

# CONCEPTUAL TRUST-BASED ACCEPTANCE MODEL FOR EVALUATING THE ADOPTION OF WEARABLE SENSING DEVICES FOR CONSTRUCTION SAFETY AND HEALTH MONITORING

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**ABSTRACT:** Despite the numerous benefits of wearable sensing devices (WSDs) as reported in existing studies, their adoption and implementation in the construction industry have been slower than that of other industries such as healthcare, logistics, sports and fitness, etc. This slow uptake has been attributed to construction workers' and industry professionals' lack of trust rooted in privacy and security concerns. A deeper understanding of the factors associated with these concerns is expected to enable users and stakeholders to gain better insights into their relationships and how they influence the future of WSDs in the construction industry. This study proposes a conceptual model for assessing the impact of data privacy, security, and trust on the adoption and implementation of WSDs for safety and health management in construction. First, the constructs and factors associated with privacy, security, and trust are identified, defined, and characterized. Second, applicable theories and models for adoption and implementation with respect to privacy, security, and trust in WSDs are reviewed. Thereafter, a conceptual framework that could be used to evaluate key stakeholders' perceptions of the impact of data privacy, security, and trust in adopting WSDs is developed. It is expected that the insights generated from the application of the developed model will help foster the effective adoption and implementation of WSDs among construction stakeholders for the prediction and prevention of injuries, illnesses, and fatalities in the construction industry.

## 1. INTRODUCTION

The construction industry has a high incident rate, with more than 26,000 worker deaths in the United States within the last twenty years (Kurien et al. 2018). Construction environments are often labor-intensive and fraught with potential hazards, resulting in workplace injuries, early retirements, and long-term health issues among employees (Chen et al. 2023). In contrast to the multiple shortcomings of traditional techniques of assessing safety performance, automated safety monitoring holds considerable promise for precise and continuous monitoring of workers' safety and health performance on construction sites (Mark and Teizer 2012; Park et al. 2016). Implementing emerging technologies in construction to analyze and interpret health and safety data can enhance our understanding of the current work environment and the health of construction workers, potentially leading to improved workplace safety practices (Abuwarda et al. 2022). Emerging technologies, such as wearable sensing devices (WSDs) hold great potential to enhance the safety and health management of construction workers (Awolusi et al. 2018; Ahn et al. 2019). These devices monitor workplace safety and human health by collecting real-time data from users and their surrounding environment (Chen et al. 2023). WSDs such as smart watches, smart vests, and smart clothing continuously monitor the users' health data (e.g., their heart rate, blood pressure, and body temperature),

while also collecting environmental information like their movements and location (Choi et al. 2017). They can also measure brain activity, fatigue, posture, and acceleration (Abuwarda et al. 2022), with several studies reporting that the primary use of WSDs in construction includes preventing musculoskeletal disorders, fall prevention, evaluating physical exertion, mental fatigue, and hazard-recognition abilities (Ahn et al. 2019; Nnaji et al. 2021).

Although WSDs have been thoroughly researched in fields like healthcare, yielding significant insights into patient health, their application in construction remains sparse, with a slow uptake in the construction sector (Nnaji et al., 2021). Privacy, security, and trust concerns about the collected or transmitted health data and user hesitancy to wear the devices have impeded implementation and are a social challenge in the widespread adoption of WSDs in construction (Abuwarda et al. 2022). Privacy and security are essential for establishing and sustaining trust. When individuals perceive that their personal information is protected and secure, they are more likely to trust the entities that collect and manage it (Leschanowsky et al. 2024). Trust in emerging technologies, such as WSDs, can significantly control acceptance and implementation as distrust may reduce the likelihood of adoption (Afroogh et al. 2024). This study presents a conceptual model that could be used to evaluate the crucial role of trust in user adoption, alongside privacy and security, and how these elements affect the perspectives and readiness of construction workers and stakeholders to adopt WSDs. This evaluation is expected to provide insights that lay the groundwork for comprehending the future of WSDs in construction and improving trust in these devices, ultimately enhancing safety and health monitoring.

