Critical drivers for the adoption of wearable sensing technologies (WSTs) for construction safety monitoring in Ghana: A Fuzzy Synthetic Analysis

Abstract

Purpose: The construction industry is one of the most hazardous working environments globally. Studies reveal that wearable sensing technologies (WSTs) have practical application in construction occupational health and safety management. In the global south, the adoption of WSTs in construction has been slow with few studies investigating the critical drivers for its adoption. The study therefore bridges this gap by investigating the factors driving WSTs adoption in Ghana where investments in such technologies can massively enhance health and safety through effective safety monitoring.

Design/Methodology: To meet the objectives of this study, research data was drawn from 210 construction professionals. Purposive sampling technique was used to select construction professionals in Ghana and data was collected with the use of well-structured questionnaires. The study adopted the Fuzzy Synthetic Evaluation Model (FSEM) to determine the significance of the critical drivers for the adoption of WSTs.

Findings: According to the findings, perceived value, technical know-how, security, top management support, competitive pressure, and trading partner readiness obtained a high model index of 4.154, 4.079, 3.895, 3.953, 3.971, and 3.969, respectively, as critical drivers for WSTs adoption in Ghana. Among the three broad factors, technological factors recorded the highest index of 3.971, followed by environmental factors and organizational factors with a model index of 3.938 and 3.916 respectively.

Implications: Theoretically, findings are consistent with studies conducted in developed countries, particularly with regards to the *perceived value* of WSTs as a key driver in its adoption in the construction industry. This study also contributes to the subject of WSTs adoption and, in the case of emerging countries. Practically, findings from the study can be useful to technology developers in planning strategies to promote WSTs in the global south. To enhance construction health and safety in Ghana, policymakers can draw from the findings to create conducive conditions for worker acceptance of WSTs.

Originality/Value: Studies investigating the driving factors for WSTs adoption have mainly centered on developed countries. This study addresses this subject in Ghana where studies on WSTs application in construction process is uncommon. It also uniquely explores the critical drivers for WSTs adoption using the Fuzzy Synthetic Evaluation Model.

Keywords: Adoption, Critical drivers, Fuzzy synthetic evaluation model, global south, Safety, Wearable sensing technologies (WSTs).

1. Introduction

The construction industry is notably one of the most hazardous and accident-prone working environments globally (Li, 2019). The physically demanding and dangerous nature of the industry has resulted in higher number of injuries, illnesses, and increased work-related musculoskeletal disorder and chronic diseases (Choi et al., 2017). Traditional methods of relying on safety training, use of PPEs, following safety guidelines, precautions and systems have proven inadequate, necessitating a new paradigm in safety risk management (Okpala et al., 2020). Studies suggest complementing traditional onsite safety practices with technological advancements (SmartMarket Report, 2017). Few of these technologies include wearable sensing technology (WSTs), information communication technology, geographic information system (GIS), global positioning system (GPS), remote sensing (RS) technology, radio frequency identification (RFID), and virtual reality (Zhou et al., 2013). According to Choi et al. (2017), these technologies can be instrumental in advancing and improving construction processes. Inaji et al. (2018) also noted that the inadequate technology adoption into construction safety practices is a contributing factor to the poor safety performances of the industry.

The advent of wearable sensing technologies (WSTs) has created opportunities for workers' safety and health data (Ahn et al., 2019). WSTS are devices that consists of sensors, output devices, a power generator unit, and an embedded computer, which may be implanted, worn, or carried around by users (Perez and Zeadally, 2017). Examples of these include the smart glasses, smartwatch, smart ring, GPS watch, E-textiles, etc. (Tarabasz and Poddar, 2019). WSTs can be used to monitors heart rate, blood pressure, and other biofeedback, and doing so in real time (Gao et al., 2015; Jiang et al., 2015). These technologies also enable tracking workers' location and movement (Jebelli et al., 2015; Torres-Huitzil and Alvarez-Landero, 2015). The healthcare industry and the military are fields that actively employ WSTs in their operations (Led et al., 2015; Kodam et al., 2020). Other industries that incorporate WSTs in their operations include the sports, communication, and management (Park, 2020).

WSTs are largely utilized in the construction industry for safety monitoring, activity recognition, and risk assessment of work-related musculoskeletal conditions (Antwi-Afari et al., 2020). In construction operations, WSTs enables continuous monitoring of workers and early detection of risks to health and safety, and provides real time feedback of such risks identified (Hwang et al., 2016; Yan et al., 2016). Heart rate sensors, IMU (motion sensors), and GPS allow onsite workers to be monitored and to detect early risks to safety while providing real-time feedback regarding the identified risks (Choi et al., 2017). Workers' location within a dangerous area can thus be determined, as well as assessing risks of work-related musculoskeletal disorders and near-misses, and determining their levels of fatigue and physical conditions (Hwang et al., 2016; Yang et al., 2016; Yan et al., 2017). These sensory technologies and their functionality can be easily incorporated into workers' PPEs, hard hats, safety vests, and safety glasses.

According to Tarabasz and Poddar (2019), WSTs is expected to be a game-changer in society and in business with a predicted a high growth rate in the future. Despite the potential of WSTs in construction health and safety as well as its increasing popularity and utility in several industries, the construction industry has been slow to adopt WSTs into its operations (Okpala et al., 2020). Balamurugan et al. (2022) confirmed that only 9.6% of workers in the industry use WSTs. Pantelpoulos and Bourbakis (2010) stressed on workers concern over risks to personal privacy as a common challenge to adopting WSTs. Research evidence suggests that perceived usefulness, social influence, and perceived privacy risks are factors that that drive workers' intention to adopt of WSTs in the United States (Choi et al., 2017, Kritzler et al., 2015). A study in Dubai confirmed similarly that WST's product attributes, its perceived ease of use, and its perceived usefulness influenced its adoption (Tarabasz and Poddar, 2019). An attribute of WSTs such as its look-and-feel was a key factor influencing younger demographic to adopt them (Adapa et al., 2018). According to Park (2020), in Korea, users are willing to accept and adopt WSTs on account of these factors, which are satisfaction, enjoyment, usefulness, flow state, and cost. Since WSTs are commonly used in developed countries both in industries and by individuals, research studies on the factors influencing WSTs adoption are primarily conducted in developed countries. These influencing factors constitute the drivers of WSTs adoption. Moreover, few of these studies pertain to construction processes.

