Journal of Applied Research and Technology

www.jart.icat.unam.mx

Journal of Applied Research and Technology 22 (2024) 897-906

Original

Technologies for safety and health management in large companies in Ecuador: A worker-centric exploration from technology adoption attitudes

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Received 12 11 2024; accepted 09 26 2024
Available 12 31 2024

Abstract: Implementing I4.0 technologies to promote a safe work environment is essential to safeguard worker safety and health (OSH), however, the status of the use of new technology concerning welfare and occupational safety based on IoT in the context of large companies in Ecuador remains unclear. The core hypothesis drawing the research path is that Unified Acceptance model based on Perceived Risks, Perceived Usefulness and Ease of Use as determinants of the workers' attitude, influence the adoption of IoT technology for data exchange in the context of large companies in Ecuador. Service and commerce business companies gathering most workers shows a positive and significant correlation among operation and supervision responsibilities, especially in OSH (78.31%). A positive correlation is depicted among factors building workers´ attitude. The use of portable devices, combined with workflow applications, is positively correlated with sharing data to identify risks, bridging collective and individual OSH. Monitoring activities, data collection, and training concentrate the key technological applications in large companies in Ecuador.

Keywords: Occupational health and safety, use of technology, risk perception, wearable technology

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

1. Introduction

The fourth technological revolution aims to enhance industrial production in terms of efficiency, flexibility, and quality through the implementation of automated and computerized processes. However, this transformation undoubtedly impacts the way work is structured and performed, potentially resulting in negative repercussions for employees' health and safety (Ynzunza Cortés et al., 2017).

The use of technology during times of crisis has shed light on the necessity of certain job positions, the adjustment of roles, and the challenge of returning to the workplace under new occupational health and safety conditions for workers (OHS) (Sinclair et al., 2020). Many have reported successfully implementing years' worth of digital transformation plans within a few months, as stated by Kane et al. (2021).

In the Americas region, there are significant health and safety challenges that require organizations to anticipate how current public health issues will permanently alter the work environment and management practices based on the digital paradigm in the middle technological gap and the pursuit of sustainable objectives, where the Internet of Things (IIoT), cybersecurity, big data, cloud computing, and the emerging artificial intelligence (AI) seem to be the crucial determinants of the Industry 4.0 concept created by Kagermann et al. (2011), particularly significant in Latin America. Until now, Latin American companies have not implemented comprehensive technological policies that enable them to efficiently engage in Industry 4.0 (Mamani & Sucari, 2022), explaining the limited or non-existent availability of official data to assess the implementation of emerging technologies and quantify the level of digitization in industrial processes. In Ecuador, this reality becomes evident due to the challenging access to information from the industrial park. Therefore, the strategy for obtaining and analyzing information relied on the perception of workers holding operational, professional, and technical positions in a big company.

There have been several works focused on analyzing the impact of the application of technologies driving the industry 4.0 on work organization, regulatory frameworks, and occupational health and safety (OHS) (Badri et al., 2018; Adem et al., 2020; Karatas et al., 2022; Lemos et al., 2022). The analyses concentrate on enhancing behavior analysis capabilities and error anticipation, improving interaction between teams/machinery and anomaly detectors, remote monitoring and control, enhanced flexibility and accessibility, rapid hazard recognition and learning, improved assessment and comparison of scenarios and work methods, among others. Specifically, some references (Rodríguez-Gómez, 2019; Abdel-Basset et al., 2021) mention artificial intelligence, big data, and cybersecurity as key determinants for OHS data recording in significant service companies operating in a virtual work mode. Furthermore, the emergence of the Internet of Medical Things (IoMT) is discussed for controlling and monitoring biological crises (Silva-Atencio et al., 2022). The interconnection of heterogeneous sensors, objects, patients, and users facilitating remote, real-time tracking and monitoring prioritizes IoT implementation within the Industry 4.0 context (Lampropoulos et al., 2019; Park et al., 2023). This includes the design of alarm systems combining IoT and big data for detecting hazardous/toxic gases, monitoring indoor air quality index (IAQ), and total volatile organic compounds (TVOC) (Al-Okby et al., 2022; Song et al., 2022).

