plotting the Johor Free WiFi Poles coverage. It starts with opening Google Earth Pro, inputting precise pole coordinates, and marking them for clarity. A 150m radius circle around each pole visually represents their coverage. Defining the survey area is done with a polygon. Surveyed coordinates get color-coded for network performance: green for "Good coverage," yellow for "Moderate," and red for "Poor." This systematic approach evaluates WiFi comprehensively in specific locations, providing insights.

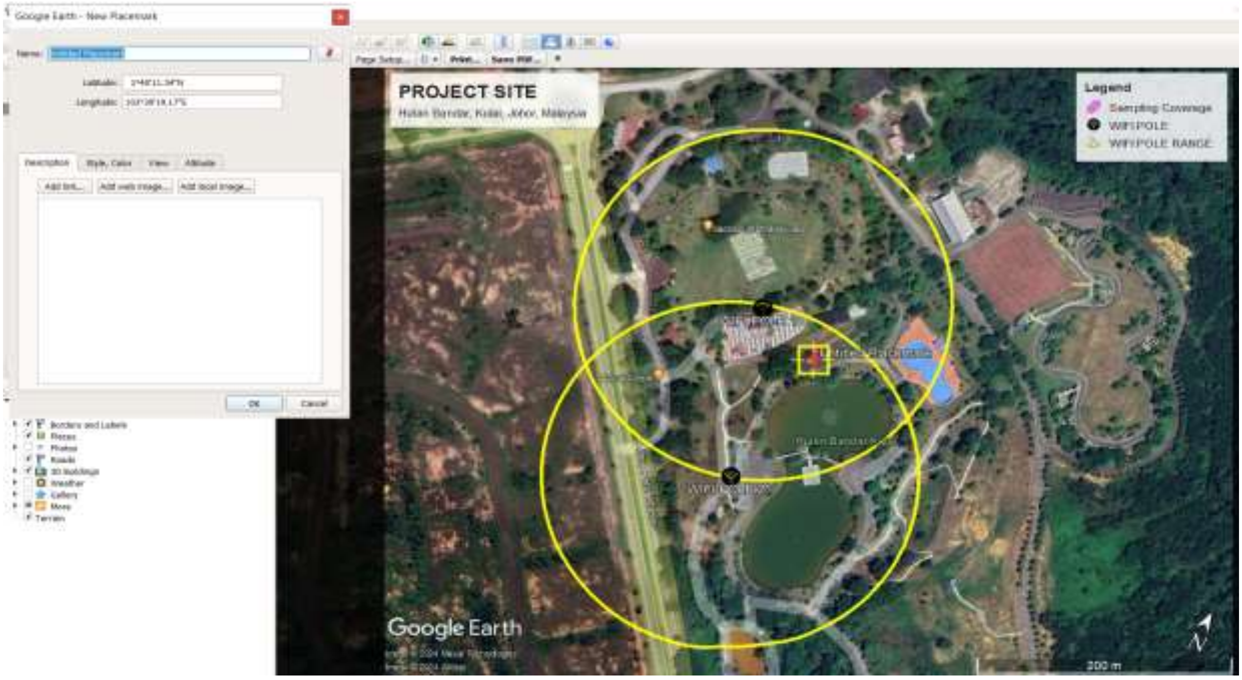

Figure 5. Wi-Fi Poles Coordinate and range placement in Google Earth Pro

3.4. ArcMap

ArcGIS, a robust geographic information system (GIS) software, employs heat mapping and kriging for spatial analysis. Heat maps visually represent Wi-Fi pole effectiveness in Johor Bahru using color intensity based on survey data. Factors like signal strength, reliability, and speed contribute to identifying areas with optimal Wi-Fi performance, aiding sensor placement and digital city development. Kriging, a geostatistical technique, creates a continuous Wi-Fi performance surface, offering insights into distribution. Leveraging ArcGIS capabilities, the study visualizes survey data to inform decision-making on optimal sensor deployment for enhanced safety monitoring and construction site management.

