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A SOCIO-TECHNICAL FRAMEWORK FOR INTERNET OF THINGS (IOT) ADOPTION IN URBAN FARMING: MALAYSIA

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Abstract:

Urban farming represents a essential strategy for improving food security, sustainability and resource management efficiency in rapidly urbanising countries such as Malaysia. Accelerating urbanisation and the implementation of digital transformation initiatives in smart agriculture technologies changes the agricultures landscape. The Internet of Things (IoT) has notably enhanced the efficiency, sustainability and productivity of urban farming systems, particularly in hydroponic and vertical farming. However, IoT implementation in urban farming remains limited due to budgetary constraints, insufficient digital literacy, infrastructural constraints, technical complexity, legislative barriers, and resistance to behavioural change. Existing research has focused on technology implementation and system

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performance, with limited analysis of the interplay among technological, behavioural, infrastructural, and institutional elements. Although the socio-technical aspects of technology adoption have been widely examined in the broader agricultural context, a comprehensive framework specifically addressing IoT adoption in Malaysian urban farming remains lacking. Therefore, this research proposes an integrated socio-technical framework based on Socio-Technical Systems Theory (STS) with technological and non-technological determinants to describe the adoption of IoT in Malaysian urban farming. A qualitative literature-based method was employed by synthesising findings from selected studies on smart agriculture, hydroponics, vertical farming, IoT technologies, and technology adoption. The findings indicate that IoT technologies enhance the efficiency, sustainability, productivity, and resource management of urban farming systems. Still, these benefits can only be fully realised with support from economic readiness, government support, technical competency, good infrastructure and positive user behaviour. The proposed framework integrates technological, infrastructural, policy, behaviour, and economic into a socio-technical framework for the Malaysian context. In addition, it provides practical guidance for policymakers, educators, practitioners, and urban communities to sustain urban farming and strengthen national food security initiatives.

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Keyword:

IoT; Malaysia; Smart Agriculture; Technological Trends; Urban Farming

Introduction

Worldwide, the food production system is affected by urbanisation, population growth, and climate change. In Malaysia, urban areas have limited land due to the increasing human population. In addition, the land is reserved for agricultural purposes, but this has become limited, affecting food security and sustainable agriculture (Marzuki and Jais, 2020). The old agriculture method has limitations for implementation in urban settings due to a lack of land, worker shortages, environmental constraints, and additional operational costs.

Urban farming refers to any agricultural activities conducted within or around urban areas. The activities include vertical farming, rooftop farming, hydroponics, and indoor agriculture. Murdad et al. (2022) stated that urban farming became increasingly significant during the COVID-19 pandemic due to disruptions in food supply chains and increased awareness of food security. The implementation encourages communities in urban areas to grow their own food, thereby automatically improving food accessibility. Indirectly, by reducing food imports, food consumption can be significantly reduced to support sustainable lifestyles.

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Technologies like IoT, automation, cloud computing, artificial intelligence (AI), and data analytics are now part of modern agriculture under the Industrial Revolution 4.0. IoT uses networked sensors and cloud systems to monitor conditions such as humidity, temperature, soil moisture and nutrient levels in real time. As an example, Cloudfarm lets farmers manage their farms remotely through mobile or web applications, making operations more accessible and efficient (Rousalis et al., 2018). Smart farming systems help boost productivity and reduce manual work by automating tasks such as nutrient delivery, environmental control, and watering (Kamal and Saxena, 2026). Recent studies show that IoT is useful in vertical farming and hydroponics. Thinakaran et al. (2025) created a Smart Vertical Farming System (SVFS) with IoT to track factors like soil moisture, light and temperature. They found that this system led to higher leaf yields and better growth than traditional methods. Similarly, En et al. (2026) found that IoT based hydroponic systems improved plant growth and allowed for better monitoring of pH, water temperature and nutrients.