Other studies focus on designing surveillance systems for monitoring industrial processes, minimizing accident and collision risks using WiFi communication, computer vision, and wearable technologies (Manikandan et al., 2019; Khan et al., 2022; Montanaro et al., 2022; Bastico et al., 2022). Additionally, the concept of Education 4.0 emerges with the increasing need for competencies to enhance safety education as a challenge in the adaptation process to Industry 4.0 (Cano, 2022).

Cano et al. (2022) mention applications that underscore the use of technology in Latin America to improve workplace safety systems and conditions using drones, mobile applications, simulators, and remote-control systems. However, despite the positive impact brought by new technologies, their adoption is influenced by various factors related to human behavior. Therefore, attitude is fundamental in assessing an individual's perspective regarding the use of new technologies in OHS, and to determine the factors influencing technology adoption within the context of large companies in Guayaquil, by analyzing workers' attitudes toward IoT-based welfare and occupational safety solutions (Häikiö et al., 2020; Battistoni et al., 2021; Al-Rawashdeh et al., 2022).

1.1. Theoretical framework

Internet of Things adoption in industry (IIoT)

The Internet of Things (IoT) represents a network of autonomous devices connected via the internet, using software applications that enable sensor integration for monitoring, data collection, processing, communication, and networking. In the industrial context, IIoT contributes to the value chain by supporting decision-making to increase production, improve product or service delivery, while reducing labor costs and energy consumption (Boyes et al., 2018). The growing interest in workplace safety and health is supported by compliance with health and safety standards. For instance, ISO 45001 and ANSI Z10 provide frameworks for organizations to establish and maintain an occupational safety and health management system. In Ecuador, companies implement the Worker Safety and Health Regulation (*Reglamento de Seguridad y Salud de los Trabajadores*). However, the inclusion of technological solutions for OHS monitoring and control is not considered, despite the additional complexities associated with technology implementation.

Bavaresco et al. (2021), focusing on the Internet of Things context in the industry and workers' occupational well-being, conducted a study on technologies employed in health and wellness matters. This study allowed associating worker perceptions toward data exchange technology with aspects addressed in the literature on IIoT over the last 10 years (Figure 1).

Overall, the implemented technologies have focused on real-time monitoring and early alerting of risk situations, identifying patterns and trends in process behavior for decision-making, industrial process automation, and simulation-based training and immersive reality.

Determinants influencing worker' attitudes toward the use of technology

The Acceptance Model (TAM) (Davis et al., 1989) asserts that perceived usefulness (perception of performance improvement) and ease of use (minimization of pressure when adopting technology) are the two most critical factors affecting people´s decisions to accept or reject technology. The model is widely used in literature reviews due to its user-friendliness and flexibility (Selçuk, 2021). Additionally, based on the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology Organization Environment framework (TOE), it is acknowledged that perceived risk significantly affects workers' attitudes toward technology adoption, while perceived trust positively influences ease of use and technology use behavior (Hewavitharana et al., 2021). Häikiö et al. (2020) proposed trust and data sharing as factors promoting technology adoption. The trust model distinguishes three dimensions: the product, through knowledge of the security monitoring system and self-monitoring, social influence through perception of common interest, and security through workers' risk perception. Data sharing is defined through behavioral and personal health data exchange and concern for shared personal data.

The core hypotheses are based on the statement that combined influence of this these perspectives could provide information about the current adoption of IoT technology in Ecuador. The primary research questions are presented below, stemming from the analysis of the hypothesis system in the study (Figure 2a):