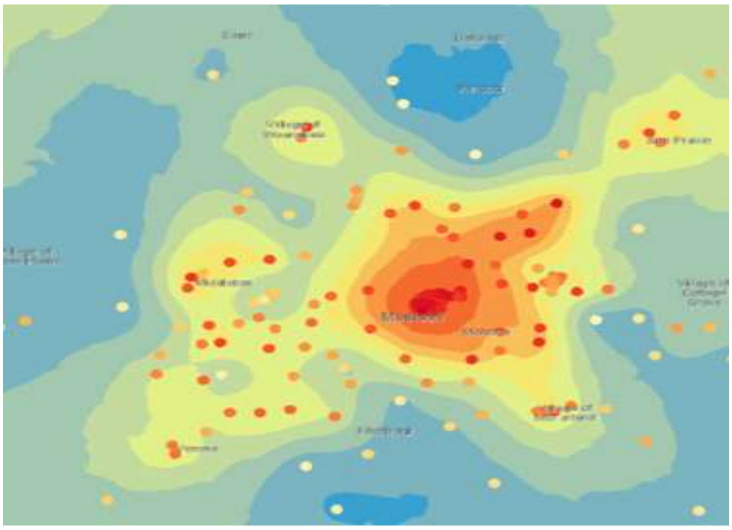

Figure 6. Kriging Map using the ArcGIS software

4.0 RESULT AND DISCUSSION

This study evaluated the performance of the Johor Public Wi-Fi network for supporting smart sensors, with a focus on wearable sensors. Surveys were conducted in Hutan Bandar, Kulai, Johor, gathering data on bandwidth, network providers, Wi-Fi infrastructure, and demographics of construction employees. The results highlight a predominantly male workforce with diverse qualifications and experience. The study explores Wi-Fi coverage, signal strength, and the potential use of wearable sensors, providing insights into the current status of the network and emphasizing the importance of reliable Wi-Fi infrastructure near construction sites.

4.1. Demographic

Demographic data underwent frequency analysis in SPSS software (version 27), with results presented in Table 3. Of the 15 respondents, 13 were males (66.7%) and 2 females (33.3%). The majority fell in the 31-40 age range, mostly holding bachelor's degrees, with 60% aged 31-40 and 6.7% above 40. The majority identified as Malay (73.3%), with the remaining 26.7% being Chinese. All respondents (100%) possessed a diploma or higher education, indicating a well-educated group with significant exposure to the construction industry. Among the 15 respondents, 11 had a bachelor's degree, and 2 had a diploma. Work experience varied, with 20% having less than 5 years, 20% between 5-10 years, and 60% with over 10 years. Despite differing experience levels, the study focuses on participants' opinions and feasible solutions, minimizing the impact of shorter work experience on result accuracy.

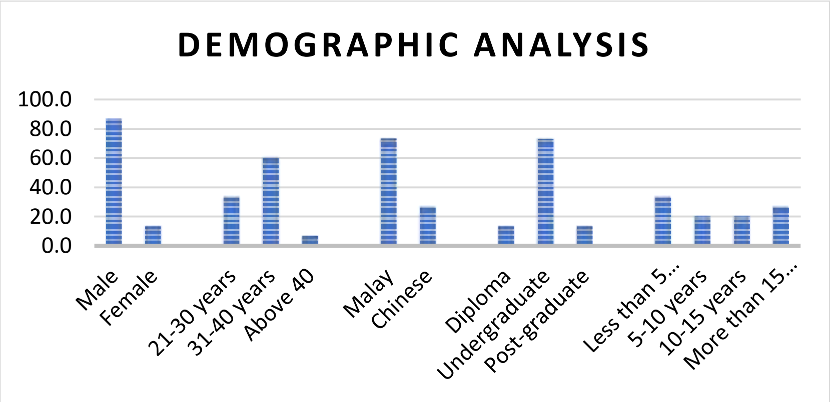

Figure 7. Graphical representation of Respondent Demographic

Table 3. Demographic information.