## **2. LITERATURE REVIEW**

### **2.1 WSDs in Construction Safety and Health Monitoring**

Due to the significant and inherent risks associated with construction activities, the construction industry imposes higher standards for safety protocols to prevent worker injuries and fatalities on job sites (Chen et al. 2023). Research has been conducted to develop technologies that assist in monitoring workers, addressing the limitations of human oversight alone. These technologies include WSDs that gather data such as physiological monitoring, environmental sensing, proximity detection, and location tracking (Awolusi et al. 2018; Chen et al. 2023). The data collected by these devices is often stored within the device itself or uploaded to cloud software that compiles the information, raising substantial privacy and security concerns among users (Awolusi et al. 2019).

WSDs are currently utilized in construction to gather information about user health and location. Human health is monitored by kinematic and physiological sensors, including cardiac, skin, muscle, eye, and brain sensors, which track user health. On the other hand, user location is monitored using location or positioning sensors, such as GPS, Bluetooth, and radio proximity detection (Awolusi et al. 2018; Ahn et al. 2019). Monitoring this data has fostered a safer working environment, improving work efficiency and worker health (Chen et al. 2023). Despite the advantages of WSDs in construction, research has identified user concerns about the privacy and security of their collected health data, which hinders the implementation of these devices (Nnaji et al. 2021).

### **2.2 Trust of WSDs and Concerns Regarding Privacy and Security**

Trust in emerging technologies, like WSDs, is crucial for their acceptance and implementation. A lack of trust can considerably impede the chances of adoption (Afroogh et al. 2024). Previous studies have examined and identified the components of data privacy, security, and consumer trust in the adoption of innovative technologies, such as WSDs and Internet of Things (IoT) devices (Sicari et al. 2015; Okonkwo et al. 2025). These earlier studies have pinpointed factors that may influence stakeholders' perceptions of WSDs and the concerns contributing to the industry's reluctance to implement these devices. They have primarily focused on individuals' willingness to adopt WSDs through a conventional technology acceptance model framework, overlooking the evaluation of a trust-based perspective as a core element. Additionally, most existing studies have centered on evaluating the behaviors of current users (Choi et al. 2017; Awolusi et al. 2024), lacking research regarding the behavior of potential users. The role of trust and its direct impact on the behavioral intention to adopt WSDs has not been evaluated. In the conceptual model proposed in

this study, the trust of prospective WSD users may be assessed regarding the handling and monitoring of the collected data. Further analysis of trust and technology adoption is necessary to better understand the challenges related to privacy, security, and trust in the adoption of WSDs within the construction industry. Therefore, a model that identifies trust as a primary factor in adoption is needed to provide valuable insights into behavioral intention and the potential for improvement in trust.

### **2.3 Theories and Models for Evaluating Trust and Associated Constructs**

Various theoretical models support technology adoption, including the Theory of Diffusion of Innovation (DOI), the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Theory of Planned Behavior (TPB) (Okpala et al. 2021). While these models offer valuable insights, they mainly focus on predicting adoption rather than investigating the deeper factors influencing it (Amini 2014). The Technology Acceptance Model (TAM) (Davis 1989) has been used to assess factors affecting users' intent to adopt new technologies across diverse fields such as digital marketing, healthcare, and construction (Rahimi et al. 2018; Sorce and Issa 2021; Jaspers and Pearson 2022). Rooted in the theory of reasoned action from social psychology, it relies on two main components: perceived usefulness (PU) and perceived ease of use (PEOU) (Choi et al. 2017). Perceived usefulness reflects how much users believe new technologies, like WSDs, provide benefits, while perceived ease of use indicates how effortlessly they think these devices can be utilized for their intended functions (B.U. et al. 2021). Using the TAM to evaluate technology acceptance is challenging without considering additional factors that provide further context, highlighting the limitation of relying solely on TAM (Okpala et al. 2021).

