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Original Article

Developing AI-based Training Systems for Hispanic Workers in Small Construction Companies

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Abstract - *The construction industry in the United States has a significant representation of Hispanic workers, who comprise about one-third of the total workforce. Every year, about 300 Hispanic construction workers die in the workplace. Worse still, within small construction companies, this population has disproportionately higher rates of fatalities and injuries. Current safety training methods have been insufficient in addressing the specific needs of Hispanic workers due to language barriers, cultural differences, immigration concerns, and construction operational issues. To address these issues, this paper summarizes the research on enhancing construction safety for Hispanic workers in small construction companies through innovative AI-based training systems. This research first identifies the specific needs of Hispanic workers in small construction companies and designs training programs to enhance safety culture and awareness. Next, it investigates how AI and information technology (IT) can improve training effectiveness by focusing on communication, safety culture establishment, workers' rights awareness, and construction operational safety. Finally, this research will establish innovative AI-based training systems tailored for Hispanic workers in small construction companies. The proposed intelligent training systems provide a platform to connect Hispanic construction worker communities and generate comprehensive safety programs suited explicitly to Hispanic workers' needs. By addressing critical issues faced by this demographic, this research develops an infrastructure to create a safer and healthier workplace for Hispanic construction workers.*

Keywords - *Construction safety, Hispanic workers, Artificial Intelligence (AI), IT, AI-based training Systems.*

1. Introduction

The US construction sector is leading in employing Hispanic workers. The Bureau of Labor Statistics (2023) indicates that the share of Hispanic workers is approximately 33% of the construction labour. Unfortunately, the sector is also a leader in the number of fatalities among Hispanic workers across all industries. Alarmingly, in 2022, this demography accounted for 37.4% of all construction fatalities (Safety + Health, 2024), which emphasizes the critical safety challenges faced by this workforce. Indeed, within small construction companies, the rates of fatalities and injuries among Hispanic workers are disproportionately higher (Cunningham et al., 2018). These companies have limited resources and funding to develop comprehensive safety training programs (Cunningham et al., 2014). In this regard, designing the proper training program is a promising step to solve the issue of worker safety. According to the previous research, current training methods are insufficient to address the unique challenges Hispanic workers face. Therefore, the integration of Artificial Intelligence (AI) and Information Technology (IT) into safety training presents a novel approach to improve its effectiveness (Schuur et al., 2021; Upadhyay and Khandelwal, 2019). Previously, several studies have studied the reasons for Hispanic labour fatalities in the construction industry (Al-Bayati et al., 2017; Morrison, 2015). This research categorizes these causes into the following four aspects: language, immigration, culture, and operations (Figure 1). In the context of the current paper, these categories are important for identifying and addressing the specific challenges Hispanic workers face.

