清華大學土木水利学院
SCHOOL OF CIVIL ENGINEERING
TSINGHUA UNIVERSITY

建造業安全周2026
CONSTRUCTION SAFETY WEEK

人工智慧賦能施工安全
Enhancing Construction Safety with AI

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Outline

1. Safety Challenges and LCB approach

2. Cognitive Failure and AI Driven Safety

3. The Value of Generative AI for CSKM

4. Applications and Conclusions

1. Safety Challenges and LCB approach

Construction accidents happen everywhere in the world, posing a serious threat to workers' safety and health. In China, nearly 3,000 construction workers die each year.

Fire

On November 26, 2025, a five-alarm fire broke out at a residential estate in Tai Po, Hong Kong, killing 168 people.

Lifting Injury

On September 1, 2025, a tower crane collapsed at the construction site of the Zhenlizhu Project in Chengdu, causing 5 deaths.

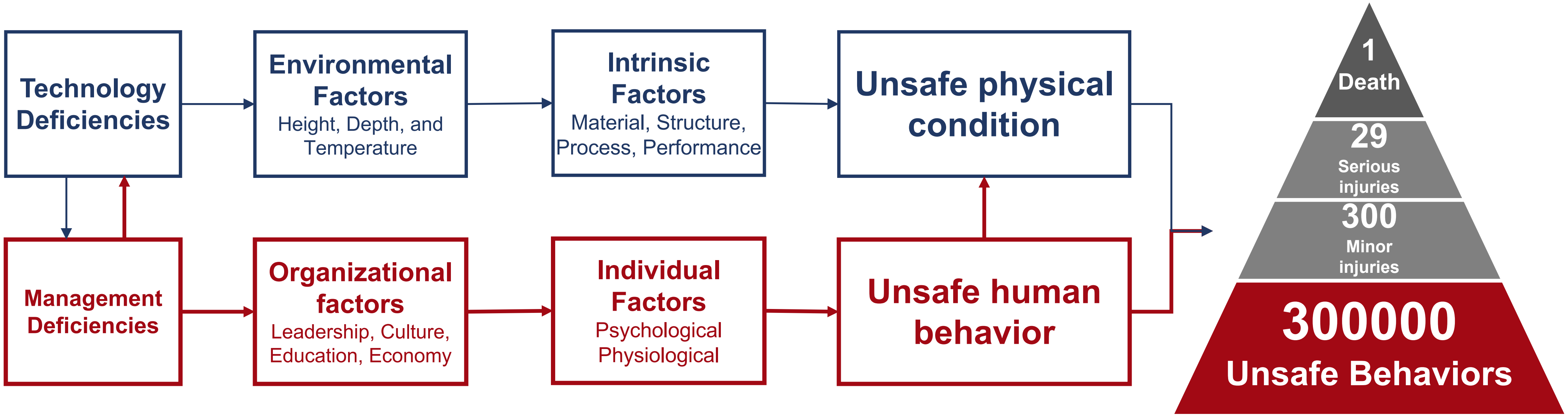
Fall from Height

On July 17, 2025, a fall accident during climbing formwork jacking on the Fuzhou Airport Second Expressway Project killed 5 people.

Structural Collapse

On March 28, 2025, a 30-story building under construction in Bangkok collapsed during an earthquake, killing at least 44 people.

Accidents are the result of the combined effect of unsafe physical conditions and unsafe human behavior.



Unsafe physical conditions have been improved significantly,
but unsafe behavior remains a major challenge everywhere in the world

1. Safety Challenges and LCB approach

Unsafe behavior exists in the causation chain of around 80% of accidents.

Insufficient safety training, lack of safe operating knowledge
14%

Violation of operating procedures or labor discipline
18%

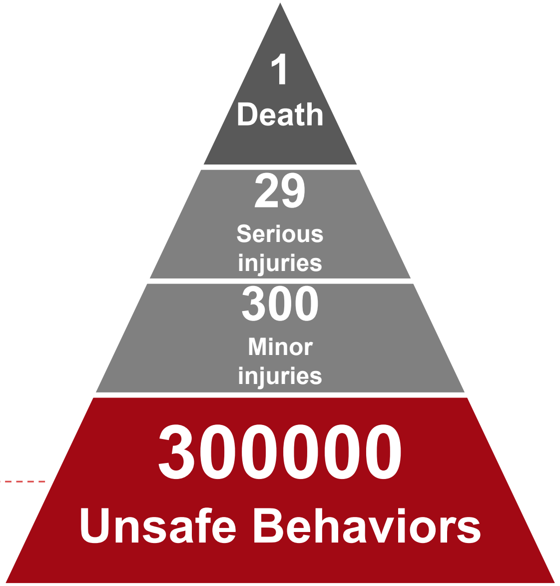
Missing or defective safety facilities
12%

Missing or defective PPE
16%

Unhealthy workplace environment
10%

Lack of inspection or misdirecting of on-site work
9%

Accident Causation Statistics



Accident Triangle

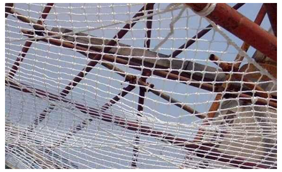
Examples of Unsafe Behaviors

Safety training

Superficial

PPE

Hard hat
Safety harness
Safety net



Not properly used

Safety rules

Non-compliance

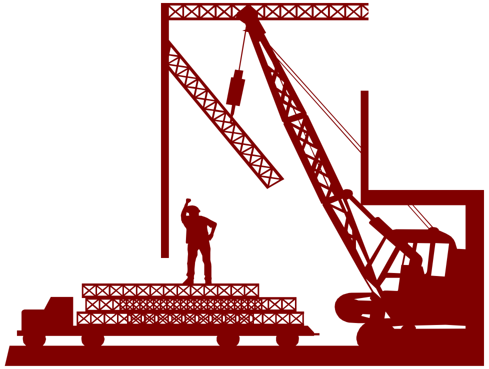
Safety investment

Insufficient

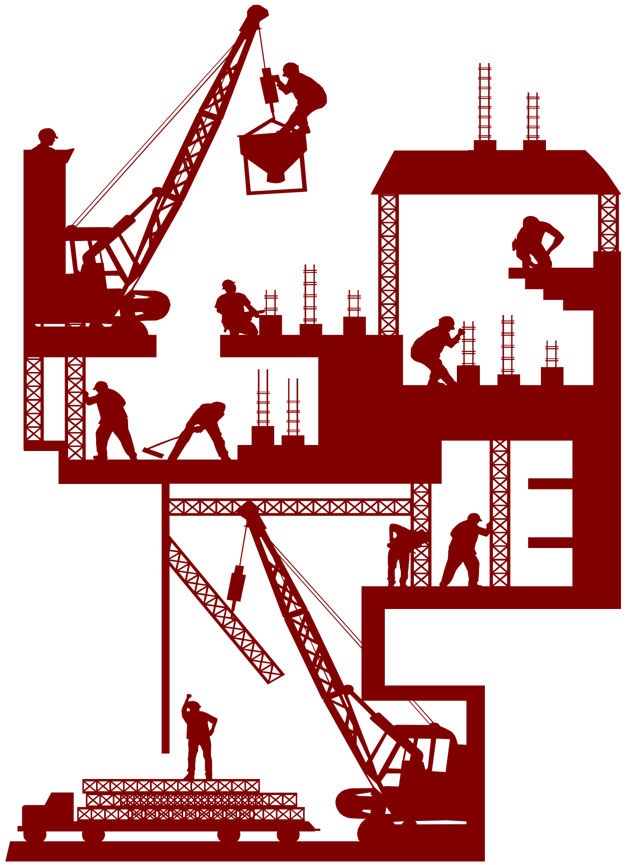
Unsafe Behaviours

Since 2000, research has focused on the unsafe behavior of construction workers, which is regarded as the primary direct cause of accidents on construction sites.

Workers' Unsafe Behavior



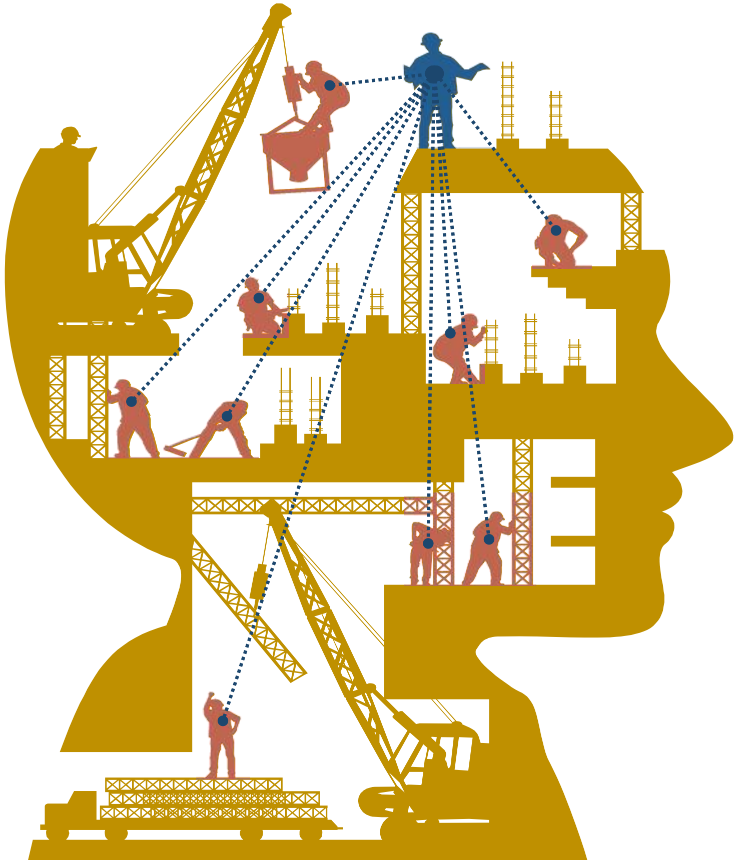
Later on, research was extended to organizational unsafe behaviors, which have a direct and significant impact on workers' unsafe behaviors.



Workers' Unsafe Behavior

Organizations' Unsafe Behavior

The follow-up research then focused on safety culture and safety leadership, since we strongly believe in their unique influence on safety behaviors.



Workers' Unsafe Behavior

Organizations' Unsafe Behavior

Safety Culture

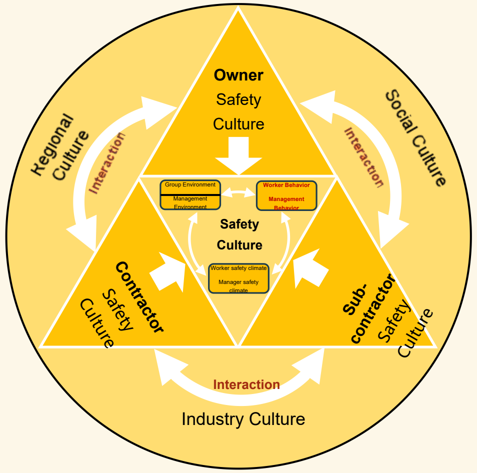
Safety Leadership

Transformational Safety Leadership

Role modeling, insparational motivation, caring and respect

1. Safety Challenges and LCB approach

A safety culture interaction model, to mirror the unique attributes of the construction industry, has been developed to clarify the interaction mechanism of major stakeholders' safety culture in construction sites.

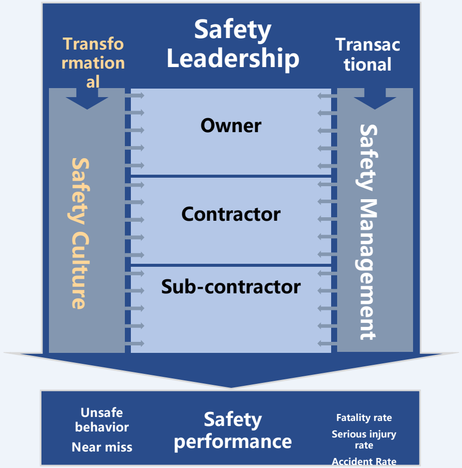


Safety Culture Dimensions

- Safety Supervision
- Safety Training
- Safety Engagement
- Safety Communication
- Safety Management System
- Safety Commitment

Fang, D., Wu, H., 2013. Development of a Safety Culture Interaction (SCI) model for construction projects. Safety Science 57, 138–149.

A safety leadership model for the construction industry was also developed to reveal the role of its transformational dimensions in influencing the constructing safety culture across organizations.



Safety leadership dimensions

- Transfor-mational
  - Role Modeling
  - Vision Motivation
  - Caring and respect
- Transac-tional
  - Performance control

Wu, C., Wang, F., Zou, P.X.W., Fang, D., 2016. How safety leadership works among owners, contractors and subcontractors in construction projects. International Journal of Project Management 34, 789–805.

1. Safety Challenges and LCB approach

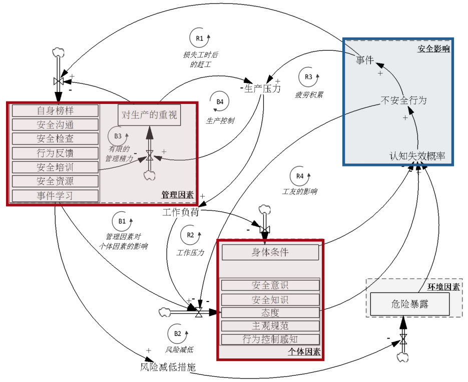
The relationships and mechanisms among leadership, culture, cognition, and behavior were revealed from both micro and macro perspectives.