As the TAM has been extensively used in technology acceptance (B.U. et al. 2021), the model has been modified to integrate technology acceptance with privacy, security, and trust dimensions. The Trust-Based Acceptance Model (TBAM), which recognizes trust as pivotal for this study, evaluates trust's role in technology adoption. The extended TBAM identifies key factors such as behavioral intention, PU, and PEOU that affect technology adoption (Patel et al. 2021). By analyzing PU, PEOU, and the element of trust, we can gain deeper insights into the industry's willingness to adopt these technologies and how trust could be improved.

## **3. RESEARCH METHOD**

### **3.1 Literature Review and Model Development**

To achieve the study's objective, existing literature was gathered, evaluated, and synthesized to conduct a comprehensive literature review on WSDs and technology adoption. This review aimed to identify applicable technology adoption theories that establish factors related to technology adoption. A conceptual model to assess pre-adoption behaviors was developed based on the applicable findings. The Trust-Based Acceptance Model (TBAM) is used to model the relationship between privacy and security factors in relation to their impact on organizational trust in WSD adoption for construction safety and health monitoring. Similar studies have been conducted to evaluate the impact of trust and privacy concerns in technology adoption in other industries, such as healthcare, using perceived usefulness (PU) and perceived ease of use (PEOU) and how they impact behavioral intention to adopt these technologies (Dhagarra et al. 2020). For instance, a study on facial recognition indicates that perceptions of privacy and security affect behavioral intentions, influenced by trust, perceived usefulness (PU), and perceived ease of use (PEOU) (Zhang, 2024). These studies assisted in synthesizing a new framework where PU and PEOU will directly impact trust and behavioral intention. Therefore, this study utilized TBAM in developing a conceptual framework to evaluate the impact of privacy and security on trust and the direct impact of trust, PU, and PEOU on behavioral intention to adopt WSDs.

### **3.2 Expert Review**

Four experts with significant expertise and experience in construction management, WSDs, and mobile information technology utilization carefully examined the conceptual model. These experts were purposively selected due to their strong background and expertise in this domain and the possession of

advanced degrees with industry and research experience ranging from 10 to 15 years. Their review was focused on ascertaining the validity of the proposed conceptual model and the selected constructs and measurement items. Using the feedback and insights obtained from these experts, the model was revised and improved.

## 4. FINDINGS

### 4.1 Trust and Associated Constructs Impacting WSD Adoption in Construction

#### 4.1.1 Privacy

Privacy includes an individual's control over sharing their personal or identifiable information, and determining when, how, and to what extent this information is disclosed (Afroogh et al. 2024). It covers various aspects: maintaining the confidentiality of communications, securing identity-related information, protecting location data, controlling who can access information, and managing how data is processed and shared (Afroogh et al. 2024; Mehri and Tutschku, 2017). Due to the nature of the personal data that WSDs collect on their users, concerns related to data privacy have emerged. Many workers may feel uncomfortable knowing that their employer or supervisor might have access to their personal health data from these devices (Thomas 2024). Industry buy-in and worker compliance have both been challenging due to these privacy concerns and questions surrounding who has access to the collected data (Schall et al. 2018). Any information that can be traced back to an identifiable individual, such as their health, biometrics, or racial identity, is classified as personally identifiable information (PII) (Thomas 2024; Okonkwo et al. 2025).

In a 2018 study on WSDs in the workplace, users were asked to identify their greatest concern regarding WSDs; their responses indicated that employee privacy and confidentiality were primary concerns, with employees reacting negatively to being monitored (Schall et al. 2018). Enhancing personal data privacy includes using PIN locks on devices, using password-protected cloud storage, avoiding storing data on local devices, and utilizing secured networks to transfer data to the cloud, thus minimizing the risk of data leaks (Vijayan et al. 2021). By ensuring PII data privacy through these measures, user information can be safeguarded from misuse or harm by unintended parties (Thomas, 2024). Trust can be fostered in WSDs when personally identifiable information data is considered private. Thus, the following hypothesis is put forward.

