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Assessing the Economic Impact of Safety Investments on Supply Chain Performance in Large Construction Projects: A Case Study of the Third Ring Road Project in Tripoli, Libya

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Abstract

The construction industry is highly hazardous, where accidents cause human and financial losses and disrupt supply chains. This study investigates the economic impact of safety investments on supply chain performance, using the Third Ring Road Project in Tripoli, Libya, as a case study. A quantitative survey of 49 professionals was analyzed using descriptive and inferential statistics (Pearson correlation). Findings show high agreement on safety's importance (mean=4.15). Critically, accident reduction is the strongest driver of supply chain resilience ($r=0.792$, $p<0.001$), and safety investment significantly impacts economic performance ($r=0.422$, $p=0.003$). However, financial expenditure alone does not guarantee safety gains, as effectiveness depends on organizational culture and training. This study provides empirical evidence from Libya, offering practical guidance for integrating safety into strategic project management to enhance sustainability.

Keywords

Occupational Safety; Safety Investment; Supply Chain Performance; Construction Management; Libya

I. Introduction

The construction industry plays a fundamental role in economic development by supporting infrastructure expansion, creating employment opportunities, and stimulating national economic growth. Despite its economic importance, construction remains one of the most hazardous industries worldwide due to its complex working environments, multiple stakeholders, hazardous equipment, and dynamic operational conditions. Occupational accidents in construction projects continue to generate substantial human, operational, and financial losses, affecting not only workers but also project schedules, organizational productivity, and supply chain performance (International Labor Organization [ILO], 2024).

Traditionally, occupational safety has been viewed as a regulatory obligation aimed primarily at protecting workers and ensuring compliance with national safety regulations. However, recent developments in construction management have shifted this perspective by recognizing occupational safety as a strategic organizational investment capable of generating measurable economic returns. Rather than representing an additional project expense, effective safety management contributes to reducing accident-related costs, minimizing operational interruptions, improving workforce productivity, and enhancing overall project efficiency (Hinze, Thurman, & Wehle, 2013; ILO, 2024).

The relationship between occupational safety and supply chain performance has received increasing attention in recent years. Modern construction projects involve highly interconnected supply chains comprising contractors, subcontractors, suppliers, consultants, logistics providers, and project owners. Any disruption caused by workplace accidents may propagate throughout the project network, resulting in delays in material deliveries, inefficient resource

utilization, increased procurement costs, contractual disputes, and schedule overruns. Consequently, maintaining high occupational safety standards contributes directly to improving supply chain resilience, operational continuity, and organizational competitiveness (Ivanov, 2021).

From an economic perspective, investments in occupational safety generate both direct and indirect benefits. Direct benefits include reductions in medical expenses, compensation claims, equipment damage, and insurance costs, whereas indirect benefits encompass enhanced employee morale, improved productivity, reduced absenteeism, better decision-making, stronger organizational reputation, and improved coordination among supply chain partners. These economic advantages increasingly position occupational safety as a strategic contributor to sustainable project management and long-term organizational performance (Fang, Zhao, & Zhang, 2020).

Although previous research has extensively examined occupational safety management, construction productivity, and supply chain performance independently, relatively few

empirical studies have investigated the economic relationship between occupational safety investments and supply chain performance within a unified analytical framework. This research gap is particularly evident in developing countries, where construction industries frequently encounter challenges related to safety culture, resource allocation, regulatory enforcement, and project coordination.

In Libya, the construction sector continues to play a vital role in national infrastructure development. Nevertheless, occupational safety management remains insufficiently investigated from an economic perspective, particularly regarding its influence on construction supply chain performance. Large infrastructure projects require effective coordination among multiple stakeholders, making safety management an essential factor in maintaining operational continuity and minimizing project risks. Despite this practical importance, empirical evidence examining the economic value of occupational safety investments within Libyan construction projects remains limited.

Accordingly, this study investigates the economic impact of occupational safety investments on supply chain performance through a case study of the Third Ring Road Project in Tripoli, Libya. Specifically, the research aims to evaluate how investments in occupational safety contribute to improving operational efficiency, reducing accident-related disruptions, enhancing supply chain performance, and supporting better economic outcomes in large construction projects. The findings are expected to contribute both theoretically and practically by expanding the current understanding of safety economics within construction supply chains and providing evidence-based recommendations for project managers, policymakers, and construction organizations.

II. Literature Review

2.1 Occupational Safety in Construction Projects

Occupational safety has become one of the fundamental pillars of successful construction project management. Owing to the dynamic nature of construction activities, workers are continuously exposed to various hazards, including falls from height, equipment failures, electrical accidents, material handling injuries, and unsafe working environments. Consequently, construction projects consistently report higher accident rates than many other industrial sectors, emphasizing the necessity of systematic occupational safety management (International Labor Organization [ILO], 2024).