The African continent generally often tends to lag behind in adopting new or advanced technologies (Amankwah-Amoah, 2019). The incorporation of WSTs into construction operations is rare on most construction sites in the global south (Huhn et al., 2022). In Ghana, the construction industry records more occupational accidents and injuries than any other industry in the country (Osei-Asibey et al., 2021). Fatonde and Allotey (2016) revealed that although the industry employs 2.3% of the Ghanaian working force, it records about 40% of all work-related fatalities. The adoption of WSTs in the construction industry can prove revolutionary in effectively managing health and safety in a developing nation like Ghana. Given that most existing studies on the drivers of WSTs adoption in construction have focused on developed countries, the generalizability of these studies is questionable. It is unclear what drivers influence the adoption of WSTs in the construction industry in Ghana. Therefore, this study aims at investigating the critical drivers of adopting WSTs in managing occupational health and safety in the Ghanaian construction industry.

2. Literature review

2.1 WSTs for construction safety monitoring

The hazardous nature of construction sites puts workers in a constant state of risk to the health and safety throughout the construction process (Seo et al., 2015). Activities in construction are labour-intensive, requiring physical strain in order to meet the challenges and complexities of tasks. According to Awolusi et al. (2018), most traditional techniques used to measure health and safety performance indicators are manual. A promising way to remedy the flaws of manual effort is to automate the process of monitoring health and safety performance on site. Using WSTs to automate this process has shown to increase accurate and enable continuous monitoring (Huhn et al., 2022). Adopting WSTs enables a broad range of signals to be monitored, with an added early warning system which alerts high health-risk workers to be alerted (Ananthanarayan and Siek, 2010). The construction industry employs WSTs in the form of smart hard hats, tags, smart boots, wristbands, clips, safety vests, smartwatches, and more. The use of magnetometers, accelerometers, and gyroscopes in WSTs are used in analyzing human motion to reduce falls and regulate balance. Fall related injuries can be significantly reduced with WSTs application (Antwi-Afari et al.,2020). EquipTags, Spot-r Clips, Zephyr, and SmartBoots, which are construction-applied WSTs combine a number of functions onto one, compact, power-efficient platform. This allows for measurement of time spent in work areas, trips and falls, slips, step count, fatigue, risk of future dehydration, heart rate, location of workers and equipment (Awolusi et al. 2018). Other WSTs available measure temperature, body impact and acceleration, heart rate, posture, breathing rate, and heart variability (Cousins, 2018).

Several types of WSTs have been employed in construction over the years and some have been positively beneficial (Hussain et al., 2017). Examples of WSTs include Inertial Measurement Units (IMUs), Heart Rate (HR) monitors, wearable insole sensors, electromyography (EMG) and electroencephalogram (EEG) (Safavi and Shukur, 2014; Tarabasz and Poddar, 2019). Both industry experts and researchers are seeking to use the initial implementation of these technologies as learning platforms and to improve upon them. Ferreira et al. (2021) revealed that project data can now be accessed and shared from remote worksites using mobile devices. With WSTs, previous data gathered can be exploited to design ergonomically friendly work environments in order to minimize site injuries and fatalities (Nath et al., 2017). Ergonomic risks can be easily identified and eliminated at the source using WSTs, ultimately preventing reoccurrence (Nath et al., 2017).

2.2 Theoretical Framework Adopted for the Study

There has been an astronomical increase in modern times regarding the number, variety, and forms of wearable devices ever since mobile devices and wearable technology became a global trend. Evidence suggests that WSTs, when effectively implemented, will improve worker safety (Ahn, et al., 2019). It does this through accurate, real-time data collection and analysis, and by making available other information necessary to minimize risks to workers (Ananthanarayan and Siek 2010; Nath et al. 2017; Awolusi et al. 2018). By evaluating the critical drivers for WSTs adoption, the diffusion of these WSTs into mainstream construction processes can be accelerated. Using the Technology-Organization-Environment (TOE) framework, these key drivers can be evaluated from the perspectives of the environment, the organization, and technological components (Tornatzky and Fleischer, 1990).

According to Aboelmaged (2014), the TOE framework has been examined across disciplines and context to demonstrate its theoretical strength, empirical support and usefulness in investigating the readiness, adoption and deployment of various forms of innovation at the organizational level. Several studies in the construction industry have used the TOE framework in the study of e-procurement (Tran et al., 2014, Ibem et al., 2016), BIM implementation (Ahuja et al., 2016, Chen et al., 2019), and project complexity evaluation (Bosch-Rekveldt et al., 2011, Penaloza et al., 2020). Furthermore, the TOE framework presumes that when the organization considers internal and external factors, the process of adopting an innovation at the organizational level will occur effectively (Tornatzky and Fleischer, 1990).

Technological factors comprise of issues of complexity, availability, compatibility, and relative advantage (Wang and Wang, 2010). With the release of consumer products into the markets, WSTs has become readily available, making it easier to adopt them (Skiba, 2013). Relative advantage is also considered as a positive contributor because WSTs enable the extension of mobile device capabilities as well as the quantification and recording of user's condition and surroundings (Patel et al., 2012). Due to the advanced technical needs and low level of maturity of WSTs in today's setting, complexity is expected to be a barrier to WSTs adoption (Kritzler et al., 2015). As ubiquitous as mobile devices are, being compatible with WSTs positively influences their adoption (Profita et al., 2013).

Organizational factors likewise include firm size, support of top management, and the technological readiness of the firm (Tornatzky et al., 1990). The adoption of WSTs needs the support of top management, because management has a great influence on the attitude of the organization toward technological innovations. Having the support of top management is therefore a positive factor. Organizations with larger firm size can better or easily manage the costs and risk of incorporating WSTs into their work processes (Safavi and Shukur, 2014). To manage the connection, security, and privacy requirements of WSTs, an organization's IT infrastructure and personnel will need to adapt (Skiba, 2014; Backman and Tenfalt, 2015); thus, technology readiness is a positive factor in WSTs adoption.

Environmental factors encompass information intensity, competitive pressure, government regulation, trade partner readiness, among others (Wang and Wang, 2010). WSTs provide organizations with an advantage over their competitors by enhancing data accuracy and accessibility, as well as operational efficiency (Swan, 2009; Boss, 2015). Competitive pressure, therefore, favours the adoption of WSTs. It is relatively rare to encounter organizations that employ WSTs. Most of them are in their beta stages (Skiba, 2013; Wright and Keith, 2014; Backman and Tenfalt, 2015). Trading partner readiness was found to be a neutral factor for WSTs adoption in 2015 (Profita, 2014). Moreover, the inherent use of WSTs requires information monitoring and transmission, and this information is of value to users in many ways. Consequently, this information intensity positively affects WSTs adoption (Profita, 2014). According to Shukur and Safavi (2014), information security, privacy, and customer consent in interactions often pose challenges to WSTs adoption. That said, government regulation negatively impacts WSTs adoption. Table 1 represents the critical drivers for WSTs adoption.