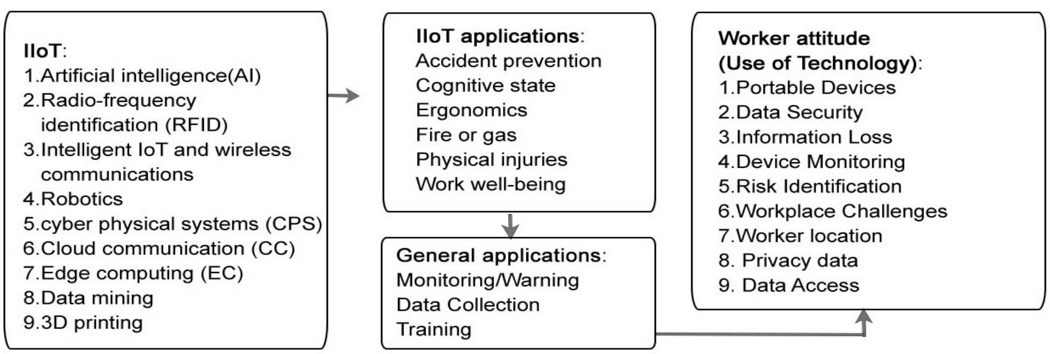
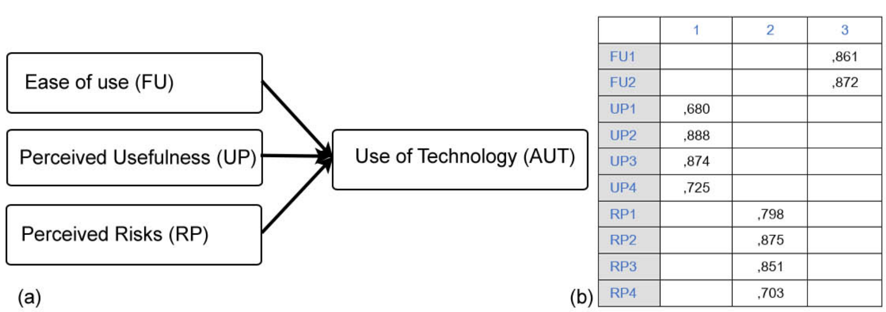


Figure 1. Relationship between aspects addressed in IIoT (Bavaresco et al., 2021) and aspects of perceived attitude towards data sharing from IoT determinants.



	1	2	3
FU1			,861
FU2			,872
UP1	,680		
UP2	,888		
UP3	,874		
UP4	,725		
RP1		,798	
RP2		,875	
RP3		,851	
RP4		,703	

Figure 2. (a) Adapted TOE/TAM Technology acceptance model, based on perceived attitude towards data sharing (Häikiö et al., 2020). (b) Principal components analysis with *direct oblimin rotation*.

What are the factors influencing the adoption of IoT technology for data exchange by workers in the context of large companies in Ecuador?

What is the status of new technology usage concerning welfare and occupational safety based on IoT, in the context of large companies in Ecuador?

The research started with a descriptive, non-parametric correlational quantitative investigation, based on determinants influencing worker attitudes toward technology usage, for gathering occupational safety and welfare data (Silva & Pizarro, 2023).

2. Materials and methods

2.1. Exploratory analysis

A principal component analysis with direct oblimin rotation was conducted using the IBM-SPSS statistical package to verify the accuracy of latent variables explaining the attitude of workers in large Ecuadorian companies toward technology usage. The validation assumed that the independent variables are the factors or components, while the items are the dependent variables in this design. The reported measures were determinant of the correlation matrix: 0.0023, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy: 0.769, and total explained variance: 67.91%.

2.2. Working with large companies

According to available information from the Ecuadorian National Institute of Statistics and Censuses (INEC), companies are classified based on two criteria: the number of workers and annual sales. Large companies meet the following criteria: 200 workers or USD$ 5,000,001 and above (INEC, 2021). Particularly, it was established that large companies are entities capable of adopting new technological trends in their processes due to their available resources. As of the latest 2020 records, Guayaquil has 1005 registered large companies (INEC, 2021), grouped into six major economic sectors: agriculture, livestock, forestry, and fishing; mining exploitation; manufacturing industries; commerce; construction; and service, simplifying the economic structure. However, due to the difficulty in accessing information in these companies, workers holding managerial, operational, professional, and technical positions were consulted to assess technology adoption in Ecuador.

Some authors note that in studies involving socially challenging groups, a representative sample may not necessarily promote the best candidates. Instead, they recommend selecting a sample based on specific criteria, such as their willingness to participate, among others (Hernandez-Ávila & Carpio Escobar, 2019; Campbell et al., 2020; Del Estal Garcia & Melián González, 2022). Hence, non-probabilistic convenience sampling was used to determine the current situation in occupational safety and health based on IIoT. The cross-sectional study was conducted during November and December of the year 2022, with 527 responses from employees of officially registered Ecuadorian companies in the city of Guayaquil, of which 277 were obtained from 'large company' workers.

2.3. Instrument

An anonymous online questionnaire ('Occupational Safety based on the Internet of Things from Workers' Perspective') was used to gather data regarding workers' perceptions of safety and workplace well-being based on IIoT.

