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SAFETY CLIMATE IN LARGE CONSTRUCTION ENTERPRISES

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Abstract

Recent studies on safety climate in large construction enterprises show a decrease in accident rates at work sites. Their severe accident rates are significantly lower in relation to their share in the construction industry. The research objective is assessing and exploring the various parameters affecting the safety climate in large construction enterprises. A safety climate model based on the Fishbone diagram was developed, implemented, and validated. The model divided the safety climate factors into four core categories: workers, equipment and technology, organizational environment, and work site environment. The data for the developed model was gathered using a field survey answered by 20 foremen at 20 different construction projects of large construction enterprises. The survey included 45 questions that established an indication of the four factor groups. It also documented the projects' accident ratio based on their severity, in addition to near-miss incidents. To validate the model, accident analysis was conducted on two sub-groups of projects containing five projects each, representing the characteristics of the model in its two poles, and between the two projects with the lowest and highest safety climate characteristics. The results show that there is a correlation between project size and its safety climate, in most cases, the larger the project, the better its safety climate. The core factors of safety climate in large construction enterprises are the organizational safety environment, physical environment management, equipment safety and operation, and workers' training and skill. The model can be implemented through preventive actions that focus on these core factor groups. The validation shows that the average accident ratio is lower in the sub-group with high safety climate. However, the average number of near-miss incidents was higher. The project with the highest safety climate had significantly lower accident ratio than the one with the lowest safety climate.

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Keywords: Equipment and technology, large construction enterprises, safety climate.

1. Introduction

The construction industry stands as a cornerstone of economic development in all modern societies. Its dynamic nature, constantly evolving processes, and multifaceted projects present a plethora of complexities and risks. These risks emanate from various factors such as workforce congestion, project intricacies, ever-changing work environments, and the imperative need for system synchronization. Consequently, the construction industry ranks among the most hazardous sectors, characterized by high rates of casualties compared to other industries. Large construction enterprises, concurrently engaged in multiple high-budget projects spanning residential, infrastructural, commercial, and industrial domains, confront unique engineering challenges. In response, these enterprises allocate significant resources toward developing methodologies and tools to foster a culture of safety while concurrently meeting stringent quality and efficiency benchmarks. Smaller projects have higher accident rates [1].

The recognition that fostering a safety-centric work environment yields both financial savings and risk mitigation has become internalized within large construction enterprises. The costs associated with accidents far outweigh investments in workplace safety. Hence, these companies proactively invest in safety measures and training programs prior to project execution. This stands in stark contrast to smaller enterprises, which typically deal with simpler projects, lower budgets, and fewer safety challenges, often opting to minimize costs to maximize project profitability [2].

Effective communication has a pivotal role in promoting safe work practices. Transparent, direct, and open communication channels that encourage participation, feedback, and educational initiatives to enhance safety outcomes [3]. Previous studies have highlighted the central role of safety communication in safety climates, and the current research emphasizes the importance of effective communication for safety outcomes.

There is a clear correlation between higher safety investment ratios and lower total accident cost ratios, indicating a convex relationship between these variables [4]. Construction companies typically allocate approximately 0.62% of a project's value to preventive safety measures, contributing to a total safety cost of around 4.93% of the project's scope [5]. However, recent field survey findings reveal that, on average, contractors invest only half of the optimal value in preventive safety activities. Notably, indirect costs associated with construction accidents far outweigh direct costs, underscoring the imperative for increased investment in safety measures [5]. Moreover, such investments not only enhance profitability but also safeguard the company's reputation by mitigating the impact of fatal accidents.

Shohet et al. [5] devised an empirical analytical model to optimize safety resource allocation within the construction industry, leveraging insights from a comprehensive field study. This model aimed to delineate the requisite minimum resources essential for preventive safety measures. The study examined accident costs to discern the interplay between direct and indirect costs prevalent in Israel's construction sector. Notably, the study underscored the prevalence of indirect costs outweighing direct costs, with insurance companies typically not covering indirect costs. A study conducted by Hinze and Appelgate [6] further substantiated this trend, analyzing 573 injury reports from 185 construction projects across 34 countries. Their findings revealed that indirect costs constituted 69.4% of the total cost, dwarfing the 30.6% attributed to direct costs.