Modern safety management extends beyond compliance with legal requirements by adopting proactive strategies that focus on hazard identification, risk assessment, employee training, continuous monitoring, and preventive planning. Contemporary studies suggest that organizations implementing proactive safety management systems experience fewer accidents, higher workforce productivity, improved employee satisfaction, and better project performance (Fang et al., 2020).

Furthermore, international standards such as **ISO 45001** encourage organizations to integrate occupational health and safety into their overall management systems, emphasizing continuous improvement, organizational learning, and strategic decision-making rather than reactive accident response.

2.2 Safety Investment and Economic Performance

Traditionally, occupational safety expenditures were viewed as unavoidable project costs that reduced organizational profitability. However, recent literature increasingly recognizes occupational safety as a strategic investment capable of generating substantial economic value.

Safety investments typically include expenditures related to employee training, personal protective equipment (PPE), safety inspections, hazard prevention programs, emergency preparedness, technological monitoring systems, and organizational safety culture development. Although these investments increase initial project costs, they frequently produce significantly greater long-term financial returns by preventing accidents and minimizing operational disruptions (Hinze et al., 2013).

Several empirical studies demonstrate that organizations maintaining higher safety standards generally achieve lower accident compensation costs, reduced insurance premiums, fewer schedule delays, higher labor productivity, and stronger financial performance. Consequently, occupational safety is increasingly considered an essential component of sustainable project management and organizational competitiveness.

The economic viability of safety investments has been rigorously examined in recent empirical studies. Khan et al. (2025) conducted a comprehensive cost–benefit analysis of construction safety implementation in developing countries, identifying 33 distinct cost drivers and safety barriers. Their findings strongly recommend allocating **2.5% to 3% of total project costs** to safety measures, substantiating the tangible financial returns of such investments. Similarly, Matindana, Kajumulo, and Mohamed (2025) investigated safety costs across 255 construction firms in Tanzania, finding that total safety expenditure averages approximately **1.77%** of the contract value, with an inverse relationship between safety costs and safety performance—underscoring the necessity of proactive investment.

Corroborating these findings, Eurofound (n.d.) reported that proactive risk prevention measures yield an average return of **€2.19 for every €1 invested**, reinforcing the strategic shift from viewing safety as a cost center to recognizing it as a value-generating investment. Moreover, a 2025 study published in *Safety Science* on optimal safety resource allocation established that the **Safety Investment Ratio (SIR)** for small and medium construction enterprises should ideally be around **3.8%** of the project scope—higher than for large projects—providing a theoretical benchmark for efficient resource distribution. Mosaicapp (2026) further supports this by demonstrating that investing approximately **2.5% of project**

costs into safety training significantly improves project outcomes, with a measurable profitability increase ranging between **4% and 7%** per project.

2.3 Occupational Safety and Supply Chain Performance

Construction supply chains comprise interconnected organizations responsible for procurement, logistics, engineering, contracting, supervision, and project execution. Because these participants depend heavily on coordinated operations, disruptions occurring at one stage frequently propagate throughout the entire project.

Occupational accidents represent one of the most significant sources of supply chain disruption. Workplace incidents may interrupt construction activities, delay material deliveries, reduce equipment utilization, increase procurement costs, create contractual conflicts, and ultimately affect overall project completion.

Recent supply chain resilience research emphasizes that effective occupational safety management enhances operational continuity by reducing unexpected disruptions, improving coordination among stakeholders, strengthening communication, and maintaining workflow stability. Consequently, occupational safety has emerged as an important contributor to supply chain resilience and organizational sustainability (Ivanov, 2021).

The integration of occupational safety into supply chain management has gained considerable traction as a strategic imperative. The European Agency for Safety and Health at Work (EU-OSHA, 2024), through its LIFT-OSH Project, highlights the instrumental role of supply chains in promoting safety and health standards across the construction and agriculture sectors. The report provides actionable tools for evaluating subcontractor safety performance, emphasizing that safety cannot be managed in isolation but must permeate the entire project network. Concurrently, a 2026 study presented at the ARCOM conference on supply chain resilience modelled critical success factors for the sustainable construction sector, identifying and classifying key enablers that bridge the gap between sustainability goals and operational resilience. These studies collectively assert that supply chain resilience is inextricably linked to the safety performance of all upstream and downstream stakeholders.

2.4 Occupational Safety as a Source of Competitive Advantage

The Resource-Based View (RBV) of the firm suggests that organizations obtain sustainable competitive advantages through valuable organizational capabilities that competitors cannot easily imitate. Within this perspective, occupational safety represents more than a compliance function; it becomes an organizational capability contributing directly to operational excellence.

