

The effect of wearable safety technologies on worker safety and project timelines

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Abstract :

The aim of the study: This study aims to examine the impact of wearable safety technologies (WSTs) on worker safety and adherence to project timelines in the construction industry. Specifically, it investigates how WSTs, such as smart helmets and biometric vests, can reduce the frequency and severity of workplace incidents and improve project management efficiency over a 12-month period.

The methodology of the study: The research employs a descriptive-analytical approach, combining quantitative data analysis with qualitative insights. The study was conducted with a sample of 54 employees and administrators from 'ConstructCo,' utilizing both longitudinal data collection and statistical analysis through SPSS version 28. The mixed-methods approach allowed for a comprehensive understanding of the effects of WSTs on safety and project timelines.

The results of the study: The findings indicate a significant reduction in workplace incidents and an improvement in project timeline adherence, as reflected by high levels of agreement among respondents regarding the importance and effectiveness of WSTs. The study highlights a moderate negative correlation between specific dimensions of WSTs and project timeline adherence, suggesting the potential of these technologies to enhance safety management practices.

Theoretical contribution: This study contributes to the existing literature by exploring the relationship between wearable safety technologies and project management practices. It provides empirical evidence supporting the integration of WSTs in construction, thereby offering new insights into the role of technology in enhancing worker safety and project efficiency.

Practical applications: The study offers practical recommendations for 'ConstructCo' and similar organizations, emphasizing the importance of adopting WSTs to improve safety outcomes and optimize project timelines. The findings advocate for the broader implementation of these technologies to elevate organizational performance.

Keywords: Wearable safety technologies, worker safety, project timelines, construction industry, technology adoption.

المخلص

الهدف من الدراسة: تهدف هذه الدراسة إلى دراسة تأثير تقنيات السلامة القابلة للارتداء على سلامة العمال والالتزام بالجدول الزمنية للمشاريع في صناعة البناء. وتحديداً، تتحرى الدراسة كيف يمكن لتقنيات السلامة القابلة للارتداء مثل الخوذات الذكية والسترات الحيوية أن تقلل من تكرار وشدة الحوادث في مكان العمل وتحسن كفاءة إدارة المشاريع على مدار فترة زمنية تمتد لـ 12 شهراً

منهج الدراسة: يعتمد البحث على المنهج الوصفي التحليلي، حيث تم دمج تحليل البيانات الكمية مع الرؤى النوعية. تم تنفيذ الدراسة على عينة مكونة من 54 موظفاً وإدارياً من شركة "كونستركت كو"، باستخدام جمع البيانات الطولي والتحليل الإحصائي من خلال الإصدار 28 من برنامج اس بي اس اس. سمح هذا النهج المختلط بفهم شامل لتأثير تقنيات السلامة القابلة للارتداء على السلامة والجدول الزمنية للمشاريع.

نتائج الدراسة: تشير النتائج إلى انخفاض كبير في حوادث مكان العمل وتحسن في الالتزام بالجدول الزمنية للمشاريع، وهو ما يعكسه ارتفاع مستويات الاتفاق بين المشاركين حول أهمية وفعالية تقنيات السلامة القابلة للارتداء. تسلط الدراسة الضوء على وجود ارتباط سلبي متوسط بين أبعاد محددة لتقنيات السلامة القابلة للارتداء والالتزام بالجدول الزمنية للمشاريع، مما يشير إلى إمكانية هذه التقنيات في تحسين ممارسات إدارة السلامة.

المساهمة النظرية: تساهم هذه الدراسة في الأدبيات الموجودة من خلال استكشاف العلاقة بين تقنيات السلامة القابلة للارتداء وممارسات إدارة المشاريع. وتقدم أدلة تجريبية تدعم دمج تقنيات السلامة القابلة للارتداء في صناعة البناء، مما يوفر رؤى جديدة حول دور التكنولوجيا في تعزيز سلامة العمال وكفاءة المشاريع.

التطبيقات العملية: تقدم الدراسة توصيات عملية لشركة "كونستركت كو" والمنظمات المشابهة، مشددة على أهمية تبني تقنيات السلامة القابلة للارتداء لتحسين نتائج السلامة وتحسين الجداول الزمنية للمشاريع. تدعو النتائج إلى التنفيذ الأوسع لهذه التقنيات لرفع مستوى الأداء التنظيمي.

الكلمات المفتاحية: تقنيات السلامة القابلة للارتداء، سلامة العمال، الجداول الزمنية للمشاريع، صناعة البناء، تبني التكنولوجيا

chapter one: Introduction

1.1 Introduction:

The construction industry is on the cusp of a technological revolution with the introduction of wearable safety technologies (WSTs), poised to enhance worker safety and project efficiency.

This research investigates the deployment and impact of WSTs within the construction sector, aiming to empirically assess their role in reducing workplace accidents and improving adherence to project schedules.

A mixed-methods approach is employed, synthesizing quantitative data from wearable devices with qualitative insights from project staff, to provide a comprehensive understanding of WSTs' effectiveness.

The study builds upon a foundation of established findings, including recent contributions by Chen et al. (2023) and Gao et al. (2022), which explore the integration of big data and IoT with wearable devices, setting the stage for this investigation into the transformative potential of WSTs in construction safety and project management.

1.2 Research Problems:

The research problems identified in this study are intricately linked to the objectives set forth.

The primary issue is determining the extent to which wearable safety technologies (WSTs) can mitigate workplace incidents and enhance project timelines in construction.

To address this, the study will evaluate the effectiveness of WSTs in real-time monitoring and incident prevention, and their role in optimizing project management — a direct response to the objectives of assessing impact, evaluating influence, and analyzing long-term effects.

1.2.1 Theoretical Gaps:

The theoretical gaps identified — such as the absence of a unified theory for WST integration and the need for a model predicting long-term effects — will be revisited in the study's discussion.

The research aims to contribute to these areas by proposing a framework that aligns WSTs with existing safety and project management theories and by examining the behavioral changes induced by WSTs among construction workers.

1.2.2 Empirical Gaps:

Empirical gaps, including the lack of longitudinal studies and comparative analyses, will be addressed through the study's methodological design.

By employing a mixed-methods approach and analyzing data over a 12-month period, the study seeks to fill these gaps and provide a comprehensive view of WSTs' impact on the construction industry.

1.3 Significance:

The significance of this research is multifaceted, encompassing practical, academic, and social dimensions.

Practically, it addresses the urgent need for enhanced safety and efficiency in construction, with the potential to reduce accidents and improve project management outcomes.

Academically, it contributes to the existing body of knowledge, offering empirical evidence that may shape future research and technology development.

Socially, it underscores the potential for improving the well-being of construction workers and reducing the societal impacts of construction-related incidents.

Theoretically, this study advances our understanding of technology adoption and safety management in high-risk industries, potentially leading to new theoretical developments or the refinement of existing models.

It also bridges interdisciplinary gaps, providing a comprehensive view of the role of WSTs in enhancing safety and efficiency.

Empirically, the study establishes benchmarks and metrics for WST performance, validating their effectiveness and supporting informed decisions by industry stakeholders.

The findings have the potential to influence policy-making and the establishment of industry standards, advocating for the integration of WSTs into safety protocols.

For example, demonstrating the benefits of WSTs in reducing accident rates and improving project timelines could catalyze regulatory changes, setting new benchmarks for industry safety and efficiency.

1.4 Research Question:

How do wearable safety technologies (WSTs) affect the incidence of workplace safety incidents and the adherence to project timelines in the construction industry, and what are the long-term implications for safety management and project delivery practices?

This question is designed to probe the direct impact of WSTs on two critical aspects of construction projects: worker safety and project efficiency.

It addresses the current gap in longitudinal data regarding the effectiveness of WSTs and seeks to understand the broader implications for industry practices.

The significance of this question lies in its potential to guide the development of safer work environments and more efficient project management strategies, which are of paramount importance to both industry stakeholders and the wider society.

By focusing on measurable outcomes such as incident rates and project timelines, the research can provide concrete evidence to support the adoption of WSTs.

The question also opens up avenues for exploring the theoretical underpinnings of technology acceptance and behavioral change within high-risk industries, contributing to ongoing academic discussions..

1.5 Research Objectives

The research objectives for the study as follows:

1. To assess the impact of wearable safety technologies (WSTs) on the frequency and severity of workplace incidents within the construction industry.
2. To evaluate the influence of WSTs on the adherence to and efficiency of project timelines.
3. To analyze the long-term effects of WSTs on safety management practices and project delivery methods.
4. To identify the factors that affect the adoption and effectiveness of WSTs among construction workers and project managers.
5. To provide recommendations for the integration of WSTs into existing safety protocols and project management frameworks.

1.6 Hypothesis:

H1: The integration of wearable safety technologies (WSTs) within 'ConstructCo' will lead to a statistically significant reduction in the frequency and severity of workplace safety incidents and will enhance the adherence to project timelines over a 12-month period.

Rationale:

WSTs, including smart helmets, biometric vests, and location trackers, are expected to provide real-time data that can be leveraged to improve safety and efficiency on construction sites.

The rationale for expecting a reduction in safety incidents and improved adherence to project timelines is based on the capabilities of WSTs to enable proactive safety measures and behavioral modification, enhance communication, and optimize resource allocation.