The first section was centered on general aspects of the respondents and the work environment: three questions for sociodemographic characteristics: SD1. Age, SD2. Gender, SD3. Educational Level. Four questions related to work experience, type of company where they work, and position held: EL1. Years of experience, EL2. Number of company employees, EL3. Economic sector, EL4. Position. All were multiple-choice questions. Following this, two dichotomous questions about connectivity and internet access at the company: C1. Worker's internet access and C2. Data transfer at work.

The second part contained questions associated with determinants influencing the worker's attitude towards technology and fell within the conceptual framework established in this work (Table 1). A 5-point Likert scale was used to rate the response level, ranging from 'very low' (level 1) to 'very high' (level 5). An option was included for cases where it did not apply, or information was not desired to be shared.

3. Results analysis

3.1. General description

The 65% and 35% of the workers identified themselves as male and female, respectively, while less than 1% selected other genders. 44.5% of respondents reported having an education level up to high school, and 61% of the workers were aged between 18-34 years, with 43% of them holding a university degree. Out of the total sample, 70.4% claimed to have work experience between 1 to 10 years, with ages ranging between 18-34 years (81%). Another interesting result is that 35.4% of the respondents hold supervisory, professional, and technical positions, while operational and support roles account for 38% in companies across various economic sectors. It's noteworthy that the economic sectors with higher participation of workers in the study consist of service companies (36.5%) and commerce (23.4%).

The results indicate that 54% show a positive inclination toward using devices for supervising and monitoring work activities, which are particularly useful for ensuring occupational safety and health for workers in positions, with operational and supervisory roles concentrating most of this perception (75%).

Table 1. Measurement instrument "attitude towards the use of technology" in occupational health and safety matters.

Dimensions	Var.	Items
Willingness to use monitoring and portable devices	Ease of use (FU)	FU1. Use devices to monitoring my activities during the workday.
Willingness to use personal measurement devices		FU2. Use portable devices at work. FU3. Use measurement and body location devices.
Willingness to share data	Perceived Usefulness (UP)	UP1. Share data that help to identify risks in the work area. UP2. Share data to ensure my safety and the occupational health and safety of my co-workers. UP3. Share data to prevent loss of information.
Concern about personal data sharing	Perceived risks (RP)	RP1. Employers, bosses, or coworkers could access my personal data and misuse it. RP2. Sharing data might expose my private information to employers, bosses, or coworkers. RP3. Sharing information could lead to unauthorized access and misuse of my personal data. RP4: Data-driven technologies can create workplace problems.

3.2. Association between attitudinal aspects and general IIoT applications

Through a weighting analysis by agreement (Gómez, 2022), the underlying aspects in the items of the instrument associated with IoT determinants and applications are prioritized. We assign weights to the Likert scale categories so that the categories indicating higher agreement are overweighted compared to those indicating disagreement: use of wearable devices (0.781), data security (0.666), concern for information loss (0.658), use of monitoring devices (0.642), risk identification (0.641), detection of workflow issues (0.530), use of personal measurement devices (0.465), willingness to share personal data (0.465), confidence in data access (0.462), and monitoring information by external stakeholders. This association served as the basis for supporting the results analysis of the non-parametric rank correlation analysis.

3.3. Situation in Ecuador: non-parametric correlation analysis

The Spearman analysis is a measure of association that compares pairs of ranks between variables that are often censored and not normally distributed. The level of association, alongside the prioritization of aspects in the workers' attitude model toward technology use and data exchange, supported the instrument's results analysis. Table 2 reports the significant correlations from the study.

Attitudinal aspects and general IIoT applications

From the descriptive analysis, 42% of surveyed workers in large companies hold a third-level diploma (SD3) and use wearable devices in their tasks (0.295**), with significant negative associations toward perceived usefulness when sharing personal data and workplace safety (-0.147*). The use of wearable devices requires communication technologies such as 3G and 4G networks, Bluetooth, and wireless connections available in Ecuador (WLAN, Wifi, GSM, access points, and IEEE 802), implicating the management of available security tools. In this context, Chuquitarco (2018) highlights factors driving security adoption within an Ecuadorian organization: optimizing corporate resources, minimizing manual controls, implementing standards and quality norms, fear of cyberattacks, as well as promoting user confidence, with a direct application in physical access control to facilities and network access.

Large service and commerce companies implementing IoT technology encompass 56.02% and 42.77% of male and female workers, respectively "With ages ranging from 18 to 43 years (63.86%), 78.3% of whom hold operational and supervisory responsibilities, showing a significant association with the use of wearable devices in their work activities, such as laptops, tablets, cell phones, among others, and body measurement and location devices, e.g., temperature sensors and GPS (60.24%).