Micro Level

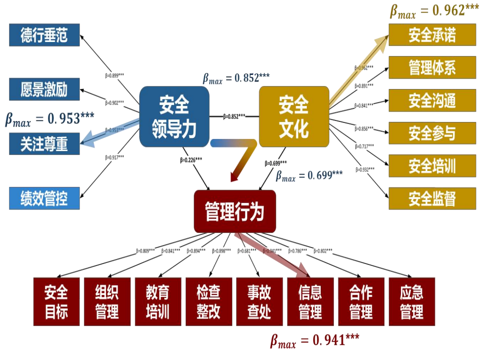
$$\boldsymbol{p_i} = p_i^* - \sum_k \phi_k \cdot \boldsymbol{x_k}$$

$$\boldsymbol{x_C} = \sum_i \sum_j \frac{c_{ij}}{n_i} /6$$

$$\boldsymbol{x_L} = \sum_i \sum_j \frac{l_{ij}}{n_i} /4$$



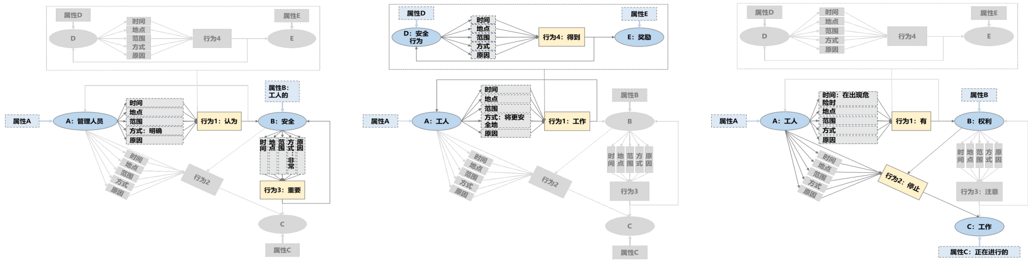
Macro Level



$$P(C_j|L_i) = \frac{\sum(L_i \cap C_j)}{\sum L_i}$$

$$\frac{P(C_j|L_i)}{P(C_j)} = \frac{\sum(L_i \cap C_j)}{\sum L_i} \times \frac{N}{\sum C_j}$$

Action Principles



Management Measure Design Methods

Type	Measures	Cognitive Issues Addressed
Off-site	Fixed Safety and Health Agenda	Perception, Understanding
On-site	Leadership Site Visits	Understanding, Thinking, Decision-making
On-site	Safety and Health Surprise Inspections	Understanding, Thinking

Jiang, Z., Fang, D., Zhang, M., 2015. Understanding the Causation of Construction Workers' Unsafe Behaviors Based on System Dynamics Modeling. J. Manage. Eng. 31.

ASCE JME Decade Award, 2025

1. Safety Challenges and LCB approach

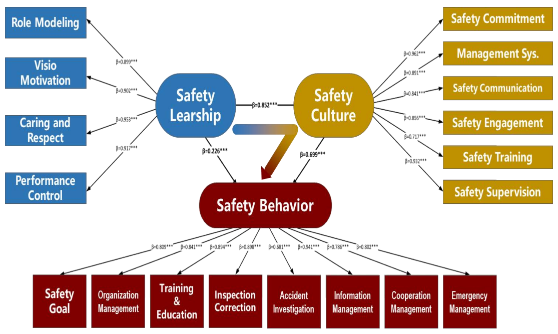
LCB approach was proposed as a new angle to understand and tackle with site safety.

Empirical and quantitative analysis

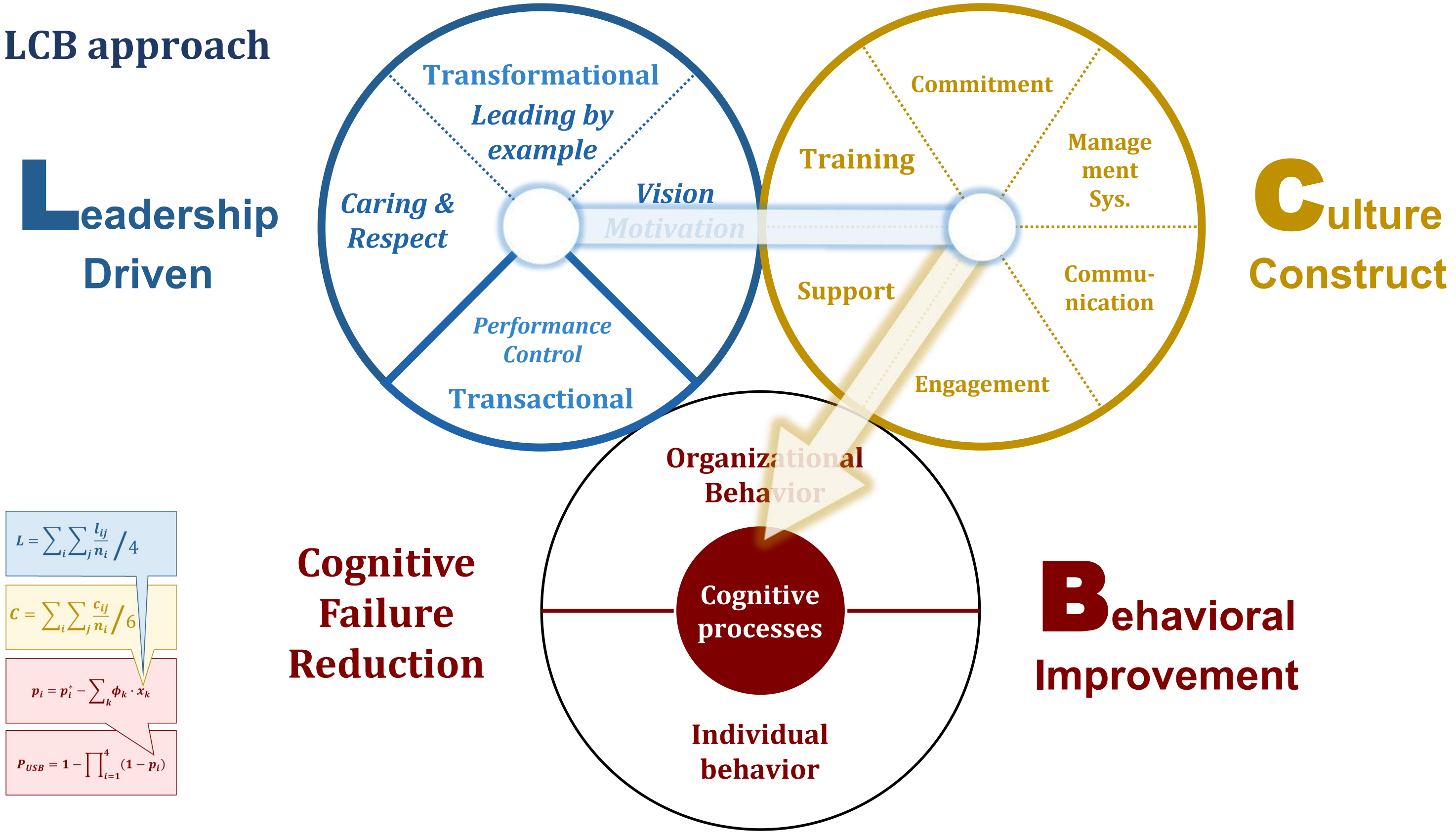
Samples

Covering provinces and cities in mainland China, Hong Kong, as well as Singapore, Malaysia, the United States and other countries and regions

- Face-to-face interviews 7,840+ people
- Questionnaire survey 30,000+ person-times
- Image collection 130,000+ copies



LCB approach



Fang D, Huang Y, Guo H, Lim H. LCB approach for construction safety. Safety Science. 2020; 128: 104761

1. Safety Challenges and LCB approach

LCB approach helped enterprises innovate their safety management practices.


Annual Safety Action Plan


Multi-Tier Safety Inspection System


Integrated Site Safety Oversight


Standardized Inspection Method


Closed-Loop Hazard Rectification


Safety Week Engagement Activities


Provincial Safety Inspection Campaign


Hazard Identification and Control


Integrated Safety Alerts


High-Risk Work Safety Inspections


Continuous Safety Education


Worker-Focused Safety Training


Hard-Hat Safety Culture


Safety Production Month


Safety Month Launch and Campaigns

Outline

1. Safety Challenges and LCB approach

2. Cognitive Failure and AI Driven Safety

3. The Value of Generative AI for CSKM

4. Applications and Conclusions

2. Cognitive Failure and AI Driven Safety

It is obvious that all of the LCB related factors are inextricably linked to human cognition, which further lead our research to a deeper and more fundamental level — cognition process.

Workers' Unsafe Behavior

Organizations' Unsafe Behavior

Safety Culture

Safety Leadership

Transformational Safety Leadership

Role modeling, vision motivation, caring and respect

2. Cognitive Failure and AI Driven Safety

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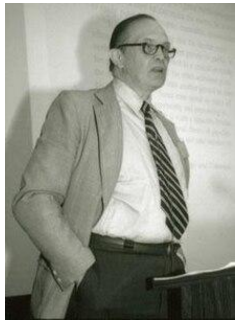
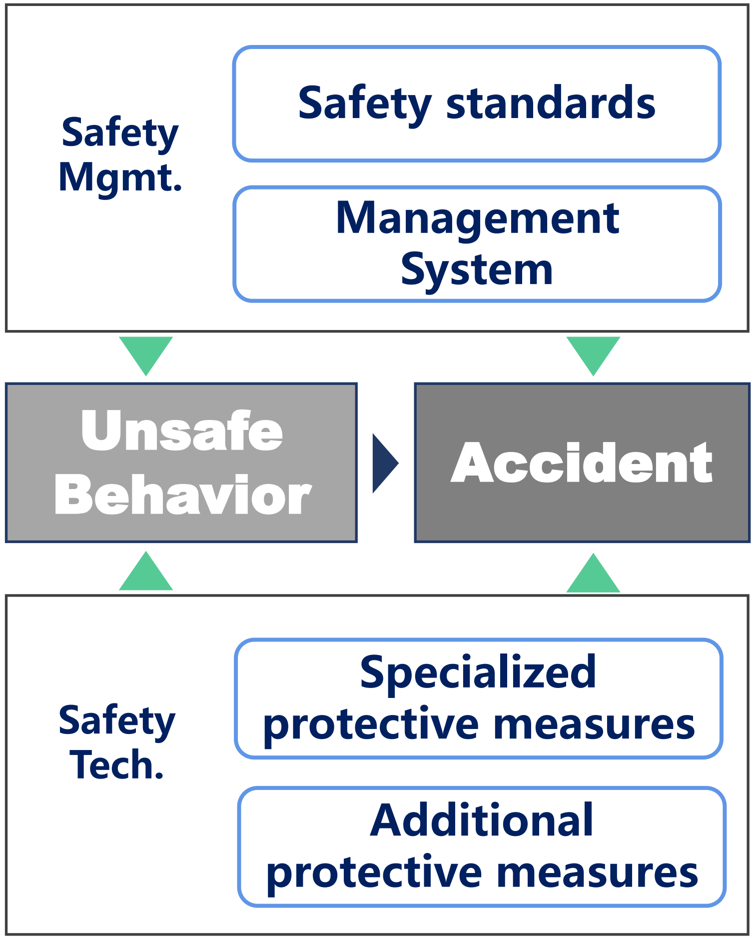
4 stages of cognition



George Armitage Miller (1920-2012)

One of the founders of **cognitive psychology**.

Perceive Risk ▶ **Understand Risk** ▶ **Think Responses** ▶ **Select a response** ▶



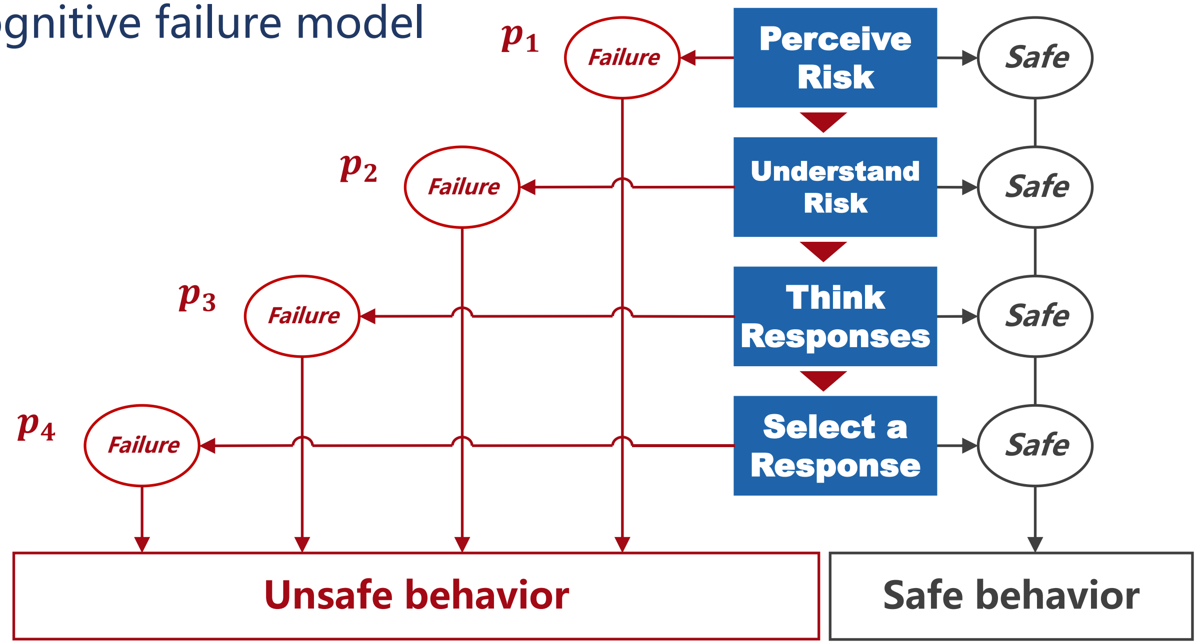
2 Critical Questions

- In research, how to reveal patterns of unsafe behavior at the cognitive level?
- In practice, how to intervene unsafe behavior from the cognition process?

2. Cognitive Failure and AI Driven Safety

A cognitive failure model of unsafe behavior was established and unsafe behaviors were investigated.