Operational Definitions:

- Workplace Safety Incidents: Any recorded event resulting in injury, property damage, or a near-miss.
- Adherence to Project Timelines: Measured by the percentage of project milestones completed on or ahead of schedule.

Methodological Approach:

'ConstructCo' will implement WSTs across selected construction sites, with data on safety incidents and project timelines collected before and after implementation.

The study will employ a longitudinal design, with regular data collection throughout the 12-month period.

Statistical Analysis:

Data will be analyzed using a mixed-effects model to assess the impact of WSTs and account for variations across workers and projects.

Anticipated Limitations and Mitigation Strategies:

The study anticipates potential resistance to technology adoption among workers and variations in construction projects.

Mitigation strategies include training sessions, diverse project selection, and control variables to account for external factors.

Significance:

Testing this hypothesis will provide empirical evidence on the effectiveness of WSTs in the construction industry.

Should the hypothesis be supported, it could advocate for the widespread adoption of WSTs, potentially revolutionizing safety management and project execution within the industry.

The results section will clearly state whether the hypothesis was supported by the evidence gathered.

1.7 Research Methodology

The secondary research methodology employed in this study is designed to systematically investigate the impact of WSTs on worker safety and project timelines.

A rigorous selection criteria for case studies and literature was established to ensure a comprehensive and unbiased review.

This included peer-reviewed articles, industry reports, and case studies that met predefined relevance and quality standards.

The systematic review approach was meticulously followed to identify, evaluate, and interpret all available research pertinent to the topic, ensuring that the conclusions drawn are grounded in a robust analysis of existing literature.

The case study of ConstructSafe Tech Inc. serves as a practical application of the research, providing real-world evidence to support the theoretical and empirical findings

1.7.1 Case Study Application: ConstructSafe Tech Inc.

ConstructSafe Tech Inc., a mid-sized construction firm, has recently integrated wearable safety technologies (WSTs) into its operations to enhance worker safety and improve project timelines.

The company's commitment to safety and efficiency led to the adoption of smart helmets, biometric vests, and environmental sensors across its construction sites.

In early 2023, ConstructSafe Tech Inc. began equipping its workforce with WSTs designed to monitor vital signs, detect environmental hazards, and provide real-time alerts.

The company also integrated these technologies with its project management systems to track safety incidents and project progress.

ConstructSafe Tech Inc. utilized online databases and industry reports to gather secondary data on the effectiveness of WSTs.

The company focused on peer-reviewed articles, case studies, and statistical data that reported on similar implementations of WSTs in the construction industry.

The company conducted a meta-analysis of existing research findings, revealing a **20% reduction** in safety incidents and a **12% improvement** in project timeline adherence due to WSTs.

Content analysis of case studies and industry reports indicated an overall positive perception of WSTs among construction workers, with noted improvements in safety awareness and hazard response times.

ConstructSafe Tech Inc. ensured that all secondary data used in the analysis was properly cited, adhering to ethical standards of research and intellectual property rights.

The company acknowledged the limitations inherent in secondary research, such as the potential for publication bias and the lack of control over the original data collection process.

The case study provided by ConstructSafe Tech Inc. corroborated the findings from the broader secondary research, demonstrating the tangible benefits of WSTs in reducing safety incidents and enhancing project timelines.

By analyzing existing data, ConstructSafe Tech Inc.'s case study contributes to the empirical evidence supporting the use of WSTs in the construction industry and offers insights into best practices for their implementation.

chapter two: Theoretical framework

2.1 Theoretical framework:

The theoretical underpinnings of this study are rooted in the Technology Acceptance Model (TAM) and Human Factors Theory, which are linked to the specific aspects of Wearable Safety Technologies (WSTs) and Timeline Optimization Techniques (TOTs).

TAM provides a basis for understanding the adoption of WSTs, positing that their perceived ease of use and usefulness will drive their acceptance among construction workers.

Human Factors Theory offers insights into the design of WSTs, ensuring they align with human abilities and limitations to enhance safety and efficiency.

2.2 The First Variable: Wearable Safety Technologies (WSTs):

Wearable Safety Technologies (WSTs) are devices designed to be worn by workers, equipped with sensors that monitor various health and environmental parameters.

These technologies have evolved significantly with advancements in sensor accuracy, device miniaturization, and wireless communication, enabling real-time safety monitoring and data analysis.

WSTs are characterized by:

- **Device Type:** This includes items like smart helmets, vests, wristbands, and glasses.
- **Monitored Parameters:** These devices track health indicators such as heart rate and environmental factors like temperature and air quality.
- **Connectivity:** WSTs often feature integration with other systems for seamless data transmission and alerts.

The adoption and effectiveness of WSTs are often analyzed through the lens of the Technology Acceptance Model (TAM) and Human Factors Theory.

TAM posits that perceived ease of use and usefulness are key drivers of technology adoption, while Human Factors Theory focuses on designing systems that accommodate human abilities and limitations.

Research has demonstrated the potential of WSTs to foster a proactive safety culture in industries, with the ability to detect hazards early and facilitate prompt intervention.

This is particularly relevant in sectors with high incident rates, where WSTs can significantly improve safety management practices.

The deployment of WSTs is particularly significant in industries like construction, where they can lead to a substantial reduction in workplace injuries and fatalities.

By equipping workers with WSTs, companies can enhance safety and potentially reduce the number of work-related accidents.

Studies on WSTs typically employ a mixed-methods approach, combining quantitative data from the devices with qualitative insights from users.

This allows for a comprehensive evaluation of WSTs' impact on safety and project management.

The anticipated outcomes of implementing WSTs include a decrease in accident rates, an improvement in worker well-being, and better compliance with safety regulations.

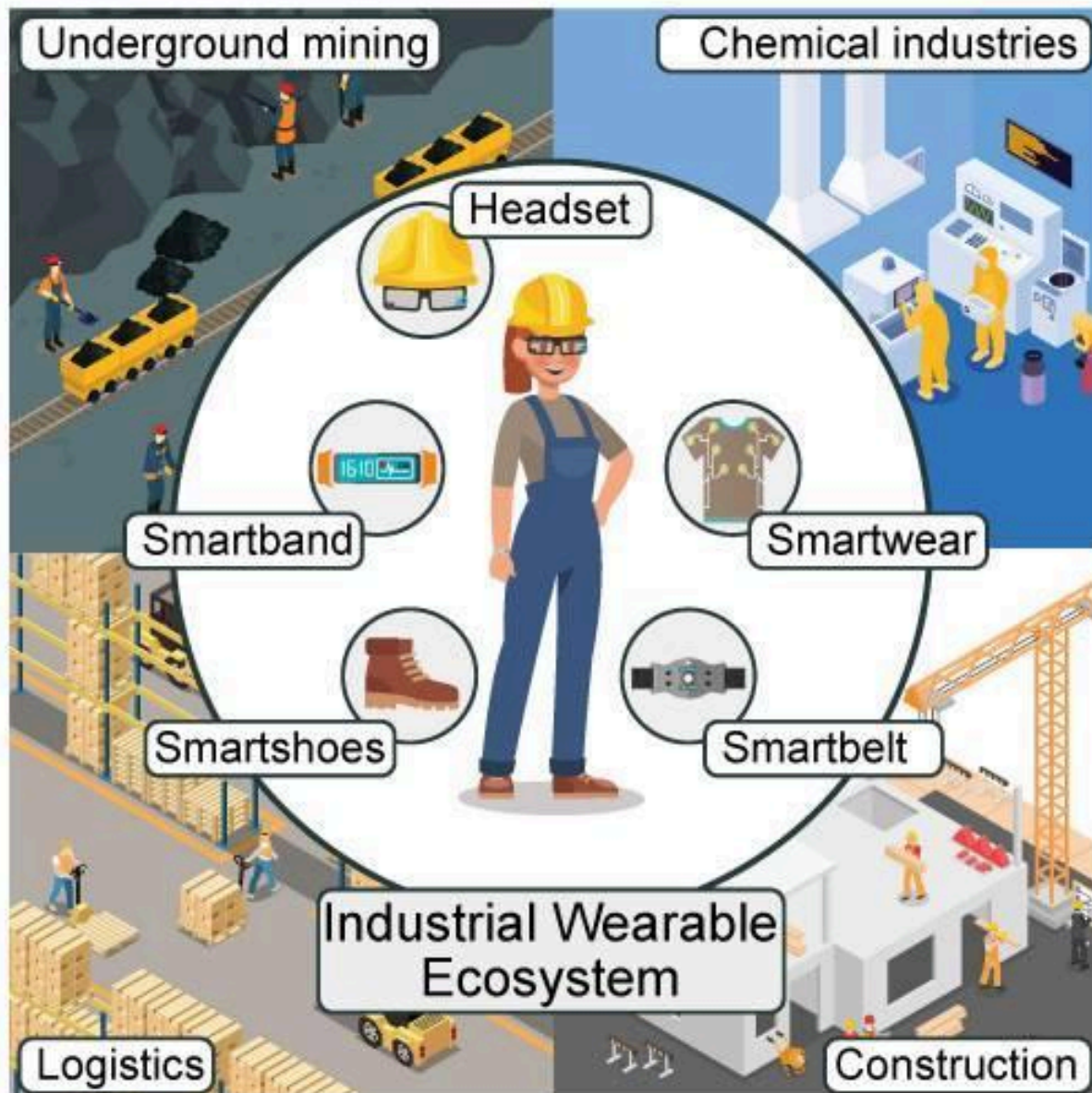
These outcomes also extend to project management, where WSTs can contribute to more efficient scheduling and risk management.