3. Research Methods

3.1 Sample size and composition

The study purposively selected construction professionals such as project managers, engineers, quantity surveyors, health and safety officers and architects who have been engaged in major construction works over the past two years. This aided in obtaining current and relevant information about the subject matter.

3.2 Questionnaire design, format and administration

The study conducted a thorough review of literature existing on this topic with articles from Scopus, Web of Science, Google Scholar, and ProQuest. The key terms used in the search for articles in these bibliographic databases include are “Drivers, factors, determinants, influencers”, “wearable sensing technologies, wearable technologies, wearable devices” and “construction safety, construction health and safety, construction safety monitoring”. The relevant papers were retrieved and thorough read where the items in Table 1 were extracted. These variables identified from the literature review were used to develop the questionnaires. The questionnaire had two main parts: Part A and Part B. Part A gathered data on the background of respondents whiles part B gathered data on the aim of the study. Pilot testing was carried out to ensure that the items used were comprehensible and that the proposed research questions aligned with the study's aims. Upon drafting the questionnaire ten were administered to construction professionals (both industry and academia) for validation. Some items in the questionnaire were then amended based on the feedback from these construction professionals. The respondents were requested to rate the variables based on a 5-point Likert Scale ranging from (1) strongly disagree, to (5) strongly agree. Over 289 professionals were contacted to participate in the survey, and 210 questionnaires were filled out and retrieved. The questionnaire survey achieved a response rate of 72%. It took an average of 15 minutes for a respondent to complete the questionnaire. The questionnaires were administered via email to construction professionals in both Greater Accra and Ashanti regions of Ghana. These two regions in Ghana are most populated with the calibre of construction firms with the financial capacity and technical expertise required to adopt and implement WSTs. Some of the answered questionnaires were retrieved on the day of submission, the rest, retrieved few days after, depending on how fast they were answered.

4. Data Analysis and Results

4.1 Reliability test

The Cronbach's alpha was used to determine the reliability and validity of the scale before employing the FSEM for further investigation (Manerikar and Manerikar, 2015). As a rule of thumb, a Cronbach's alpha value of 0.60 and above is considered good and indicates a high level of internal reliability/consistency (Hair et al., 2010). Table 2 shows that the Cronbach's alpha values obtained were greater than 0.60, indicating that all of the variables tested are reliable and valid, allowing for further analysis (Hair et al., 2018).

4.2 Respondents Profile

The background information of respondents who took part in the survey is shown in Table 3. This information may have a huge impact on opinions and decision-making towards WSTs adoption on Ghanaian construction sites.

From Table 2 above, majority of the respondents were under 30, that is, 64.8 percent, most in the age range of 26-30 years (45.7% of total). Those above 30 constituted 35.2 percent. Meyer (2011) opined that younger employee are inclined to using technology and flexible enough to adapt to innovation. Also, majority of those who responded to this study were quantity surveyors (21.4%). There was an even distribution of project managers and health and safety officers (19%). Architects and engineers comprised of 18.1 percent and 14.3 percent respectively, with procurement managers being least in number, 17 of the total 210 (8.1%). From the table, half of respondents held a bachelor's degree, while 46.7 percent had a Masters' degree. A minority of 1.4 percent held a doctorate degree among the surveyed, and 1.9 percent possessed and HND. Respondents mainly had 1-5 years' experience in their profession (61.9%). Meyer (2011) discovered that a lack of work experience, which often correlates with employee age, is regarded as a driver of technology adoption due to higher level of openness and flexibility. This implies that they are more prone to adopt safety technology such as WSTs since they are young workers (Mensah and Mi, 2019). Those with 5-10 years of work experience were 40 (19.0%); and those with 11-15 years of work experience were 22 (10.5%); those with 16-20 years of work experience were 12 (5.7%); and the remaining 6 (2.9%) had more than 20 years of experience working in the construction industry. In addition, respondents were asked if they have ever used any type of WSTs. Majority of the respondents, 152 of them (72.4%), indicated 'Yes', and a lesser number of 58 (27.6%) indicated 'No'. This shows that majority of surveyed respondents use WSTs on their construction sites whereas few of them have not employed its use in delivering projects.

4.3 Fussy Synthetic Evaluation

The survey data were analyzed using the social science statistical package (SPSS) version 25. The study adopted the Fuzzy Synthetic Evaluation Model (FSEM) to determine the significance of factors influencing WSTs adoption in the construction industry. The FSEM was utilized to purposely establish the level of importance of each of the factor grouping influencing WSTs adoption in Ghana. The FSEM has been used in a number of studies to evaluate multi-criteria decision-making including health risk assessment (Sadiq and Rodriguez, 2004), risk assessment and allocation (Ameyaw and Chan, 2015; Liu et al., 2013), operational management of public-private partnership infrastructure projects (Osei-Kyei et al., 2017), and project performance management (Yeung et al., 2007). Also, this tool was used because it has the ability to handle complicated evaluations with multi levels and attributes (Xu et al., 2010). Furthermore, the method has the potential to objectively assess experts' subjective opinions and perceptions (Sadiq and Rodriquez, 2004). As a result, the FSEM was considered to be an excellent choice for determining the critical drivers for WSTs adoption in Ghana.

From reviewing existing literature, there were three main factors influencing the organizational adoption of wearable sensing technologies (WSTs). These were individually subjected to fuzzy synthetic evaluation model (FSEM) to determine their level of influence on WSTs adoption. There were three levels of fuzzy synthetic evaluation stages for the determination of factors influencing adoption of WSTs. The third level evaluated the significance of factors influencing adoption within each factor levels, the second level involved evaluation of the agreement level of the factors. The first level contained the overall level of agreement for each of the factor levels that influence adoption of WSTs within the Ghanaian construction industry. This process was considered multi-factor and multi-level fuzzy synthetic evaluation model according to (Ameyaw and Chan 2015).