Demographic information			
Respondent	Element	Frequency	Percentage (%)
Gender	Male	13	86.7
	Female	2	13.3
Age	21-30 years	5	33.3
	31-40 years	9	60
	Above 40 years	1	6.7
Race	Malay	11	73.3
	Chinese	4	26.7
Academic Qualification	Diploma	2	13.3
	Undergraduate	11	73.3
	Post-graduate	2	13.3
Work Experience	Less than 5 years	3	20
	5-10 years	3	20
	10-15 years	5	33.3
	More than 15 years	4	26.7

Rating Scale:
1 - Strongly Disagree 2 - Disagree 3 - Moderate/Not Sure 4 - Agree 5 - Strongly Agree

4.2. Satisfaction on Public Wi-Fi Performance at Construction Sites nearest to Hutan Bandar

The frequency analysis gauges’ respondents' agreement on Public Wi-Fi performance satisfaction, summarizing replies to identify prevalent opinions and points of view. Table 4, derived from the questionnaire survey results, illustrates the extent of agreement among respondents regarding satisfaction with Public Wi-Fi performance.

Table 4. Frequency analysis for satisfaction on Public Wi-Fi performance

No	Satisfaction on Public Wi-Fi	Rating of Respondents (Frequency and Percentage)				
		1	2	3	4	5
B1	Experience in using Public Wi-Fi	0%	0%	66.7%	33.3%	0%
B2	Speed & Quality	0%	20%	73.3%	6.7%	0%
B3	Connectivity Issues	0%	6.7%	40%	40%	13.3%
B4	Unavailability of high-speed internet	13.3%	20%	33.3%	26.7%	6.7%
B5	I am very satisfied with the internet speeds	0%	0%	93.3%	6.7%	0%

Based on Table 4, many respondents are uncertain about the existence of the free public Wi-Fi provided, as reflected by the high percentage of 'Moderate/Not Sure' responses in the survey. For example, 66.7%, 73.3%, and 93.3% of the respondents were uncertain about their experience using Public Wi-Fi, the speed and quality, and the internet speeds, respectively. Additionally, a notable portion of past Wi-Fi users reported issues related to internet speed. These findings suggest that while the existing Public Wi-Fi infrastructure offers some connectivity, it falls short in providing the high-speed service necessary to support IoT applications and wearable sensor technologies on construction sites. Moreover, increased awareness and promotion are needed to boost usage. Addressing these concerns could significantly enhance overall satisfaction and the effectiveness of the infrastructure.

4.3. What challenges or issues have you experienced with Wi-Fi connectivity at construction sites?

The survey results highlight several challenges and issues related to Wi-Fi connectivity at construction sites. Table 5 presents the frequency analysis of these issues.

Table 5. Frequency analysis for issues faced with Wi-Fi on construction sites.

Issues	Frequency	Percent	Valid Percent	Cumulative Percent
Inconsistent connection	8	21.1	21.1	21.1
Lack of Wi-Fi infrastructure	9	23.7	23.7	44.7
Limited coverage area	9	23.7	23.7	44.7
Security concerns	1	2.6	2.6	68.4
Slow internet speed	2	5.3	5.3	71.1
Weak signal strength	9	23.7	23.7	76.3
Total	38	100.0	100.0	100.0

Table 5 reveals that the most common problems include a lack of Wi-Fi infrastructure (23.7%), limited coverage area (23.7%), and weak signal strength (23.7%). These findings suggest that while Wi-Fi is available at some sites, its reach and reliability are often insufficient for consistent, effective use. Additionally, inconsistent connections (21.1%) and slow internet speeds (5.3%) further exacerbate these issues, potentially hindering the deployment of IoT and wearable sensor technologies, which rely on stable and robust connectivity for real-time monitoring. Although security concerns were noted by a small percentage of respondents (2.6%), the overall focus remains on improving the quality and reach of Wi-Fi infrastructure to better support digital solutions on construction sites.