Organizations characterized by strong safety cultures generally experience lower workforce turnover, higher employee commitment, improved organizational learning, better quality performance, and enhanced stakeholder confidence. These advantages collectively strengthen project competitiveness while improving both operational and financial performance.

Moreover, proactive safety management supports Environmental, Social, and Governance (ESG) objectives, which have become increasingly important in evaluating organizational sustainability and long-term investment performance.

2.5 Research Gap

Although previous studies have independently investigated occupational safety management, economic performance, construction productivity, and supply chain resilience, relatively limited research has examined the direct economic relationship between occupational safety investments and supply chain performance within large infrastructure projects.

Most available studies have focused either on accident prevention or regulatory compliance, while fewer investigations have evaluated occupational safety from an economic investment perspective. Furthermore, empirical evidence from developing countries—particularly Libya—remains scarce despite the rapid expansion of national infrastructure projects.

Accordingly, this study addresses this research gap by investigating the economic impact of occupational safety investments on supply chain performance using empirical evidence collected from the Third Ring Road Project in

Tripoli, Libya. The study integrates occupational safety, economic performance, and supply chain management into a single analytical framework, thereby contributing both theoretically and practically to construction management literature.

The empirical gap in occupational safety research is particularly pronounced in fragile and developing contexts, such as Libya. Elkaseh, Zakaria, Shamsudin, Mazlan, and Vighio (2025) made a significant contribution by adapting the ISO 45001:2018 framework to the Libyan construction sector, developing two innovative safety performance assessment tools (COSPL 1.0 and FLARE 1.0). Their analysis of data from **121 professionals** across four Libyan construction firms revealed a stark reality: **5,816 construction-related accidents** were recorded in Libya between 2015 and 2020, representing **27%** of all workplace incidents. Their study identified leadership commitment and worker participation as the most critical factors for cultivating a robust safety culture.

Further enriching this contextual understanding, a 2025 study in *Behavioral Sciences* investigated the influence of **Psychosocial Safety Climate (PSC)** on safety behavior and employee engagement among Libyan construction workers, utilizing a dataset of **366 valid responses**. The findings confirmed that PSC positively influences safe work behavior, and critically, that **safety leadership** significantly moderates this relationship, reinforcing the pivotal

role of managerial practices. Additionally, Omran, Muftah, Said, and Hussin (n.d.) provided qualitative evidence through case studies, documenting the practical challenges contractors face in implementing safety requirements on Libyan construction sites.

Table 1. Summary of Previous Studies

Author(s)	Country	Research Focus	Methodology	Main Findings	Research Gap
Hinze et al. (2013)	USA	Safety Management	Case Study	Safety investment reduces project losses	Did not examine supply chain performance
Fang et al. (2020)	China	Construction Safety	Survey	Strong safety culture improves project performance	Limited economic analysis
Ivanov (2021)	International	Supply Chain Resilience	Conceptual	Risk management strengthens supply chain resilience	Occupational safety not directly investigated
ILO (2024)	Global	Occupational Safety	Global Report	Safety contributes to productivity and sustainable development	No project-level empirical analysis
Present Study (2026)	**Libya**	**Safety Investment & Supply Chain Performance**	**Questionnaire Survey**	**Examines the economic impact of safety investment on supply chain performance**	**Provides empirical evidence from Libya**

III. Research Methodology

3.1 Research Design

This study adopted a **quantitative research design** to investigate the economic impact of occupational safety investments on supply chain performance within large-scale construction projects. A quantitative approach was considered appropriate because it enables the systematic collection, measurement, and statistical analysis of participants' perceptions regarding occupational safety practices and their contribution to operational and economic performance.

A **case study strategy** was employed using the **Third Ring Road Project in Tripoli, Libya**, one of the country's largest infrastructure projects. The project was selected because of its complexity, large workforce, extensive supply chain network, and multiple stakeholders, making it an

appropriate environment for evaluating the relationship between occupational safety investments and supply chain performance.

3.2 Study Population and Sample

The target population consisted of professionals directly involved in the execution and management of the Third Ring Road Project. Participants included project managers, resident engineers, site engineers, occupational safety engineers, supervisors, logistics personnel, contractor representatives, consultants, and other technical staff responsible for project execution.

A structured questionnaire was distributed among professionals with practical experience in construction safety management and supply chain operations. Only completed and valid responses were included in the statistical analysis to ensure the reliability and consistency of the research findings.

3.3 Data Collection Instrument

Primary data were collected using a structured questionnaire developed following an extensive review of previous studies on occupational safety management, construction project performance, supply chain resilience, and safety economics.

The questionnaire consisted of **five sections**:

1. Respondents' demographic information.
2. Occupational Safety Investment.
3. Accident Reduction.
4. Economic Performance.
5. Supply Chain Performance.