Most earlier studies on IoT in urban farming have focused on how well the technology works, such as sensor accuracy, automation efficiency, cloud-based monitoring, irrigation optimisation, and crop productivity, but have overlooked on factors like user readiness, government support, policy, and how people adapt to new technology (Thinakaran et al., 2025; En et al., 2026; Syafiq et al., 2025). Some studies have looked at the social and technical sides of smart farming and the implementation of technology. Bahari et al. (2024) used the Technology–Organisation–Environment (TOE) framework to study organisational and environmental factors while Sa'don and Salim (2021) explored behavioural factors using the Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB). Jazman et al. (2025) also pointed out the role of social and technical interactions in their studies.

In Malaysia, there is a gap where urban farming has been implemented. Factors like national food security, fast urban growth, different levels of digital skills, infrastructure, and government support play a major role. Even though IoT use in Malaysia is increasing but there is still no complete framework that explains how all the factors integrate to make sure the IoT adoption success. This research aims to fill the gap by providing the socio-technical framework for Malaysia. In this research, the main theory used is Socio-Technical Systems Theory (STS). The theory emphasises the interaction between technical and social systems. It considers the relationship between the factor like user readiness, organisational support, digital infrastructure, policy and behavioural. In addition, this research integrates well-known technology adoption theories, including the Technology Acceptance Model (TAM), the Technology–Organisation–Environment (TOE) framework, the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Diffusion of Innovations (DOI).

Literature Review

Urban Farming and Food Security in Malaysia

Urban farming is increasingly seen as an important way to address food security concerns and promote sustainable urban growth in Malaysia. Rapidly growing urban populations, rising food prices, and disruptions to food supply systems have heightened public interest in local food production. Murdad et al. (2022) reported a substantial increase in urban agricultural initiatives during the COVID-19 pandemic, with households turning to alternative food sources and self-sustaining techniques. Urban farming methods offer benefits such as lower transportation costs, greater access to fresh veggies, and more efficient land use. Hydroponics and vertical farming are among the most common forms of urban farming, as they are well-suited to the constraints of urban space. Yapp et al. (2025) has been reported that hydroponic and vertical farming are gaining accepted in Malaysia since these method boost crop yields while using limited land. Urban farming helps the environment by cutting down the food transport distances, support eco-friendly habits and encourage use of resources efficiently. Ivascu et al. (2021) found that people in urban areas are more likely to accept urban farming compare rural area.

IoT Technologies in Urban Farming

IoT technologies plays a key role in today's smart farming systems by making automation, remote monitoring, and data driven agricultural management possible. These systems use sensors, microcontrollers, cloud platforms, and communication networks to collect and process real time data. Thinakaran et al. (2025) introduce a Smart Vertical Farming System using IoT to track temperature, soil moisture, and light. The results showed that IoT solutions improved plant growth and reduced the manual checking. En et al. (2026) also created an IoT hydroponic system with Arduino platforms and used the cloud to monitor the plant.

Jazman et al. (2025) built a smart hydroponic farming systems using ESP8266 microcontrollers, relay modules, ultrasonic sensors, and mobile-based monitoring using the Blynk application. They found that the automation makes farming more accessible and reduces manual labour in urban areas. In addition, Syafiq et al. (2025) designed an IoT-based smart agricultural system known as Agrilink that can optimise water use and environmental control in urban farming systems.

There are various benefits of integrating IoT technologies into agriculture, including:

- Monitoring of environmental conditions in real time
- Automated irrigation and nutrient management
- Better resource efficiency
- Reduced labour requirements
- Data-driven decisions
- Increased crop productivity

Smart Farming Adoption and Technology Acceptance

Many factors shape how the IoT technologies are adopted in agriculture, including technological, economic, organisational, and society. Researchers have been used different models to describe human's behaviour when technology has been adopted in smart farming. The Technology Acceptance Model (TAM) emphasises that people are more likely to accept technology if the technology is beneficial and easy to use. Sa'don and Salim (2021) used TAM and TPB theory when studying the adoption of IoT in urban farming. They found that social influences are the main factor for urban farming. The Technology-Organisation-Environment (TOE) framework is another common approach in research on smart farming. Bahari et al. (2024) created a model based on TOE, highlighting the government support, digital infrastructure, technological compatibility, and financial readiness, as key determinants for adopting IoT in agriculture. Yaacob et al. (2026) found that farmers decided to adopt IoT technologies based on usefulness, and easy to use besides support from the government.