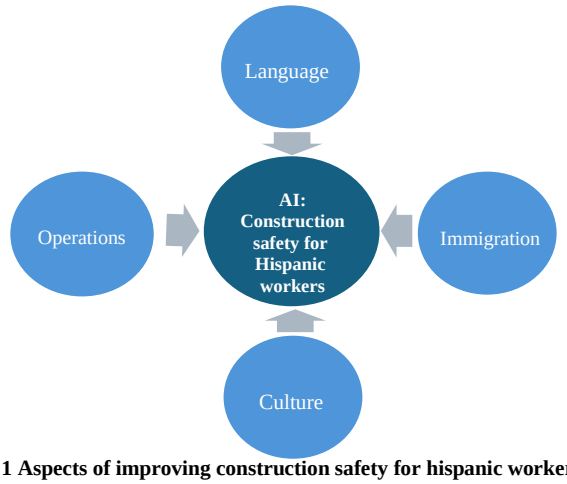

Fig. 1 Aspects of improving construction safety for hispanic workers

Three main research gaps were found concerning the training systems for Hispanic workers. The first gap is ineffective training methods. Despite various efforts to establish training systems for Hispanic construction workers by academic institutions and organizations like the Occupational Safety and Health Administration (OSHA), the University of Massachusetts at Lowell, Georgia Tech, and the University of California at Berkeley, traditional training methods remain less effective for this demographic (Al-Bayati et al., 2017). The second gap focuses on a lack of AI-based training systems. AI has enhanced training effectiveness (Paranjape et al., 2019; Vogan et al., 2020). For example, existing research by Hussain et al. (2024) has only addressed communication issues. However, broader challenges include language, cultural, immigration, and operational barriers in safety training for Hispanic construction workers employed by small companies. Lastly, the third gap is the absence of a connected community to disseminate the training data related to these challenges (Marin et al., 2015). Thus, there is a gap in research and application concerning the use of AI in training systems and community connections to improve safety for Hispanic workers in small construction firms. Therefore, this research aims to address this gap by developing novel AI-based training systems for Hispanic workers in construction. The objective of this paper is to summarize the approach that will be taken to develop these training systems.

2. Literature Review

2.1. Hispanic Workers in Construction

The Hispanic workforce is one of the rapidly expanding laborers in the construction industry. The U.S. Department of Labor (USDOL) reported a 34.5% increase in the Hispanic workforce between 2003 and 2014. This number is expected to expand. Hispanic workers face significant challenges related to their health, well-being, and workplace safety. This group experiences higher fatality rates compared to any other ethnic group (Brunette 2005). Moreover, when injuries do occur, they tend to be more severe among Hispanic workers (Hurley and Lebbon 2012).

Hispanic workers in the construction sector hold a range of roles, from day laborers to managerial positions. This is reflected in the findings from the Center for Construction Research and Training (CPWR 2013) that the majority of them are employed as laborers (27%), followed by carpenters (13%) and painters (10%). Only 6% of Hispanic workers occupy management-level roles. This indicates that more than 90% of this population hold labor-type roles, making them particularly vulnerable to OSHA's "Fatal Four" construction hazards: falls, electrocution, being caught in, and being struck by objects. As a result, injury rates are likely to be higher among Hispanic labor, pointing out the importance of addressing the factors that contribute to injuries and fatalities within this group. This is supported by NIOSH (2015), which states that "young Hispanic workers employed by small construction companies are likely to encounter significant occupational safety and health challenges compared to most other employee groups of industries in the United States".

2.2. Underlying Causes of Elevated Fatalities among Hispanic Workers

A review of key studies highlights several contributing factors to fatalities among Hispanic workers, including language barriers, knowledge and level of education, insufficient experience, younger age, cultural differences, and immigration status (Al-Bayati et al. 2017; Dong et al. 2009; Roelofs et al. 2011). This section summarizes the following four underlying causes: language, culture, immigration and construction operations.

2.2.1. Language

One of the biggest challenges in advancing safety among immigrant employees is the language barrier between immigrant workers and their supervisors (Flynn, 2014). This issue is widespread in regions of the U.S. where there is minimal or no bilingual support infrastructure. Language barrier is considered a treatable cause, and many measures have been introduced to reduce its impact. These efforts focus on three approaches: translating training materials into Spanish, employing bilingual supervisors, and utilizing visual aids, such as photos, to bridge terminology gaps (Al-Bayati et al., 2016).

2.2.2. Culture

Cultural factors influencing workplace safety include immigrants' perceptions of work and their relationships with coworkers and employers. Also, these involve how these perceptions differ from their experiences in their home countries and how they view workplace hazards compared to other daily risks (Flynn, 2014). Moreover, cultural differences give rise to varying beliefs, behaviors and expectations among individuals and groups (Gany et al., 2011). If these differences are not acknowledged and managed, they can cause miscommunication between workers and supervisors, potentially compromising safety performance (Al-Bayati et al., 2017).

2.2.3. Immigration

Immigration is a challenging and unmanageable reason for safety in construction. As stated by Al-Bayati et al. (2016), this category falls outside the direct control of the construction industry. This fear of deportation or job loss most often discourages migrant workers from reporting safety concerns or injuries. As a result, they become vulnerable to increased risk of exploitation and unsafe working conditions. Therefore, addressing and clarifying the rights of immigrant workers is important to reduce these risks and encourage them to report safety issues without fear of deportation.