Gender correlates positively with educational level (0.228**) in surveyed medium and large companies. 33.83% and 65.55% identify as female and male, respectively, with a higher than university level of education (female: 66.96%, male: 41.01%). Among the remaining sample, a larger proportion of male workers have education levels below university degrees. At least 70% of workers with high education (>high school) hold operational and support positions, supervisory and technical (-0.398**) in large companies in Guayaquil. 67% of these workers have internet access (-0.225**), and with increased responsibility, there's a greater need for data transfer (88 although the use of wearable devices is not significant for this purpose. There's also no strong correlation between the data they share and the monitoring of their activities within the workday.

On the other hand, 100 workers surveyed in different companies in the manufacturing and services sector, with a range of age 18-34 years (more than 50%), middle school or technical education, predominantly occupying supervisory and middle management positions in general (more than 70%), The high level of education among workers in the service sector, and with less than 5 years of experience, associated IIoT technologies with the use of facial or fingerprint recognition devices, and wireless devices for personnel location, embedded in clothing or worn on the body for health monitoring. It is worth noting the higher level of education among workers in the service sector. The individuals where there is greater use of portable devices in their work activities comes from respondents with a university degree (42%), these two aspects are associated with innovation and ease of use.

The perception of the risk of violation of labor privacy and the negative consequences of the use of this data is a concern for 67% of workers with some degree of higher education, who work mainly in large service and commerce companies (0.161**), performing supervisory or technical tasks. 59.01% of workers in large companies (level of education > high school, male: 63.41%, female: 0.01%) use measurement and body location devices, with a negative perception of the use of this data by third parties (0.162**).

Occupational health and safety aspects

A positive correlation between factors associated with ease of use (FU) and perceived usefulness (UP) and risk perception (RP) is evident. The use of portable devices to monitor activities during the workday was associated with the detection of problems in the workflow, positive correlations exist between data transfer aiding in risk identification in the workplace, ensuring personal and colleagues' occupational safety and health, especially with the use of body measurement and location devices (Table 3).

Table 2. Spearman´s nonparametric correlation analysis.

Ítem	ρ	Ítem	ρ	Ítem	ρ
SD1	EL1 (0.677**) UP1 (-0.142*) UP3 (-0.151*)	C1	C2 (0.424**) FU1 (-0.318**) FU2 (-0.309**) UP1 (-0.172**)	FU3	UP1 (0.486**) UP2 (0.447**) UP3 (0.327**) RP3 (0.162**)
SD2	SD3 (0.228**) EL3 (0.121*) FU2 (0.132*)	C2	FU1 (-0.353**) FU2 (-0.357**) FU3 (-0.225**) UP3 (-0.194**) RP1 (-0.126*) RP2 (-0.128*) RP3 (-0.143*)	UP1	UP2 (0.742**) UP3 (0.551**) RP3 (0.132*) RP4 (0.125*)
SD3	EL3 (0.143*) EL4 (-0.398**) C1 (-0.225**) C2 (-0.326**) FU1 (0.185**) FU2 (0.295**) UP2 (-0.147*) RP1 (0.161**) RP2 (0.161**) RP3 (0.140*)	FU1	FU2 (0.495**) FU3 (0.313**) UP1 (0.320**) UP2 (0.219**) UP3 (0.360**) RP3 (0.128*) RP4 (0.156*)	UP2	UP3 (0.570**) RP3 (0.123*) RP4 (0.125*)
				UP3	RP3 (0.132*) RP4 (0.168**)
EL4	C1 (0.135*) C2 (0.237**) FU1 (-0.172**) FU2 (-0.280**) RP1 (-0.139*)	FU2	FU3 (0.191**) UP1 (0.252**) UP2 (0.212**) UP3 (0.348**) RP2 (0.142*) RP4 (0.125*)	RP1	RP2 (0.675**) RP3 (0.562**) RP4 (0.364**)
				RP2	RP3 (0.672**) RP4 (0.453**)
				RP3	RP4 (0.513**)

ρ rank correlation coefficient
** Significant correlation at the 0.01 level
* Significant correlation at the 0.05 level.

Table 3. Adoption of IIoT- based technology in large companies by sector.