It has been established from literature that the overall accuracy of the FSEM rest on the accuracy of the weightings assigned to each FLI and FL (Lo, 1999). According to Hsiao (1998), Lo (1999), Ameyaw and Chan (2015), several methods are available for accurate estimations of the weightings from survey data using a Likert scale such as analytic hierarchy process (AHP), direct point allocation (DPA), unit weighting, tabulated judgement method and normalized mean method. This study employed the normalized mean method based on recommendation of Ameyaw and Chan (2015). The weighting functions were obtained by employing the normalization of the mean scores of each factor and factor groups following the works of Xu et al. (2010). The weighting was important to establish the relative significance (agreement) as rated by the survey respondents. The weights of the factor groups for each of the three main factors influencing adoption of WSTs were determined using the formula below;

$$W_i = \frac{M_i}{\sum_1^k M_i}, 0 \leq W_i \leq 1, and \sum_1^k W_i = 1$$

4.4 Weight and Membership Functions of Factor and Group

The study used normalized mean method of fuzzy analysis upon recommendation of Ameyaw and Chan (2016) and Caleb et al., (2021). The weighting functions were constructed applying the normalization of the mean scores of each factor following the works of Xu et al. (2010) and Caleb et al., (2021). The weighting was important to establish the relative relevance of the indicators to the construct as rated by the respondents.

The membership function (MF) of each factor was estimated from the percentage responses of the respondents to each of the indicators. It ranged between 0 and 1 where close to 1 indicated high proportion to that set of scale and close to 0 mean low proportion to the set of measurement (Ameyaw and Chan, 2016). The membership function of each factor was estimated from the membership functions of the factor group within each factor level. This membership functions of each factor and factor groups were used to develop the fuzzy matrix. The scale of measurement in the study was 5-point Likert scale comprising; 1: strongly disagree, 2: disagree, 3: neutral, 4: agree and 5: strongly agree. The ratio of responses for the respective scale presented in Table 5, Table 7, Table 9 and Table 10 (membership functions level 2 and 1). The membership functions (level 2) form the foundation for estimating the membership functions (Level 1) of the factors. Membership functions level 1 was obtained from the products of factors weightings and membership functions level 2 (fuzzy matrix), thus, fuzzy evaluation matrix.

4.4.1 Technological Factors Influencing the Adoption of WSTs

The weighting functions of technological factors influencing adoption of WSTs were estimated and results presented in Table 4. The weight provided the relative significance of each of the indicators as rated by the respondent. Table 5 showed the membership functions associated to each of the indicators (Level 2) under each factor and the factors (Level 1). This helped form fuzzy matrix to determine the index of each factor.

From the ratings of the respondents, 1.4 percent strongly disagree, 11.4 percent disagree, 26.7 percent were neutral, 45.2 percent agreed, and 15.2 percent strongly agreed with regards to high capacity of storage devices under performance characteristics of WSTs (Table 4). Therefore, the membership function Level 3 of high capacity of storage devices can be expressed as (0.014, 0.114, 0.267, 0.452, 0.152). All the membership functions in Table 5, were obtained in similar approach.

4.4.2 Organizational Factors (OF) Influencing the Adoption of WSTs

Table 6 and Table 7 below presented the weightings and membership functions of the organizational factors influencing WSTs adoption in Ghana respectively. The weight scores determined the relative significance of the criteria in the decision-making process on adoption. Higher weight indicated higher rating to that scale of measurement. The membership function showed the extent to which the measurement scale was rated by the respondents. The fuzzy matrix showed the proportion of the logic for each of the indicators of organizational factors influencing adoption of WSTs. This was used to estimate the membership function level 1. From the ratings of the scales by the respondents (Table 7) on size of firm, resources of the firm had the following proportion, 1.0 percent strongly disagree, 7.1 percent disagree, 14.3 percent were neutral, 46.7 percent agreed, and 31.0 percent strongly. Therefore, the membership function Level 2 of resources of the firm can be expressed as (0.010,0.071,0.143,0.467,0.310). All the membership functions in Table 7 were obtained through similar approach.

4.4.3 Environmental Factors Influencing the Adoption of WSTs

Table 8 and Table 9 presented the weightings and membership functions of the environmental factors influencing WSTs adoption in Ghana respectively. The weightings for each of the indicators of environmental factors were assigned using normalized approach and results shown in (Table 8). The membership functions at both level 2 and level 1 were presented in Table 9.

4.4.4 Overall Index for Factors Influencing Adoption of WSTs

The overall index for factors influencing WSTs adoption is shown in Table 10 and Table 11 below. The membership functions (Level 2 and Level 1) presented in Table 10 formed the basics for the estimation of the indices of the main factors (constructs). The Level 1 was obtained from the product of the group factor weights and the membership function Level 2 matrix.

4.5 Discussion

Table 11 summarizes the results, including the indices, weights for all elements, linguistic measurements, and ranking of thirteen (13) critical drivers for WSTs adoption in the global south. Table 11 further shows that all of these drivers had very high indices, indicating their importance in decision making regarding the adoption of WSTs. As a result, stakeholders must pay close attention to these crucial determinants when making decisions about WSTs adoption.

The highly ranked technological factor identified as critical for WSTs adoption is *perceived values*, which had a model index of 4.154 (high). Followed by *technical know-how*, with index of 4.079 (high). *Security* (3.895) was third. *Size of the firm*, under organizational factor, recorded the highest index, followed by *top management support*, with respective indices of 4.053 (high) and 3.953 (High). Under environmental factors, *competitive pressure* and *trading partners' readiness* had highest index of 3.971 and 3.969 respectively. Among the three broad factors, technological factors recorded the highest index (3.971), followed by environmental factors (3.938) and then organizational factors (3.916).

Perceived value

Perceived value was ranked as the most significant technological factor that influenced the adoption of WSTs on Ghanaian construction site. This outcome was consistent with research studies by Chwelos et al. (2001) and Musawa and Wahab (2012). The functional value of WSTs is most likely to be considered by prospects before purchasing them. *Perceived value* implies the degree to which WSTs can improve job performance (Davis, 1989; Davis et al., 1989), in this context, how workers safety. These values include, but not limited to, the ability of WSTs to improve incident reporting, enhance firm's safety management program, improve worker's safety, enable real-time monitoring of workers and resources, and improve workforce efficiency (Choi et al., 2017).

Technical know-how

Technical expertise was regarded by respondents as having a significant influence on WST adoption. Tarhini et al. (2015), Marakhimov et al. (2017) and Awolusi et al. (2019) confirmed this in their studies. This factor considers whether Ghanaian construction professionals possess the necessary skills to work with these technologies. This leads to the question of whether construction firms have a technical/maintenance unit, whether technical officers are employed, and whether staff are regularly trained on WSTs. In the absence of technical know-how, it will be nearly impossible for a firm to adopt and implement WSTs.