2.2.4. Operations

Knowledge and understanding of safe work practices are critical to prevent occupational injuries and illnesses. Immigrant workers coming to the U.S. usually find jobs in new industries (Flynn et al., 2012). This lack of familiarity includes machinery, chemicals and materials they encounter, along with the associated hazards. Even those with previous experience in the industry generally face new practices in the U.S. (Flynn, 2014). Thus, providing adequate training and ensuring that these workers are informed about operations and safe work practices is crucial for their protection and effective integration into the workforce.

2.3. Artificial Intelligence (AI) in Construction Safety Training

AI is an area of science that enables computers to perform tasks that usually require human understanding. It includes various disciplines such as linguistics, psychology, philosophy, and computer science. AI has been extensively applied to construction safety management in recent years and has shown effectiveness in improving safety.

However, its application in construction safety training is rather new. This section reviews the literature on using AI technologies such as Natural Language Processing, Machine Learning, Computer Vision and Deep Learning in construction safety training.

2.3.1. Natural Language Processing (NLP)

NLP plays a key role in personal safety training in construction (Hussain et al., 2024). The study employed conversational AI to enhance migrant workers' VR safety training. This approach seeks to overcome the language barriers and lack of personalized engagement found in traditional training methods. By incorporating NLP, the training becomes more interactive and accessible, especially for non-native speakers, which enhances understanding and retention. NLP is also widely used in behavioral safety (Zhu et al., 2022; Seo, Park, and Koo, 2024) incorporating chat bots and interactive learning tools to improve hazard identification and improve safety training. NLP chatbots can simulate real-time hazard scenarios and provide instant feedback, reinforcing safety behaviors.

2.3.2. Machine Learning

Jeelani et al. (2018) used machine learning and computer vision to deliver personalized safety training based on eye-tracking data. This method addresses the shortcomings of standard, one-size-fits-all training programs by offering tailored training that adapts to individual needs and learning speeds. In process safety, machine learning is applied in a cyber-physical postural training system for construction workers, as detailed by Akanmu et al. (2020). This system aims to address gaps in ergonomic training by providing real-time feedback on workers' movements to prevent musculoskeletal injuries.

2.3.3. Computer Vision

Lee and Yu (2023) used computer vision for hazard awareness on construction sites through AI-based object recognition. This method addresses the gap in real-time hazard detection and monitoring, allowing for the identification of potential dangers that human observers might miss. The advantage of computer vision is its ability to operate continuously and provide immediate alerts.

2.3.4. Deep Learning

In the study by Ho et al. (2022), deep learning is used in technological safety, particularly in safety-aware human-robot collaboration. Integrating deep learning in mixed reality systems aims to improve safety by predicting and mitigating risks in human-robot interactions. The gap addressed is the lack of advanced safety measures in environments where humans and robots work closely together. Deep learning models can analyze large volumes of data to predict potential hazards and optimize the interaction between humans and robots.

2.4. Safety Training Benefits of AI Applications

2.4.1. Real-time Monitoring

Construction safety training can benefit from AI for real-time monitoring and compliance. These intelligent systems can continuously scan construction sites for potential hazards using image recognition technology. For instance, if a worker is not wearing a hard hat or is operating machinery incorrectly, the AI system can instantly alert supervisors (Shanti et al., 2022). This approach to safety helps prevent accidents.

2.4.2. Virtual Reality (VR) and Mixed Reality (MR)

Other important applications of AI in safety training are immersive simulations and VR training. Using VR and MR technologies, realistic training environments can be created that simulate construction sites and potential hazards (Huang et al., 2020). Workers can practice recognizing and responding to dangerous situations in these virtual environments, providing a safe space to learn and make mistakes. This hands-on experience helps workers internalize safety procedures more effectively than traditional classroom-based training, leading to better preparedness and safer behaviors on the job.

2.4.3. Conversational AI

Interactive learning tools, such as conversational AI and chatbots, enhance the learning experience by providing instant feedback and guidance. These AI tools can answer safety-related questions, guide workers through training modules, and simulate real-life scenarios requiring safety-critical decisions (Zhu et al., 2022). Chatbots support learning by engaging workers in interactive dialogues and provide a better understanding and recognition of safety protocols (Rajagopal, 2017).