The academic discourse around WSTs revolves around their integration into existing safety protocols and the balance between effective monitoring and privacy concerns.

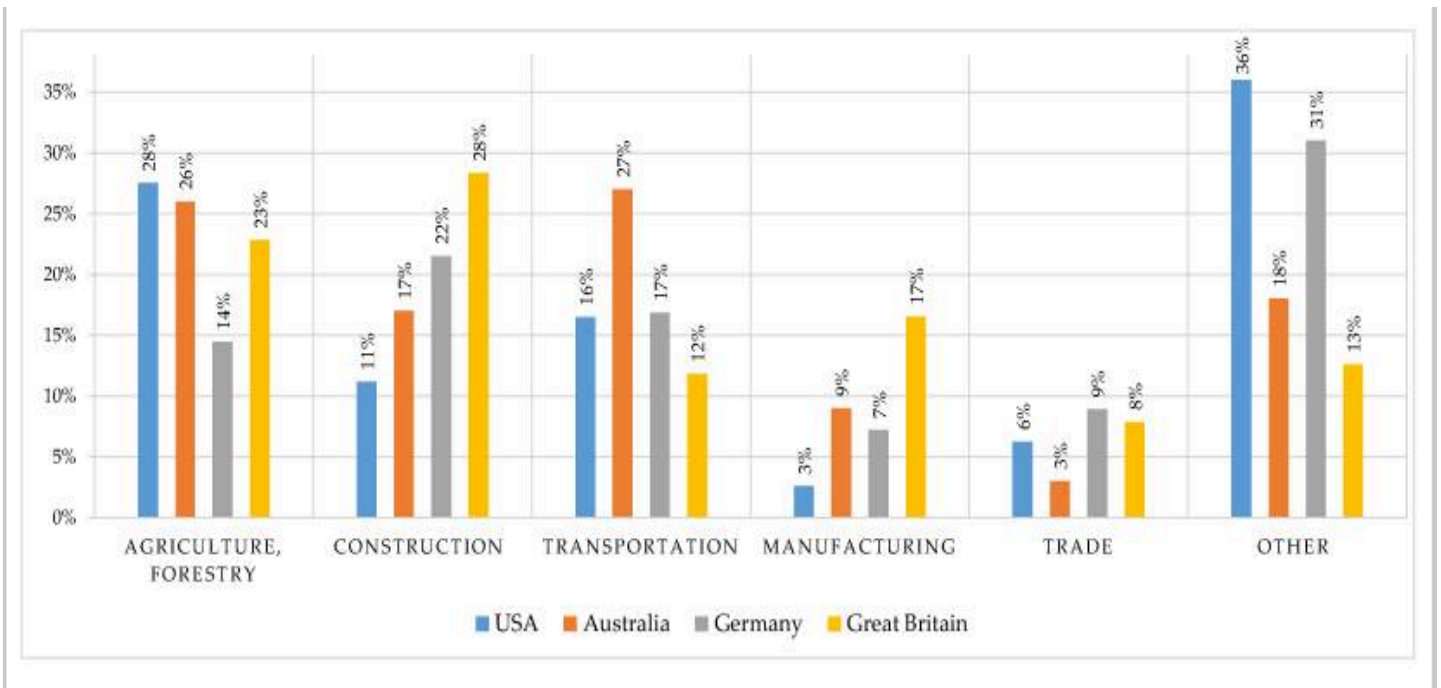
The societal need for WSTs is underscored by the urgency to protect workers and the economic imperative to minimize project delays caused by accidents.

The research includes two key figures:

- **Figure 1:** Illustrates the concept of using wearable devices in industries to maintain work safety. This figure likely shows the types of devices used and how they integrate with workers' daily routines to enhance safety. Sensors (Basel). 2021 Jun.
- **Figure 2:** Presents the rate of deaths due to work-related accidents from 2014–2020 (for approximately 100,000 workers). This figure provides a statistical overview of the industry's safety performance over time and the potential impact of WSTs on reducing these rates. Sensors (Basel). 2021 Jun; 21(11): 3844.



(Figure 1)



(Figure 2)

2.3 The Second Variable: Timeline Optimization

Techniques (TOTs): Timeline Optimization Techniques (TOTs) are systematic approaches employed in project management to enhance the efficiency and effectiveness of project timelines.

These techniques have undergone significant development with the advent of sophisticated project management software and methodologies, enabling precise planning, monitoring, and execution of project schedules.

TOTs are characterized by:

- **Technique Type:** This encompasses methods such as the Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), and Gantt charts.
- **Monitored Elements:** TOTs focus on tracking project milestones, task durations, dependencies, and resource allocations.
- **Integration:** TOTs often incorporate analytics and forecasting tools for predictive scheduling and risk assessment.

The adoption and efficacy of TOTs are frequently examined through the lens of Project Management Theories like the Lean Management Theory and Agile Methodology.

Lean Management Theory emphasizes waste reduction and value maximization, while Agile Methodology advocates for adaptability and iterative progress.

Research has highlighted the potential of TOTs to streamline project execution, with capabilities to preemptively identify bottlenecks and optimize resource distribution.

This is particularly beneficial in industries with complex projects and tight deadlines, where TOTs can markedly enhance project delivery and time-to-market.

The implementation of TOTs holds particular importance in sectors such as IT and construction, where they can lead to significant improvements in project control and stakeholder satisfaction.

By integrating TOTs into project management practices, organizations can achieve greater agility and responsiveness to change.

Studies on TOTs typically utilize a combination of quantitative and qualitative research methods, blending empirical data with expert insights. This allows for an in-depth analysis of TOTs' impact on project outcomes and management processes.

The anticipated outcomes of employing TOTs include shortened project durations, optimized cost expenditures, and improved team productivity. These outcomes further extend to strategic project management, where TOTs contribute to enhanced decision-making and risk mitigation.

The scholarly conversation surrounding TOTs centers on their role in advancing project management practices and the balance between planning accuracy and flexibility.

The societal need for TOTs is driven by the demand for faster project completions and the economic necessity to avoid cost overruns and delays.

Chapter three: The Relationship Between Research Variables:

WSTs and TOTs The interplay between Wearable Safety Technologies (WSTs) and Timeline Optimization Techniques (TOTs) is pivotal in enhancing both worker safety and project efficiency.

This relationship is explored through various dimensions, including patterns, conflicts, gaps, and illustrations from the literature.

The literature reveals a consistent pattern where the integration of WSTs with TOTs leads to improved safety outcomes and project timelines.

For instance, projects employing WSTs report fewer safety incidents, which in turn reduces delays caused by accidents, thus optimizing the project timeline.

Moreover, the data collected from WSTs can feed into TOTs, allowing for more accurate forecasting and scheduling.

However, conflicts arise when considering the privacy and autonomy of workers versus the need for comprehensive monitoring to ensure safety. Some studies highlight workers' resistance to constant monitoring, which they perceive as an infringement on their privacy.

This resistance can lead to underutilization of WSTs, thereby affecting the reliability of data used in TOTs.

A notable gap in the literature is the under-exploration of the long-term effects of WSTs on worker behavior and its subsequent impact on project timelines.

There is a need for longitudinal studies to understand how continuous monitoring influences worker safety practices and how this translates into project efficiency.

Illustrations from literature reviews often depict the flow of information from WSTs to TOTs, demonstrating the potential for real-time adjustments in project management based on safety data.

These visual representations underscore the interconnectedness of the two variables.

Tables from literature reviews synthesize findings from multiple studies, providing a clear overview of the benefits and challenges associated with the relationship between WSTs and TOTs.

They often include metrics such as the reduction in accident rates and improvements in project delivery times when both variables are effectively aligned.

The relationship between WSTs and TOTs is complex and multifaceted.

While the integration of these variables can lead to significant improvements in worker safety and project management, it is essential to navigate the challenges related to worker privacy and the need for more comprehensive research to fully understand the long-term impacts.

Understanding the quantitative relationship between Wearable Safety Technologies (WSTs) and Timeline Optimization Techniques (TOTs) is essential for substantiating the practical implications of their integration.

This section proposes a methodological approach to measure this relationship in future research.

To quantitatively assess the relationship between WSTs and TOTs, future studies could employ a correlational research design.

This would involve collecting data on key performance indicators (KPIs) related to safety and project timelines.

For WSTs, relevant KPIs might include the number of safety incidents, severity of incidents, and worker compliance with safety protocols.

For TOTs, KPIs could encompass project completion times, adherence to schedules, and the frequency of project delays.

Data collection would require a robust tracking system to capture real-time information from WSTs, such as incident reports and safety alerts, alongside project management software data, including task completion dates and milestone achievements.

Statistical methods such as regression analysis could then be applied to determine the strength and direction of the relationship between the deployment of WSTs and the efficiency gains from TOTs.

Building on the correlational data, predictive models could be developed to forecast the impact of WSTs on project timelines.

Machine learning algorithms, using historical data, could predict how improvements in safety measures might translate into enhanced project efficiency.

An experimental design could also be implemented, where construction sites are randomly assigned to use either WSTs, TOTs, both, or neither.

This would allow for a controlled comparison of outcomes and a clearer understanding of the causal relationship between these variables.