All questionnaire items were measured using a **five-point Likert scale**, ranging from

1 = Strongly Disagree to **5 = Strongly Agree**, allowing respondents to express the degree of agreement with each statement.

The questionnaire items were adapted from internationally recognized studies and modified to reflect the characteristics of large infrastructure projects within the Libyan construction industry.

3.4 Data Analysis

The collected data were analyzed using **Microsoft Excel statistical functions** to generate descriptive statistical indicators and evaluate respondents' perceptions regarding occupational safety investments.

The statistical analysis included:

- Frequency distributions.
- Percentage analysis.
- Mean values.
- Standard deviations.
- Ranking of questionnaire items.
- Dimension-level descriptive analysis.
- Dashboard visualization of the research findings.

The interpretation of mean scores followed the commonly adopted five-point Likert scale, where values above **3.68** indicate a high level of agreement among respondents.

3.5 Validity and Reliability

To ensure the quality of the research instrument, the questionnaire was developed based on an extensive review of international literature related to occupational safety, construction management, and supply chain performance.

The questionnaire was reviewed by specialists in project management and occupational safety before distribution to ensure **content validity**, clarity, and consistency of the measurement items.

Furthermore, only fully completed questionnaires were included in the statistical analysis to enhance the reliability of the collected data.

3.6 Conceptual Framework

The conceptual framework assumes that occupational safety investment improves organizational performance through a sequence of interconnected relationships. Increased investment in occupational safety enhances workplace safety performance by reducing occupational accidents and operational disruptions. Improved safety performance subsequently strengthens supply chain efficiency through better coordination, uninterrupted workflow, and increased operational reliability. Ultimately, enhanced supply chain performance contributes to improved economic performance by reducing project costs, increasing productivity, and supporting sustainable project delivery.

Accordingly, the proposed conceptual model consists of the following relationships:

- Occupational Safety Investment → Safety Performance
- Safety Performance → Accident Reduction
- Accident Reduction → Supply Chain Performance
- Supply Chain Performance → Economic Performance

3.7 Research Hypotheses

Based on the reviewed literature and the conceptual framework, the study proposes the following hypotheses:

H1: Occupational safety investment has a positive impact on accident reduction.

H2: Occupational safety investment has a positive impact on supply chain performance.

H3: Occupational safety investment has a positive impact on economic performance.

H4: Accident reduction positively contributes to supply chain performance.

H5: Improved supply chain performance positively influences project economic performance.

IV. Results and Discussion:

4.1 Respondents' Profile

A total of **49 valid questionnaires** were included in the final statistical analysis after excluding incomplete responses. The respondents represented a broad range of professionals involved in the Third Ring Road Project, including project managers, construction engineers, safety engineers, site supervisors, logistics personnel, consultants, and contractor representatives.

The diversity of respondents ensured that the collected data reflected different professional perspectives regarding occupational safety management, project execution, and construction supply chain operations. Consequently, the dataset provides a comprehensive representation of occupational safety practices within large infrastructure projects.

4.2 Descriptive Statistics of Study Dimensions

To evaluate the overall perception of respondents regarding occupational safety investments and their impact on project performance, arithmetic means and standard deviations were computed for each of the four primary dimensions. The interpretation of mean scores followed the widely adopted five-point Likert scale criteria, where scores above **3.68** indicate a high level of agreement, scores between **2.34 and 3.67** indicate a moderate level, and scores below **2.34** indicate a low level of agreement.

Table 2: Arithmetic Means and Standard Deviations for Study Dimensions

Dimension	Arithmetic Mean	Standard Deviation	Level of Agreement
Occupational Safety Investment	4.54	0.43	High
Accident Reduction	3.73	0.44	High
Economic Performance	4.45	0.45	High
Supply Chain Performance	3.90	0.46	High
Overall Mean	**4.15**	**0.45**	**High**

As shown in Table 2, all four study dimensions achieved mean scores exceeding the high-level threshold of 3.68. The **Occupational Safety Investment** dimension recorded the highest mean score (M = 4.54, SD = 0.43), indicating that respondents strongly affirm the necessity of allocating adequate financial and managerial resources to proactive safety management. This was closely followed by **Economic Performance** (M = 4.45, SD = 0.45), reflecting a widespread belief that safety investments yield measurable financial returns.

The **Supply Chain Performance** dimension (M = 3.90, SD = 0.46) and **Accident Reduction**

(M = 3.73, SD = 0.44) also demonstrated high levels of agreement, though comparatively lower than the previous two. This suggests that while respondents acknowledge the positive role of safety in reducing disruptions and improving

logistical fluidity, they also perceive significant room for improvement in translating safety efforts into tangible accident prevention and uninterrupted workflow.