2.4.4. Personalized Training

Some recent uses of AI in safety training include AI-driven analytics to improve personalized training programs during training. For example, Luo et al. (2023) explored that AI enables personalization through customizing training to individual workers' styles and needs of learning. Choi et al. (2023) evaluated workers' learning performance through biometric responses using AI. Other studies utilized eye-tracking technologies to observe trainees' attention during simulations and improve their hazard recognition abilities, demonstrating that personalized training programs using AI address individual weaknesses and ensure that each worker receives effective training (Jeelani et al., 2018).

2.4.5. Continuous Learning

AI technologies enable continuous learning through on-demand access to training materials and safety information. Workers can utilize mobile apps or online platforms to review safety procedures, watch instructional videos, and take quizzes to stress their knowledge. AI systems monitor their progress and suggest additional resources as necessary, ensuring continuous learning and reinforcement of safety protocols (Sudharsan and Vinayagam, 2024).

By targeting specific gaps in conventional training, the application of AI in construction safety training becomes distinct. Safety training can benefit from AI through real-time monitoring, virtual reality and augmented reality technologies, personalized training, and conversational AI and chat Bots.

3. Methodology

This section presents the methodology of the research. The research will be implemented according to the following activities.

Step 1: Conduct a comprehensive literature review to understand current challenges, practices and solutions related to construction safety training for Hispanic workers and AI applications.

Step 2: Collect data: A questionnaire survey will be carried out to understand the needs of Hispanic workers in overcoming the language barrier, understanding cultural differences, their rights about immigration status and the need for training on construction processes and operations. This questionnaire survey will be administered anonymously to Hispanic workers in small Kansas, Texas, and Michigan construction companies. Another questionnaire will be executed with supervisors to understand their expectations of the AI-based training systems.

Step 3: Develop AI-based Training System: after analyzing the literature review and collecting data from questionnaires by Hispanic workers and their supervisors, the research will design the personalized training content using natural language processing and adaptive learning algorithms.

Step 4: Develop an application for an AI-based Training System: The application will be developed similarly to ChatGPT. This app will help Hispanic workers communicate with their colleagues and understand the work process through the built-in translation tool.

Step 5: Perform pre-test and post-test: two types of tests will be conducted. A pre-test will be performed, and a post-test will be carried out with an AI-based training system. The results will be evaluated to assess the AI-based training system's effectiveness in understanding and knowledge retention.

Step 6: A questionnaire survey will be administered among Hispanic workers and their supervisors to collect their perceptions and feedback about the AI-based training system. This will help researchers understand the need for continuous improvement.

Step 7: Analyze and evaluate: the pre-test and post-test results will be analyzed to assess the effectiveness of the developed system.

4. AI-Based Training System

This section summarizes the functions and architecture of the AI-based training system.

4.1. Functions of AI Training System

An AI training system offers a range of functions designed to enhance learning and adapt to individual needs. Table 1 outlines the functions of the AI training system, covering four aspects: language, culture, immigration and operations. The research involves identifying specific needs through a literature review, questionnaires, surveys, interviews, and statistical analyses of each aspect. Additionally, the study investigates how AI and IT can improve the efficiency and accessibility of the training program across all four aspects.

In the language aspect, based on the evaluation of language needs, a training system is designed to assist with translation from English to Spanish and vice versa, with a particular emphasis on construction-specific terminology. Furthermore, a software agent is developed for each worker's personalized learning plans, which considers their individual learning needs and abilities.

Similarly, the underlying cultural reasons contributing to casualty among Hispanic workers will be investigated from a cultural perspective. The research also explores cultural differences between Hispanic and American construction workers and supervisors to identify potential conflicts and misunderstandings. The outcome of these activities is an intelligent training system designed to educate Hispanic workers about job safety, focusing on the importance of cultural awareness in creating a safe workplace.