In certain sectors such as the chemical industry, aviation, and marine drilling, the documentation of near-miss incidents is a common practice. These industries have recognized a significant reduction in safety incidents through reporting programs. Conversely, the construction industry lags in embracing such reporting practices, indicating a need for greater integration within the sector. Marks et al. [7] devised a model for managing near-miss incident programs, serving as a fundamental framework for safety managers in documenting, analyzing, and effectively utilizing safety data. Near-miss data could significantly enhance safety outcomes [8].

Kima et al. [8] examined safety climate factors in small and medium construction enterprises (SMEs). Through a comprehensive survey with construction foremen. Focusing on equipment, management, environment, and Workers, the study revealed notable gaps in safety management practices despite high ratings for equipment safety. Moreover, significant variability in management scores across construction sites highlights inconsistencies in implementation.

2. Method

The data gathering process involved a field survey administered to 20 foremen overseeing various construction projects within large construction enterprises. This survey comprised 45 questions that were based on a Likert scale from 1 (Not performed/Disagree) to 5 (Performed/Agree). Providing insights into four key construction safety factor groups. Additionally, the survey documented accident counts across different severity levels and recorded near-miss incidents. The survey was conducted through open interviews with the foremen at their respective construction sites. Table 1 presents details regarding the type and cost of the projects.

Based on the survey findings, a safety climate model for large construction enterprises was developed, utilizing the Fishbone diagram. This model categorizes safety climate factors into four groups: workers, equipment and technology, organizational environment, and work site environment, serving as indicators of a project's safety climate. To validate the model, two sub-groups of projects representing opposite safety climate poles were compared. Each sub-group comprised five projects, and a T-test with a significance level of 5% demonstrated the differences in statistical significance between them. Inferential statistics were then employed to analyze the differences in accident ratios and near-miss incidents between the sub-groups. Furthermore, incident analysis was conducted on two projects with distinct safety climate characteristics, one exemplifying the best safety climate and the other the worst, both falling under the same project classification. Finally, an examination of the model results, sub-groups, and the correlation between project scope and safety climate was undertaken.

Table 1. The research data base projects type and cost.

Project symbol	Project type	Project scope (10^6 NIS)
A	Offices + parking + shopping plaza	480
B	Infrastructures	1,000
C	Hotel + Residential	1,000
D	Commercial spaces + office buildings + parking lot	1,500
E	Office building + parking lot	330
F	Transportation infrastructure	390
G	Transportation infrastructure	320
H	Transportation infrastructure	230
I	Transportation infrastructure	237
J	Transportation infrastructure	207
K	Transportation infrastructure	219
L	Residential	142
M	Transportation infrastructure	145
N	Transportation infrastructure	140
O	Offices + hotel + parking lot	150
P	Infrastructures	80
Q	Residential	500
R	Residential	150
S	Residential	500
T	Residential	190