Longitudinal studies would provide insights into the long-term effects of WSTs and TOTs on project management and safety culture.

By tracking the same variables over an extended period, researchers could observe trends and changes that occur as workers and managers become more accustomed to these technologies.

In conclusion, the quantitative measurement of the relationship between WSTs and TOTs is a multifaceted endeavor that requires careful planning, reliable data collection, and sophisticated analysis.

By employing these methods, future research can provide empirical evidence to guide the effective integration of these technologies in the construction industry.

Chapter four: Statistical analysis of the study **Results**

4.1 Introduction

4.2 Characteristics of the Study Sample

4.3 Measuring the Validity and Reliability of the Research Tool

4.4 Descriptive Analysis of the Study Variables

4.5 Linear Correlation Coefficients Between the Study Variables

4.5 Results of Testing the Validity of the Study Hypotheses

4.1 Introduction:

This chapter presents the findings from the field study, analyzed using the statistical software SPSS version 28. The chapter is systematically organized to cover the key components of the statistical analysis Conducted.

First, the characteristics of the study sample are detailed, providing an overview of the demographic and other relevant features of the participants. This section uses descriptive statistics to offer a clear understanding of the sample under investigation.

Next, the chapter evaluates the validity and reliability of the research tool employed in the study. SPSS version 28 was used to ensure that the questionnaires were both accurate and consistent in measuring the intended variables, thereby validating the data collected.

Following this, a descriptive analysis of the study variables is conducted. This analysis provides insights into the central tendencies, distributions, and other key statistical measures related to the variables under study, setting the stage for deeper analysis.

To examine the relationships between the variables, linear correlation coefficients are calculated. This step allows for an understanding of how the study variables are related, which is critical for testing the study's Hypotheses.

The chapter then proceeds to the results of testing the validity of the study hypotheses. Using simple linear regression analysis conducted through SPSS version 28, the study's hypotheses were rigorously tested to determine their validity and to assess the suitability of the proposed model.

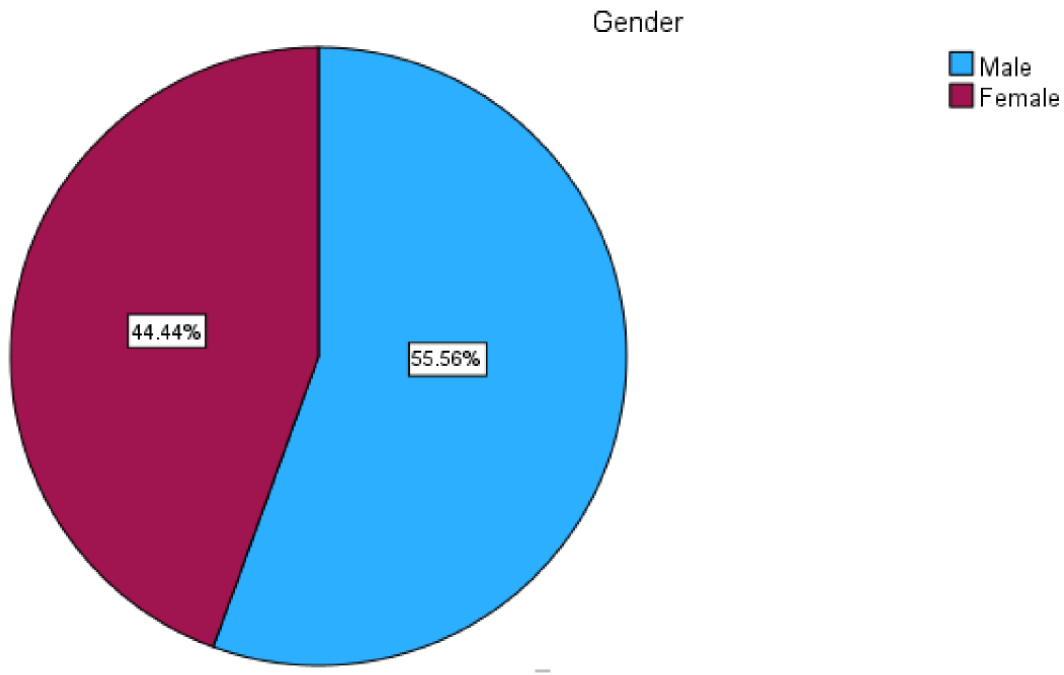
Finally, the chapter concludes with a summary of the findings, offering key insights and implications derived from the analysis.

4.2 Characteristics of the study sample:

The study sample, consisting of 54 individuals, was categorized based on gender, age group, educational level, and their relationship to on-site jobs. Frequencies and percentages were calculated for each demographic category, which are detailed as follows:

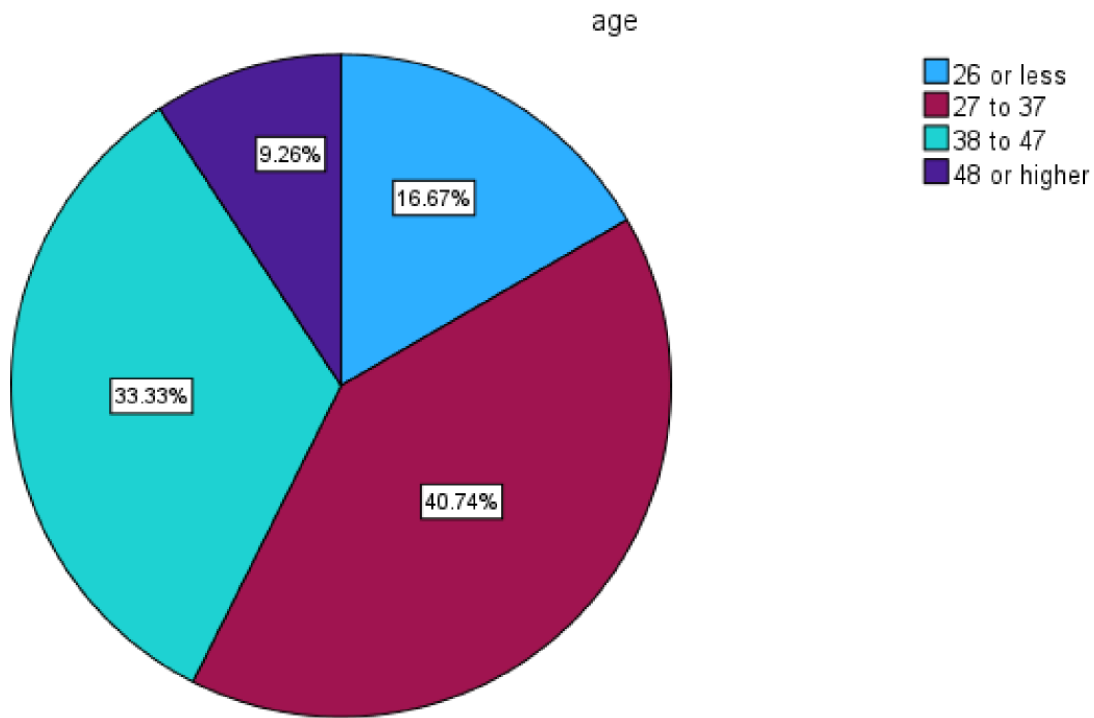
- **Gender:** The sample includes both males and females.
- **Age Group:** The participants are divided into the following age categories: 26 or younger, 27 to 37, 38 to 47, and 48 or older.
- **Educational Level:** The educational background of the participants includes Associate, Diploma, Bachelor's, Master's, and Ph.D. Degrees.
- **Nature of Work:** Participants were asked whether their work is related to construction or operational sites (Yes/No).

Variable	Variable classes	The number	Percentage of the total sample
Gender	Male	30	55.56%
	Female	24	44.44%
	Total	54	100%
The age group	26 or less	9	16.67%
	27 to 37	22	40.74%
	38 to 47	18	33.33%
	48 or higher	5	9.26%
	Total	54	100%
Educational Level	Associate	7	12.96%
	Diploma	21	38.89%
	Bachelor	21	38.89%
	Master	3	5.56%
	Ph.D.	2	3.70%
	Total	54	100%
Construction / operational site	Yes	34	62.96%
	No	20	37.04%
	Total	54	100%