Table 1. Functions of AI training system

Aspects	Activities	Functions
Language	Understand the language needs of Hispanic construction workers using questionnaires, surveys, interviews, and statistical analyses.	Translate from English to Spanish and vice versa (including construction terminology/terms).
	Investigate how AI and IT can be used to improve language training courses.	Generate learning plans according to Hispanic worker's language learning needs and abilities.
Culture	Investigate root causes of injuries and fatalities related to cultural reasons.	Generate learning plans to educate Hispanic workers on job safety, including explanations of cultural differences.
	Study how AI and IT can be used to improve culture training courses.	
	Understand cultural differences between Hispanic and American construction workers and supervisors.	
Immigration	Investigate immigration issues among Hispanic workers.	Design a virtual immigration consultant (software agent) to help inform Hispanic workers of their rights.
	Study how AI and IT can be used to establish worker rights training courses.	
Operation	Investigate construction operations with the largest shares of Hispanic workers.	Establish training courses to cover common practices in the investigated construction operations.
	Study how AI and IT can be used to establish construction operation training courses.	Design a software agent to automatically generate learning plans according to Hispanic worker's learning needs and abilities.

For example, cultural training will be integrated into safety training and framed to protect loved ones and collective well-being. Another aspect addressed is "empowering workers to speak up" since reluctance to question authority is a common issue in Hispanic culture. Moreover, a "Cultural sensitivity training module" will be developed for supervisors, including the importance of hierarchy in Hispanic cultures, family values and communication styles for Hispanic workers.

In the immigration aspect, the specific immigration issues impacting Hispanic workers in the construction industry will be examined. This will include understanding their legal status, rights and challenges they face. The research will also investigate how AI and IT can be used to develop comprehensive worker rights training programs to educate workers about their rights and protections. Consequently, a virtual immigration consultant will be developed to assist Hispanic workers with information about their rights.

Finally, the operations aspect will identify construction operations with high Hispanic worker representation. The research develops a targeted training course covering necessary skills and safety practices by identifying this. The research employs AI and IT to optimise learning and create personalized learning plans based on individual worker needs and abilities. This approach will help improve Hispanic worker safety and raise productivity within the construction industry.

The novelty of this research lies in the scope of categories it addresses. Previous research primarily focused on language barriers only.

However, this study examines four key challenges Hispanic workers face in the U.S. construction industry: language, cultural differences, immigration rights, and construction-specific technical skills.

This system uses advanced AI algorithms to create personalized and adaptive learning experiences that considerably improve understanding and retention.

4.2. System Architecture

This section presents an overview of the AI-based training system architecture. The system's main components include a Client, Chat Bot, AI Agent, and NLP. The definition of each component is shown below.

- Client: The end-user, a Hispanic construction worker.
- Chat Bot: A software application reproduces human conversation through text and voice communication.
- AI Agent: A software application that uses AI to perform tasks and make decisions.
- NLP (Natural Language Processor): A software application designed to understand, interpret, and produce human language.
- Database: an organized collection of structured information such as culture, immigration, language and operations.

The system architecture workflow is illustrated in Figure 2. The client interacts with the Chat Bot in the front end by typing or speaking a phrase. After receiving the user input, Chat Bot processes the process by sending the phrase to the NLP engine to extract the relevant translation. The NLP component processes the input and sends the translation response to the AI agent. The AI agent finds the relevant data from the database based on the query related to language, culture, immigration or operations. The AI agent analyzes the retrieved data and generates a response through translation, learning plans, cultural training, worker rights training, or operations training courses. The next step is response generation, in which the AI agent sends a response back to Chat Bot and presents it to the client