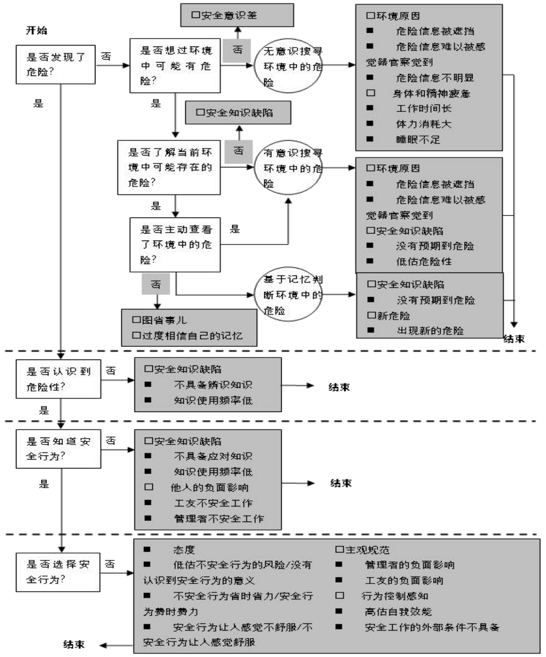
Cognitive failure model



Cognitive failure and behavioral safety analysis methods

$$P_{USB} = 1 - \prod_{i=1}^{4}(1 - p_i) = \frac{N_{USB}}{N_B}$$

Cognitive failure cause tracing method



Unsafe behavior

- **9** major categories
- More than **130** kinds

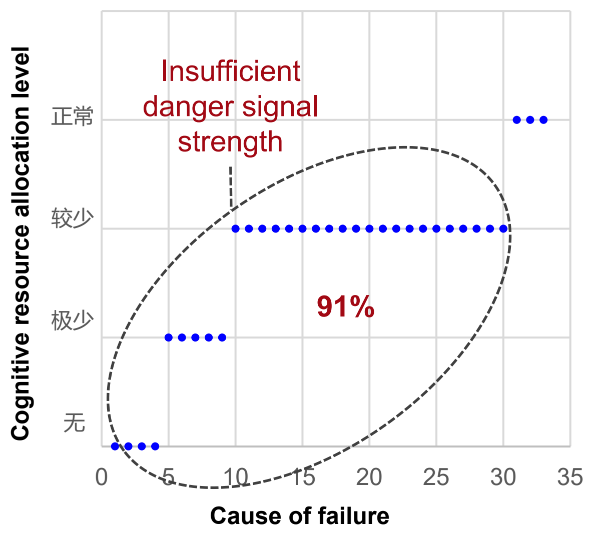
Causes of failure

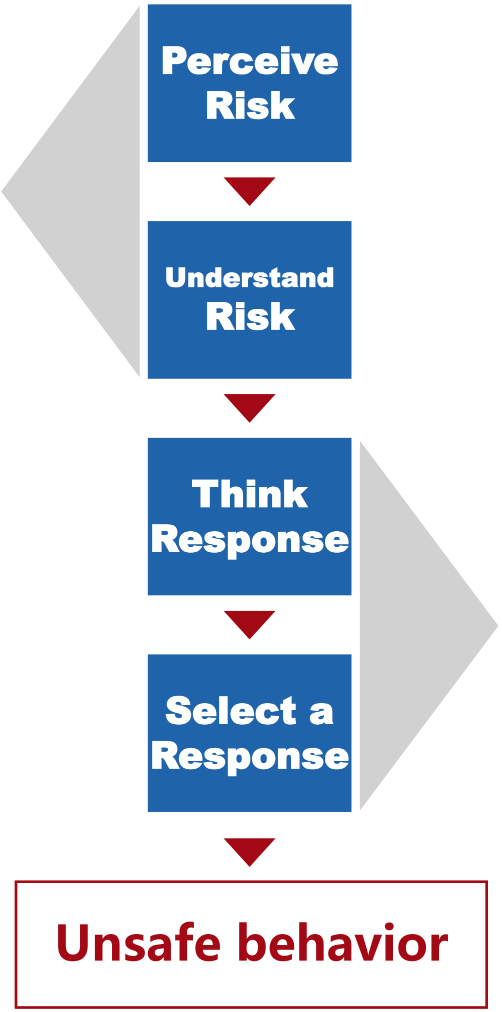
- **10** major categories
- More than **300** kinds

Fang, D., Zhao, C., Zhang, M., 2016. A Cognitive Model of Construction Workers' Unsafe Behaviors. J. Constr. Eng. Manage. 142, 04016039.

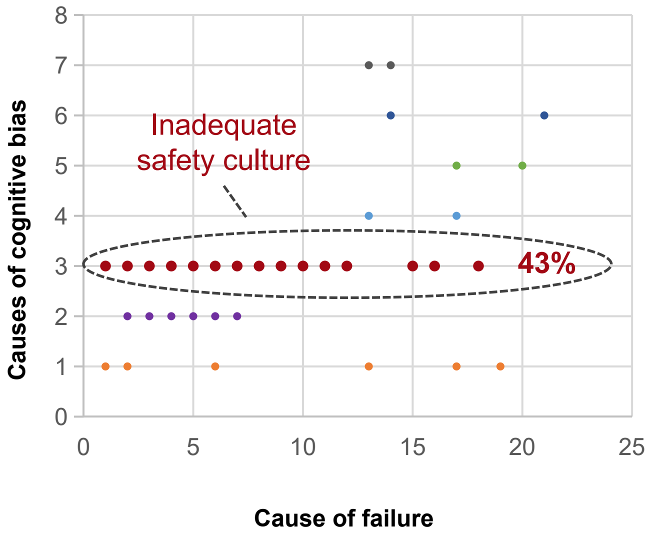
Two types of cognitive failure modes were discovered — **Unintentional & Intentional.**

Unintentional
Failure Mode

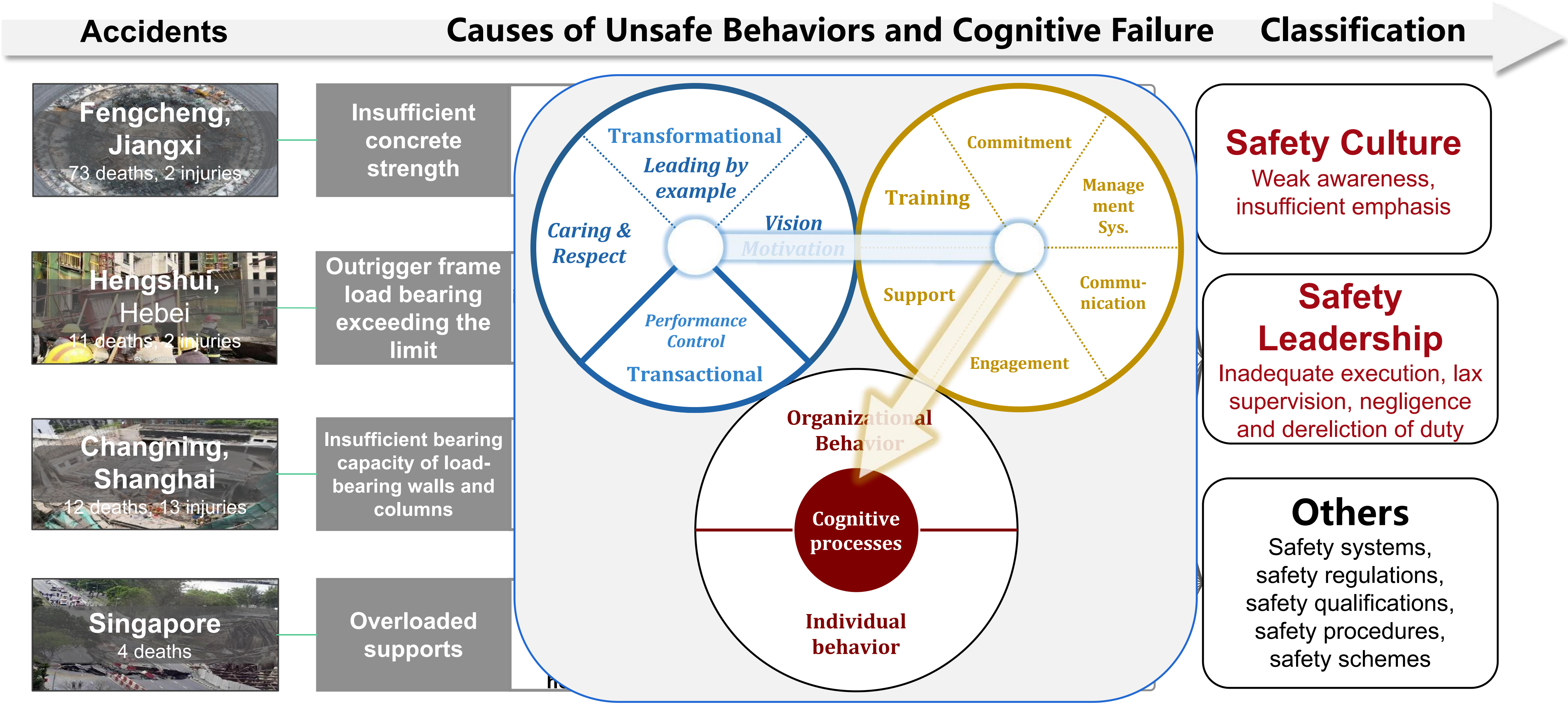




Intentional
Failure Mode



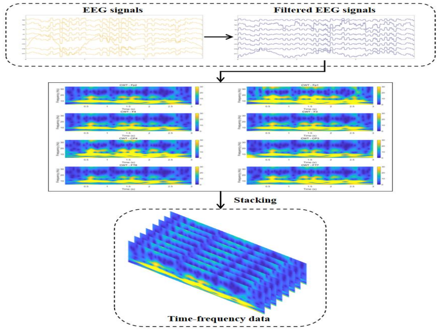
Intentional Failure — In numerous accident and unsafe behavior investigations, many organizational factors exert a significant impact on the cognitive process. Among these, insuficient safety culture and safety leadership are most frequently referred to.



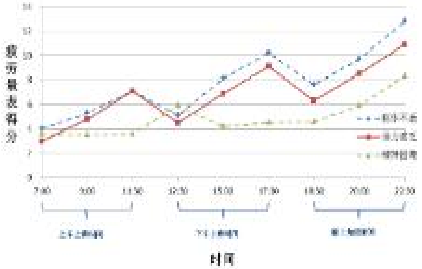
2.1 Fatigue-Induced Unsafe Behavior & Fatigue Detection

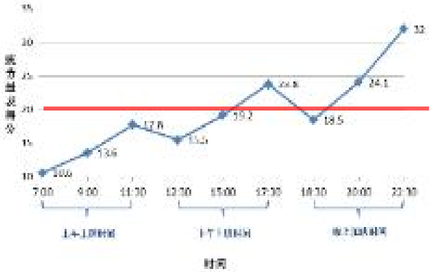
Unintentional Failure — Fatigue has been identified as a major driver of increased unsafe behaviors among workers. Our experiment finds that workers suffer from **physical fatigue** fail to perceive and understand safety hazards in a timely manner.

Fatigue-Unsafe Behavior Experiment



Physiological characterization





英文版建筑工人疲劳测评量表

题项	来源	分类
Q1. Lacking in energy	FQ	脑力疲劳
Q2. I have less strength in muscles	FQ	体力疲劳
Q3. Legs feel tired/heavy	疲劳症状自评量表	体力疲劳
Q4. My body movement slows down	工人访谈	体力疲劳
Q5. My thoughts easily wander	CIS	脑力疲劳
Q6. Arms/legs feel numb	工人访谈	体力疲劳
Q7. Shoulders feel stiff/pain	疲劳症状自评量表	体力疲劳
Q8. My joints (e.g. knee, elbow) feel achy	工人访谈	体力疲劳
Q9. Eyes feel strained	疲劳症状自评量表	脑力疲劳
Q10. I feel cramps in muscles	工人访谈	体力疲劳

中文版建筑工人疲劳测评量表

题项	来源	分类
Q1. 腰部感到酸痛	工人访谈	体力疲劳
Q2. 肩膀感到酸痛	英文版量表	体力疲劳
Q3. 手脚关节酸痛	英文版量表	体力疲劳
Q4. 身体不容易挺直	工人访谈	体力疲劳
Q5. 肌肉乏力	英文版量表	体力疲劳
Q6. 双腿感到沉重	英文版量表	体力疲劳
Q7. 动作变慢	英文版量表	体力疲劳
Q8. 精神难以集中	工人访谈	脑力疲劳
Q9. 感觉发困	工人访谈	脑力疲劳
Q10.眼睛疲乏	英文版量表	脑力疲劳

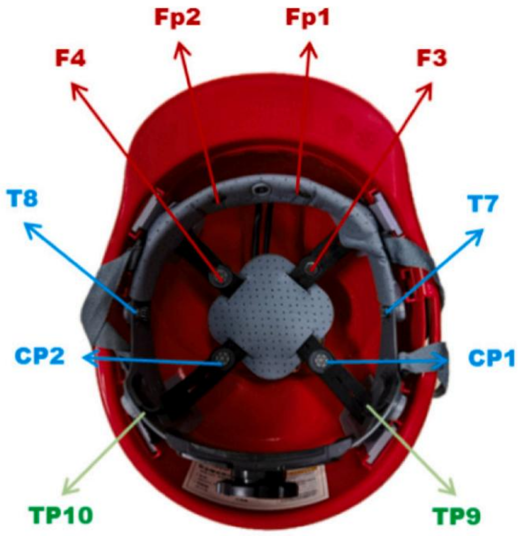
Psychological characterization

$$ER(f) \approx \begin{cases} 8, & 0 < f < 20 \\ 0.015f - 0.2, & f \geq 20 \end{cases}$$

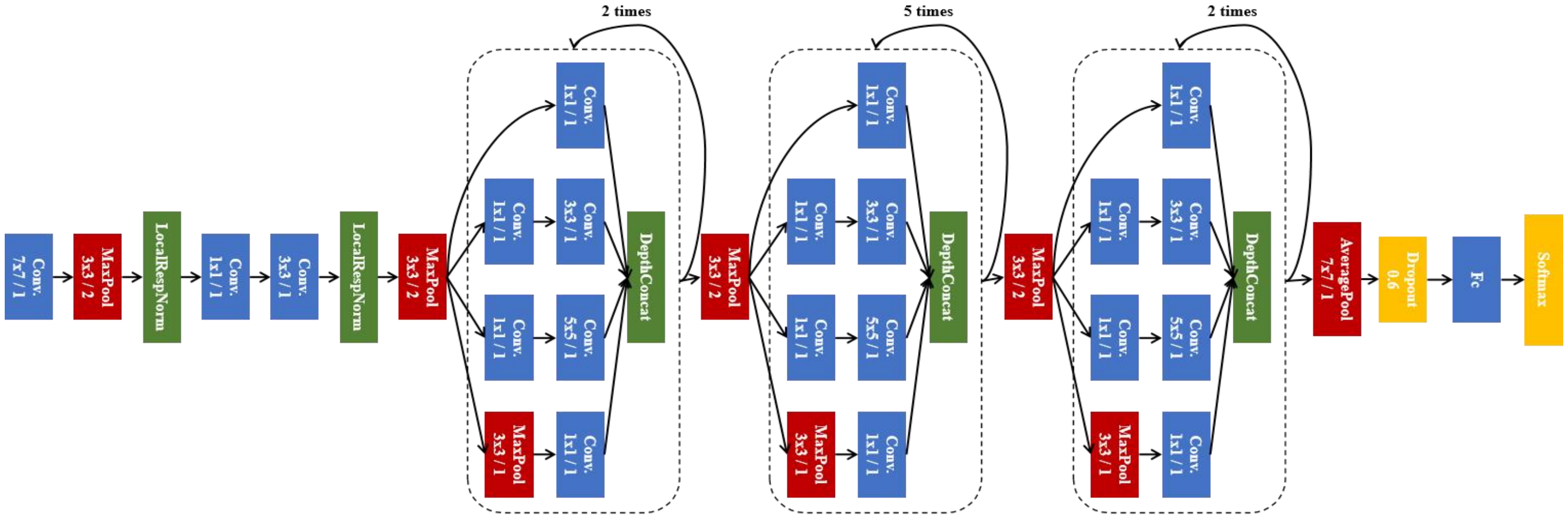
D. Fang, Z. Jiang, M. Zhang, H. Wang, 2015. An experimental method to study the effect of fatigue on construction workers' safety performance. Safety Science 73:80–91.