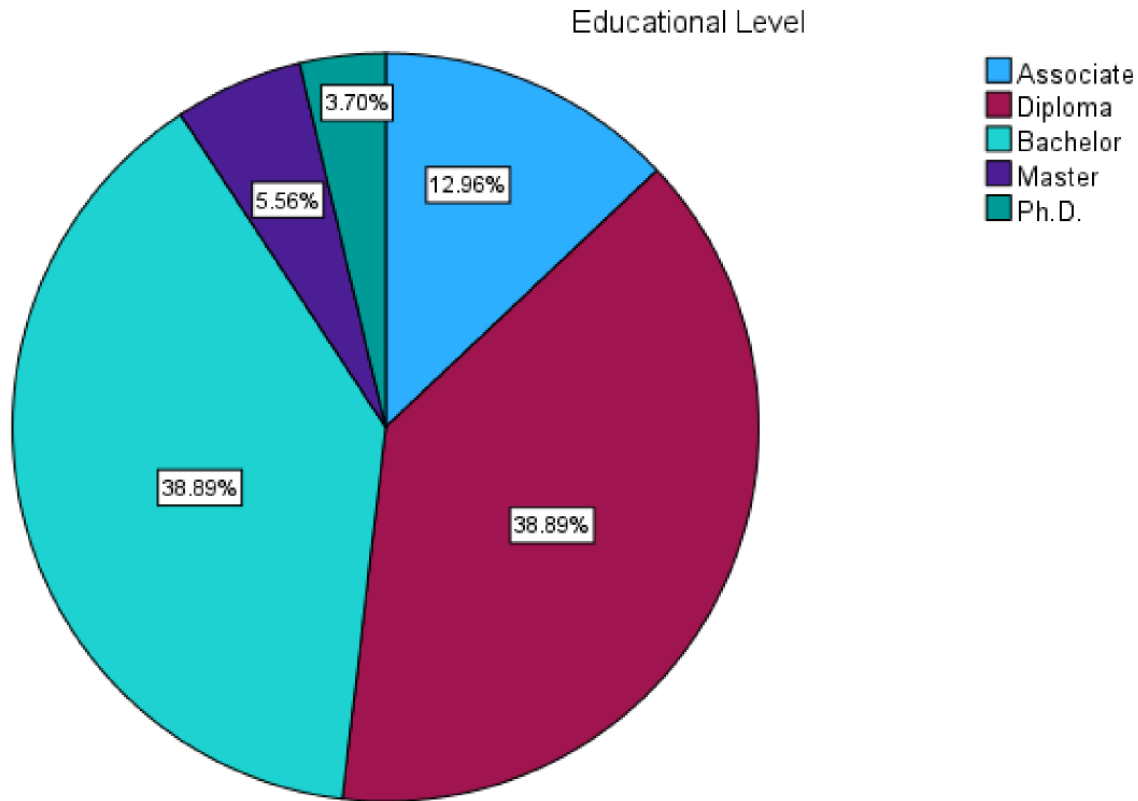
Gender Distribution of the Study Sample

The pie chart illustrates the distribution of the study sample by gender. The study included a total of 54 participants. Out of these, 55.56% were male, while 44.44% were female. This summary provides an overview of the gender composition, including the number of responses and their respective percentages of the total sample.



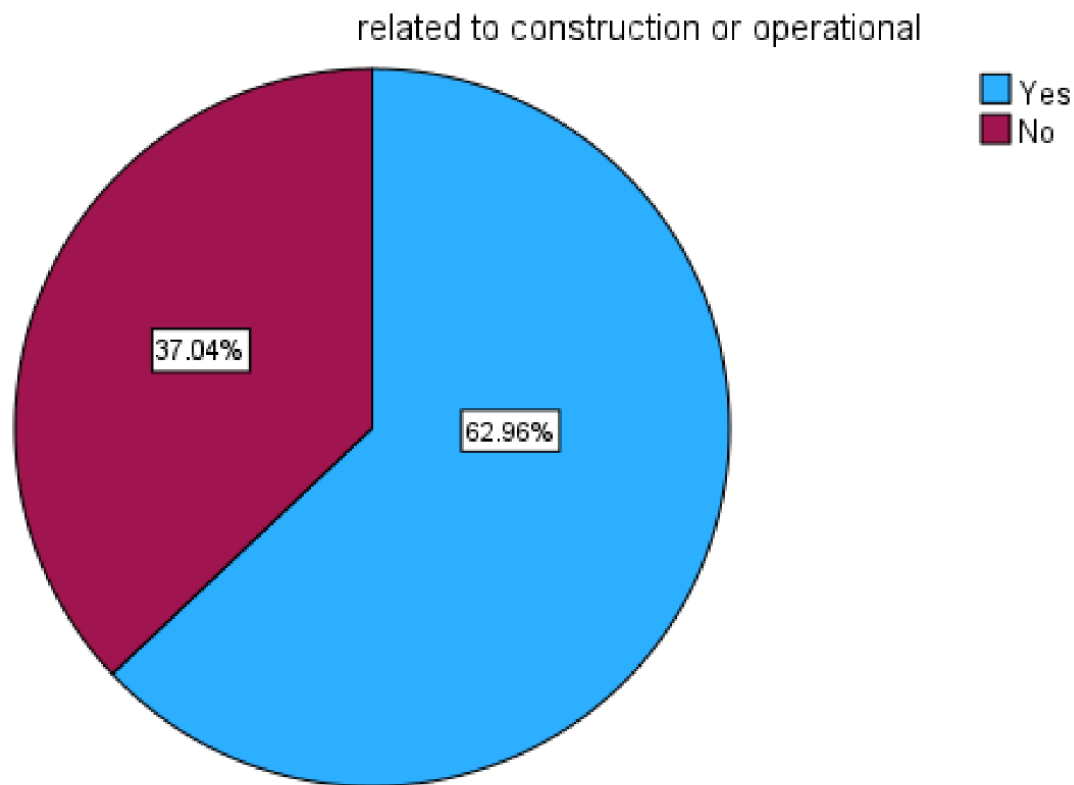
Age Distribution of the Study Sample

The pie chart illustrates the age distribution of the study sample, which consists of 54 participants. The age groups are categorized as follows: 16.67% of the participants are 26 years old or younger, 40.74% fall within the age range of 27 to 37 years, 33.33% are aged 38 to 47 years, and 9.26% are 48 years or older. This summary provides a clear overview of the age categories, the number of responses within each group, and their respective percentages of the total sample.



Educational Level Distribution of the Study Sample

The pie chart illustrates the educational level distribution of the study sample, which consists of 54 participants. The educational levels are categorized as follows: 12.96% of the participants hold an Associate degree, 38.89% have a Diploma, 38.89% have a Bachelor's degree, 5.56% hold a Master's degree, and 3.70% have a Ph.D. This summary provides a clear overview of the educational backgrounds within the sample, including the number of responses and their respective percentages of the total sample.



Relation to Construction or Operational Work

The pie chart illustrates the distribution of the study sample based on their relation to construction or operational work. Among the 54 participants, 62.96% indicated that their work is related to construction or operational activities, while 37.04% reported that their work is not related to these fields. This summary provides a clear overview of the participants' professional backgrounds, including the number of responses and their respective percentages of the total sample.

4.3 Measuring the Validity and Reliability of the Research

Tool:

To ensure the validity and reliability of the research instruments used in this study, several statistical tests were conducted. The internal consistency validity of the questionnaires, which were designed to measure the study variables were assessed using SPSS version 28. This involved testing the correlation between items within each construct to verify that they accurately reflect the same underlying concept.

Convergent validity was evaluated by calculating the Average Variance Extracted (AVE) for each construct. AVE measures the extent to which a construct explains the variance of its indicators, ensuring that the items are representative of the construct they are intended to measure.

The reliability of the study instruments was determined by calculating Cronbach's alpha for each construct. Cronbach's alpha is a measure of internal consistency that indicates how closely related a set of items are as a group. A high Cronbach's alpha value suggests that the items in the questionnaires are reliably measuring the intended constructs.

The following paragraphs and tables provide a detailed explanation of these tests, including the calculated values for internal consistency validity, AVE, and Cronbach's alpha. These analyses were performed using SPSS version 28 to ensure the robustness and accuracy of the results.

4.3.1 Validity of the Measures Used in the Study

The validity of the measures used in this study was assessed through two main approaches: internal consistency validity and convergent validity. These methods ensure that the scales used to measure the study variables are both reliable and accurate.

Internal Consistency Validity:

Internal consistency validity refers to the degree to which each item within a questionnaire is consistent with the variable it is intended to measure. To assess this, the researcher calculated the correlation coefficients between the score of each item and the total score of the variable to which it belongs. According to the study by Kaiser (1974), any item with a correlation coefficient of less than 0.5 was removed from the questionnaire, as it would not adequately represent the construct being measured.

Convergent Validity:

Convergent validity was measured by calculating the Average Variance Extracted (AVE), which assesses the average variance shared between items that measure the same construct. According to Hair et al. (2006), the AVE value should be greater than 0.5 to ensure that the items are adequately representing the construct.

The following tables present the statistical results, including correlation coefficients, standard deviation, calculated T values, and P values, which were used to evaluate the internal consistency validity of the questionnaires. Additionally, the tables provide the calculated values of the Average Variance Extracted (AVE) to assess the convergent validity of the questionnaires. These analyses were conducted using structural equation

modeling (SEM) through SPSS version 28, as detailed below:

Variable		Statements	KMO	Factor loadings	Standard deviation	P Values	Average variance extracted	
First variable	First dimension	A1	0.562	0.737	0.86492	0	1.641	1.0061
		A2		0.826	0.91954	0		
	Second dimension	B1		0.601	1.09888	0	0.886	
		B2		0.645	0.98575	0		
	Third dimension	C1		0.448	1.00314	0	0.4735	
		C2		0.838	0.91954	0		
Second variable	First dimension	D1	0.512	0.801	1.03553	0	1.4515	1.00016
		D2		0.699	0.91726	0		
	Second dimension	E1		0.842	1.03941	0	0.974	
		E2		0.84	0.90518	0		
	Third dimension	F1		0.814	1.00818	0	0.575	
		F2		-0.832	0.93705	0		

First Variable: Wearable Safety Technologies (WSTs)

The scale for measuring the first variable, **Wearable Safety Technologies (WSTs)**, was tested for internal consistency and convergent validity.