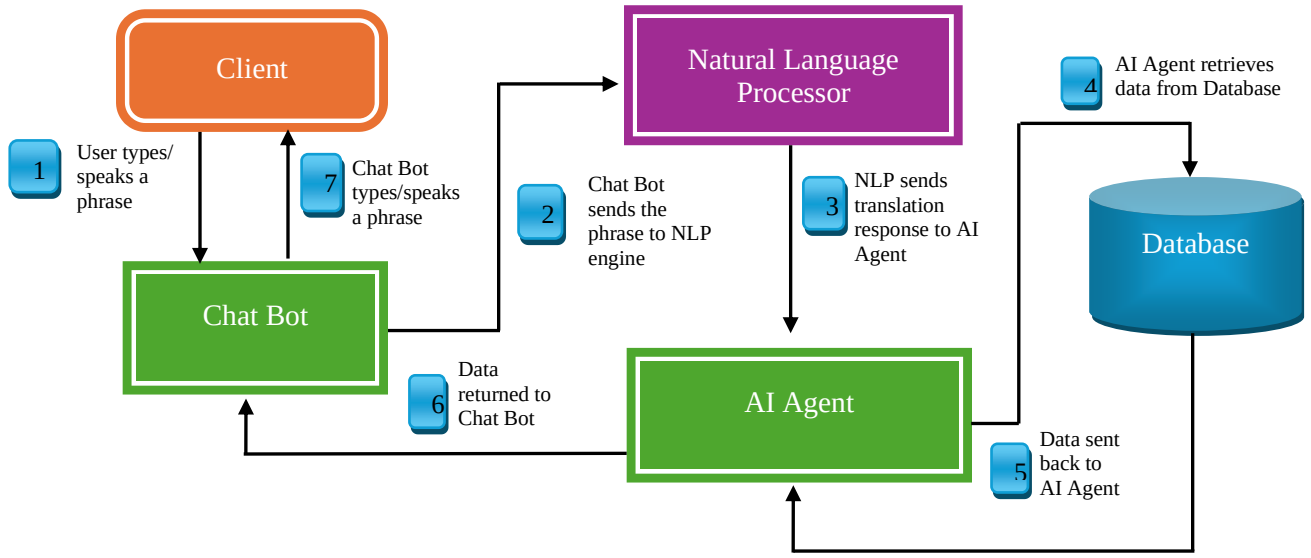

Fig. 2 AI-based training system architecture

5. Results and Discussion

The previous research identified that language barriers are a significant challenge for Hispanic construction workers, directly contributing to the high rates of accidents and fatalities. Surveys, interviews, and statistical analyses from previous studies revealed that many Hispanic workers struggle with understanding safety instructions and communicating effectively with supervisors and colleagues, particularly in English-dominated environments.

This language gap impedes their ability to follow safety protocols and limits their access to crucial safety training materials. To address this issue, this paper summarized the AI and IT solutions proposed to enhance language training. By incorporating NLP for speech processing and translation response, the proposed system considerably enhances the validity of safety training for Hispanic workers. The AI agent is a personalized virtual instructor that provides real-time feedback, answers questions and guides the workers throughout the training.

The capability of the AI agent to understand the context and generate the responses in accordance with the individual learning needs results in better knowledge transfer. This system can also solve the training difficulties for Hispanic workers with low literacy who cannot read in Spanish. By sending spoken queries and receiving spoken responses, Hispanic trainees will be able to understand the training material. Cultural considerations are other essential factors in creating a safe workplace for Hispanic workers. Similar to language barriers, the absence of knowledge about cultural differences between Hispanic and American work cultures often leads to misunderstandings and unsafe practices (Al-Bayati et al., 2018).

For instance, the reluctance to question authority, prevalent in many Hispanic cultures, may prevent workers from speaking up about unsafe conditions. While OSHA mandates that employers implement various solutions to address language barriers, there are no such requirements to address issues related to cultural differences. The study determines these demographics' main differences and cultural perceptions by investigating the cultural differences between Hispanic and American construction workers and their supervisors.

Information related to cultural differences is stored in the Database component of the system. The AI-agent retrieves the information from the Database and generates learning plans to educate Hispanic workers on job safety, including explaining cultural differences. The training course will also benefit supervisors by helping them understand the cultural distinctions that affect worker safety and communication. Immigration issues were identified as one of the impactful aspects affecting the safety of Hispanic workers. The fear of

deportation or job loss often discourages undocumented workers from reporting safety concerns or injuries. This vulnerability makes them more susceptible to exploitation and unsafe working conditions. Immigration issues are considered beyond the direct scope of the construction industry. Nevertheless, this research develops an AI-driven virtual immigration consultant.