Security

Security has been an issue and concern when adopting most technologies, WSTs included (Hwang et al., 2016; Yang et al., 2016; Aryal et al., 2017). People are concerned whether data collected with these devices would be secured without any intrusion. It is to this end that the respondents indicated security as a factor in their decision to use WSTs. Security in this context means that WSTs provide high confidentiality in communication, that there is a low risk of information theft, and that there are sufficient laws to protect users' interests (Yan et al., 2016). According to Choi et al. (2017), workers are not comfortable sharing details of their location with management, especially during their period of rest. As such, management would have to their part in alleviating these concerns in workers.

Size of firm

Among the organizational factors, *size of firm* recorded the highest index, consistent with findings of Tornatzky et al. (1990). Organizations with larger firm size can better or easily manage the costs and risk of incorporating WSTs into their work processes unlike organizations with smaller firm sizes (Safavi and Shukur, 2014).

Top management support

The support from top management of any organization is much needed to ensure WSTs adoption on construction sites. Respondents believe that receiving top-management support will influence their decision to implement WSTs. As a result, when top management expresses interest in WSTs and supports their use, they are more likely to be adopted. Having the support of top management will therefore serve as a facilitator to the adoption of WSTs within the

Ghanaian construction industry. The results are similar to that of Schillewaert et al. (2005), Low et al. (2011), Ramdani et al. (2009) and Teo et al. (2009).

Competitive pressure

Companies and firms compete amongst themselves for a substantial stake in the market in order to earn revenue and make profits. To gain a competitive advantage, firms resort to innovativeness and enhancing their human resource asset. WSTs are one such innovative resort that improves construction operations on site, particularly health and safety (Choi et al., 2017). Therefore, firms are more inclined toward adopting WSTs if there is a perceived competitive advantage in it (Teo et al., 2009; Oliveira and Martins, 2010; Wang et al., 2010; Low et al. 2011). A competitive market will push firms to go in for WSTs in order to beat out competing firms.

Trading partners' readiness

Respondents believe that the readiness of trading partners markedly drove the adoption of WSTs. The ability of trading partners, such as subcontractors, to accept, adopt, and assimilate WSTs in their operations is worth considering when firms intend introducing WSTs. If trading partners are not ready to evolve their operations to incorporate WSTs, it places a damper on its effective adoption and assimilation. Moreover, trading partners must have the knowledge and skillset among its human resources to be able to embrace WSTs. Lack of readiness or otherwise on the part of trading partners is therefore a factor worth considering (Teo et al., 2009; Oliveira and Martins, 2010; Wang et al., 2010; Low et al., 2011).

5.0 Implications of findings

Theoretical Implications

This study, unlike previous ones, is grounded in the context of developing countries. The findings are however consistent with studies conducted in developed countries, particularly with regards to WSTs perceived value (or usefulness) as a key driver in its adoption into construction process (Choi et al., 2017). Using the fuzzy synthetic evaluation model, the study identified important drivers to WSTs adoption in the global south. The quantitative approach used allows the findings of the study to be reproduced with negligible subjective judgement. This study also contributes to the subject of WSTs adoption and, in the case of emerging countries, would inspire additional research into the matter in other countries.

Practical Implications

Findings from the study can be useful to WSTs developers in planning strategies to promote WSTs in the global south. In order to make WSTs attractive, there should be a strong value perceived in using it, workers must feel that their privacy is secured, and workers should have the know-how to operate WSTs devices. The adoption of WSTs must provide firms and professionals value for money. Perceived value also encapsulates other considerations like heightened professional image and respect, satisfaction from use, ease of use, aesthetic, comfort, interface, among others (Adapa et al., 2018). These make it an attractive investment. Firms and professionals must be able to appreciate how cost savings from prevented accidents and injuries together with increased revenues from efficient operations outweigh the cost of WSTs purchase and implementation.

Policy Implications

Policymakers can draw from the findings in this study to enhance construction health and safety. These drivers of WSTs adoption also provide insight as to the conditions necessary to encourage acceptance and use of these technologies in construction. With research evidence pointing to positive benefits to employing WSTs in construction project safety performances (Ahn, et al., 2019), policymakers can create conducive conditions for the adoption of WSTs by construction firms. Construction firms can be incentivized through national policy or subsidies to employ these devices on the construction site.

6.0 Conclusions and limitations

Existing literature lends credibility to the advantages of Wearable Sensing Technologies (WSTs) at both the industrial and individual level. Some of these studies have explored factors influencing the acceptance and adoption of WSTs by users and even by industries, including the construction industry. However, this study explored the critical drivers of WSTs within the context of Ghana's construction industry. The objective of the study was to identify critical drivers for WSTs adoption in the global south. A questionnaire was developed and tested through a quantitative data analysis of 210 construction professionals. The critical drivers were analyzed under three broad categories based on the Technology-Organization-Environment framework. The findings revealed perceived value, technical know-how and security as the most influential technological factors determining WST's adoption. Size of firm and top management support were the most influential organizational factor. And competitive pressure and trading partners' readiness ranked as the most influential environmental factors affecting WSTs adoption. Technological factors were the most significant of all three categories. The following limitations of the study must be addressed in future studies. This study gathered information from two advanced industrial locations in Ghana. As a result, the findings should be applied with caution to different geographical areas. Moreover, future studies must expand the geographical reach of the study to other regions in the country. Considering WSTs adopters and non-adopters are of different understanding and limited awareness of their usage exist in the construction industry. It is recommended that future studies on WSTs should be conducted on both adopters and non-adopters, analyzed separately to identify any significant differences in their responses. There must be training and awareness creation for construction professionals to the know and understand the use of WSTs. Moreover, construction professionals must be allowed to try the wearable technology at real project settings to assist them know they work.