2.1 Fatigue-Induced Unsafe Behavior & Fatigue Detection

A smart helmet was developed to acquire EEG signals from the prefrontal cortex (PFC) for **cognitive fatigue** detection based on continuous wavelet transform (CWT) and a convolutional neural network (CNN).



F: key acquisition point
CP/T: complementary point
TP: denoising point

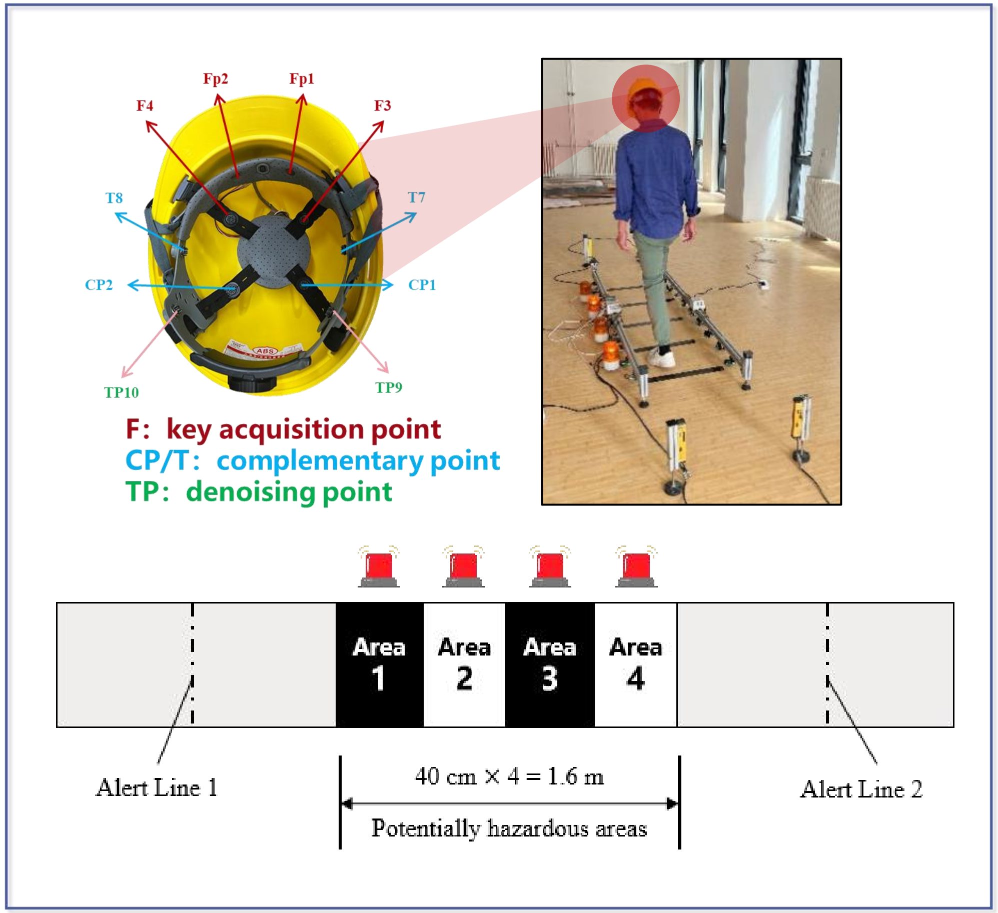


Convolutional Neural Network (CNN).

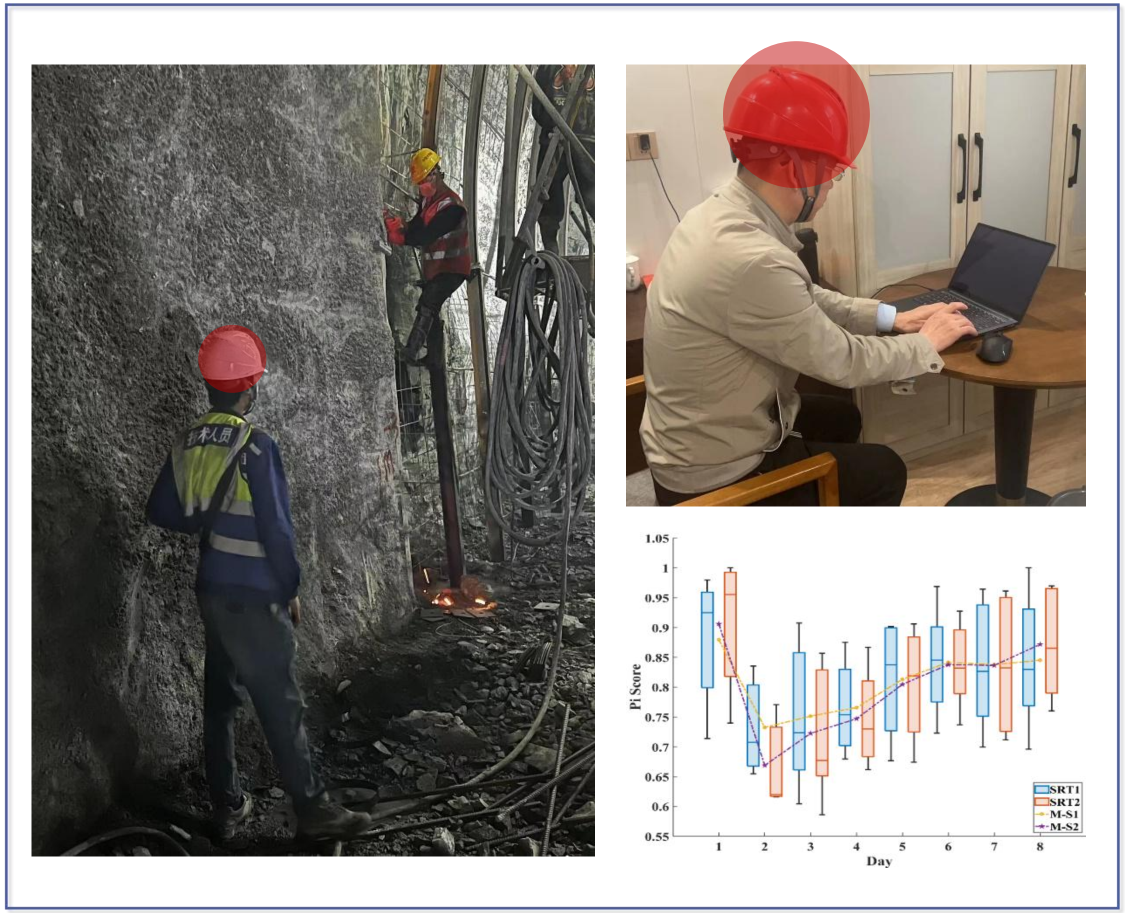
Wang, Yao, et al. "Measuring and identifying pre-service fatigue due to hypoxic exposure." Automation in Construction 160 (2024): 105307.

2.1 Fatigue-Induced Unsafe Behavior & Fatigue Detection

Cognitive fatigue was monitored in both laboratory and real construction environments by combining the use CWT and CNN, with an overall accuracy of 91%.

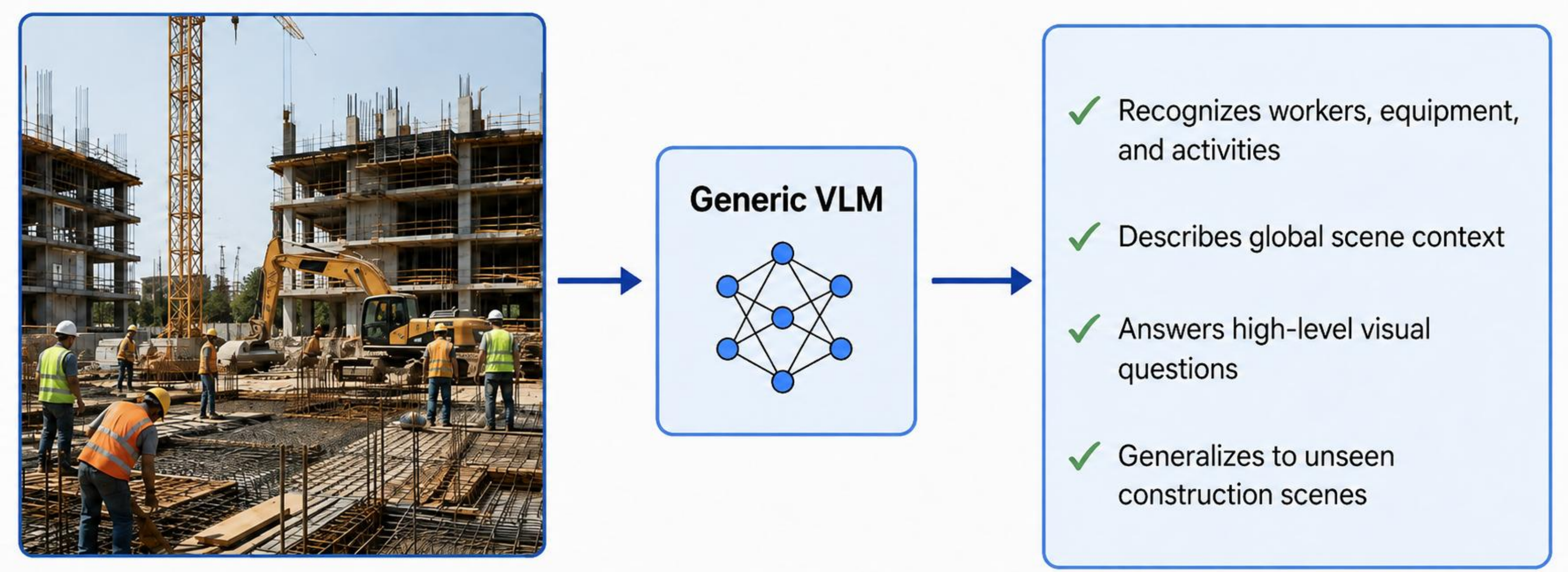


Fatigue Monitoring in Experimental Scenarios



Fatigue Monitoring in Real-World Work Scenarios

Unintentional Failure — insuficient cognition resources. **VLMs provide strong general visual-semantic understanding for construction scenes**. They can describe global scene context, recognize common objects and activities, and perform coarse reasoning.

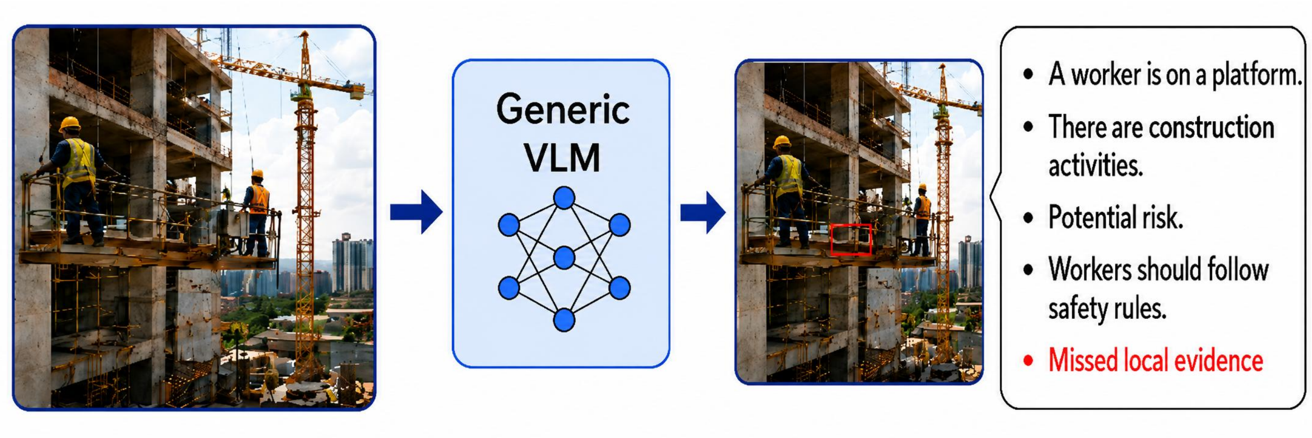


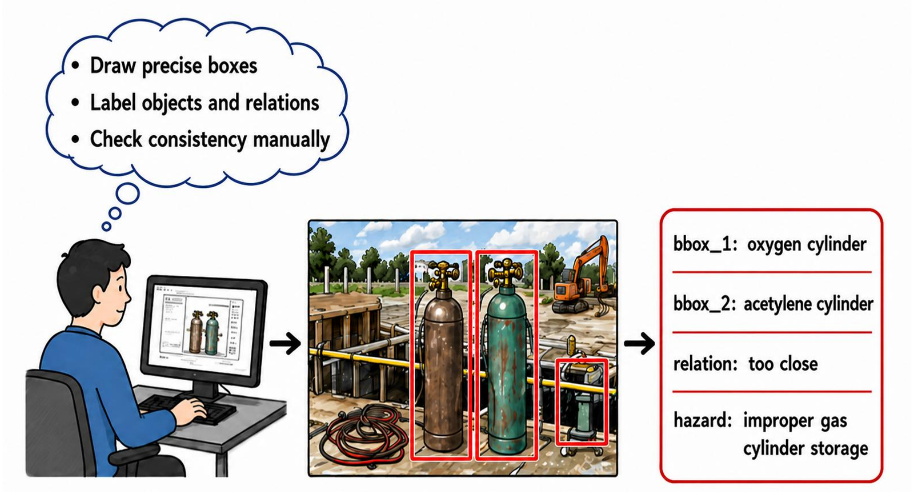
Existing VLMs understand "what is happening" in the scene, providing a strong foundation for safety inspection.