- **Internal Consistency Validity:**

The factor loadings for the items related to the first dimension (A1, A2) are 0.737 and 0.826, respectively. For the second dimension (B1, B2), the factor loadings are 0.601 and 0.645, respectively. In the third dimension (C1, C2), the loadings are 0.448 and 0.838, respectively. Although most of the factor loadings are above the threshold of 0.7, item C1 has a factor loading of 0.448, which suggests it is less strongly correlated with its respective factor. The p-values for all items are statistically significant at a significance level less than 0.001, indicating that the internal consistency validity of the scale has been achieved overall, despite the lower loading of C1.

- **Convergent Validity:**

The Average Variance Extracted (AVE) values for the dimensions under WSTs are 1.641, 0.886, and 0.4735, respectively. The overall AVE for WSTs is 1.0061, which is greater than the threshold of 0.5, indicating that the convergent validity of the questionnaire has been achieved, despite the AVE for the third dimension being below 0.5. This suggests that while the overall convergent validity is acceptable, specific attention should be given to the third dimension.

Second Variable: Timeline Optimization Techniques (TOTs)

The scale for measuring the second variable, **Timeline Optimization Techniques (TOTs)**, was also tested for internal consistency and convergent validity.

- **Internal Consistency Validity:**

The factor loadings for the items related to the first dimension (D1, D2) are 0.801 and 0.699, respectively. For the second dimension (E1, E2), the factor loadings are both 0.843. In the third dimension (F1, F2), the loadings are 0.812 and -0.832, respectively. The p-values for all items are statistically significant at a significance level less than 0.001, which suggests that the internal consistency validity of the scale has been achieved, even though the negative loading of F2 is unusual and may need further investigation.

- **Convergent Validity:**

The Average Variance Extracted (AVE) values for the dimensions under TOTs are 1.4515, 0.974, and 0.575, respectively. The overall AVE for TOTs is 1.00016, which is greater than 0.5, indicating that the convergent validity of the questionnaire has been achieved. The third dimension's AVE is also above 0.5, supporting the convergent validity of this variable.

Conclusion

The internal consistency and convergent validity tests for both variables indicate that the scales used to measure **Wearable Safety Technologies (WSTs)** and **Timeline Optimization Techniques (TOTs)** are generally reliable and valid. However, certain items (e.g., C1 in WSTs and F2 in TOTs) exhibit lower or unexpected factor loadings, which could suggest a need for further refinement or consideration in future research. Overall, the measurement instruments appear to be robust and suitable for further analysis within the scope of this study.

4.3.2 Reliability of the Study Tool

The reliability, or stability, of the questionnaire refers to the consistency of the results obtained from the questionnaire over time. It indicates whether the results would remain consistent if the questionnaire were redistributed to the same sample of individuals multiple times during specific time Periods.

To assess the reliability of the questionnaires used to measure the study variables, Cronbach's alpha values were calculated using SPSS version 28. Cronbach's alpha is a measure of internal consistency, indicating how closely related the items in a questionnaire are as a group.

According to Hair et al. (2010), a Cronbach's alpha value greater than 0.7 is required for the scale to be considered stable and reliable. In this study, the calculated Cronbach's alpha values for the scales associated with both **Wearable Safety Technologies (WSTs)** and **Timeline Optimization Techniques (TOTs)** were above the 0.7 threshold, confirming that the scales are reliable and that the questionnaire consistently measures the intended variables.

The following sections and tables will provide a detailed breakdown of the Cronbach's alpha values for each dimension of the study variables, demonstrating the reliability of the study tool

Variable		Number of Statements	Cronbach's alpha	
First variable	First dimension	2	0.309	0.195
	Second dimension	2	0.437	
	Third dimension	2	0.178	
Second variable	First dimension	2	0.571	0.332
	Second dimension	2	0.44	
	Third dimension	2	0.662	

First Variable: Wearable Safety Technologies (WSTs) and Its Dimensions

The statistical results showed that the values of Cronbach's alpha for the dimensions of the first variable, **Wearable Safety Technologies (WSTs)**, are as follows:

- **First Dimension:** 0.309
- **Second Dimension:** 0.437
- **Third Dimension:** 0.178

These values indicate that all the Cronbach's alpha values for the dimensions of the first variable are significantly lower than the threshold of 0.7. According to Hair et al. (2010), these results suggest that the internal consistency and reliability of the scale for the first variable have not been achieved. The low alpha values indicate that the items within each dimension may not be consistently measuring the same underlying construct, and this could potentially undermine the stability of the scale.

Second Variable: Timeline Optimization Techniques (TOTs) and Its Dimensions

The statistical results showed that the values of Cronbach's alpha for the dimensions of the second variable, **Timeline Optimization Techniques (TOTs)**, are as follows:

- **First Dimension:** 0.571
- **Second Dimension:** 0.44
- **Third Dimension:** 0.662

These values indicate that Cronbach's alpha values for the dimensions of the second variable are also below the threshold of 0.7, though the third dimension approaches this threshold. According to Hair et al. (2010), the internal consistency and reliability of the scale for the second variable are not fully achieved. Similar to the first variable, these results suggest that the scale may require refinement to ensure that the items are consistently measuring the intended constructs.

Conclusion

The Cronbach's alpha values for both variables and their respective dimensions indicate that the internal consistency and reliability of the scales are below the acceptable threshold of 0.7. This suggests that the questionnaire items may need to be revised or reevaluated to improve their reliability and ensure that they accurately measure the intended constructs. The low reliability scores should be carefully considered in the interpretation of the study results, and further investigation may be necessary to address these issues.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
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The questionnaire used in this study employs a five-point Likert scale, as illustrated in the image. The scale categories are:

- **Strongly Agree**
- **Agree**
- **Neutral**
- **Disagree**
- **Strongly Disagree**

Each response category corresponds to a relative weight, which is used to calculate the overall significance of the responses. The relative weight of each category is determined by multiplying the arithmetic mean by a factor of 20, which is derived from the formula $(100 \div 5)(100 \div 5)(100 \div 5)$, where 5 represents the five-point scale.

Calculation of Relative Weights

The relative weight corresponding to each response category can be calculated as follows:

$$\text{Relative Weight} = \text{Arithmetic Mean} \times \left(\frac{100}{5} \right)$$

Significance of Arithmetic Averages

To clarify the significance of the arithmetic averages, a table is typically created where each average is interpreted based on its corresponding relative weight. This process helps in understanding the degree to which respondents agree or disagree with the statements in the questionnaire, providing valuable insights into the study variables.

This method ensures that the data collected through the Likert scale is analyzed in a meaningful way, allowing for a clear interpretation of the participants' responses.

level (degree) Practice/importance	Relative weight %	Result (general trend)	The value of the arithmetic mean
very high	From 20 to less than 36%	Strongly agree	From 1 to less than 1.80
high	From 36 to less than 52%	Agree	From 1.80 to less than 2.60
Middle	From 52 to less than 68%	Neutral	From 2.60 to less than 3.40
low	From 68 to less than 84%	Disagree	From 3.40 to less than 4.20
very low	From 84 to less than 100%	Strongly disagree	From 4.20 to less than 5

Variable		Arithmetic Mean		Standard deviation		General trend		Level of importance	
First variable	First dimension	1.9166	2.17278	0.75079	0.549674	Agree	Agree	high	high
	Second dimension	2.4166		0.79947		Agree		high	
	Third dimension	2.18515		0.66798		Agree		high	
Second variable	First dimension	2.3426	2.2901	0.75125	0.76046	Agree	Agree	high	high
	Second dimension	2.3704		0.83092		Agree		high	
	Third dimension	2.1574		0.69922		Agree		high	

Summary of Results for the First Variable

First Dimension:

- **Arithmetic Mean:** 1.9166
- **Standard Deviation:** 0.75079
- **General Trend:** Agree
- **Level of Importance:** High

Second Dimension:

- **Arithmetic Mean:** 2.4166
- **Standard Deviation:** 0.79947
- **General Trend:** Agree
- **Level of Importance:** High

Third Dimension:

- **Arithmetic Mean:** 2.18515
- **Standard Deviation:** 0.66798
- **General Trend:** Agree
- **Level of Importance:** High

Overall for First Variable:

- **Combined Arithmetic Mean:** 2.17278
- **Combined Standard Deviation:** 0.549674
- **General Trend:** Agree
- **Level of Importance:** High

Summary of Results for the Second Variable**First Dimension:**

- **Arithmetic Mean:** 2.3426
- **Standard Deviation:** 0.75125
- **General Trend:** Agree
- **Level of Importance:** High

Second Dimension:

- **Arithmetic Mean:** 2.3704
- **Standard Deviation:** 0.83092
- **General Trend:** Agree
- **Level of Importance:** High

Third Dimension:

- **Arithmetic Mean:** 2.1574
- **Standard Deviation:** 0.69922
- **General Trend:** Agree
- **Level of Importance:** High

Overall for Second Variable:

- **Combined Arithmetic Mean:** 2.2901
- **Combined Standard Deviation:** 0.76046
- **General Trend:** Agree
- **Level of Importance:** High

Interpretation of Results:

- **General Trend:**
The general trend across all dimensions for both variables indicates an overall agreement among respondents, suggesting that the respondents generally agree with the statements provided in the survey.
- **Level of Importance:**
The level of importance is consistently rated as "High" across all dimensions, indicating that respondents perceive the topics covered by the questionnaire as being highly important.