This virtual agent is designed to inform Hispanic workers of their rights and provide guidance on navigating immigration-related challenges. Although managing immigration status can be difficult, workers will have access to consultations about their rights and resources available in case of injury or medical emergency. The information about worker rights is stored in the Database, and the virtual immigration consultant generates responses by retrieving this information. By empowering workers with knowledge about their rights and available resources, the system aims to reduce the fear of reporting safety issues and improve overall workplace safety.

The study also explores the specific operational challenges Hispanic workers face in construction, especially in construction operations where a significant portion of the workforce is Hispanic. Over 90% of Hispanic workers were employed as construction labourers, with more than half involved in drywall installation, roofing and painting – roles with higher exposure to OSHA's "Fatal Four" hazards. The research develops AI-powered training courses focused on the most common construction practices involving Hispanic workers to address these operational challenges. These courses are designed to be interactive and adaptive, providing real-time feedback and adjusting to the workers' learning skills and needs. The training system includes a software agent that automatically generates personalized learning plans based on the specific operational tasks and risks associated with each worker's role.

AI and IT integration into safety training systems offers solutions to the unique challenges Hispanic construction workers face. Along with addressing the language, cultural, and immigration barriers, the AI-based training systems provide customized training for specific construction operations. Thus, it delivers personalized content that meets Hispanic workers' individual needs. Moreover, the creation of connected communities facilitated by AI is crucial for disseminating safety training data and best practices. By fostering a network of informed and empowered workers, we can more effectively transfer knowledge.

To achieve this, the research will engage with stakeholders such as small construction companies that employ Hispanic workers, community groups like trade unions and the Hispanic community, and public works departments, including the Department of Labor and city workforce centres. Community engagement is a significant aspect of this study for data collection, research findings dissemination, and broader impact across different communities.

This study's results will significantly impact the construction industry, particularly for small companies with minimal resources. By adopting AI-based training systems, these companies can overcome the barriers that have traditionally hindered effective safety training for Hispanic workers. The proposed safety training system will improve safety outcomes for workers through customized, culturally sensitive training that addresses the specific needs of Hispanic workers. This will reduce miscommunication, increase cultural awareness, and encourage speaking up and supporting language. Furthermore, training supervisors on cultural sensitivity creates a more supportive work environment. This approach enhances worker safety while contributing to the construction industry's overall productivity and sustainability with reduced fatality rates among Hispanic workers.

6. Conclusion

The paper summarizes the research approach for developing AI-based training systems, particularly within small construction companies with limited resources for comprehensive safety training. The research highlights that language barriers, cultural differences, immigration status, and operational challenges significantly contribute to the elevated rates of casualties among this demographic. To mitigate these risks, integrating Artificial Intelligence (AI) and Information Technology (IT) into safety training systems presents a promising solution.

The AI-based training systems proposed in this study offer tailored training that addresses the unique needs of Hispanic workers, from language and cultural training to immigration-related guidance and operational safety. By incorporating AI technologies such as NLP, Chat Bot, and AI-agent as core elements of the system, the innovative training system will be able to generate training courses adapted to the specific needs and learning skills of Hispanic workers. These training systems are expected to be more effective in transferring knowledge. Furthermore, they enhance the effectiveness of safety training and empower workers by providing personalized learning experiences and creating connected communities for better dissemination of safety knowledge.

The implications of this research extend beyond the immediate improvement of safety for Hispanic construction workers. The construction industry can foster a safer, more inclusive work environment that benefits all workers by adopting AI-based training solutions. Moreover, this approach can contribute to reducing the industry's overall injury and fatality rates, aligning with broader goals of improving occupational safety and health.

In conclusion, integrating advanced technologies in safety training is a critical step forward in addressing the disproportionate safety risks Hispanic construction workers face. As the industry evolves, embracing AI and IT innovations will ensure that all workers, regardless of background, access effective safety training that protects their health and well-being.

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Author Contribution Statement

GA and CHK conceptualized and designed the research. GA wrote the manuscript, investigated, and analyzed the data. CHK supervised and administered the research and reviewed and edited the manuscript. All authors read and approved the manuscript.

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