*H1: Privacy has a positive impact on trust in the use of WSDs*

#### 4.1.2 Security

Data security is closely related to data privacy, as it involves actions taken to maintain privacy and protect data from unauthorized use by unintended parties. The perception of data security reflects the extent to which consumers believe their protected personal information (PPI) can be kept secure and safeguarded from inappropriate access by unauthorized entities, such as viewing, storing, or manipulating data during transit and storage (Flavián and Guinalú 2006). The Confidentiality, Integrity, and Availability (CIA) Triad, illustrated in Figure 1, has significantly impacted the development and implementation of security practices in organizations and shaped our theoretical understanding of information security fundamentals (Samonas and Coss 2014). A trustworthy environment is considered established when providers of cloud computing, IoT storage, and WSDs ensure users' confidentiality, integrity, and availability, keeping their data secure (Mohanty et al. 2018). Trust develops when data confidentiality, integrity, and user availability of data are provided. The following can be hypothesized:

*H2: Security has a positive impact on trust in the use of WSDs*

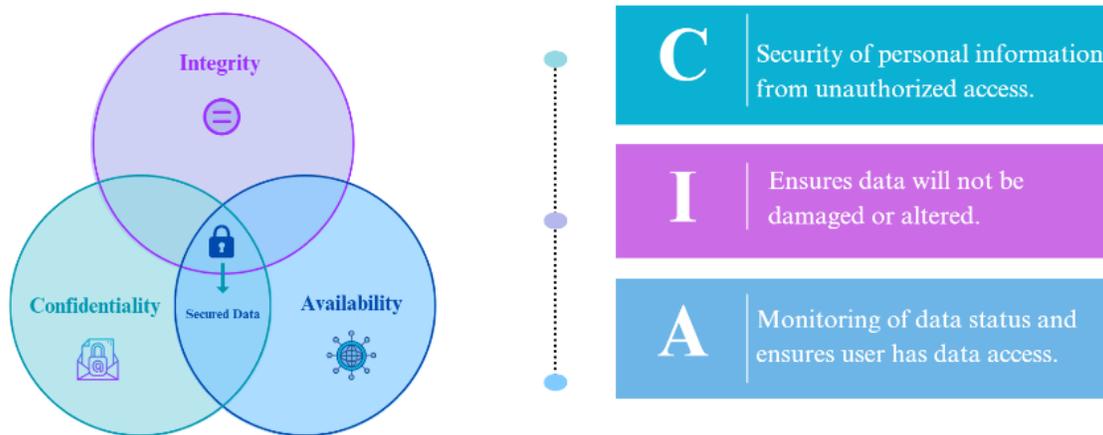


Figure 1: CIA Model Secured Data

#### 4.1.3 Trust

Trust is a crucial dynamic factor associated with technology adoption and develops over time, varying between initial and ongoing trust (Afroogh et al. 2024). Industry trust in WSDs is fundamental for adopting these technologies for widespread use in construction safety, as well as for trust in the operation and functionality of the devices (Thomas 2024). The growth in technological complexities and information processing with emerging technologies such as WSDs has only increased consumer distrust regarding collecting and storing data (Flavián and Guinalú 2006). Essential qualities of trustworthiness include "ability," "benevolence," and "integrity," which help establish the necessary attributes and characteristics for developing trust, as trust does not develop in isolation (Scharowski et al. 2024). These elements of trust are outlined in Figure 2.