4.4. The need for wearable sensors for construction worker monitoring on-site.

The results from the RII-based ranking of perceived contributions of wearable sensors provide valuable insights into participants' opinions.

The highest-ranking factor is the perceived need for wearable sensors, with an RII of 0.827, indicating that respondents strongly believe in the essential role of wearable sensors in improving safety on construction sites. This high score suggests a consensus among participants regarding the critical importance of wearable sensors for enhancing safety measures in the construction industry.

Following closely is the effectiveness of wearable sensors in productivity, with an RII of 0.747. This indicates a substantial acknowledgment of the positive impact that wearable sensors can have on the productivity of construction workers. The close ranking of these two factors underscores the interconnectedness of safety and productivity in the participants' perceptions.

Perceived impact on work quality and cost-effectiveness share the same RII score of 0.533, indicating a moderate level of agreement among respondents. While wearable sensors are perceived to contribute positively to work quality, there is an acknowledgment of the need for cost-effectiveness in their implementation. This balance in ranking suggests that participants recognize the importance of achieving a cost-effective solution while maintaining or improving work quality.

Table 6. RII-based ranking of perceived contribution of wearable sensors.

Wearable sensor Usage		RII	Rank
B1	Perceived Need	0.827	1
B2	Effectiveness in Productivity	0.747	2
B3	Perceived Impact on Work Quality	0.533	3
B4	Cost-Effectiveness	0.533	3

Table 7. Descriptive analysis for need for wearable sensors on construction sites

Item	Minimum	Maximum	Mean	Std. Deviation	Variance
Perceived Need: The use of wearable sensors is essential for improving safety on construction sites.	3.00	5.00	4.1333	0.74322	0.552
Effectiveness in Productivity: The use of wearable sensors positively impacts the productivity of construction workers.	2.00	5.00	3.8667	0.91548	0.838
Perceived Impact on Work Quality: Wearable sensors are perceived to improve the quality of work on construction sites.	2.00	5.00	3.2000	0.94112	0.886
Cost-Effectiveness	2.00	5.00	3.2000	0.94112	0.886

In summary, the RII-based ranking reflects a strong consensus on the essential need for wearable sensors in improving safety and productivity in the construction industry. Participants also consider the impact on work quality and cost-effectiveness as important factors, providing a nuanced understanding of their perceptions regarding the implementation of wearable sensor technology in construction sites.

4.5. Assessing Endorsement Levels: Wearable Sensors with Wi-Fi Connectivity for Construction Site Operations

The data reflects respondents' attitudes towards recommending the utilization of wearable sensors with Wi-Fi connectivity in construction site operations. Among the 15 participants, 6.7% expressed an "Extremely likely" inclination, indicating a high level of endorsement for this technology. The largest segment, constituting 33.3%, fell under the "Moderately likely" category, suggesting a moderately positive stance. Conversely, 6.7% expressed a clear disinterest, stating they are "Not likely at all" to recommend the technology. A notable 26.7% reported a "Somewhat likely" perspective, indicating a moderate level of interest. Another 26.7% fell into the "Very likely" category, showing a strong inclination towards recommending the use of wearable sensors. This breakdown illustrates a diverse range of attitudes, with the majority leaning towards positive recommendations.

Table 8. Frequency distribution of how likely respondents recommend WSDs.

How likely are you to recommend the use of wearable sensors with Wi-Fi connectivity for construction site operations?		
Response	Frequency	Percentage (%)
Extremely likely	1	6.7
Moderately likely	5	33.3
Not likely at all	1	6.7
Somewhat likely	4	26.7
Very likely	4	26.7
Total	15	100.0

4.6. Absence of Wearable Sensor Adoption in Johor's Construction Industry

The information from Table 9 strongly indicates a notable absence of the adoption of wearable sensors or IoT devices for monitoring and data collection at construction sites in Johor. With all 15 respondents having not used such technologies, it points towards a prevailing trend of non-adoption within Johor and possibly Malaysia. The data suggests a gap in the integration of these advanced monitoring tools, potentially signaling either a lack of awareness, reluctance, or other barriers hindering their adoption in the construction industry in Johor.