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Theoretical Foundation

Socio-Technical Systems Theory (STS) theory states that both technical and social systems must work together for organisational performance and new technology adoption rather than focusing solely on the technology. STS highlights the importance of aligning technology with human communities. Earlier research has used theories such as the Technology Acceptance Model (TAM), the Technology Organisation Environment (TOE) framework, the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Diffusion of Innovations (DOI) to study technology adoption. However, these theories usually focus on only certain parts of the adoption process.

Methodology

This research carried out a qualitative literature-based review. The relevant literature has been searching using the Google Scholar database with keywords: *Internet of Things*, *IoT*, *urban farming*, *smart agriculture*, *hydroponics*, *vertical farming*, *technology adoption*, and *ASEAN*. The review focused on peer-reviewed journal articles published between 2018 and 2026 that catered to IoT applications, smart farming, urban agriculture, technology adoption, and social and technical factors. The articles were excluded if emphasises solely on hardware development without adoption, were not written in English, or were conference or duplicate.

A total of twenty-first (21) relevant articles were selected for qualitative analysis. These articles were review using thematic analysis to identify common trend in technology, social and technical challenges and factor influence adoption. The five main processes undergone in methodology has been illustrated in Figure 1.

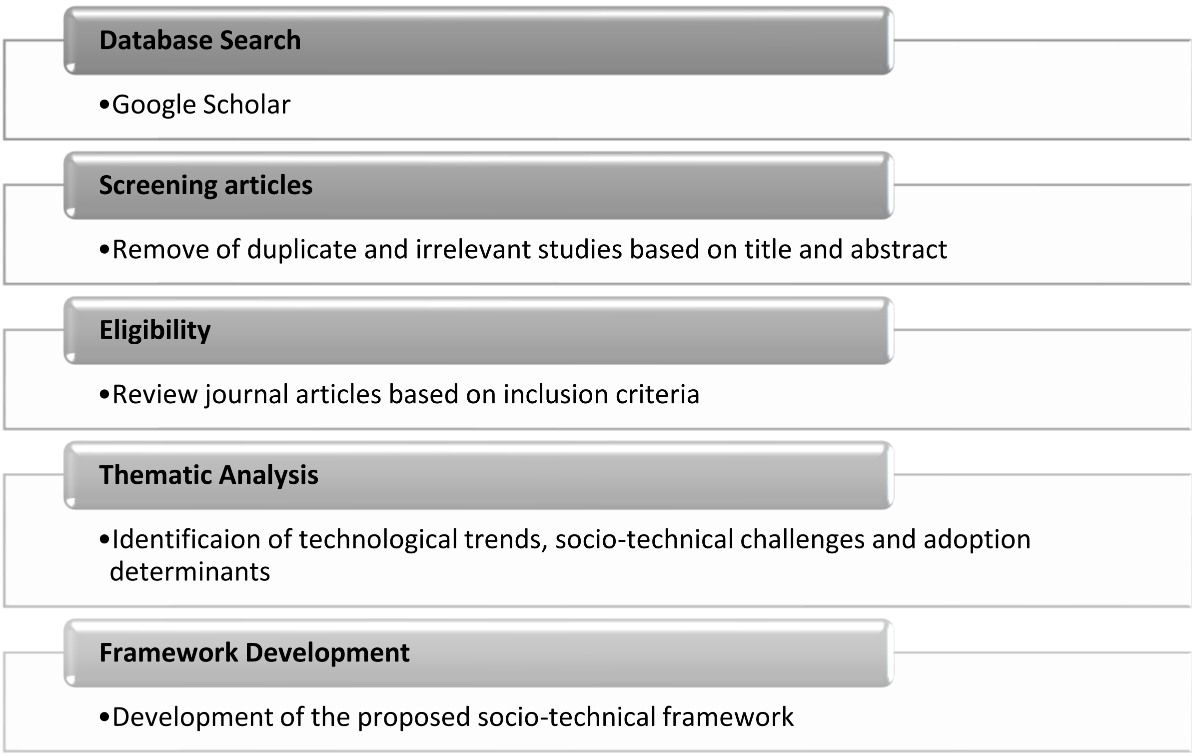

Figure 1: Methodology Process

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Results and Discussion

Technological Trends and Socio-Technical Challenges of IoT Adoption in Urban Farming