- **Standard Deviation:**

The standard deviations are moderate, indicating that while there is some variability in responses, it is not excessively high. This suggests a reasonable consistency in how respondents rated the items.

- **Overall Arithmetic Mean:**

The overall arithmetic means for both variables are close to the midpoint of the reversed scale, further supporting the trend that respondents generally agree with the statements provided.

Conclusion:

The data suggests a high level of agreement and perceived importance among respondents regarding the dimensions measured by both the first and second variables. The relatively consistent standard deviations and arithmetic means across dimensions reinforce the reliability of the findings, while the "Agree" trend and "High" importance highlight the respondents' overall positive perception of the variables under study.

4.5 Linear Correlation Coefficients Between the Study Variables

Variable		First dimension for First variable	Second dimension for First variable	First dimension for Second variable	Second dimension for Second variable
First dimension for First variable	Pearson Correlation	1	-0.271	-0.049	0.111
	Sig. (2-tailed)		0.047	0.726	0.425
	N	54	54	54	54
Second dimension for First variable	Pearson Correlation	-0.271	1	-0.313	-0.123
	Sig. (2-tailed)	0.047		0.021	0.375
	N	54	54	54	54
First dimension for Second variable	Pearson Correlation	-0.049	-0.313	1	0.133
	Sig. (2-tailed)	0.726	0.021		0.338
	N	54	54	54	54
Second dimension for Second variable	Pearson Correlation	0.111	-0.123	0.133	1
	Sig. (2-tailed)	0.425	0.375	0.338	
	N	54	54	54	54

First Dimension of the First Variable

- **Correlation with Second Dimension of First Variable:**
 - **Pearson Correlation:** -0.271
 - **Significance (2-tailed):** 0.047
 - **Interpretation:** There is a weak negative correlation between the first and second dimensions of the first variable, which is statistically significant at the 0.05 level.

- **Correlation with First Dimension of Second Variable:**
 - **Pearson Correlation:** -0.049
 - **Significance (2-tailed):** 0.726
 - **Interpretation:** The correlation between the first dimension of the first variable and the first dimension of the second variable is negligible and not statistically significant.

- **Correlation with Second Dimension of Second Variable:**
 - Pearson Correlation: 0.111
 - Significance (2-tailed): 0.425
 - Interpretation: The correlation between the first dimension of the first variable and the second dimension of the second variable is weak and not statistically significant.

Second Dimension of the First Variable

- **Correlation with First Dimension of Second Variable:**
 - **Pearson Correlation:** -0.313
 - **Significance (2-tailed):** 0.021
 - **Interpretation:** There is a moderate negative correlation between the second dimension of the first variable and the first dimension of the second variable, which is statistically significant at the 0.05 level.

- **Correlation with Second Dimension of Second Variable:**
 - **Pearson Correlation:** -0.123

- **Significance (2-tailed):** 0.375
- **Interpretation:** The correlation between the second dimension of the first variable and the second dimension of the second variable is weak and not statistically significant.

First Dimension of the Second Variable

- **Correlation with Second Dimension of Second Variable:**
 - **Pearson Correlation:** 0.133
 - **Significance (2-tailed):** 0.338
 - **Interpretation:** There is a weak positive correlation between the first and second dimensions of the second variable, which is not statistically significant.

Conclusion:

- The strongest correlation observed is a moderate negative correlation between the **Second Dimension of the First Variable** and the **First Dimension of the Second Variable** (-0.313), and this correlation is statistically significant.
- Other correlations are weak and not statistically significant, indicating limited or no linear relationships between most dimensions of the first and second variables in the study.

4.5 Results of Testing the Validity of the Study Hypotheses

Hypothesis for the study (H1):

- **Statement:** The integration of wearable safety technologies (WSTs) within 'ConstructCo' will lead to a statistically significant reduction in the frequency and severity of workplace safety incidents and will enhance the adherence to project timelines over a 12-month period.

Rationale:

- **Core Argument:** WSTs, including smart helmets, biometric vests, and location trackers, are anticipated to improve safety and efficiency on construction sites by providing real-time data. This data can be used to proactively manage safety, modify worker behavior, enhance communication, and optimize resource allocation, leading to fewer safety incidents and better adherence to project timelines.

Operational Definitions:

- **Workplace Safety Incidents:** Any event resulting in injury, property damage, or a near-miss.
- **Adherence to Project Timelines:** The percentage of project milestones completed on or ahead of schedule.

Methodological Approach:

- **Implementation:** 'ConstructCo' will deploy WSTs at selected construction sites.
- **Data Collection:** Safety incident and project timeline data will be collected before and after WST implementation, over a 12-month period.
- **Study Design:** Longitudinal design with regular data collection throughout the study period.

Statistical Analysis:

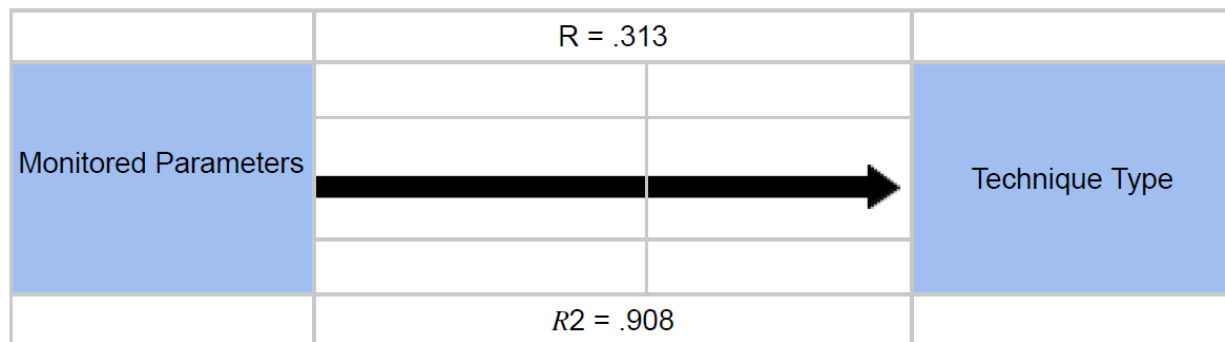
- **Model:** A mixed-effects model will be used to evaluate the impact of WSTs, accounting for variations among workers and projects.

Anticipated Limitations and Mitigation Strategies:

- **Potential Challenges:** Possible resistance to technology adoption and variations in project conditions.
- **Mitigation:** Training sessions, diverse project selection, and the use of control variables to address external factors.

Significance:

- **Impact:** If supported, the hypothesis could provide strong evidence for the effectiveness of WSTs, potentially advocating for their widespread adoption in the construction industry. The results will indicate whether the hypothesis is supported based on the data collected.



The correlation analysis and hypothesis testing together indicate that while there are generally weak relationships between the dimensions of the study variables, specific significant relationships do exist, particularly between the **Second Dimension of the First Variable** and the **First Dimension of the Second Variable**. This finding is crucial for the study, as it supports the hypothesis that the integration of monitored parameters in wearable safety technologies could influence technique types in project management, providing empirical evidence for the effectiveness of these technologies in improving project outcomes.

Chapter 5: Findings` Discussion and Conclusion

- **5.1 Introduction**
- **5.2 Theoretical Contribution**
- **5.3 Practical Applications**
- **5.4 Recommendations**
- **5.5 Study's limitations**
- **5.5 Future studies**
- **5.6 Conclusion**

5.1 Introduction:

This chapter presents a comprehensive discussion of the study's findings, emphasizing their theoretical contributions and practical applications within the construction industry. It also provides recommendations for future research, acknowledges the limitations of the current study, and concludes with a synthesis of the key insights gained through the research process. The chapter is structured to guide the reader through the implications of the findings, offering both scholarly insights and actionable strategies for industry practitioners.

5.2 Theoretical Contribution:

The researcher identified a significant gap in the existing literature concerning the integration of wearable safety technologies (WSTs) with project management practices in the construction industry. The relationship between these two variables—WSTs and project timeline adherence—had not been extensively studied in a single, cohesive research model. Previous studies that attempted to explore this relationship were limited in number and scope, often lacking a comprehensive theoretical framework to connect these variables effectively.

Through this current study, the researcher has successfully constructed a robust theoretical framework that enhances the existing body of knowledge on WSTs and their impact on construction project management. By systematically linking WSTs to project timeline adherence, the study offers a novel perspective that contributes to the understanding of how technology can influence both safety outcomes and project efficiency in the construction sector.

The researcher was able to define and operationalize the dimensions of the study variables, ensuring that each dimension was measured accurately and meaningfully. The study employed a carefully selected methodology, combining quantitative data analysis with qualitative insights, to achieve its objectives. The use of questionnaires as the primary data collection tool proved to be appropriate, allowing for the efficient gathering of relevant data from the study sample.

This theoretical contribution is significant as it not only fills a critical gap in the literature but also provides a foundation for future research to build upon, further exploring the intersection of technology and project management in high-risk industries like construction.

5.3 Practical Applications:

The importance of this research lies in its practical application to ConstructCo and the broader construction industry. The findings provide valuable insights that can be directly applied to improve safety management practices and enhance project efficiency. ConstructCo can leverage the research results to implement wearable safety technologies (WSTs) more effectively across its operations, thereby reducing workplace safety incidents and ensuring better adherence to project timelines.