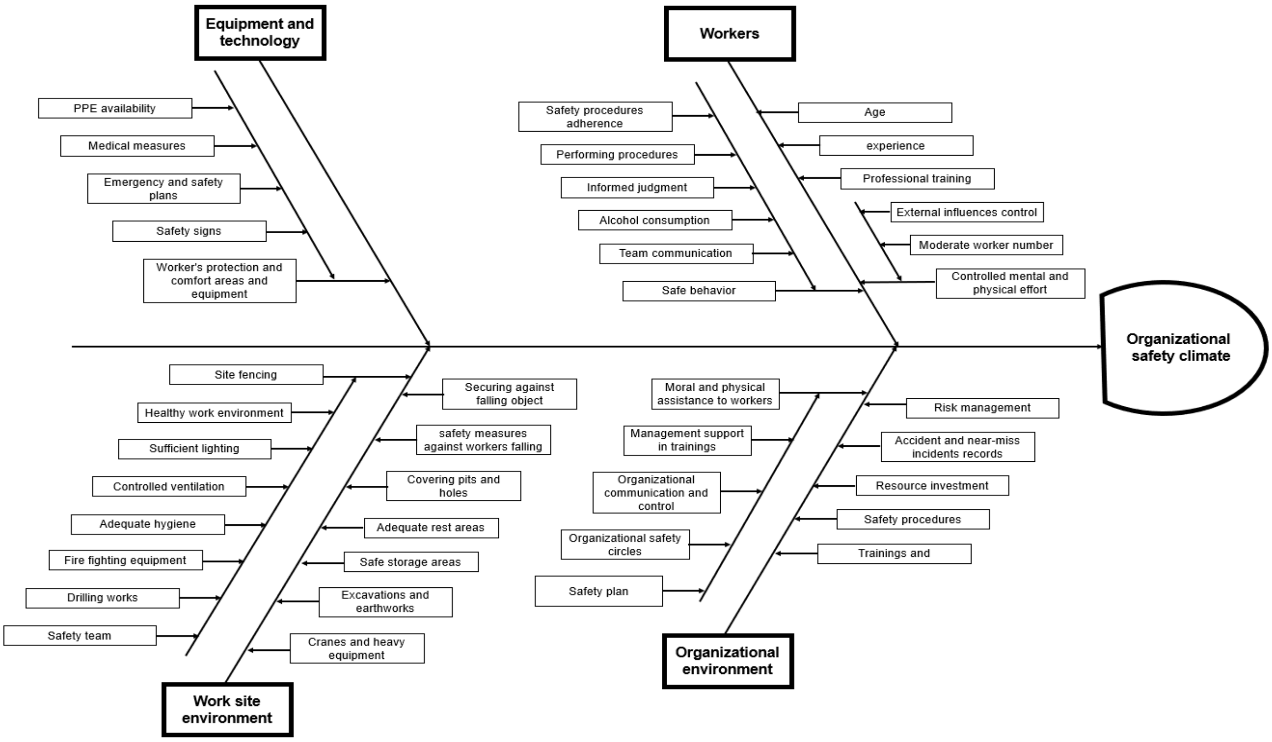
Fishbone diagram model components

The developed Fishbone diagram is presented Fig. 1. The following aspects were used to build it:

1. **Safety measures:** Construction sites require robust safety measures to protect workers. This includes accessible medical facilities, well-defined emergency plans, and prominent safety signs to guide workers. These measures are critical for creating a safe working environment [9].
2. **Supportive environment:** Management support and colleague cooperation are pivotal for fostering a supportive environment at construction sites. Providing comprehensive safety training enhances workers' understanding of safety protocols and promotes a culture of responsibility. When workers feel supported and valued, they are more likely to prioritize safety [10].
3. **Safe work environment:** Ensuring a safe work environment involves factors such as adequate lighting, proper ventilation to mitigate airborne hazards, and hygiene protocols. Additionally, protection against specific hazards like electrocution and infectious diseases like COVID-19 is essential for worker well-being. These measures contribute to sustained productivity while meeting stringent safety standards [10].
4. **Fall prevention:** Falling accidents, especially from heights, pose significant risks at construction sites [11,12]. It's crucial to secure the site from falling objects and implement safety barriers to prevent workers from falling.
5. **Accident prevention:** Accident prevention strategies involve proactive steps such as gathering feedback from workers, maintaining records of past accidents, and encouraging the reporting of

near-miss incidents. Investing in resources for safety and consistently monitoring safety practices are integral to accident prevention efforts.