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Tables

Table 1: Critical Drivers for WSTs Adoption from literature review

Critical drivers of WSTs	Source
Technological Factors	
1. High capacity of storage devices	Cho et al. (2018); Nnaji et al. (2019)
2. Number of sensors available to employees	Won et al. (2013); Gao et al. (2015); Nnaji et al. (2019)
3. High sensitivity of device	Nnaji et al. (2019); Cho et al. (2018)
4. Small and lightweight of WSTs	Ozorhon and Karahan (2016); Cho et al. (2018)
5. Low power consumption	Won et al. (2013); Awolusi et al., (2019); Nnaji et al. (2019)
6. High level of accuracy and precision of WSTs	Reitsma and Hilletofth (2018); Nnaji et al. (2019)
7. Multi-parameter monitoring of device	Gambatese and Hallowell (2011); Gao et al. (2013); Nnaji et al. (2019)
8. Appropriate data processing and transmission	Okpala et al. (2019); Nnaji et al. (2019)
9. Appropriate frequency band for efficient networking	Suermann and Issa (2019); Ozohon and Karah (2017)
10. Appropriate device location and mounting	Jacobs et al. (2019)
11. Low implementation and maintenance cost	Ozorhon and Karahan (2016); Nnaji et al. (2019)
12. Trial period to decide whether to adopt it on site	Suermann and Issa (2009); Ozorhon and Karahan (2016)
13. Availability of technical/maintenance unit	Tarhini et al. (2015); Awolusi et al, (2019); Marakhimov et al. (2017)
14. The number of technical officers employed	Ozorhon and Karahan (2016)
15. Regularity of staff training on WSTs	Tarhini et al. (2015); Ozorhon and Karahan (2016)
16. Existence of WSTs experts	Ozorhon and Karahan (2016); Nnaji et al. (2019)
17. Fit between the new and existing technologies	Won et al. (2013); Nnaji et al. (2019)
18. Fit between the new systems and existing work procedures	Tarhini et al. (2015)
19. Fit between the new systems and corporate values	Tarhini et al. (2015); Ozorhon and Karahan (2016); Nnaji et al. (2019)
20. Improved incident reporting accuracy	Chien et al. (2014); Ozorhon and Karahan (2016)
21. Enhanced firm's safety management program	Khosrowshahi and Arayici (2012); Ozorhon and Karahan (2016)
22. Improved workers' safety	Tarhini et al. (2015); Lee et al., (2015)
23. Enabling real-time monitoring of workers and location of resources	Tarhini et al. (2015); Ozorhon and Karahan (2016)

24. Improved workforce efficiency	Bryde et al. (2003); Ozorhon and Karahan (2016)
25. High confidentiality in communication using WSTs	Awolusi et al, (2019); Okpala et al. (2019)
26. Low risk of information being stolen	Nnaji et al. (2019); Ahn et al. (2019)
27. Sufficient laws to protect user's interest	Tarhini et al. (2015)
Organisational factors	
28. Resources of the Firm	Nnaji et al. (2019); Cho et al. (2018)
29. Skills and Experience	Ozorhon and Karahan (2016
30. Level of resilience	Ozorhon and Karahan (2016); Reitsma and Hilletofth (2018)
31. Top management creates support for WSTs	Ozorhon and Karahan (2016)
32. Top management promotes the use of WSTs	Nnaji et al. (2019
33. Top management is interested in the news about using WSTs	Ahn et al. (2019)
34. Influence by others	Dinh-Le et al. (2019)
35. Collaboration between organizations	Boktor et al. (2014)
36. Strong belief in group norms	Won et al. (2013)
37. Fear of group penalty	Tarhini et al. (2015)
38. Reducing cost associated with operational expansion	Khosrowshahi and Arayici (2012)
39. Reduction of external costs of operations	Bryde et al. (2003)
40. Integration of units and independent partners at a low cost	Suermann and Issa (2019)
Environmental factors	
41. Grants/donations	Low et al. (2011)
42. Transfer of technical assistance	Choi et al. (2017)
43. Soft loans	Aryal et al. (2017)
44. Loan guarantee and loan insurance	Yang et al. (2016)
45. Subsidies and tax relieve operations	Hwang et al. (2016)
46. Operational necessity	Awolusi et al, (2019)
47. Strategic necessity	Marakhimov et al. (2017)
48. Vendor or third-party support	Wang et al. (2010), Ahn et al. (2019)
49. Competitors adopt it	Oliveira and Martins (2010)
50. Partners want integration	Adapa et al. (2018)
51. Partners believe in the innovation's values	Won et al. (2013), Yan (2016)
52. Partners have the technical resources	Bryde et al. (2003)

Table 2. Test for reliability and internal consistency

Cronbach's alpha	Number of items	Interpretation
0.897	**52**	**High**

Table 3. Background information of the respondents

	Frequency	Percent
Age range	-	
Less than 20 years	2	1
20-25 years	38	18.1
26-30 years	96	45.7
31-35 years	36	17.1
36-40 years	26	12.4
41-45 years	10	4.8
46-50 years	2	1
Total	210	100
Profession	-	
Project manager	40	19.0
Architect	38	18.1
Quantity surveyor	45	21.4
Engineer	30	14.3
Health and Safety Officers	40	19.0
Procurement Manager	17	8.1
Total	210	100
Highest academic qualification	-	
Highest National Diploma (HND)	4	1.9
Bachelor's degree	105	50
Masters' degree	98	46.7
Doctorate degree	3	1.4
Total	210	100
Years of experience in the construction industry	-	
1-5 years	130	61.9
5-10 years	40	19.0
11-15 years	22	10.5
16-20 years	12	5.7
More than 20 years	6	2.9
Total	210	100
Ever adopted any form of wearable sensing technologies in your organization	-	
Yes	152	72.4
No	58	27.6
Total	210	100

Table 4. Weightings for TFs and TFGs for Adoption of WSTs

Code	Technological Factors TFs and TFGs	Mean score	Weighting for each TFs	Total Mean for each TFs	Weighting for each TFG
PEC	**Performance Characteristics of WSTs**	-		**42.827**	**0.400**
PEC1	High capacity of storage devices	3.61	0.084		
PEC2	Number of sensors available to employees	3.85	0.090		
PEC3	High sensitivity of device	3.95	0.092		
PEC4	Small and lightweight of WSTs	3.81	0.089		
PEC5	Low power consumption	3.86	0.090		
PEC6	High level of accuracy and precision of WSTs	4.00	0.093		
PEC7	Multi-parameter monitoring of device	3.91	0.091		
PEC8	Appropriate data processing and transmission	4.04	0.094		
PEC9	Appropriate frequency band for efficient networking	3.93	0.092		
PEC10	Appropriate device location and mounting	4.01	0.094		
PEC11	Low implementation and maintenance cost	3.85	0.090		
PT	**Perceived Trialability**			**3.876**	**0.036**
PT1	Trial period to decide whether to adopt it on site	3.88	1.000		
TKH	**Technical Know-How**			**16.305**	**0.152**
TKH1	Availability of technical/maintenance unit	4.08	0.250		
TKH2	The number of technical officers employed	3.93	0.241		
TKH3	Regularity of staff training on WSTs	4.17	0.256		
TKH4	Existence of WSTs experts	4.12	0.253		
PC	**Perceived compatibility**			**11.647**	**0.109**
PC1	Fit between the new and existing technologies	3.80	0.326		
PC2	Fit between the new systems and existing work procedures	3.90	0.334		
PC3	Fit between the new systems and corporate values	3.96	0.340		
PV	**Perceived Values**			**20.786**	**0.194**
PV1	Improved incident reporting accuracy	4.06	0.195		
PV2	Enhanced firm's safety management program	4.19	0.201		
PV3	Improved workers' safety	4.24	0.204		
PV4	Enabling real-time monitoring of workers and location of resources	4.20	0.202		
PV5	Improved workforce efficiency	4.11	0.197		
SEC	**Security**			**11.681**	**0.109**
SEC1	High confidentiality in communication using WSTs	3.83	0.328		
SEC2	Low risk of information being stolen	3.94	0.338		
SEC3	Sufficient laws to protect user's interest	3.91	0.334		