The consistently low standard deviation values (ranging from 0.43 to 0.46) indicate a strong consensus among participants across all professional backgrounds, reinforcing the reliability and internal consistency of the collected data.

4.3 Occupational Safety Investment

The Occupational Safety Investment dimension achieved the highest evaluation among all research dimensions.

Statement **S1** recorded the highest mean score (**Mean = 4.72**), while Statements **S2**, **S3**, and **S4**

achieved mean values ranging between **4.52 and 4.54**.

These findings demonstrate that respondents strongly believe that allocating sufficient financial and organizational resources to occupational safety significantly enhances project execution and improves workplace conditions.

The consistently low standard deviations indicate a high level of agreement among participants, suggesting that occupational safety investment is widely recognized as a strategic organizational priority rather than merely a regulatory requirement.

4.4 Accident Reduction

The accident reduction dimension generally achieved positive evaluations.

Most questionnaire items recorded high mean values, indicating respondents' confidence that occupational safety investments contribute significantly to reducing workplace accidents and minimizing operational disruptions.

However, one questionnaire item recorded a comparatively lower evaluation (**Mean = 3.38**), suggesting that although respondents recognize the importance of preventive safety measures, certain accident prevention practices still require additional improvement within construction projects.

Overall, the results indicate that strengthening preventive safety programs remains an important opportunity for improving construction safety performance.

4.5 Economic Performance

Respondents demonstrated strong agreement regarding the positive economic impact of occupational safety investments.

Mean values ranged between **4.36 and 4.50**, indicating that participants believe occupational safety contributes directly to reducing accident-related costs, improving operational efficiency, minimizing financial losses, and supporting overall project profitability.

These findings reinforce the emerging concept that occupational safety should be viewed as a productive investment capable of generating measurable financial returns rather than an unavoidable operational expense.

4.6 Supply Chain Performance

The Supply Chain Performance dimension also achieved favorable evaluation levels.

Mean values ranged from **3.68 to 3.98**, indicating a generally high level of agreement regarding the contribution of occupational safety investments to improving supply chain performance.

Respondents emphasized that effective occupational safety management supports uninterrupted workflow, enhances communication among project participants, improves logistics coordination, minimizes unexpected project delays, and increases the overall resilience of construction supply chains.

These findings demonstrate that occupational safety contributes not only to protecting workers but also to improving organizational coordination and operational stability throughout project implementation.

4.7 Inferential Statistics: Correlation and Hypothesis Testing

To examine the strength and direction of the relationships between the study variables, a Pearson correlation coefficient (r) was computed for each of the five proposed hypotheses. Statistical significance was tested at the conventional alpha level of 0.05. The detailed results of the correlation analysis are presented in Table 3.

Table 3: Pearson Correlation Coefficients and Significance Levels

Hypothesis	Relationship	Correlation (r)	P-Value	Significance (α = 0.05)
H1	Safety Investment → Accident Reduction	0.081	0.58	Not Supported
H2	Safety Investment → Supply Chain Performance	0.148	0.31	Not Supported
H3	Safety Investment → Economic Performance	0.422	0.003	Supported
H4	Accident Reduction → Supply Chain Performance	0.792	< 0.001	Strongly Supported
H5	Supply Chain Performance → Economic Performance	-0.037	0.80	Not Supported

As shown in Table 3, the results indicate a mixed level of support for the research hypotheses. The strongest and most significant positive correlation was observed between accident reduction and supply chain performance ($r = 0.792$, $p < 0.001$). Additionally, a moderate yet statistically significant positive relationship was found between safety investment and economic performance ($r = 0.422$, $p = 0.003$).

Conversely, the correlations for H1 ($r = 0.081$, $p = 0.58$), H2 ($r = 0.148$, $p = 0.31$), and H5 ($r = - 0.037$, $p = 0.80$) were found to be statistically non-significant, indicating that the linear relationships between these specific variables were not strongly evident within the current dataset.

4.8 Thematic Analysis of Open-Ended Responses

To complement the quantitative findings and gain a deeper understanding of the operational realities, participants were invited to provide open-ended responses regarding the primary challenges they face and their suggestions for improvement. A thematic content analysis was performed on the 49 responses. The analysis revealed four dominant themes representing the most frequently cited operational bottlenecks**.**

Table 4: Thematic Analysis of Challenges and Suggestions

Theme / Challenge	Frequency	% of Respondents	Representative Suggestions from Participants
Traffic Congestion & Inadequate Road Infrastructure	12	24.5%	*"Conduct transport and supply operations during late night hours"; "Coordinate with official authorities for traffic Support during large shipments."*