6. **Safety facilities:** Providing personal protective equipment (PPE), designated rest areas, and smoking zones are fundamental for ensuring worker safety. Properly designated storage areas also contribute to minimizing workplace hazards and promoting organization. Avoiding PPE use is a common hazard [12].
7. **Worker well-being:** Addressing factors such as fatigue and external stressors through supportive measures and proper workload management can significantly enhance worker safety. In addition to external influences on workers, such as a production-oriented culture without emphasis on safety in the workplace [13].
8. **Fire and heat risks:** Construction sites are prone to fire and heat hazards. Implementing fire suppression systems and designating specific smoking areas for workers are critical preventive measures. These precautions help mitigate risks and ensure a safer working environment.
9. **Knowledge and skills:** Equipping workers with adequate safety knowledge and skills is imperative for accident prevention. Proper safety training during onboarding ensures that workers understand safety protocols and can perform their duties safely.
10. **Safety behavior:** Encouraging adherence to safety protocols and regulations is vital for maintaining workplace safety. This involves procedures compliance for various tasks, such as working at heights, handling electricity, and effective communication. Safety behavior is a cornerstone of overall safety performance and directly impacts other safety aspects [5].
11. **Control and Surveillance:** Regular inspections and supervision are essential for maintaining safety standards at construction sites. Ensuring the proper functioning of equipment and technology through vigilant monitoring helps prevent accidents resulting from equipment failures. There is a direct correlation between site supervision, site safety, and the project's regulatory compliance [13].
12. **Risk Assessment:** Continuous risk assessment and hazard identification are necessary to address potential risks and hazards throughout the construction project. As construction sites are dynamic environments, ongoing risk assessments are crucial for adapting to changing conditions and minimizing potential hazards.
13. **Worker Characteristics:** The assessment of demographic characteristics, particularly age and experience, is pivotal in understanding workers' perception of safety climate. Research conducted by Marks et al. [7] emphasizes the importance of addressing psychosocial pressures in the work



environment, such as high temperatures and overcrowding, especially for younger workers who may require additional organizational support.

Fig. 1. Safety climate in large construction enterprises Fishbone model.

3. Results

3.1. Safety climate model

The results of the survey are presented in Table 2-Table 5 and **Hiba! A hivatkozási forrás nem található.** categorized into four distinct groups: workers, equipment and technology, organizational environment, and work site environment. The average age of the surveyed foremen stands at 40.3 years, with a standard deviation of 18.8 years. Below are the key findings within each group.

Work site environment (A)

The findings related to the work site environment (Group A) are presented in Table 2 . Across the spectrum of questions encompassing this domain (questions A1-22), the results exhibit a predominantly high rating, particularly notable in aspects such as conducting risk surveys, foreman and safety supervisor appointments, presence of safety signage, provision of personal protective equipment and first aid kits, as well as availability of trained personnel for administering first aid (questions A1-3, A5, A9,10), all of which received commendable scores of 4.80 or higher.

However, certain areas warrant attention due to their comparatively lower ratings. Site hygiene, for instance, received a less impressive average score of 3.45 (A14), while the presence of designated smoking areas received a score of 3.7 (A21). Notably, the lowest score was attributed to the presence of an appointed Corona officer, scoring 2.95 (A4).

It is noteworthy that apart from the presence of the appointed Corona officer and designated smoking areas (A4, A21), the standard deviation remains relatively low. This suggests minimal variance across different construction sites, regardless of their safety climate status. The substantial investment in large construction enterprises as opposed to smaller counterparts likely contributes to these results.

Organizational environment (B)

The findings pertaining to the organizational environment (Group B) are summarized in

Table 3. The evaluation encompassing questions in this category (questions B1-17) reveals noteworthy insights. Safety-related practices such as holding safety trainings for employees on-site and implementing a safety plan for project management received the highest rating of 5.0, with minimal standard deviation, indicative of their consistent implementation across all sites. However, aspects pertaining to the comprehensive execution of safety procedures by all employees and the full adherence to safety protocols on-site (B7,8) received comparatively lower scores of 3.9 and 3.8, respectively. Nevertheless, supervision levels (B9) were rated relatively high at 4.30, reflecting consistent oversight across sites.

Communication levels (B4) were generally favorable, scoring 4.45, indicative of effective communication practices promoting safety throughout the project. Conversely, exposure of foremen to historical accident records (B10) received a lower score of 3.25, showcasing significant variation across sites. Encouraging reporting of near-miss incidents (B16) received an average score of 3.75, indicating a room for improvement in fostering a culture of reporting incidents for proactive risk mitigation. Factors contributing to employee burden (B11) received a notably low score of 2.40, highlighting considerable variability between sites and differing managerial perspectives. Similarly, factors influencing unsafe work behavior (B12) attained the lowest score of 1.95, suggesting a prevalent emphasis on safety over productivity across large construction enterprises. Conducting surveys and feedback sessions among employees regarding safety issues and risk re-assessment at each project stage (B14) received a moderate score of 3.70, indicating scope for enhancement in these areas of management practice.