Previous research showed that IoT technologies are increasingly being incorporated into urban farming systems in Malaysia, particularly in hydroponic and vertical farming applications. These systems employ sensors, cloud platforms, mobile applications, and automation technologies to enhance monitoring, irrigation, environmental management, and agricultural productivity (Thinakaran et al., 2025; En et al., 2026; Syafiq et al., 2025). IoT-enabled smart sensors facilitate precision farming through real-time monitoring and automation (Kamal & Saxena, 2026), while cloud-based systems are critical to enhancing farm data management and remote accessibility (Rousalis et al., 2018). Furthermore, Jazman et al. (2025) found that IoT-based hydroponic systems improve accessibility and reduce labour dependence in urban settings.

The outcome emphasises the contribution of IoT technology to sustainability, productivity, and effective resource management in urban agricultural settings. Nevertheless, these technological gains are hampered by various socio-technical hurdles in the IoT adoption. Ahmad et al. (2025) and Yapp et al. (2025) highlighted financial constraints, high operational costs, and maintenance costs as major impediments to adoption. Furthermore, Omar et al. (2024) and Yaacob et al. (2026) stated that a lack of digital literacy and technical skills hinders the effective use of IoT systems. Implementation is also negatively affected by infrastructure limitations such as inconsistent internet access and limited digital facilities (Rousalis et al., 2018; Bahari et al., 2024). In addition, behavioural and lifestyle characteristics influence readiness to adopt, since users are more likely to accept technologies that are accessible, user-friendly, and fit with daily routines (Jazman et al., 2025; Sa'don & Salim, 2021). These findings suggest that IoT adoption in urban farming is affected not only by technological capabilities but also by economic, infrastructural, behavioural, and socio-technical factors in the Malaysian urban farming ecosystem.

The results show that the benefits of IoT depend on the social and technical factors that support its success. IoT able to improve productivity, resource use, sustainability but need to rely on economic situation, user competency, infrastructure, policy support and behavioural acceptance. This emphasises that having technology does not confirm the success of IoT adoption in urban farming.

Proposed Socio-Technical Framework for IoT Adoption in Urban Farming

This research proposes a socio-technical framework for understanding the scenarios in Malaysia when IoT has been adopted. Figure 2 describes the framework with combine the related factors influencing the IoT adoption. The supporting references are listed in Table 1.

The proposed socio-technical framework shows that IoT adoption in Malaysian depends on how of technology, technical, economic, technical, policy, society behavioural, and infrastructure interact. The framework highlights that both technical skills and social factors are important for successful adoption. The combination of these dimensions eventually leads to sustainability, higher production, and improved food security for urban agricultural ecosystems in Malaysia.