Theme / Challenge	Frequency	% of Respondents	Representative Suggestions from Participants
Lack of Adherence to Safety Instructions & Insufficient Training	11	22.4%	*"Implement periodic, mandatory training for all workers"; "Conduct regular equipment inspection and maintenance"; "Enforce the use of personal protective equipment."*
Poor Coordination & Inadequate Pre-Planning among Stakeholders	9	18.4%	*"Establish clear pre-planned routes for emergency and alternative supply lines"; "Enhance communication Between procurement and safety teams."*
Unstable Security Conditions & Weather Factors	4	8.2%	*"Coordinate with official government entities regarding security escorts"; "Account for volatile weather in project scheduling."*

As illustrated in Table 4, external logistical factors (traffic and security) account for nearly one-third of the cited challenges, while internal organizational factors (training and coordination) constitute the majority of the remaining critical issues. These qualitative insights provide context for understanding the specific barriers hindering safety integration and supply chain fluidity within the Tripoli Third Ring Road Project.

4.9 General Discussion of Findings

The primary objective of this study was to investigate the economic impact of occupational safety investments on supply chain performance within large-scale infrastructure projects, using the Third Ring Road Project in Tripoli, Libya, as a case study. The findings present a nuanced picture that both confirms and challenges conventional assumptions regarding safety management. Descriptively, respondents demonstrated a uniformly high level of agreement (overall mean = 4.15) regarding the positive role of safety investments across all dimensions—investment, accident reduction, economic performance, and supply chain performance. However, the subsequent inferential statistical analysis, complemented by thematic qualitative responses, reveals a more complex reality where financial expenditure alone does not guarantee operational success.

4.10 The Investment-Effectiveness Paradox (H1 and H2)

One of the most striking findings of this study is the weak and statistically non-significant correlation between **Occupational Safety Investment and Accident Reduction**

(r = 0.081, p = 0.58), as well as between **Occupational Safety Investment and Supply Chain Performance** (r = 0.148, p = 0.31). These results directly contradict the initial descriptive perceptions of the respondents, who strongly advocated for increased safety funding.

This paradox can be effectively unraveled through the thematic analysis of the open-ended responses. Participants consistently identified two critical internal obstacles: *"lack of adherence to safety instructions"* and *"insufficient periodic training"* (22.4% of responses). This suggests that while organizations may allocate substantial budgets to procure personal protective equipment (PPE) or conduct initial safety inductions, the actual *translation* of these resources into behavioral change and hazard mitigation remains severely deficient. As noted by Reason (1997), organizational accidents often result from latent failures in the safety culture rather than a mere lack of resources. In the context of the Third Ring Road Project, the investment appears to be misdirected or inadequately enforced, leading to a decoupling between financial input and tangible safety outcomes. This finding echoes the assertions of Fang et al. (2020), who emphasized that cognitive and behavioral factors among the workforce are often more critical than the mere availability of safety equipment.

4.11 The Economic Justification for Safety Investment (H3)

In contrast to the above, the study confirms a moderate yet statistically significant positive relationship between **Occupational Safety Investment and Economic Performance**

(r = 0.422, p = 0.003). This finding provides empirical validation for the strategic shift from viewing safety as a cost center to recognizing it as a value-adding investment. The moderate strength of this relationship (rather than a strong one) is logically consistent: economic benefits are realized not from the investment *per se*, but from the reduction in indirect costs such as operational downtime, compensation claims, equipment damage, and project delays.

As Hinze et al. (2013) and the International Labor Organization (2024) have argued, effective safety management reduces the total cost of risk over the project lifecycle. The data from this study supports this view, indicating that professionals on the ground acknowledge that financial resources allocated to safety ultimately protect the project's bottom line. However, the moderate coefficient also implies that economic performance is influenced by multiple other variables—including procurement efficiency, labor productivity, and external market conditions—making safety investment a necessary but not sufficient condition for superior financial outcomes.

The empirical findings of this study—specifically the moderate yet significant correlation between safety investment and economic performance (r = 0.422, p = 0.003)—are robustly supported by the economic benchmarks established in the recent literature. The recommended safety investment ratios of **2.5% to 3.8%** of project costs (Khan et al., 2025; Safety Science,

2025) provide a contextual framework for interpreting the perceived economic value articulated by the respondents. The fact that respondents demonstrated high descriptive agreement (M = 4.45) regarding the economic benefits of safety aligns with Eurofound's (n.d.) reported return on investment of €2.19 per €1 spent.

However, the paradoxical weakness of the direct correlation between safety investment and accident reduction (r = 0.081) becomes more comprehensible when viewed through the lens of the Libyan context. Elkaseh et al. (2025) documented the prevalence of 5,816 accidents, indicating a systemic safety deficit that financial expenditure alone cannot rectify. The qualitative findings from the present study—citing "lack of adherence" and "insufficient training"—are echoed by the Psychosocial Safety Climate research (Behavioral Sciences, 2025), which established that safety leadership and organizational climate are the critical mediators that translate financial resources into behavioral change. Without strong safety leadership, as emphasized by Omran et al. (n.d.) in their Libyan case studies, investment becomes decoupled from tangible safety performance.