Sector	%	IIoT- based technology
Services	36.82	-Intelligent electronic devices incorporated in clothing. -Wireless devices for personnel location and/or temperature measurement. -Facial or fingerprint recognition devices. -Training on the use of OSH technologies.
Wholesale and retail trade	23.11	-Workplace safety inspection and monitoring systems.
Manufacturing	18.05	-Inspection and security control systems in the workplace. -Facial or fingerprint recognition devices. -Training on the use of OSH technologies. -Wireless devices for personnel location and/or temperature measurement.
Agriculture and Livestock	18.05	-Facial or fingerprint recognition devices. -OSH inspection and control systems in the workplace. -Training on the use of OSH technologies. -Wireless devices for personnel location and/or temperature measurement.
Others	3.97	-Intelligent devices for monitoring occupational medical examinations. -Training on the use of OSH technologies. -OSH inspection and control systems in the workplace -Facial or fingerprint recognition devices.

Evidence suggests that process automation and task supervision with technology can increase mechanical, physical, and chemical risks, especially psychosocial risk (job insecurity, control and autonomy, lack of clarity in roles and expectations, among others). In this context, usability perception tends to decrease due to functional stupidity perception, while risk perception increases due to insecurity in sharing or transferring data with colleagues and immediate supervisors (Leso et al., 2018). The need for continuous training to keep skills updated is important in economic sectors (Arana-Landín et al., 2023) and increases with company size (Table 3).

Monitoring technologies, such as wearable technology, continuously monitor employees' well-being and the status of equipment, machinery, and facilities (Rodríguez-Gómez, 2019; Hernandez-Ávila & Carpio Escobar, 2019). Technologically speaking, such monitoring can provide real-time alerts indicating the need to adopt preventive measures designed to stop dangerous hazards, re-establishment of security procedures, injury avoidance, and enabling an injured worker to seek help.

Overall, technological solutions in occupational health and safety (OHS) can be found in the literature according to the type of risk (Arana-Landín et al., 2023), which could explain the findings of this study in future work: fall detection and hidden risk identification, improvement of workplace comfort (air quality, temperature), reduction of internal travel and weight for employees through voice search and camera use, collection of movement data for workplace improvement using cameras, reduction of potentially hazardous jobs through visual communication, prevention of accidents involving machinery, employees, and transportation vehicles, distrust toward personnel regarding privacy matters, minimization of manual handling of information, reduction of contact infections through devices, among others (Moore, 2019; Zorzenon et al., 2022; González-Cañizalez & Flor-Mosquera, 2022).

4. Conclusions

Attitude toward technology has been used as a mechanism to analyze factors influencing technology adoption in the context of large companies in Guayaquil, exploring the use of new technologies in the safety and health of workers.

Service and commerce companies stand out in the analysis of technology adoption from the workers' perspective. Generally, groups of younger workers (<45 years) in operational and supervisory positions using technology were a significant part of the sample, with a tendency towards using portable IoT-connected devices for work data transfer, including body measurement and location.

Factors influencing IIoT-based technology adoption in large Ecuadorian companies can be summarized as follows: higher educational levels positively correlate with workers' perception of ease of use and heighten concerns about personal data sharing. The utility of technology in OHS (perceived usefulness) reflects workers' concern for cybersecurity, motivated by the perception of third-party access to information and potential workplace issues. Information security follows perceived risk due to external stakeholders monitoring information. According to the exploratory nature of the findings, the perceived risks could be the main factor leading the worker´s attitude to the adoption of IIoT- based technology.

The current state of using new technologies in well-being and occupational safety based on IoT in the context of large Ecuadorian companies is oriented towards facial or fingerprint recognition, workplace safety inspection and control, and training on the use of technologies in OHS.

There is not enough evidence to stablish a strong linear relationship between some variables evaluated in terms of their classification or range, so a deep parametric analysis should be conducted.

Due to the exploratory nature and sampling type, the strength of correlations was not strong but was significant enough to stablish the panorama of technology use related to OHS in large companies.

Future work

A This research raises questions that need to be answered, related to the influence of each Industry 4.0 (I40T) technology on each type of OSH risk in Ecuador. Particularly, the impact of artificial intelligence technology on supervising workplace safety and health risks. Additionally, determining digital competence barriers for successful technology adoption and implementing health management algorithms also becomes a research need in the future.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

This research was supported by project FCI-007 (University of Guayaquil, Guayaquil, Ecuador).

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