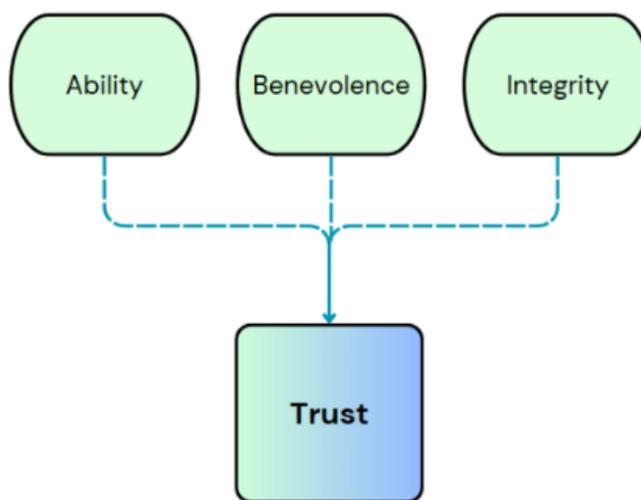


Figure 2: Elements of Trust

As trust develops, it influences technology adoption and long-term user engagement. Trust reflects users' intentions to adopt and consistently utilize wearable sensing devices. Therefore, grasping the trust-behavior connection is essential for integrating these devices into the construction industry. Existing literature shows that trust affects user behavior (Zhang 2024). Based on this, the following hypothesis has been proposed.

*H8: Trust has a positive impact on behavioral intention to use WSDs*

#### 4.1.4 Perceived Usefulness and Trust

Perceived usefulness (PU) is a key element of TAM, indicating how much users believe a technology can improve their job performance (Davis 1989). Recent studies on construction technologies (Afroogh et al. 2024) show that when workers find a technology useful, their confidence in the technology grows. Therefore, the following hypothesis is put forward.

*H3: Perceived usefulness positively impacts trust in the use of WSDs*

#### 4.1.5 Perceived Ease of Use and Trust

Davis (1989) argues that user-friendly technologies promote trust, as individuals associate usability with reliability and minimized risk. When wearable sensor devices are straightforward, user confidence increases, enhancing trust in the device and its results. This contributed to the development of the following hypothesis.

*H4: Perceived ease of use has a positive impact on trust in the use of WSDs*

#### 4.1.6 Perceived Ease of Use and Perceived Usefulness

According to Davis (1989), technologies perceived as easy to use are often regarded as more useful, allowing users to achieve results with less effort. This is supported by Okpala et al. (2021) who also found that the ease of use in learning the WSDs affects the perception of how helpful the device would be for project activities. As a result, the following hypothesis is presented.

*H5: Perceived ease of use has a positive impact on the perceived usefulness of WSDs*

#### 4.1.7 Perceived Usefulness and Behavioral Intention

Perceived usefulness was identified as vital for behavioral intention, with users adopting technology they believe enhances performance (Davis 1989). In the construction industry, Okpala et al. (2021) found that workers are more likely to use wearable sensing devices (WSDs) if they view them as beneficial or useful for safety and health purposes. Hence, the following hypothesis is proposed.

*H6: Perceived usefulness has a positive impact on behavioral intention to use WSDs*

#### 4.1.8 Perceived Ease of Use and Behavioral Intention

On the use of WSDs in construction, Choi et al. (2017) found that ease of use significantly affects workers' willingness to adopt them. Employees who perceive WSDs as easy to use without disrupting their tasks are more likely to adopt the technology. Therefore, it is hypothesized that:

*H7: Perceived ease of use has a positive impact on behavioral intention to use WSDs*

### **4.2 Relationship Between Trust and Associated Constructs**

Privacy, security, and trust overlap, creating additional concerns such as auditability, accountability, and access control (Muchahari and Sinha 2012). Privacy and security are often linked as they both influence in relation to consumer trust, as shown in Figure 3 (Flavián and Guinalíu 2006). Privacy and security can often be synonymous through the lens of the consumer; however, they are distinctly different as privacy includes the practices involved with handling collected personal data while security is the technical aspects associated with keeping sensitive information secure (Flavián and Guinalíu 2006). Trust can be fostered through effective privacy and security measures that ensure reliability and dependability, meeting the expectations of both organizations and consumers.