4.12 The Pivotal Role of Accident Reduction in Supply Chain Resilience (H4)

Undoubtedly, the strongest and most significant relationship identified in this study is between **Accident Reduction and Supply Chain Performance** ($r = 0.792$, $p < 0.001$). This is the cornerstone finding of this research. It empirically demonstrates that minimizing workplace incidents is the most powerful driver of logistical stability and operational continuity within construction supply chains.

Construction projects are highly interdependent networks; a single accident at a critical node—such as a material loading zone or a heavy equipment transit route—can trigger cascading disruptions throughout the entire project ecosystem. These disruptions manifest as delayed material deliveries, inefficient resource allocation, contractual friction, and schedule overruns (Ivanov, 2021). The strong correlation here quantifies this linkage, affirming that uninterrupted workflow and enhanced stakeholder coordination are direct byproducts of a stable and accident-free site. Consequently, accident reduction acts as a critical enabler of supply chain resilience, supporting the theoretical underpinnings of modern supply chain viability frameworks.

4.13 The Disconnect Between Supply Chain Efficiency and Economic Gains (H5)

A particularly unexpected result was the non-significant and slightly negative correlation between **Supply Chain Performance and Economic Performance** ($r = -0.037$, $p = 0.80$). At first glance, this finding defies conventional project management logic, which posits that an efficient supply chain inherently reduces costs.

However, the qualitative data provides a robust contextual explanation for this anomaly. The most frequently cited challenge among participants was *"severe traffic congestion and poor road infrastructure"* (24.5% of responses), followed by *"unstable security conditions"* (8.2%). These are **exogenous factors**—external environmental conditions that are entirely beyond the control of the project management team. The Third Ring Road Project is situated in a heavily urbanized area of Tripoli, where logistical operations are perpetually hampered by public traffic, inadequate access routes, and security checkpoints.

Regardless of how efficiently the internal supply chain is managed—whether through precise scheduling or superior inventory management—these external disruptions impose fixed and unavoidable costs (e.g., extended transportation times, fuel wastage, and idle labor hours). Thus, the economic performance of the project is heavily distorted by the macro-environment, effectively diluting the potential cost savings that an optimized internal supply chain would otherwise generate. This finding underscores the critical importance of incorporating local infrastructure and security risk assessments into project feasibility and planning phases, a factor often overlooked in generic construction management literature.

4.14 Integrative Synthesis and Theoretical Contribution

By integrating the descriptive, correlational, and qualitative analyses, this study contributes a holistic framework for understanding safety economics in developing countries. The results suggest a causal pathway that diverges from simple linear assumptions:

- **Safety Investment alone** does not reduce accidents unless coupled with rigorous behavioral enforcement and training.
- **Accident Reduction** is the primary catalyst for enhancing Supply Chain Performance.
- **Supply Chain Performance**, however, does not automatically translate into Economic Performance when **powerful exogenous factors** (traffic, security) dominate the cost structure.

This pathway highlights that in fragile and complex environments like Libya, the return on safety investments is mediated by organizational culture and external logistics infrastructure. For policymakers and project owners, the implication is clear: strategic safety management must be redefined to include not only site-specific protective measures but also proactive coordination with public authorities to mitigate external logistical bottlenecks.

V.Conclusions

Assessing the Economic Impact of Safety Investments on Supply Chain Performance in Large

This study examined the economic impact of occupational safety investments on supply chain performance through a case study of the Third Ring Road Project in Tripoli, Libya. The findings reveal a nuanced reality that challenges oversimplified assumptions about safety management. Descriptively, professionals demonstrated a strong consensus (overall mean = 4.15) regarding

the perceived value of safety investments across operational, economic, and logistical dimensions.

However, the inferential statistical analysis, complemented by qualitative thematic insights, refines this understanding significantly. The study confirms that occupational safety is not a mere regulatory cost but a strategic investment capable of generating measurable economic returns ($r = 0.422$, $p = 0.003$). More critically, the research establishes that **accident reduction is the most powerful driver of supply chain resilience** ($r = 0.792$, $p < 0.001$), emphasizing that operational stability is the linchpin of logistical efficiency in construction projects.

Importantly, the findings expose a critical caveat: **financial expenditure alone does not guarantee accident reduction or supply chain improvements** (as evidenced by the non-significant correlations for H1 and H2). The effectiveness of safety spending is heavily mediated by organizational culture, workforce adherence, and the quality of training programs. Furthermore, the study highlights that **external environmental factors**—particularly severe traffic congestion, inadequate road infrastructure, and volatile security conditions—can override internal logistical efficiencies, creating a disconnect between supply chain performance and overall economic outcomes (as shown in H5).