2.2 Lightweight RL-based VLM

Existing VLMs lack **fine-grained reasoning** grounded in localized visual evidence for hazard inspection, resulting in a low identification rate and difficulties for implementation.

Fine-tuning generic VLMs for fine-grained construction safety reasoning **requires structured annotations** of local safety-critical evidence; however, acquiring such annotations is labor-intensive and costly.



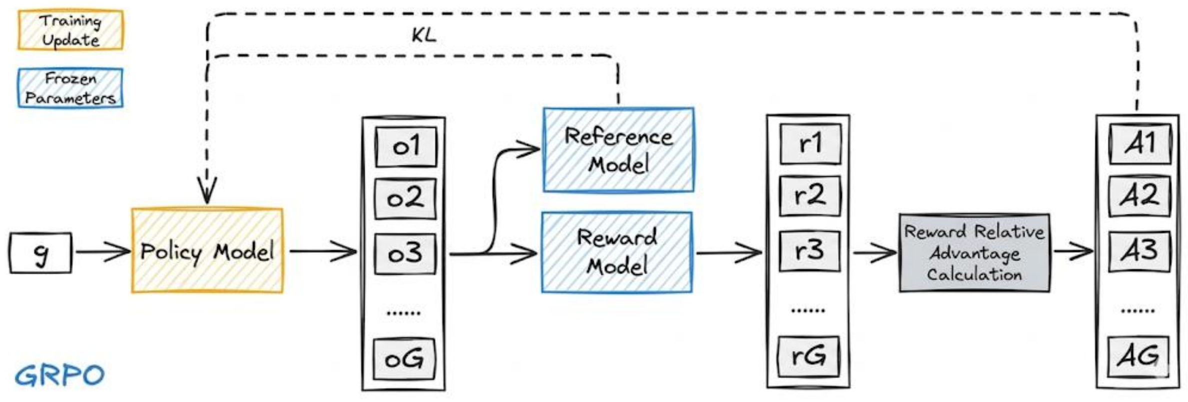


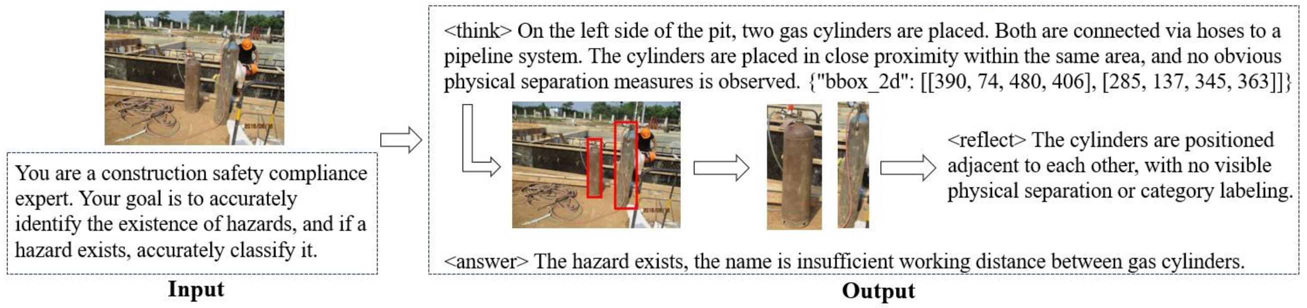
Generic VLMs recognize potential hazards, but cannot reliably ground and verify them with localized visual evidence.

Annotating local safety-critical evidence requires non-trivial manual effort.

2.2 Lightweight RL-based VLM

Lightweight RL-based VLM is proposed in which hazard localization and reasoning are integrated through **reward signals**, without requiring extra localization annotations. **Better hazard identification and description performance is achieved** over other training methods and larger models.





RL paradigm is the first to use reward signals to integrate hazard localization with reasoning without relying on expensive annotations.

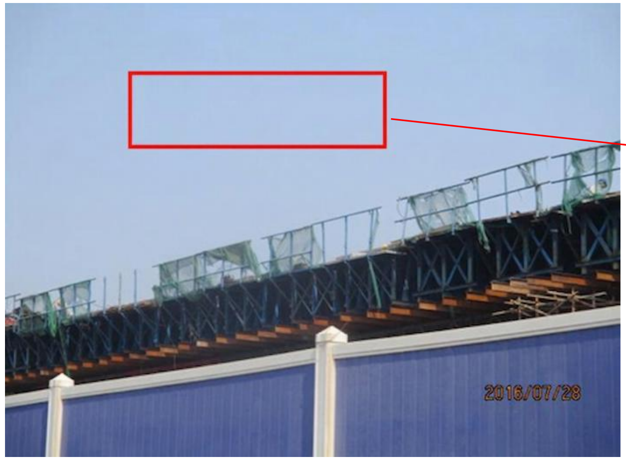
Model	Parameters	Identification Accuracy (%)	Description Accuracy (%)
GLM-4.5V	106B	53.1	67.6
Qwen3-VL	235B	50	67.6
GPT-5.1	Unknown	57.9	68.6
Ours (Qwen-VL)	**3B**	**75.3**	**85.2**

Training Method (Qwen-VL 3B)	Identification Accuracy (%)	Description Accuracy (%)
Few-Shot Prompting	53.7	61.4
Chain-of-Thought	52.5	60.0
RAG	50.5	69.0
Supervised Fine-Tuning (SFT)	70.4	79.0
Ours	**75.3**	**85.2**

Lightweight RL model outperforms other training methods and larger models on identification and description.

2.2 Lightweight RL-based VLM

Improved hazard reasoning is enabled by **more accurate localization** of safety-critical regions in construction scenarios.



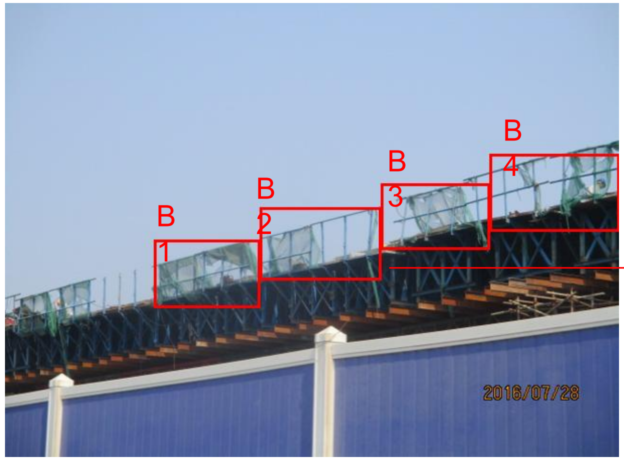
Baseline:

Current methods fail to produce reasoning chains with accurately localized hazard-relevant regions.

{Coordinate: [129, 71,399, 152]} ⟶ **Incorrect coordinate**

The image clearly shows continuous guardrails and protective netting installed along the edge of the elevated work platform. No obvious violations or defects corresponding to the hazard category are found. ⟶ **Incorrect reasoning**

There are no hazards. ⟶ **Incorrect conclusion**



Ours:

RL-based method achieves more accurate hazard localization, reasoning, and final hazard assessment.

<think> Parts of the mesh along the beam edges are missing or detached. In some areas, the mesh appears to be connected only by central support bars, without forming a continuous enclosed barrier. {Coordinate： [B1[156, 248, 267, 319], B2[267, 214, 394, 290], B3[394, 189, 508, 258], B4[508, 158, 644, 239]]}

<reflect>The mesh is incomplete and loosely installed, without a fully enclosed protective barrier. This matches the visual signs of inadequate edge protection.

<answer>Hazards exist and the type is non-compliant edge protection. </answer>

2.2 Lightweight RL-based VLM

Key insights for future development of Multimodal Large Models for hazard identification

01 From single-image reasoning to world-aware video understanding

Current VLMs reason over static images, but construction safety is inherently dynamic, depending on temporal cues and spatial relations across frames.

Moving toward multi-frame reasoning allows the model to understand construction activities as events unfolding in a 3D physical environment and provides a foundation for world-model-like safety reasoning.

revealing risks that single images may miss

02 From pre-trained large model to fine-tuned lightweight model

Generic large VLMs are powerful but often inefficient and insufficiently grounded for domain-specific safety inspection. They may generate plausible global descriptions while missing safety-critical evidence.

A lightweight fine-tuned VLM is more suitable for construction deployment, while RL-based alignment further improves localization, reasoning, and final hazard inspection.

more accurate, lower deployment cost

2.3 Safety Management - BESAFE as a solution

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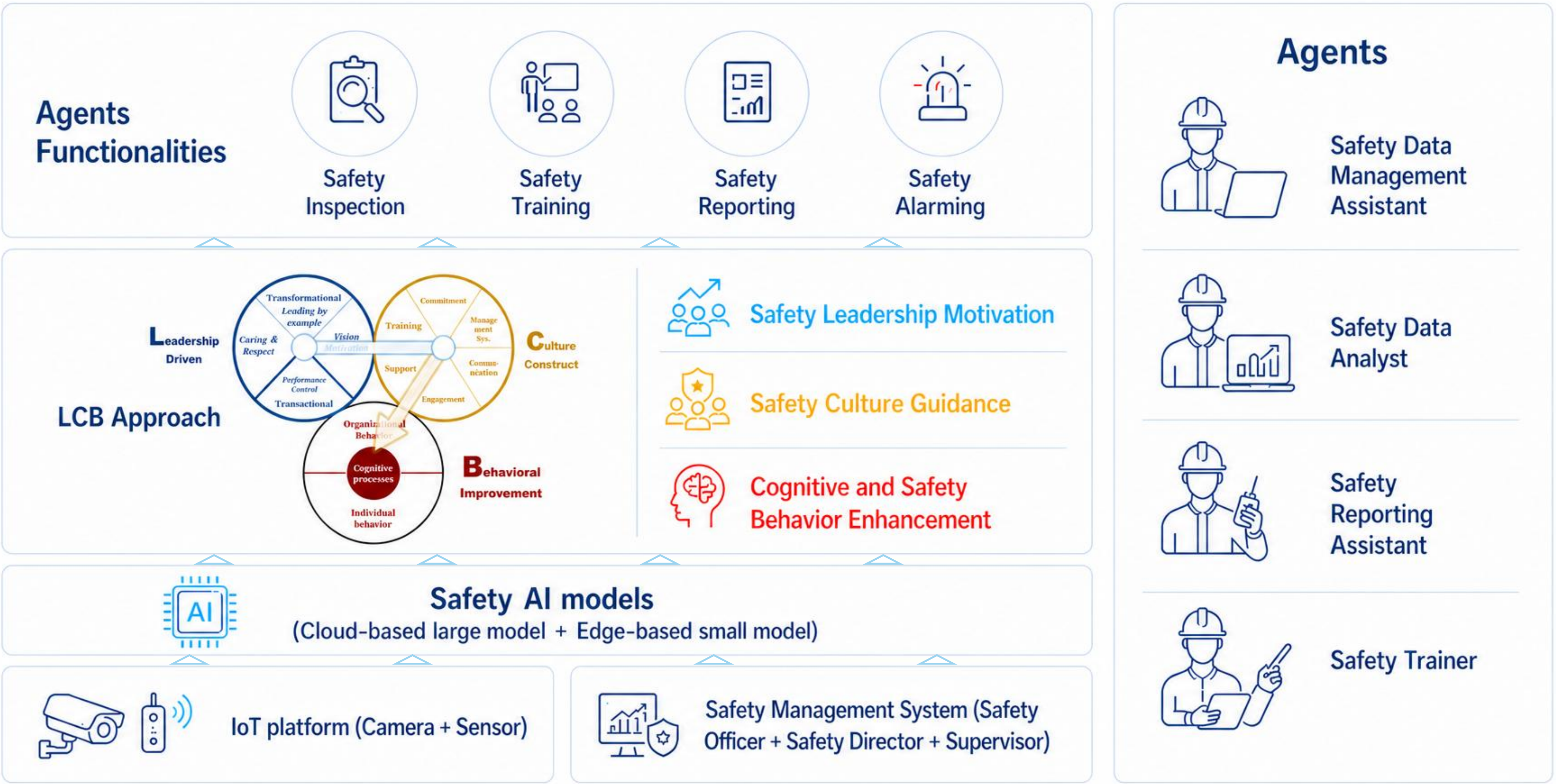
BESAFE AI Agents Architecture