Equipment and technology (C)

The findings pertaining to equipment and technology (Group C) are summarized in

Table 4. Safety protocols concerning the operation of cranes and other machinery (C1) and the proper activation of equipment (C2) garnered notably high scores of 4.7 and 4.75, respectively. However, the assessment of potential risks by workers (C3) received a relatively lower score of 3.85. Despite this variation, all questions exhibited consistent responses across different sites, indicating a uniform adherence to safety measures in this domain.

The human factor - workers (D)

The findings pertaining to human factor (Group D) are summarized in Table 5. The site managers' feedback on the collaboration among employees regarding safety and security indicated consistently positive outcomes across different sites. Assessing the adequacy of workers' qualifications for their assigned tasks (D1) yielded a score of 4.20, showing minimal variation between sites. Notably, there were no complaints from foremen regarding a shortage of competent personnel. However, compliance with health regulations while adhering to safety protocols (D3) received a lower rating of 3.75. This suggests that despite lectures and training sessions, employees may not have fully internalized the information provided. Inquiring about alcohol consumption before work (D2) elicited unanimous responses indicating that no employee engages in such behavior. This unanimous denial is attributed to the demanding nature of the tasks, which require high levels of concentration. Supervisors remain vigilant to detect any signs of alcohol consumption, promptly denying access to the work site to ensure the safety of all employees.

Table 2. Site safety environment parameters.

Question symbol	Question	Mean	S.D.
A1	Are updated risk surveys conducted on the site (once a week) - safety at work and safety in traffic?	4.90	0.30
A2	Foreman appointment and his presence on the site	5.00	0.00
A3	Safety officer appointment and his presence on the site	5.00	0.00
A4	Is there an appointed Corona officer on the site?	2.05	2.38
A5	Are there safety and warning signs on the site?	4.80	0.40
A6	Are there available methods of communication in case of emergency situations/accidents by the information system for crime victims and officials on the site?	4.65	0.58
A7	Is the work environment sufficiently ventilated?	4.45	0.67
A8	Completeness and integrity of the site fencing including appropriate signage?	4.65	0.48
A9	Are PPEs available and accessible on site for each task in the project?	4.85	0.36
A10	Is there a first aid kits, including a person trained to provide medical care on site?	4.90	0.30

A11	What is the level of fire protection on the site?	4.70	0.46
A12	Is the lighting in the work environment sufficient?	4.75	0.43
A13	Is the work environment on site sufficiently ventilated?	4.70	0.40
A14	Is the level of hygiene on the site acceptable?	3.45	0.82
A15	Existence of safety measures preventing objects falling from a height?	4.75	0.43
A16	What is the level of safety on the site against workers falling from a height?	4.75	0.43
A17	Safety when performing drilling work?	4.65	0.57
A18	Existence of protection against electrocution on site?	4.75	0.44
A19	Are there rest areas on the site (for drinking/eating/resting)?	4.60	0.55
A20	Are designated accessible storage areas defined on the site?	4.70	0.43
A21	Are there designated smoking areas on the site?	3.70	1.23
A22	Is there fencing, signage and covering pits and openings on site?	4.65	0.48

Table 3.Safety management parameters (organizational environment).

Question symbol	Question	Mean	S.D.
B1	Is there a project safety management plan?	5.00	0.00
B2	Are safety trainings for all employees and personal present held on the site?	5.00	0.00
B3	Rate the content and presentation of the safety trainings information on the site?	4.25	0.62
B4	How would you rate the level of communication on the site?	4.45	0.48
B5	Are the safety procedures clear to all employees?	4.20	0.63
B6	Did the employees went through sufficient training that prepared them to work safely in all areas of work relevant to them?	4.30	0.66
B7	To what extent are the safety procedures are implemented by all employees on the site?	3.90	0.50
B8	Are the safety procedures fully implemented on the site?	3.80	0.40
B9	Is there adequate safety supervision on the site?	4.30	0.64
B10	Are you exposed to historical records of accidents in the company?	3.25	1.33
B11	Does the degree of load (mental load and/or physical load - work progress without considering safety) affect the safety performance of the employees?	2.40	1.02
B12	Are there external factors (management, colleagues) that influence you to work in an unsafe manner?	1.95	0.77
B13	Does the management promote the issue of safety on the site (trainings/instructing/safety checks/raising morale and motivation/giving incentives)?	4.65	0.57
B14	Does the management conduct surveys/feedback among the employees regarding safety?	3.70	1.07
B15	Do the management carry out safety surveys, safety procedures and risk reassessments at each stage of the project?	4.65	0.57
B16	Does the management encourage reporting near miss incidents?	3.75	1.06
B17	Does the management invest resources to create a safety climate?	4.40	0.67