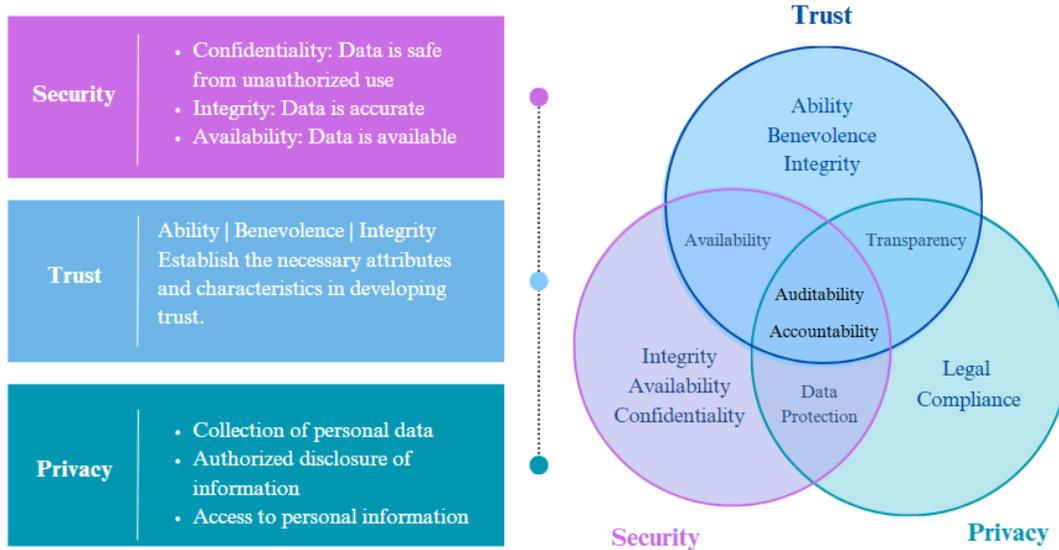


Figure 3: Privacy, Security, and Trust Diagram

### 4.3 Conceptual Trust-Based Acceptance Model for WSD Adoption

For this study, the TAM model has been adapted to incorporate both technological acceptance and the dimension of trust, creating a Trust-Based Acceptance Model (TBAM) that encompasses trust as a dimension necessary for this study (B.U. et al. 2021). TBAM will be used to evaluate how these privacy and security factors impact trust, perceived usefulness (PU), and perceived ease of use (PEOU) leading to the user intent to adopt WSDs in construction safety and health monitoring. Figure 4 outlines the model and how factors of privacy, security, and trust impact technology adoption.