TF: Technological Factors indicators and TFG: Groups of Technological Factor

Table 5. Membership Functions (MF) of Technological Factor (TF) and Groups (TFG) Influencing Adoption of WSTs

Code	Technological Factors (TFs) and TFGs	Weighting for each TFs	Membership Function Level 2	Membership Function Level 1

PEC	**Performance Characteristics of WSTs**	-		
PEC1	High capacity of storage devices	0.084	(0.014,0.114,0.267,0.452,0.152)	(0.010,0.055,0.204,0.490,0.240)
PEC2	Number of sensors available to employees	0.090	(0.010,0.014,0.310,0.448,0.219)	-
PEC3	High sensitivity of device	0.092	(0.000,0.043,0.186,0.548,0.224)	-
PEC4	Small and lightweight of WSTs	0.089	(0.024,0.081,0.214,0.429,0.252)	-
PEC5	Low power consumption	0.090	(0.019,0.071,0.200,0.448,0.262)	-
PEC6	High level of accuracy and precision of WSTs	0.093	(0.014,0.057,0.162,0.452,0.314)	-
PEC7	Multi-parameter monitoring of device	0.091	(0.010,0.029,0.224,0.514,0.224)	-
PEC8	Appropriate data processing and transmission	0.094	(0.000,0.048,0.124,0.567,0.262)	-
PEC9	Appropriate frequency band for efficient networking	0.092	(0.000,0.038,0.181,0.590,0.190)	-
PEC10	Appropriate device location and mounting	0.094	(0.005,0.038,0.171,0.519,0.267)	-
PEC11	Low implementation and maintenance cost	0.090	(0.010,0.081,0.224,0.419,0.267)	-
PT	**Perceived Trialability**			
PT1	Trial period to decide whether to adopt it on site	1.000	(0.014,0.043,0.186,0.567,0.190)	(0.014,0.043,0.186,0.567,0.190)
TKH	**Technical Know-How**			
TKH1	Availability of technical/maintenance unit	0.250	(0.014,0.071,0.062,0.524,0.329)	(0.005,0.056,0.132,0.472,0.336)
TKH2	The number of technical officers employed	0.241	(0.000,0.062,0.200,0.486,0.252)	-
TKH3	Regularity of staff training on WSTs	0.256	(0.000,0.043,0.124,0.452,0.381)	-
TKH4	Existence of WSTs experts	0.253	(0.005,0.048,0.143,0.429,0.376)	-
PC	**Perceived compatibility**		-	
PC1	Fit between the new and existing technologies	0.326	(0.010,0.071,0.214,0.524,0.181)	(0.005,0.057,0.200,0.527,0.211)
PC2	Fit between the new systems and existing work procedures	0.334	(0.000,0.071,0.162,0.567,0.200)	-
PC3	Fit between the new systems and corporate values	0.340	(0.005,0.029,0.224,0.490,0.252)	-
PV	**Perceived Values**		-	
PV1	Improved incident reporting accuracy	0.195	(0.010,0.033,0.119,0.562,0.276)	(0.007,0.041,0.098,0.496,0.358)
PV2	Enhanced firm's safety management program	0.201	(0.010,0.038,0.076,0.510,0.367)	-
PV3	Improved workers' safety	0.204	(0.000,0.071,0.057,0.433,0.438)	-
PV4	Enabling real-time monitoring of workers and location of resources	0.202	(0.005,0.029,0.114,0.471,0.381)	-
PV5	Improved workforce efficiency	0.197	(0.010,0.033,0.124,0.510,0.324)	-
SEC	**Security**		-	
SEC1	High confidentiality in communication using WSTs	0.328	(0.019,0.043,0.243,0.476,0.219)	(0.010,0.057,0.225,0.446,0.262)
SEC2	Low risk of information being stolen	0.338	(0.005,0.071,0.205,0.414,0.305)	-
SEC3	Sufficient laws to protect user's interest	0.334	(0.005,0.057,0.229,0.448,0.262)	-

Table 6. Weightings for OFs and OFGs for Adoption of WSTs

Code	Organizational Factors OFs and OFGs	Mean score	Weighting for each OFs	Total Mean for each OFs	Weighting for each OFGs
SF	**Size of the Firm**			**12.166**	**0.239**
SF1	Resources of the Firm	4.00	0.328		
SF2	Skills and Experience	4.08	0.335		
SF3	Level of resilience	4.09	0.336		
TMS	**Top management support**			**11.847**	**0.233**
TMS1	Top management creates support for WSTs	3.88	0.328		
TMS2	Top management promotes the use of WSTs	3.99	0.337		
TMS3	Top management is interested in the news about using WSTs	3.98	0.336		
SN	**Subjective norms**			**15.381**	**0.302**
SN1	Influence by others	3.79	0.246		
SN2	Collaboration between organizations	3.92	0.255		
SN3	Strong belief in group norms	3.89	0.253		
SN4	Fear of group penalty	3.78	0.246		
SBO	**Scope of Business operations**			11.471	**0.226**
SBO1	Reducing cost associated with operational expansion	3.73	0.325		
SBO2	Reduction of external costs of operations	3.87	0.337		
SBO3	Integration of units and independent partners at a low cost	3.87	0.337		

TF: Organizational Factors indicators and TFG: Groups of Organization Factors

Table 7. Membership Functions (MF) of OFs and OFGs for Adoption of WSTs

Code	Organizational Factors OFs and OFGs	Weighting for each OFs	Membership Function Level 2	Membership Function Level 1
SF	**Size of the Firm**		**-**	
SF1	Resources of the Firm	0.328	(0.010,0.071,0.143,0.467,0.310)	(0.007,0.041,0.160,0.474,0.317)
SF2	Skills and Experience	0.335	(0.000,0.038,0.143,0.519,0.300)	-
SF3	Level of resilience	0.336	(0.010,0.014,0.195,0.438,0.343)	-
TMS	**Top management support**		**-**	
TMS1	Top management creates support for WSTs	0.328	(0.019,0.048,0.243,0.414,0.276)	(0.019,0.059,0.181,0.437,0.305)
TMS2	Top management promotes the use of WSTs	0.337	(0.010,0.071,0.162,0.433,0.324)	-
TMS3	Top management is interested in the news about using WSTs	0.336	(0.029,0.057,0.138,0.462,0.314)	-
SN	**Subjective norms**		**-**	
SN1	Influence by others	0.246	(0.010,0.076,0.295,0.357,0.262)	(0.004,0.064,0.270,0.408,0.255)
SN2	Collaboration between organizations	0.255	(0.000,0.052,0.205,0.510,0.233)	-
SN3	Strong belief in group norms	0.253	(0.000,0.052,0.271,0.410,0.267)	-
SN4	Fear of group penalty	0.246	(0.005,0.076,0.310,0.352,0.257)	-