Table 9. Frequency distribution of how many respondents have used wearable sensors on site

Have you used wearable sensors or IoT devices for monitoring and data collection at construction sites?		
Response	Frequency	Percentage (%)
No	15	100.0
Yes	0	00.00

4.7. Wi-Fi coverage level

Wi-Fi signal speed readings are assessed in units of signal strength (dBm). The Wi-Fi analyzer employs three scale readings for Wi-Fi signal strength: -100 dBm to -85 dBm (indicated as poor (1)), reflecting weak signal strength; -84 dBm to -60 dBm (marked as moderate); and -59 dBm to -40 dBm (noted as good) (Nayan et al., 2016). The fieldwork aimed to determine the coverage area of Public Wi-Fi, and Figure 8 illustrates areas categorized as Poor (Red), Moderate (Yellow), and Good (Green).

After obtaining signal strength data, it is transferred to the ArcMap Software to generate heatmaps, illustrated in Figure 8, providing a visual representation of Public Wi-Fi accessibility levels. Understanding the reach and distribution of Public Wi-Fi within Taman Merdeka is crucial for assessing its availability. The analysis of Wi-Fi coverage reveals that it is present near the poles, indicating existing Wi-Fi infrastructure. However, the signal strength is weaker or nonexistent in construction areas. This deficiency in coverage poses challenges to the implementation of wearable sensors in construction zones. The findings underscore the necessity for enhanced coverage and infrastructure to ensure the effective deployment of wearable sensors, thereby advancing the construction industry.