BESAFE

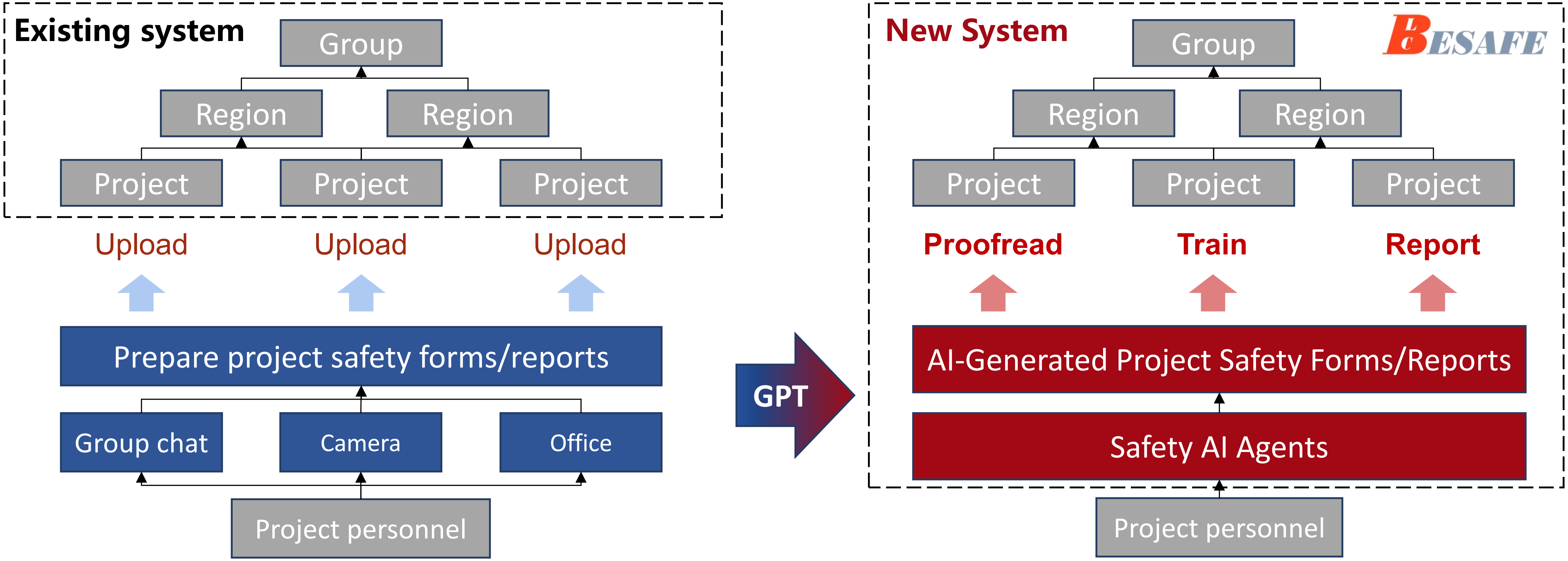


2.3 Safety Management - BESAFE as a solution

A New Online–Offline Inspection Paradigm Through Human– BESAFE AI Agents Collaboration.

2.3 Safety Management - BESAFE as a solution

BESAFE AI Agents work with most existing safety management systems.

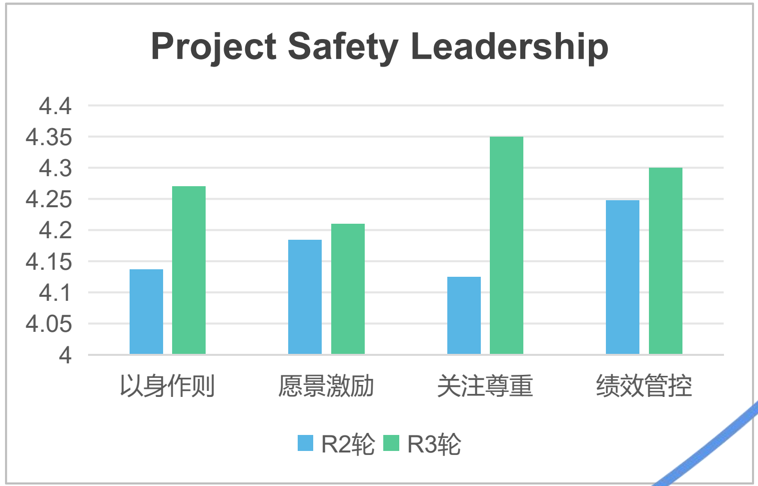


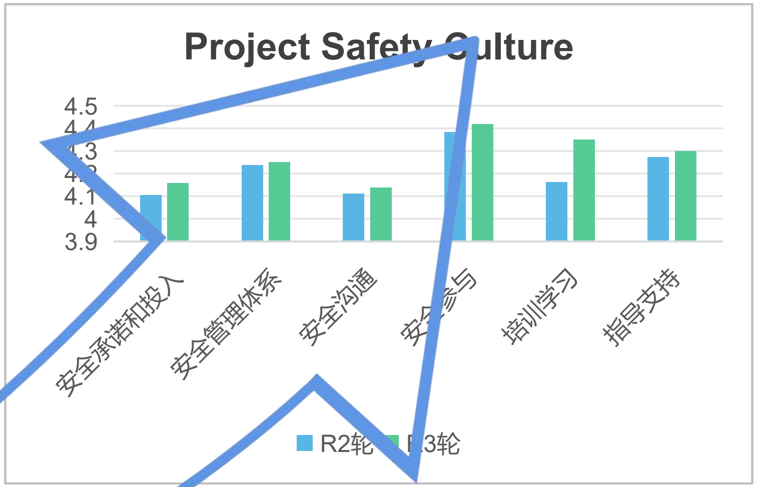
- Project personnel use tools to organize safety documentation.
- After creating safety forms/reports, project personnel manually upload them to the system.

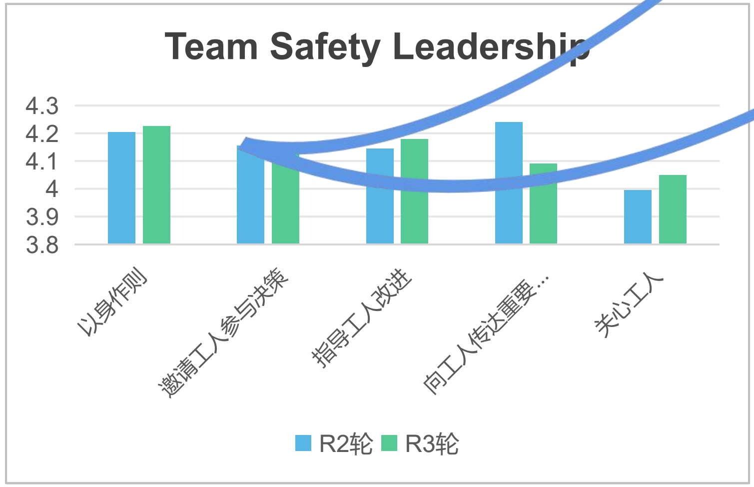
- New training and reporting features address safety management needs across all service tiers.
- The new system is compatible with existing systems, boosting inspection efficiency by 50%.
- Private data center deployment for data security

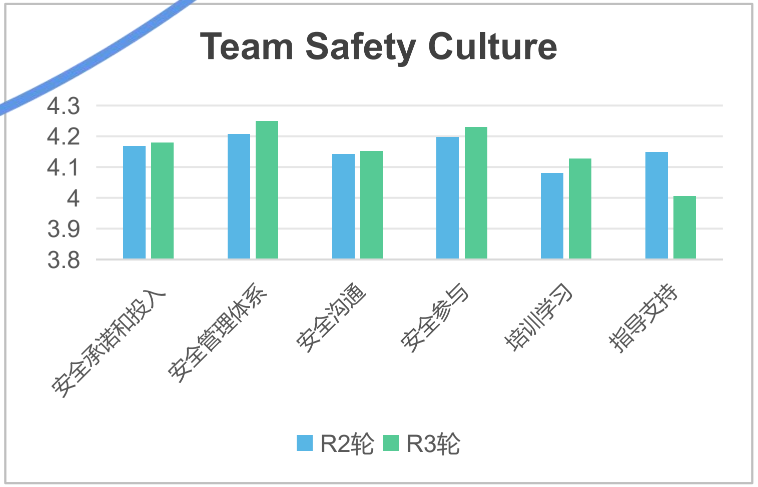
2.3 Safety Management - BESAFE as a solution

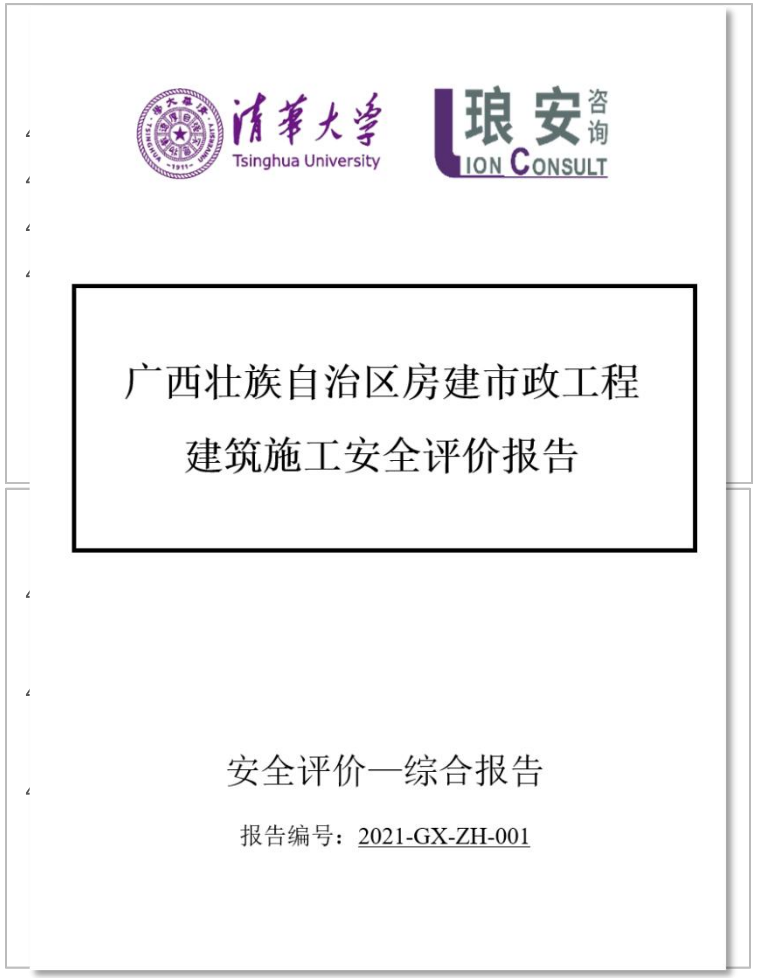
BESAFE AI Agents identify management gaps, generate intervention measures, and enhance LCB at all levels.







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广西壮族自治区房建市政工程

建筑施工安全评价报告

安全评价—综合报告

报告编号：2021-GX-ZH-001

Outline

1. Safety Challenges and LCB approach

2. Cognitive Failure and AI Driven Safety

3. The Value of Generative AI for CSKM

4. Applications and Conclusions

3. The Value of Generative AI for CSKM

Why GenAI for Construction Safety Knowledge Management (CSKM) Matters

FUTURE-READY CONSTRUCTION ENTERPRISES

Higher productivity · Stronger safety management · Sustainable competitiveness

DIGITAL EMPLOYEES

Scale safety expertise across roles, projects, and workflows

AI-ENABLED KNOWLEDGE MANAGEMENT

Deliver trusted, contextual, proactive, and actionable safety knowledge

WHICH GENERATIVE AI APPLICATIONS TO DEVELOP — AND PRIORITIZE

Multi-stakeholder evidence identifies the highest-value opportunities for CSKM.

3. The Value of Generative AI for CSKM

Effective construction safety knowledge management (CSKM) enhances safety performance by promoting the accumulation and reuse of safety experience, supporting contextualized decision-making, and driving proactive prevention in safety management.

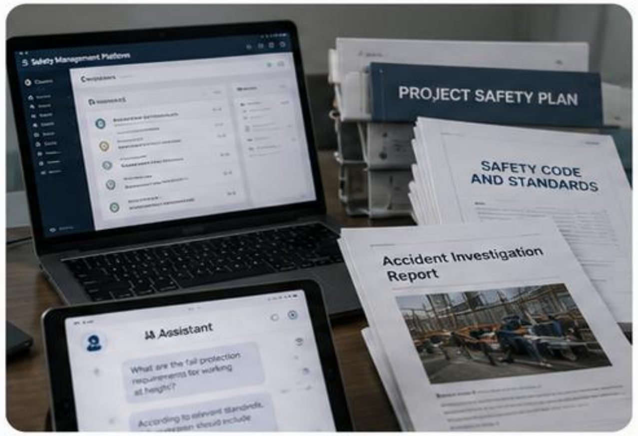
GenAI brings new opportunities for CSKM, yet limitations still persist in current practices:

- **Costly knowledge capture and organization.** → A large amount of on-site experience knowledge remains uncaptured.
- **Weak semantic retrieval and cross-document linkage.** → Search results are incomplete and poorly contextualized, undermining user trust.
- **Passive user-initiated interaction.** → Users struggle to clarify needs and obtain timely knowledge.
- **Full-transparency sharing mechanism.** → Knowledge reporting is prone to falsification and concealment, degrading knowledge quality.
- **Knowledge management often stops at dissemination without feedback.** → Knowledge understanding and on-site execution remain unverifiable.

3. The Value of Generative AI for CSKM

Existing research lacks systematic understanding of GenAI's roles across CSKM processes (acquisition, organization, sharing, and application) and its development pathways. **There is a need to consider multi-stakeholder practical needs** to inform development strategies for GenAI application in CSKM.