Table 4. Safety equipment and technology parameters.

Question symbol	Question	Mean	S.D.
C1	Safety when working with cranes, allowed lifting devices, allowed and prohibited hoists?	4.70	0.46
C2	Equipment operation on the site, having all the documents valid for the purpose of activating the equipment?	4.75	0.43
C3	Do the workers have a consideration for risk assessment in various situations such as: working at height, lifting loads, operating mechanical and electrical equipment, scaffolding, etc.?	3.85	0.36

Table 5. Workers' safety parameters.

Question symbol	Question	Mean	S.D.
D1	Do the workers have sufficient qualification to perform their job?	4.20	0.48
D2	Do the employees on the site abstain from consuming alcohol before or during work?	5.00	0.00
D3	Do the employees adhere to the health rules while adhering to safety performance methods at work?	3.75	0.44

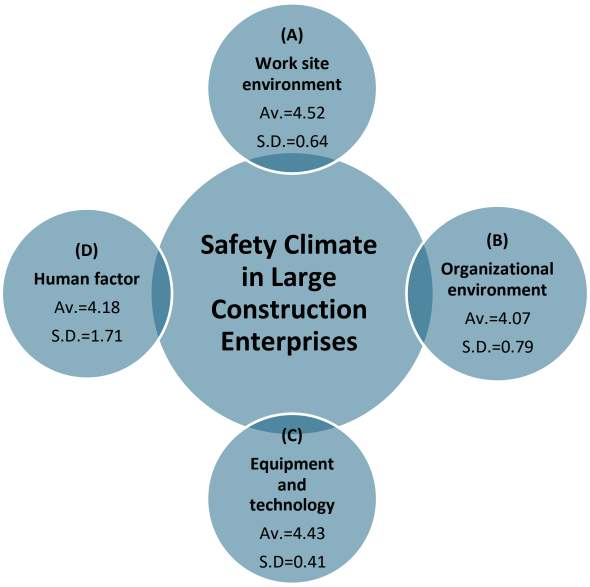


Fig. 2. Safety climate in large construction enterprises model.

Table 6. Accidents count by severity and near-miss incidents count.

Project symbol	Mild accidents	Medium Accidents	Severe accidents	Fatal accidents	Near-miss incidents
A	4	1	0	0	2
B	2	2	1	1	5
C	1	1	0	0	2
D	2	1	0	0	3
E	5	1	0	0	5
F	1	1	1	0	3
G	2	0	0	0	1
H	4	3	1	0	4
I	1	1	0	0	1
J	2	2	0	0	3
K	2	0	0	0	1
L	4	3	2	0	2
M	3	3	0	0	3
N	4	2	0	0	4
O	3	0	0	0	0
P	4	2	0	0	4
Q	4	1	0	0	3
R	4	3	0	0	2
S	2	1	0	0	2
T	1	0	0	0	2

3.2. Safety Climate Model Validation

Inferential statistics were employed to validate the results of the developed model. Two sub-groups of projects were utilized to represent the model's spectrum, ranging from favorable to unfavorable safety climates. Sub-group A comprised five projects with an average model score exceeding 4.3, resulting in a group average of 4.46 (Table 7). Meanwhile, Sub-group B consisted of five projects with average model variables below 4.0, yielding an average score of 3.82. Both groups exhibited relatively small standard deviations (0.08 and 0.17, respectively).