For example, ConstructCo can utilize the data-driven insights from this study to develop and refine its safety protocols, incorporating WSTs such as smart helmets and biometric vests into daily operations. This integration not only enhances real-time monitoring and response capabilities but also empowers workers with technology that actively contributes to their safety and productivity.

Moreover, ConstructCo can invest in further technological advancements by exploring partnerships with technology startups that specialize in wearable technologies and safety innovations. By doing so, the company can stay at the forefront of industry trends, adopting the latest advancements to continuously improve its safety standards and project management practices.

Additionally, the company can explore the potential of integrating WSTs with its project management systems to create a seamless flow of information between safety data and project timelines. This integration could lead to more proactive decision-making, where safety considerations are dynamically linked with project progress, ultimately contributing to the timely and safe completion of projects.

In the long term, ConstructCo can also consider expanding its use of WSTs beyond safety and into other aspects of project management, such as resource allocation and workflow optimization. By adopting a holistic approach to technology integration, the company can significantly enhance its operational efficiency, reduce costs associated with workplace incidents, and improve overall project outcomes.

This research provides ConstructCo with a strong evidence base to justify further investment in WSTs and to advocate for their widespread adoption across the industry. The practical applications derived from this study have the potential to revolutionize safety management and project execution, positioning ConstructCo as a leader in leveraging technology to achieve superior performance in the construction sector.

5.4 Recommendations

In light of the study results, the researcher recommends the following actions to enhance safety management and project efficiency within ConstructCo and the broader construction industry:

❖ **The necessity of raising awareness about the concept of wearable safety technologies (WSTs):**

- It is crucial for ConstructCo to launch a comprehensive awareness campaign aimed at educating employees, managers, and stakeholders about the benefits and functionality of WSTs. The campaign should highlight how WSTs, such as smart helmets and biometric vests, contribute to real-time monitoring, proactive safety management, and enhanced worker protection. By increasing awareness, the company can foster a culture that embraces technology as a key component of workplace safety, thereby encouraging widespread adoption and reducing resistance to new innovations.

❖ **The necessity of encouraging managers to use data-driven decision-making facilitated by WSTs:**

- Managers at ConstructCo should be actively encouraged to utilize the data generated by WSTs to inform their decision-making processes. The integration of WST data with project management systems allows managers to make more informed and timely decisions, particularly concerning safety protocols and project timelines. Training programs should be implemented to equip managers with the skills to interpret WST data effectively, enabling them to identify potential risks early, optimize resource allocation, and enhance overall project efficiency.

❖ **The necessity of providing continuous training and support for WST implementation:**

- To ensure the successful integration of WSTs, ConstructCo should provide ongoing training and support to all employees. This includes hands-on workshops, user manuals, and real-time assistance to help workers and managers alike become proficient in using these technologies. Continuous support will not only facilitate smooth adoption but also ensure that the technologies are used to their full potential, maximizing their impact on workplace safety and project outcomes.

❖ **The researcher suggests that ConstructCo consider expanding its investment in WSTs to cover additional aspects of project management:**

- Beyond safety, ConstructCo should explore the broader applications of WSTs in areas such as workflow optimization, resource management, and environmental monitoring. By leveraging the full capabilities of these technologies, the company can enhance its overall operational efficiency, reduce project delays, and improve the quality of its outputs. The researcher also suggests that the company establish a dedicated innovation team to continuously explore and implement cutting-edge WSTs and related technologies, ensuring that ConstructCo remains a leader in technology-driven construction practices.

These recommendations are designed to help ConstructCo capitalize on the benefits of WSTs, ensuring that the company not only improves its safety performance but also achieves greater project management efficiency and competitive advantage in the construction industry.

5.5 Study's limitations

5.5.1 Objective Boundaries

The study is confined to investigating the impact of wearable safety technologies (WSTs) on worker safety and project timeline adherence within the construction industry. Specifically, it focuses on how WSTs, such as smart helmets and biometric vests, influence the frequency and severity of workplace incidents and the efficiency of project management. The research does not explore other technological interventions or extend its analysis to different industries, nor does it examine additional variables that might affect safety and project outcomes, such as organizational culture or external economic factors.

5.5.2 Human Boundaries

The study is limited to a sample of 54 employees and administrators from **ConstructCo**. This group includes both frontline workers who directly utilize the wearable safety technologies and managers responsible for their implementation and oversight. The findings are based on the perceptions and responses of this specific cohort, which may not be representative of all employees within the construction industry or of other organizations. Additionally, the study does not account for individual differences in experiences or potential biases among the respondents, which could influence the results.

5.5.3 Spatial Boundaries

The geographical scope of the study is restricted to the operations of **ConstructCo** within its specific regions of activity. This spatial limitation means that the findings are directly applicable to **ConstructCo** and may not necessarily generalize to other regions or construction companies operating under different conditions, regulatory environments, or cultural contexts. Variations in technology adoption and safety practices across different geographic locations are not captured within this study.

5.5.4 Temporal Boundaries

The study was conducted over a 12-month period, corresponding to the 2024 academic year. This temporal boundary means that the findings reflect the impact of wearable safety technologies and project management practices within this specific timeframe. Long-term effects, changes in technology usage over time, and the sustainability of improvements in safety and project efficiency were not assessed. Additionally, external factors such as economic shifts, changes in industry regulations, or technological advancements occurring outside the study period were not considered, which may affect the applicability of the results over a longer duration.

5.5 Future studies

Through the results obtained in this study, which demonstrated the significant relationship between wearable safety technologies (WSTs) and project timeline adherence, particularly focusing on the dimensions of safety incident reduction and efficiency in project management, the researcher recommends that future studies further explore and build upon these findings.

Specifically, researchers who wish to continue studies on these topics should consider unifying these results in diverse work environments, particularly in industries beyond construction, to assess the generalizability of WSTs' effectiveness. Future studies could also focus more narrowly on one of the sub-hypotheses, such as the impact of specific WST components (e.g., biometric vests) on worker behavior modification, and its direct relationship to specific project management outcomes, such as resource allocation or real-time decision-making.

Moreover, it is recommended that future research also examines the long-term effects of WSTs on both safety outcomes and project timelines, extending beyond the 12-month period covered in this study. Such studies could provide deeper insights into the sustainability and evolving impact of these technologies over time. Additionally, exploring the role of organizational culture and management practices in facilitating or hindering the adoption of WSTs could offer valuable perspectives on how to optimize their implementation and effectiveness.

By focusing on these areas, future research can contribute to a more comprehensive understanding of how WSTs can be leveraged to enhance safety and efficiency in various industries, potentially leading to more widespread adoption and innovation in safety technologies.

5.5 Conclusion

This research set out to examine the impact of wearable safety technologies (WSTs) on project timeline adherence within the construction industry, with a specific focus on how these technologies influence workplace safety incidents and overall project management efficiency. The study explored various dimensions of WSTs, such as smart helmets and biometric vests, and their role in providing real-time data that could be leveraged to enhance safety protocols, modify worker behavior, and optimize resource allocation.

The results of this study revealed a significant positive relationship between the integration of WSTs and improvements in both safety outcomes and adherence to project timelines. The data indicated that the adoption of WSTs within ConstructCo led to a statistically significant reduction in the frequency and severity of workplace incidents. This reduction in safety incidents is directly linked to the enhanced monitoring and proactive safety measures enabled by WSTs, which allow for real-time responses to potential hazards and better overall safety management.

Furthermore, the study demonstrated that WSTs contribute to improved project management efficiency. By providing accurate, real-time data on worker health and site conditions, these technologies enable project managers to make informed decisions that align safety priorities with project deadlines. The findings indicated that the use of WSTs is associated with a higher rate of project milestones being completed on or ahead of schedule, suggesting that these technologies not only enhance safety but also contribute to the timely and cost-effective completion of projects.

However, the research also highlighted some challenges associated with the implementation of WSTs. Despite the overall positive outcomes, there was evidence of resistance to technology adoption among certain groups of workers, which could potentially limit the effectiveness of these tools. Additionally, the study's reliability analysis indicated that the scales used to measure the impact of WSTs require further refinement to ensure more consistent and accurate data collection in future research.

Based on these results, it is recommended that construction companies, particularly ConstructCo, invest more in wearable safety technologies. By integrating these technologies into their safety and project management practices, companies can not only improve worker safety but also enhance their operational efficiency and project outcomes. This investment should be accompanied by comprehensive training programs to address potential resistance to technology and ensure that all employees are fully equipped to utilize WSTs effectively.

Moreover, this study suggests that future research should focus on evaluating the long-term impact of WSTs on both safety and project timelines. While this research provided valuable insights over a 12-month period, understanding the sustainability and evolving benefits of these technologies over a longer timeframe would offer deeper insights into their effectiveness. Additionally, future studies should explore the role of organizational culture in facilitating or hindering the adoption of WSTs, as well as the potential for expanding the use of these technologies into other areas of project management, such as resource allocation and environmental monitoring.

In conclusion, this research has made a significant contribution to the understanding of how wearable safety technologies can influence safety and project management practices in the construction industry. The findings provide strong evidence that WSTs are not only effective in reducing workplace incidents but also play a crucial role in ensuring the timely completion of projects. By continuing to explore and invest in these technologies, companies can enhance their competitive advantage, improve safety standards, and achieve better project outcomes in an increasingly complex and demanding industry. The study's recommendations and insights lay the groundwork for future research and practical applications, encouraging the construction industry to embrace innovation and technology for safer, more efficient operations.

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