Fragmented understanding

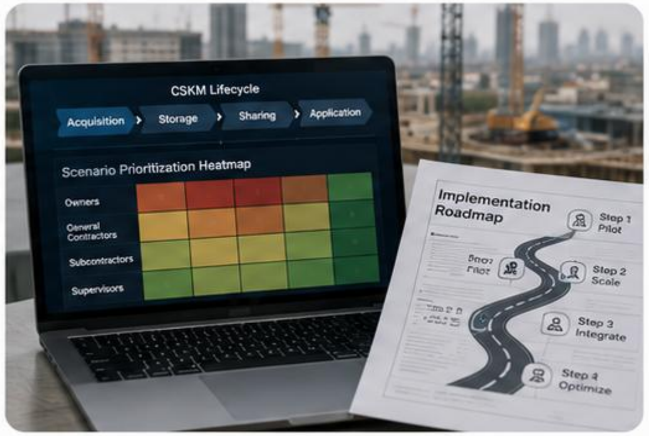


Existing studies focus on isolated tools or tasks, with limited lifecycle-level understanding of GenAI-enabled CSKM.

Lack of stakeholders' perspectives

Few studies compare how owners, contractors, subcontractors, and supervisors value GenAI scenarios.

Lack of deployment strategy



Scenario importance, stakeholder divergence, KM stage, and GenAI role are rarely integrated in one framework.

3. The Value of Generative AI for CSKM

This study develops an empirical multi-stakeholder framework to examine four parties' functional needs and value perception divergences regarding GenAI in CSKM. The findings aim to guide the industry in allocating GenAI resources to priority safety knowledge areas and enabling differentiated configurations according to stakeholder-specific needs.

1 Collect qualitative evidence

- 24 respondents from owners, general contractors, subcontractors, and supervisors
- About 90 min each
- Average 15 years experience

Output:
GenAI practical needs in CSKM

2 Analyze GenAI roles and application scenario

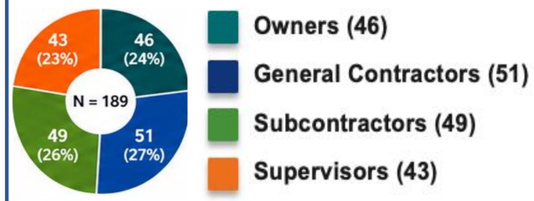
Framework analysis

- Familiarization
- Analytical framework
- Indexing
- Charting
- Mapping and interpretation

Output:
6 GenAI functional categories and 24 application scenarios in CSKM

3 Quantify differences in stakeholder needs

189 valid responses

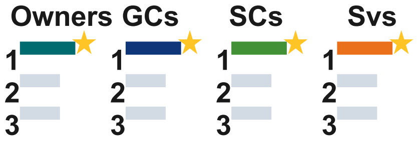


Mixed-design ANOVA

Output:
Perceived importance differences across stakeholders, KM stages, and GenAI roles

4 Proposing GenAI development priorities for CSKM

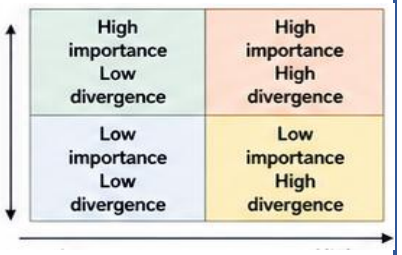
A. Stakeholder-specific priorities



B. Industry-level priority strategies

X: Between-group effect size

Y: Scenario Importance



Output:
Priority strategies

3. The Value of Generative AI for CSKM

Finding 1: 6 key areas where GenAI delivers the best value in CSKM.

01 Learning and reflective enhancement

Use generative dialogue and structured accident analysis to convert accident cases, violations and rectification records into reusable safety experience.

02 Collaborative consensus facilitation

Synthesize safety regulations, cases, and site evidence to help multiple stakeholders quickly agree on risk identification and rectification, and on clarifying responsibility boundaries.

03 Pattern insight and prediction

Integrate multi-source safety data to identify risk couplings, evolving trends, and precursors, generating safety warnings and priority inspection recommendations.

Finding 1: Six key areas where GenAI delivers the best value in CSKM.

04 Contextual solution generation

Generate multimodal content based on project phases, construction operations, and site safety contexts, supporting task‑ oriented reorganization of safety knowledge.

05 Trustworthy compliance governance

Apply source attribution, version control, evidence traceability, and compliance checks to enforce full‑ process quality control over safety knowledge, ensuring standardized supply and reliable use.

06 Adaptive knowledge service

Generate tailored safety knowledge push and interactive Q&A support for different roles and site conditions, enabling on‑ demand precise safety knowledge delivery.

3. The Value of Generative AI for CSKM

Finding 2: The mixed-design ANOVA reveals **a significant three-way interaction among KM stage, GenAI role, and stakeholder group,** indicating stakeholder preferences differ across stage-role-group configurations and highlighting the need for tailored GenAI development.

Application scenarios with greatest needs per stakeholder group.

Owner Supervisor

Trustworthy compliance governance in knowledge application stage

Using GenAI to check whether plans, safety briefings, and site practices meet safety code requirements.

General Contractor

Adaptive knowledge service in knowledge sharing stage

Deliver safety knowledge according to role and project stage to support collaborative safety management across multiple stakeholders.

Subcontractor

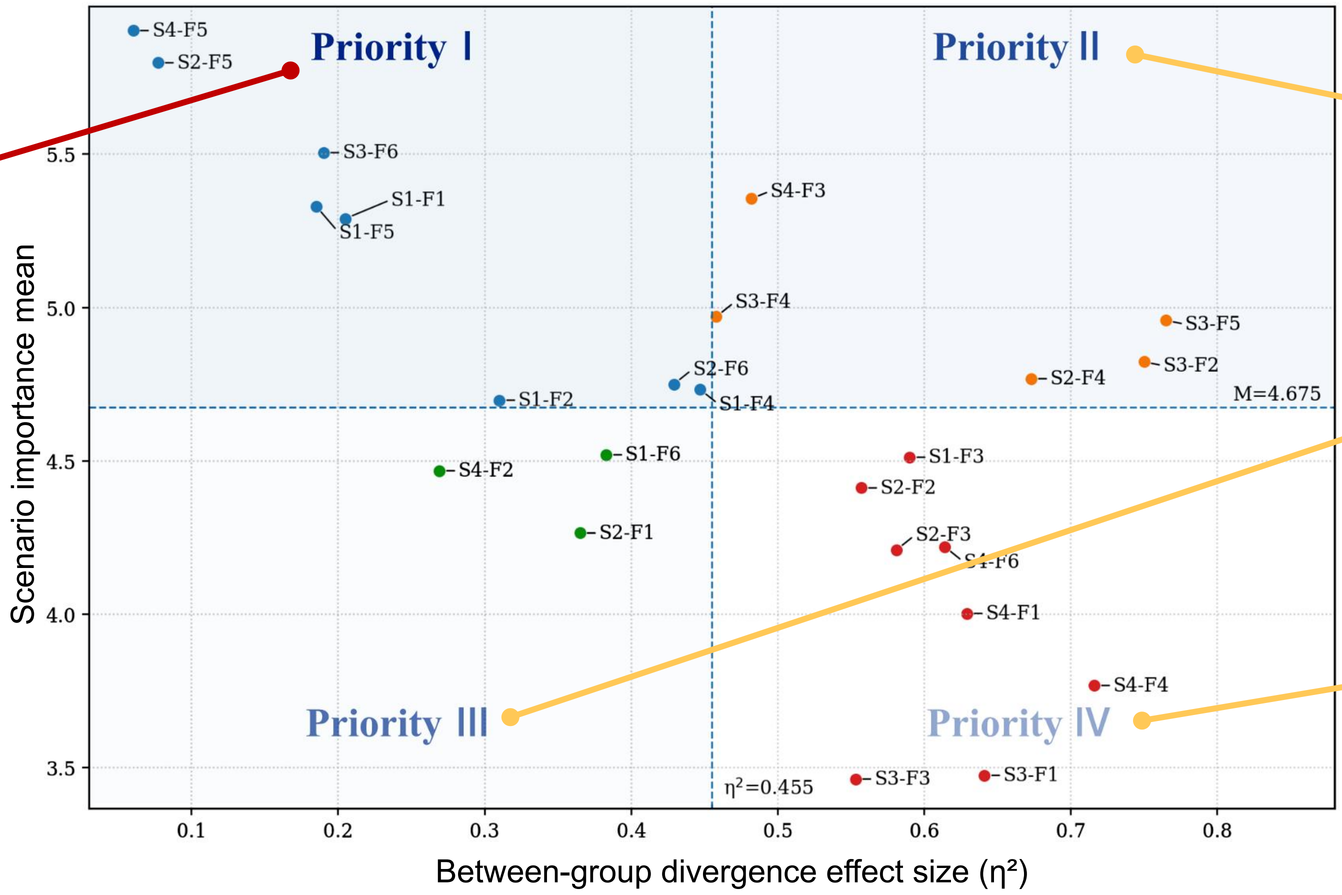
Trustworthy compliance governance in knowledge organization stage

Structuring and storing safety codes by region, project type, discipline, and version.

3. The Value of Generative AI for CSKM

Finding 3: A quadrant analysis was conducted using **scenario importance** and **between-group divergence from mixed-design ANOVA**, with **mean values** as cut-offs to identify industry-level development priorities for GenAI-enabled CSKM.

At the industry level, the findings suggest Priority I scenarios for early GenAI deployment in CSKM, as they show both high importance and low stakeholder divergence.



Customize by stakeholder role and needs (high importance, high divergence)

Selective development in the mid to long term (low importance, low divergence)

Pilot cautiously before broader deployment (low importance, high divergence)

3. The Value of Generative AI for CSKM

清華大學土木水利学院
SCHOOL OF CIVIL ENGINEERING
TSINGHUA UNIVERSITY

Summary of importance and stakeholder differences across 24 scenarios.

Priority Region	Scenario	Scenario Code	Mean Importance	Between-group divergence (η^2)	GC Importance	O Importance	SC Importance	SV Importance
Priority I	Knowledge Application × AI-enabled Compliance Governance	S4-F5	5.90	0.059	**5.75**	**6.20**	**5.71**	**5.95**
	Knowledge Organization × AI-enabled Compliance Governance	S2-F5	5.80	0.076	5.59	**6.07**	**6.00**	**5.53**
	Knowledge Sharing × AI-enabled Knowledge Orchestration	S3-F6	5.51	0.189	**6.08**	5.17	5.63	5.14
	Knowledge Acquisition × AI-enabled Compliance Governance	S1-F5	5.33	0.185	4.92	5.00	5.45	**5.95**
	Knowledge Acquisition × AI-enabled Learning and Reflection	S1-F1	5.29	0.206	4.59	**5.80**	5.24	**5.53**
	Knowledge Organization × AI-enabled Knowledge Orchestration	S2-F6	4.75	0.429	5.16	5.67	4.59	3.58
	Knowledge Acquisition × AI-enabled Contextual Generation	S1-F4	4.73	0.447	4.86	3.52	**5.70**	4.84
	Knowledge Acquisition × AI-enabled Collaboration and Consensus	S1-F2	4.70	0.310	4.24	5.37	5.27	3.91
Priority II	Knowledge Application × AI-enabled Pattern Prediction	S4-F3	5.36	0.482	**5.88**	5.59	**5.98**	3.97
	Knowledge Sharing × AI-enabled Contextual Generation	S3-F4	4.97	0.457	5.08	**5.70**	5.45	3.65
	Knowledge Sharing × AI-enabled Compliance Governance	S3-F5	4.96	0.765	**6.08**	5.65	2.57	**5.53**
	Knowledge Sharing × AI-enabled Collaboration and Consensus	S3-F2	4.82	0.749	**5.94**	**6.02**	4.96	2.37
	Knowledge Organization × AI-enabled Contextual Generation	S2-F4	4.77	0.674	5.47	2.59	**5.71**	5.30
Priority III	Knowledge Acquisition × AI-enabled Knowledge Orchestration	S1-F6	4.52	0.381	4.92	4.22	5.41	3.53
	Knowledge Application × AI-enabled Collaboration and Consensus	S4-F2	4.47	0.266	4.49	4.17	5.33	3.88
	Knowledge Organization × AI-enabled Learning and Reflection	S2-F1	4.27	0.366	4.69	3.48	5.12	3.77
Priority IV	Knowledge Acquisition × AI-enabled Pattern Prediction	S1-F3	4.51	0.590	4.94	4.93	5.39	2.79
	Knowledge Organization × AI-enabled Collaboration and Consensus	S2-F2	4.41	0.558	4.71	4.87	2.84	5.23
	Knowledge Application × AI-enabled Knowledge Orchestration	S4-F6	4.22	0.614	5.16	5.43	3.73	2.56
	Knowledge Organization × AI-enabled Pattern Prediction	S2-F3	4.21	0.582	5.53	3.09	3.43	4.79
	Knowledge Application × AI-enabled Learning and Reflection	S4-F1	4.00	0.629	5.35	4.46	3.92	2.28
	Knowledge Application × AI-enabled Contextual Generation	S4-F4	3.77	0.716	5.51	4.67	2.31	2.58
	Knowledge Sharing × AI-enabled Learning and Reflection	S3-F1	3.48	0.642	3.80	2.33	5.12	2.65
	Knowledge Sharing × AI-enabled Pattern Prediction	S3-F3	3.46	0.553	4.94	2.54	3.51	2.86

Note: Red numbers indicate the top 5 scenarios with the highest needs within each stakeholder group.

Priority I Scenarios - high importance, low divergence

S2-F5: Trustworthy and Compliant Knowledge Storage

Input

- Codes, Standards & Regulations
- Accident Cases & Lessons
- Project Documents & Site Records
- Training Materials & Inspection Reports

Key GenAI Actions

- **Compliance Check** Verify knowledge against applicable laws and current standards.
- **Conflict & Redundancy Detection** Resolve conflicting or duplicate items and keep one authoritative version.
- **Version & Traceability Management** Record source, revision history, and effective dates.

S4-F5: Compliance Assessment in Knowledge Application

Input

- Plans & Technical Documents
- Site Photos & Videos
- Equipment & Personnel Records
- Inspection Logs & Monitoring Data

Key GenAI Actions

- **Compliance Review** Compare materials with applicable requirements.
- **Risk Identification & Rating** Detect non-compliance and rate risk: High / Medium / Low.
- **Improvement Suggestions** Propose corrective and preventive actions.

Ensure Knowledge Trustworthiness at the Source

Use verification, deduplication, and version control to keep knowledge accurate, complete, and traceable.