A T-test, conducted at a significance level of 5%, rejected the Null hypothesis asserting equality of means between the two groups (t=7.44). It was observed that sub-group B had a higher average accident count across all severity levels compared to sub-group A. This validates the research hypothesis indicating that larger construction enterprises typically boast a safer working climate.

Near-miss incidents serve as valuable indicators of the learning curve and the effectiveness of preventive measures, as they allow for intervention before actual accidents occur. Consequently, these incidents contribute to reducing the overall accident rate. Notably, sub-group A demonstrated a higher level of reporting on near-miss incidents. Such incidents encapsulate key elements of safety climate in large construction enterprises, including control and supervision, management support, and consideration of human factors and site environment.

Table 7. Comparison between two subgroups representing good and poor safety climate projects.

Subgroup A Good safety climate		**Subgroup A Poor safety climate**	
Project symbol	Mean>4.3	Project symbol	Mean<4.0
D	4.51	R	3.93
I	4.53	O	3.88
F	4.51	L	3.48
C	4.44	H	3.86
S	4.31	E	3.93
Mean and S.D. of all five projects			
Mean	4.46		3.82
S.D.	0.08		0.17
Mean accident number by severity			
Mild	1.40		4.0
Medium	1.00		2.0
Severe	0.30		0.60
Fatal	0		0
Near-miss	3.20		2.6
Mean and S,D of all accident severities			
Mean	1.18		1.84
S.D.	1.02		1.30

3.3. Case study

Two projects from the infrastructure sector were chosen to validate the research findings. These chosen projects epitomize the spectrum of risk within the sample set. Project G, showcasing the most favorable outcomes in the survey, stands in contrast to Project H, which yielded the lowest results. Notably, Project G boasts a larger budget, intricate complexity, and broader scope, contributing to its superior performance with fewer accidents across all severity levels.

Project G with the best safety performance results in the field survey, ranked high in almost all parameters, except for the questions related to the effect of the degree of pressure on the workers safety performance, and the effect of external factors on the workers, these parameters received a low score of 2.0, their meaning is good since there is no effect on the worker, a low rating compared to the other projects is observed. Apart from these factors, the rest received a high rating of 4 and 5.

A comparative analysis of the two projects vividly illustrates the stark contrast between a safety-centric investment approach and a notably lesser emphasis on safety measures. These disparities are starkly reflected in the frequency and severity of reported accidents. This comparative evaluation underscores the pivotal role of core factors outlined in the safety climate model for large construction enterprises, offering valuable insights into predicting project safety performance. Noteworthy is the discrepancy in near-miss incident frequencies, with Project G reporting notably fewer incidents compared to Project H, indicating a proactive safety culture and heightened risk awareness.

Table 8. Case study projects comparative parameters.

Parameter	Project G	Project H
Average survey score	4.55	3.86
Project scope (million NIS)	300	230
Mild accidents	2	4
Medium accidents	0	3
Serious accidents	0	1
Fatal accidents	0	0
Near miss incidents	1	4
Mean accident count	0.6	2.8

4. Conclusions

Recent research on safety climate in large construction companies has revealed a notable decrease in workplace accident rates. This study explored the multifaceted factors influencing safety climate within these enterprises. A safety climate model, structured on the Fishbone diagram, was formulated, categorizing safety climate factors into four main groups: workers, equipment and technology, organizational environment, and work site environment. Data for this model was gathered through a field survey completed by 20 foremen across 20 distinct construction projects within large construction enterprises, addressing 45 questions reflecting the four factor groups. The survey also documented accident counts and near-miss incidents for each project. To validate the model, accident analyses were conducted on two sub-groups of projects, each comprising five projects, representing contrasting safety climate characteristics. The findings revealed a positive correlation between project size and safety climate, generally indicating that larger projects exhibit better safety climates. Key factors influencing safety climate in large construction enterprises encompass organizational safety environment, physical environment management, equipment safety and operation, and workers' training and skill. Implementing the model involves proactive measures targeting these core factors. The validation demonstrated that while the average accident count was lower in the sub-group with a high safety climate, the number of near-miss incidents was also elevated, suggesting a heightened reporting level of near-miss incidents in projects with safer climates. Additionally, the project with the highest safety climate exhibited significantly lower accident counts compared to the lowest safety climate project.

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