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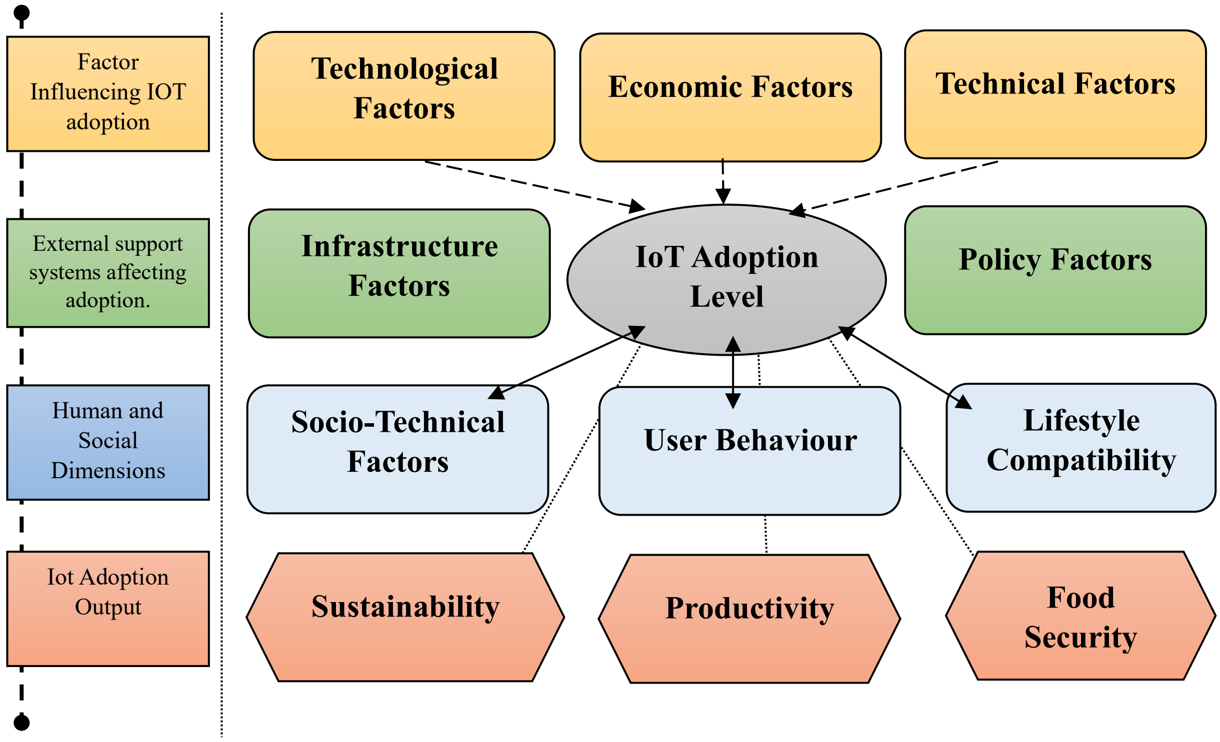

Figure 2: Proposed Socio-Technical Framework for IoT Adoption in Urban Farming

Table 1: References Related to The Proposed Socio-Technical Framework

Framework Component	Supporting References
Technological Factors	Thinakaran et al. (2025); En et al. (2026); Syafiq et al. (2025); Kamal and Saxena (2026); Rousalis et al. (2018)
Economic Factors	Ahmad et al. (2025); Omar et al. (2024); Yapp et al. (2025)
Technical Factors	Omar et al. (2024); Yaacob et al. (2026); Sa'don and Salim (2021)
Infrastructure Factors	Rousalis et al. (2018); Bahari et al. (2024); Ahmad et al. (2025)
Policy Factors	Bahari et al. (2024); Murdad et al. (2022); Yapp et al. (2025)
Socio-Technical Factors	Jazman et al. (2025); Sa'don and Salim (2021); Ivascu et al. (2021)
User Behaviour and Lifestyle Compatibility	Jazman et al. (2025); Sa'don and Salim (2021); Yaacob et al. (2026)
Sustainability, Productivity, and Food Security	Murdad et al. (2022); Yapp et al. (2025); Kamal and Saxena (2026)

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Conclusion

This research examines both the latest technologies and the social and technical challenges of using IoT in urban farming in Malaysia. The results show that IoT tools like smart sensors, cloud-based monitoring, and automation systems make the growth of plants more efficient and productive. It also allows real time monitoring and data driven operations that are beneficial for urban areas that have limited space. However, there are still obstacles using IoT, since the high costs, a lack of technical expertise, low digital skills, poor infrastructure, and resistance to accept new technology. The framework designed is based on STS theory and uses idea from well-known technology adoption theories to the Malaysian urban farming perspective. In summary, this research contributed to a better understanding of smart agriculture in Malaysia among researcher, policymakers, educator, and society and promoting sustainable urban farming as well as food security in Malaysia.

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analysis of IoT technologies and urban farming trends. Azuan Ahmad assisted in developing the socio-technical framework and interpreting adoption challenges within the Malaysian context. Shafinah Kamarudin managed the literature review, reference organisation, and critical revision of the manuscript to meet journal requirements. Amirul Asyraf Mohamad Zhahir supported data organisation, proofreading, formatting, and preparation of the final manuscript for submission. All authors reviewed and approved the final version of the manuscript before submission.

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