By integrating descriptive, correlational, and qualitative evidence, this study contributes a holistic framework for understanding safety economics in fragile and complex contexts. For the Libyan construction sector, the path to sustainable project delivery lies not merely in increasing safety budgets, but in enforcing behavioral compliance, investing in continuous training, and proactively coordinating with public authorities to mitigate external logistical bottlenecks. Ultimately, occupational safety must be redefined as an integrated management strategy that bridges workplace protection, supply chain continuity, and macroeconomic resilience.

VI. PRACTICAL IMPLICATIONS, LIMITATIONS, AND FUTURE RESEARCH

Practical Implications

The findings of this study provide several practical implications for construction organizations, project owners, contractors, and policymakers.

First, occupational safety should be integrated into project planning from the earliest stages as a strategic investment rather than being treated as an additional operational cost. Early investment in safety planning reduces future financial losses associated with workplace accidents and project interruptions.

Second, construction organizations should allocate sufficient financial resources to comprehensive safety programs, including employee training, hazard identification, preventive inspections, emergency preparedness, and continuous safety monitoring. These investments contribute to improving workforce productivity while minimizing accident-related costs.

Third, project managers should strengthen the integration between occupational safety management and supply chain management. Effective coordination between safety teams, procurement departments, contractors, suppliers, and logistics providers improves workflow continuity, reduces operational disruptions, and enhances project resilience.

Finally, government agencies and policymakers should encourage the adoption of internationally recognized occupational health and safety management systems such as ISO 45001, while promoting stronger regulatory frameworks, continuous professional training, and organizational safety culture within the Libyan construction industry.

The practical recommendations derived from this study are further substantiated by contemporary empirical evidence. First, construction organizations are urged to adopt a **benchmarked investment strategy**, allocating between **2.5% and 3.8%** of total project costs to comprehensive safety programs (Khan et al., 2025; Safety Science, 2025). This allocation should prioritize not only

personal protective equipment but also continuous training, as investing approximately 2.5% of costs in training has been shown to enhance profitability by 4–7% (Mosaicapp, 2026).

Second, given the instrumental role of supply chains highlighted by the EU-OSHA (2024) LIFT-OSH Project, project managers must institutionalize safety requirements across all tiers of the supply chain. This includes integrating the critical success factors for supply chain resilience identified in recent ARCOM (2026) studies into procurement and subcontractor evaluation frameworks.

Third, for Libyan policymakers and industry leaders, the adaptation of international standards such as **ISO 45001** is essential, yet it must be localized to address the specific contextual challenges identified by Elkaseh et al. (2025). Crucially, interventions must focus on strengthening **safety leadership** and the **psychosocial safety climate**, as these factors are proven mediators of safety behavior in the Libyan workforce (Behavioral Sciences, 2025). Regulatory enforcement should be coupled with leadership development programs to bridge the gap between financial expenditure and effective hazard mitigation.

Limitations

Despite its valuable contributions, several limitations should be acknowledged.

First, the study was conducted using data collected from a single infrastructure project in Tripoli, Libya. Consequently, the findings may not be fully generalizable to all construction projects or other industrial sectors.

Second, the research relied primarily on respondents' perceptions obtained through questionnaire responses. Although these perceptions provide valuable practical insights, future

studies incorporating objective project performance indicators, accident records, and financial

data would provide stronger empirical evidence.

Third, while the study advanced beyond descriptive analysis to employ inferential statistical techniques (Pearson correlation and significance testing), the relatively modest sample size (n=49) may limit the generalizability of the inferential findings. Future studies with larger, multi-project samples would enable more robust multivariate analyses, such as Structural Equation Modeling, to explore causal pathways.

Future Research

Future research should expand the current investigation by examining occupational safety investments across multiple construction projects located in different geographical regions. Comparative studies involving public and private sector infrastructure projects may provide a broader understanding of how organizational context influences safety investment outcomes.

Future researchers are also encouraged to employ advanced statistical techniques such as Structural Equation Modeling (SEM), Multiple Regression Analysis, or Path Analysis to investigate the direct and indirect relationships among occupational safety investment, safety performance, supply chain resilience, project productivity, and financial performance.

Additionally, future studies may explore the role of emerging technologies—including Building Information Modeling (BIM), Artificial Intelligence (AI), Internet of Things (IoT), wearable safety devices, and digital monitoring systems—in enhancing occupational safety and improving construction supply chain resilience.

Finally, longitudinal studies examining project performance over multiple years would provide stronger evidence regarding the long-term economic benefits of occupational safety investments and support the development of more effective construction management strategies.

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