SBO	**Scope of Business operations**		**-**	
SBO1	Reducing cost associated with operational expansion	0.325	(0.024,0.086,0.248,0.424,0.219)	(0.014,0.054,0.257,0.443,0.232)
SBO2	Reduction of external costs of operations	0.337	(0.014,0.024,0.281,0.438,0.243)	-
SBO3	Integration of units and independent partners at a low cost	0.337	(0.005,0.052,0.243,0.467,0.233)	-

Table 8. Weightings for EFs and EFGs for Adoption of WSTs

Code	Environmental Factors EFs and EFGs	Mean score	Weighting for each FI	Total Mean for each F	Weighting for each F
ES	External support			19.462	0.412
ES1	Grants/donations	3.76	0.193		
ES2	Transfer of technical assistance	4.04	0.207		
ES3	Soft-loans	3.91	0.201		
ES4	Loan guarantee and loan insurance	3.88	0.199		
ES5	Subsidies and tax relieve operations	3.88	0.199		
CP	Competitive pressure			15.877	0.336
CP1	Operational necessity	3.92	0.247		
CP2	Strategic necessity	4.01	0.252		
CP3	Vendor or third-party support	3.91	0.246		
CP4	Competitors adopt it	4.05	0.255		
TPR	Trading partners readiness			11.895	0.252
TPR1	Partners want integration	3.87	0.325		
TPR2	Partners believe in the innovation's values	4.03	0.339		
TPR3	Partners have the technical resources	4.00	0.336		

TF: Environmental Factors indicators and TFG: Groups of Environmental Factors

Table 9. Membership Functions (MF) of EFs and EFGs for Adoption of WSTs

Code	Environmental Factors EFs	Weighting for each EF	Membership Function Level 2	Membership Function Level 1
ES_C	**External support**		-	
ES1	Grants/donations	0.193	(0.033,0.100,0.186,0.438,0.243)	(0.013,0.063,0.227,0.407,0.288)
ES2	Transfer of technical assistance	0.207	(0.005,0.043,0.171,0.471,0.310)	-
ES3	Soft-loans	0.201	(0.005,0.067,0.271,0.329,0.329)	-
ES4	Loan guarantee and loan insurance	0.199	(0.005,0.038,0.290,0.405,0.262)	-
ES5	Subsidies and tax relieve operations	0.199	(0.019,0.071,0.219,0.395,0.295)	-
CP_C	**Competitive pressure**		-	
CP1	Operational necessity	0.247	(0.019,0.029,0.190,0.538,0.224)	(0.007,0.029,0.202,0.512,0.251)
CP2	Strategic necessity	0.252	(0.000,0.029,0.181,0.548,0.243)	-
CP3	Vendor or third-party support	0.246	(0.000,0.029,0.252,0.505,0.214)	-

CP4	Competitors adopt it	0.255	(0.010,0.029,0.186,0.457,0.319)	-
TPR_C	**Trading partners readiness**		-	
TPR1	Partners want integration	0.325	(0.019,0.043,0.190,0.543,0.205)	(0.006,0.040,0.176,0.538,0.241)
TPR2	Partners believe in the innovation's values	0.339	(0.000,0.048,0.162,0.505,0.286)	-
TPR3	Partners have the technical resources	0.336	(0.000,0.029,0.176,0.567,0.229)	-

Table 10. Overall Index for the Factors Influencing Adoption of WSTs

	Weight for each Factor Group	Membership Function (Level 2)	Membership Function (Level 1)
Technological	-	-	-
Wearable Sensing Technology (WSTs)	0.400	(0.010,0.055,0.204,0.490,0.240)	(0.008,0.052,0.174,0.490,0.275)
Perceived Trialability	0.036	(0.014,0.043,0.186,0.567,0.190)	-
Technical Know-How	0.152	(0.005,0.056,0.132,0.472,0.336)	-
Perceived compatibility	0.109	(0.005,0.057,0.200,0.527,0.211)	-
Perceived Values	0.194	(0.007,0.041,0.098,0.496,0.358)	-
Security	0.109	(0.010,0.057,0.225,0.446,0.262)	-
Organizational	-	-	-
Size of the Firm	0.239	(0.007,0.041,0.160,0.474,0.317)	(0.010,0.055,0.220,0.438,0.276)
Top management support	0.233	(0.019,0.059,0.181,0.437,0.305)	-
Subjective norms	0.302	(0.004,0.064,0.270,0.408,0.255)	-
Scope of Business operations	0.226	(0.014,0.054,0.257,0.443,0.232)	-
Environmental	-	-	-
External support	0.412	(0.013,0.063,0.227,0.407,0.288)	(0.009,0.046,0.206,0.475,0.264)
Competitive pressure	0.336	(0.007,0.029,0.202,0.512,0.251)	-
Trading partners readiness	0.252	(0.006,0.040,0.176,0.538,0.241)	-

Table 11. Overall Index for Critical Drivers for the Adoption of WSTs

	Weight for each Factor	Index	Linguistic	Ranking
Technological Factors	**-**	**3.971**	**High**	
Performance Characteristics	0.400	3.893	High	4
Perceived Trialability	0.036	3.876	High	6
Technical Know-How	0.152	4.079	High	2
Perceived compatibility	0.109	3.883	High	5
Perceived Values	0.194	4.154	High	1
Security	0.109	3.895	High	3
Organizational Factors	**-**	**3.916**	**High**	
Size of the Firm	0.239	4.053	High	1
Top management support	0.233	3.953	High	2
Subjective norms	0.302	3.846	High	3
Scope of Business operations	0.226	3.822	High	4
Environmental Factors	**-**	**3.938**	**High**	

External support	0.412	3.891	High	3
Competitive pressure	0.336	3.971	High	1
Trading partners readiness	0.252	3.969	High	2