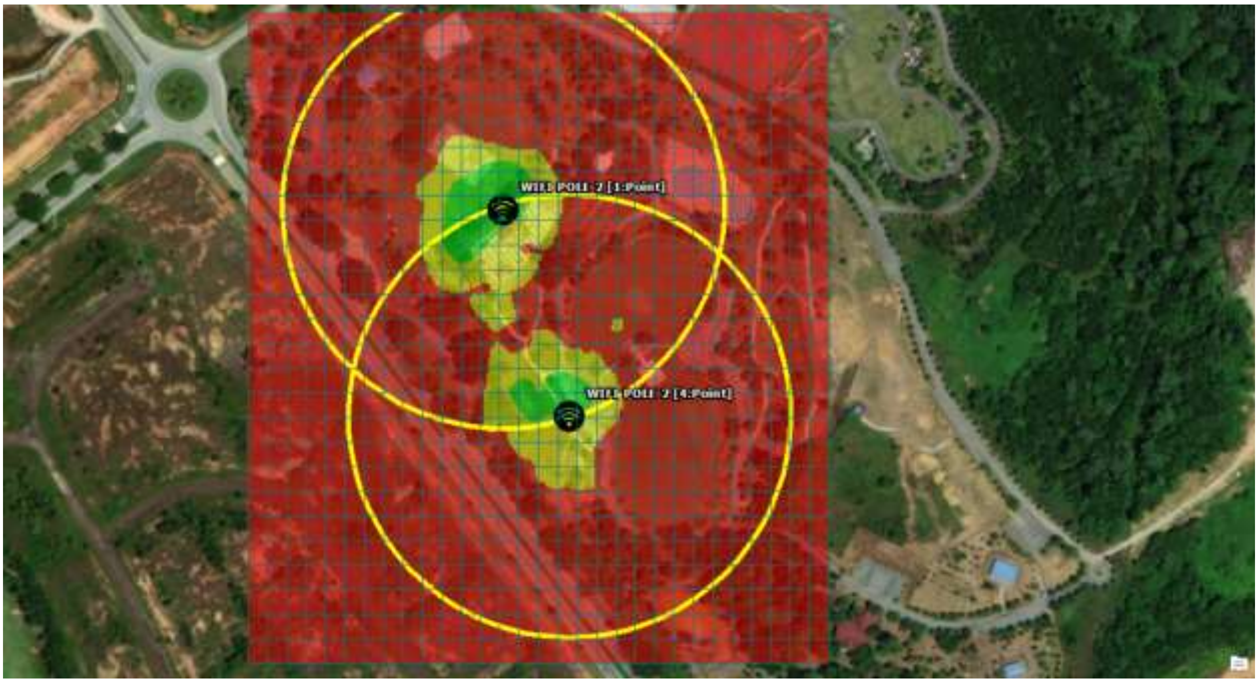

Figure 8. Kriging Heat Map of Wi-Fi connectivity and wearable sensor suitability using the ArcGIS software.

Table 10. Types of Network Provider and Data Bandwidth

Location	Type of Network Provider	Network Generation			Spot-r system by Triax Technologies
		3G (<2Mbps)	4G (< 1Gbps)	5G (> 1Gbps)	
Hutan Bandar, Kulai.	Public Wi-Fi	X	✓	X	✓
	Concessor	X	✓	✓	✓

The Table 10 indicates that for the Spot-r system by Triax Technologies to function effectively, adequate internet speeds are essential. It is apparent that this system could potentially operate on both concessor internet and the existing WiFi infrastructure in the area. However, the optimal speeds are only available in limited, specific areas in close proximity to the WiFi pole.

5.0 CONCLUSION

The study has effectively identified both capabilities and limitations of the existing Wi-Fi infrastructure in Johor concerning safety monitoring on construction sites. The analysis reveals that while coverage is concentrated near Wi-Fi poles, limitations such as inconsistent connections, limited coverage areas, and weak signal strength in construction zones pose challenges. Recommendations include strategic placement of Wi-Fi poles and enhancements in infrastructure to ensure optimal coverage.

Survey data interpretation sheds light on the effectiveness of free Wi-Fi in the area. Respondents' feedback indicates prevalent issues such as inconsistent connections, limited coverage, and security concerns. The study underscores the need for improvements in Wi-Fi infrastructure to address these challenges, emphasizing the importance of reliable connections for efficient safety monitoring and construction site management. The survey results provide a comprehensive understanding of challenges and issues faced in monitoring construction sites. These challenges include inconsistent connections, lack of infrastructure, limited coverage, slow internet speeds, and weak signal strength. The identified issues stress the necessity for enhanced coverage, improved infrastructure, and security measures to facilitate effective safety monitoring and project management.

Spatial analysis, facilitated by tools like Google Earth Pro and ArcGIS, has allowed the creation of heat maps based on manually collected data. These maps visually represent the effectiveness of Wi-Fi poles, indicating areas with poor, moderate, and good coverage. The findings emphasize the need for enhanced coverage in construction areas, ensuring reliable connections for efficient safety monitoring.

Despite the valuable insights provided, he studies relied on survey data and manual spatial analysis and focused on Johor Bahru, which may limit the generalizability and accuracy of the findings. Future research should address these limitations by incorporating broader data sources and exploring additional technological solutions to enhance Wi-Fi infrastructure and safety monitoring.

RECOMMENDATIONS

The recommendations for improving Wi-Fi infrastructure at construction sites in Johor Bahru focus on several key areas. First, enhancing the existing infrastructure is essential to address the limitations and challenges identified, ensuring that connections across construction sites are consistent and reliable. Additionally, implementing robust security measures is crucial to safeguard the Wi-Fi networks, directly addressing the concerns raised by survey respondents. Strategic placement of Wi-Fi poles should also be considered, particularly in areas where coverage gaps have been identified, to ensure effective monitoring throughout construction zones. Furthermore, continuous monitoring and feedback collection are recommended to assess the effectiveness of the Wi-Fi infrastructure, enabling ongoing improvements that can adapt to evolving challenges.

By implementing these recommendations, the construction industry in Johor can transform its Wi-Fi infrastructure to support efficient safety monitoring and real-time connectivity management, ultimately enhancing overall project management and worker safety (Yoon et al., 2024).

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