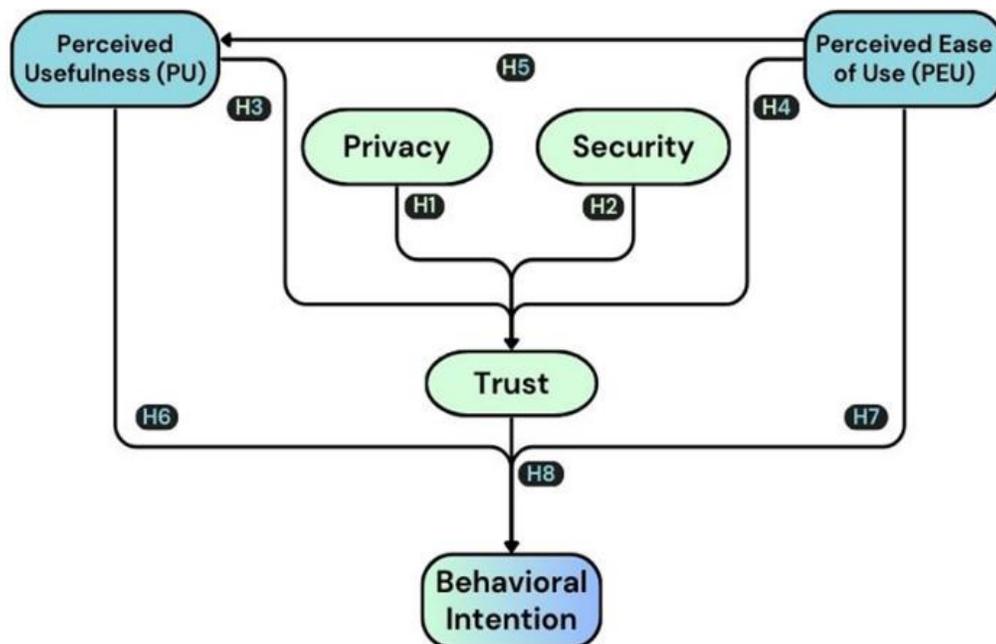


Figure 4: Conceptual Trust-Based Acceptance Model for WSD Adoption

The following hypotheses have been developed based on the conceptual model.

- H1:** Privacy has a positive impact on trust in the use of WSDs
- H2:** Security has a positive impact on trust in the use of WSDs
- H3:** Perceived usefulness has a positive impact on trust in the use of WSDs
- H4:** Perceived ease of use has a positive impact on trust in the use of WSDs
- H5:** Perceived ease of use has a positive impact on the perceived usefulness of WSDs
- H6:** Perceived usefulness has a positive impact on behavioral intention to use WSDs
- H7:** Perceived ease of use has a positive impact on behavioral intention to use WSDs
- H8:** Trust has a positive impact on behavioral intention to use WSDs

The extended TBAM can identify factors such as behavioral intention, PU, and PEOU influencing technology adoption (Patel et al. 2021). By evaluating PU, PEOU, and the integration of trust, a better understanding of the industry's intention to adopt these technologies can be developed. Factors associated with TAM include the user's perception of the device's ease of use and the potential risk-versus-benefit of using the device and collecting employee data (Kusyanti and Prastanti, 2017). By collecting data on both PE and PU, a better understanding of the industry's intention to adopt these technologies can be developed. Conceptual models such as the TBAM can identify factors such as behavioral intention, perceived usefulness, ease of use, privacy, security, and trust that can influence technology adoption.

## 5. CONCLUSIONS

While there have been substantial advances in WSDs across health, logistics, and fitness, their adoption in construction has progressed slowly. This delay can be largely attributed to concerns about privacy, security, and personal health data management, which affects stakeholder trust. To encourage the adoption of WSDs in the construction industry, it is essential to gain a deeper understanding of the factors contributing to these concerns. This study, in an attempt to fill part of the knowledge gaps, introduces a conceptual model that could be deployed to evaluate potential user perceptions of privacy, security, and trust concerning the use of WSDs for monitoring health and safety on construction sites.

A structured review was conducted to collect, assess, and synthesize relevant studies on WSDs and technology adoption. This review aided in identifying, defining, and categorizing the essential constructs linked to these three factors. Consequently, a conceptual model, TBAM was developed along with the associated hypothesis to extend the original TAM by integrating trust as a primary component and examining its relationships with privacy and security in technology adoption. TBAM analyzes the impact of privacy and security concerns on perceived usefulness (PU) and perceived ease of use (PEOU), both of which influence behavioral intentions regarding WSD adoption. TBAM can offer comprehensive insights into decision-making among construction industry members before adopting WSDs by exploring these relationships.

Ultimately, it is expected that this model will provide practical insights that could promote the effective integration of WSDs into construction practices and address stakeholders' challenges, thereby advancing efforts to prevent illnesses, injuries, and fatalities through data-driven safety and health monitoring. As this study neither tests the model and hypotheses nor collects empirical data, an extended study is currently being conducted to implement this model for data collection and analysis to confirm and enhance its relevance in promoting safer construction environments.

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