Ensure Compliant Safety Judgments in Application

Use intelligent comparison and risk review to identify issues early and support better safety decisions.

Conclusions

- Immediate priorities: Strengthen safety asset quality and accessibility by externalizing tacit knowledge and consolidating fragmented knowledge into trusted assets, and then use these assets to support on-site safety review and just-in-time targeted knowledge sharing.
- Areas to defer: More advanced uses, such as generating context-specific safety solutions for dynamic site conditions, knowledge-behavior gap intervention, reflective learning support, prediction of weak points in knowledge sharing, etc., should be deferred until stronger data and technical foundations support cautious piloting.

Outline

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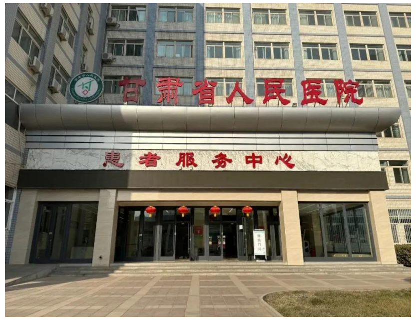
BESAFE AI Agents is currently serving over 100 projects across 10 provinces.


Medical Center

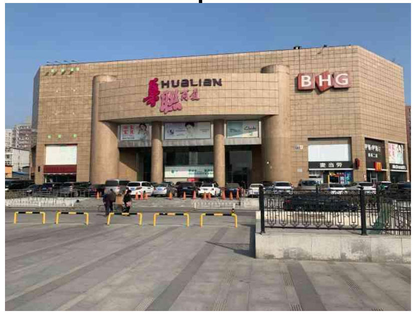

University Redevelopment



Hospital


Public Rental Housing


Technology Park



Shopping Center Renovation


Old Residential Renovation


Library


Dilapidated Building Reconstruction

BESAFE

Jiangsu Gansu Shanxi Hainan

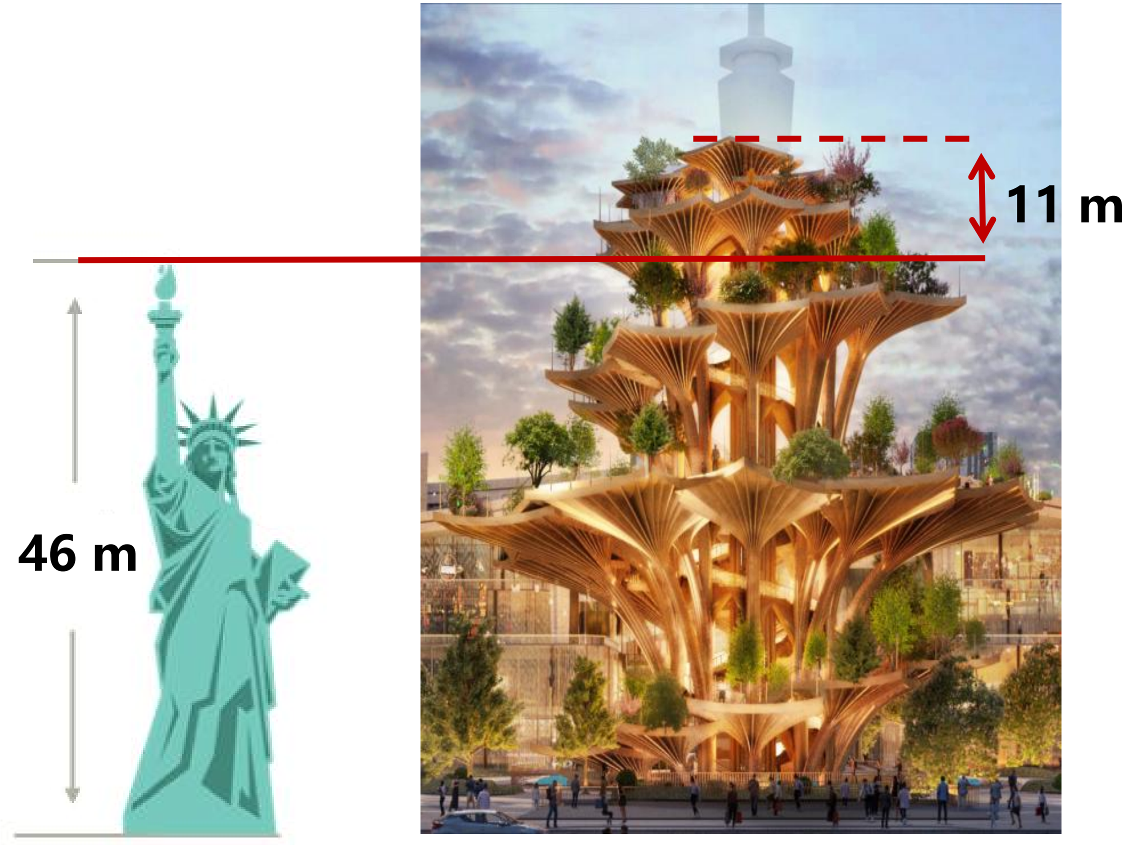
Shandong Shanghai Chongqing

Fujian Anhui

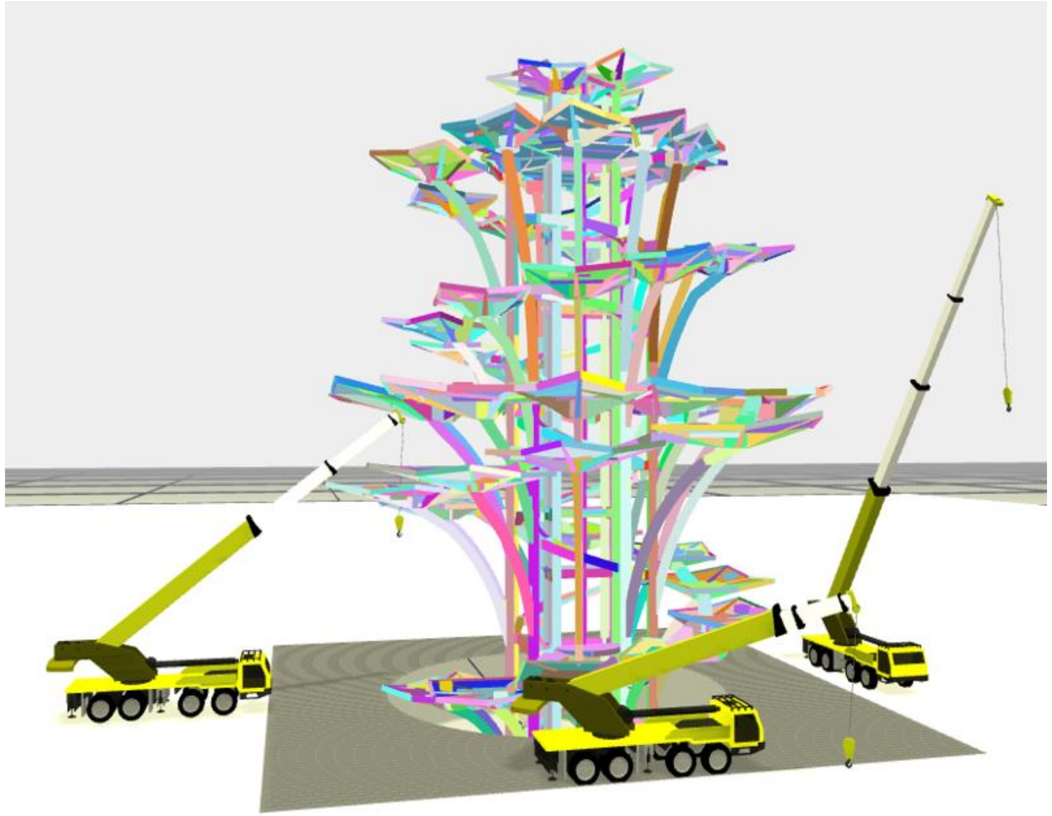
Beijing

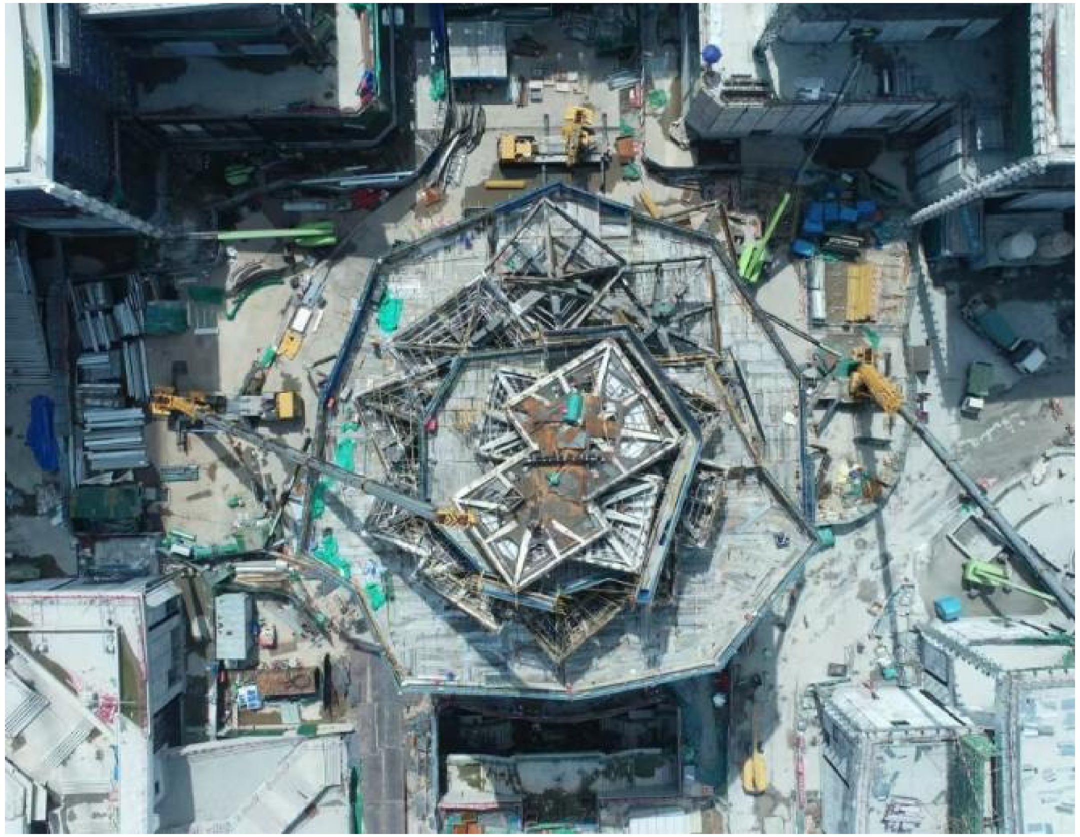
4. Applications and Conclusions

The "Tree of Life" is a very unique design with 57 meters high. 4100 tons of steel were used to support the plants with soil and visitors on the TREE.



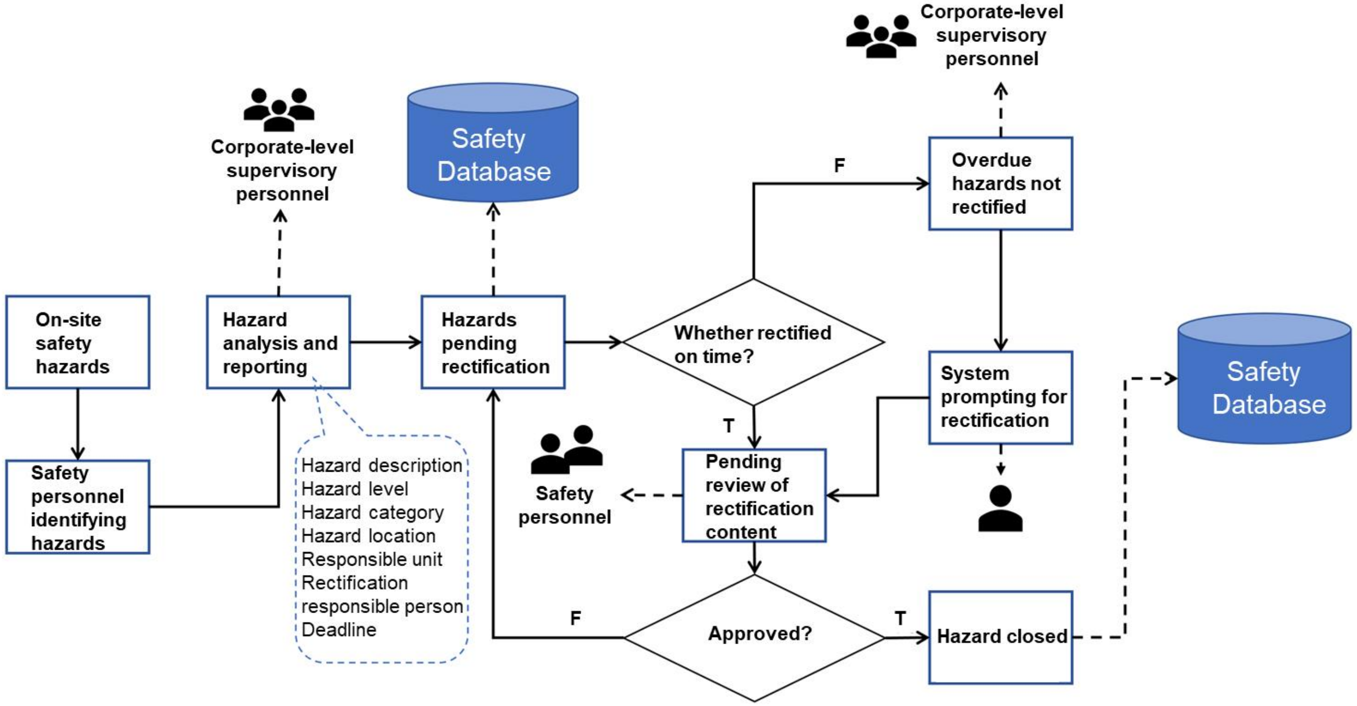
The construction process is restricted within a 60-meter diameter. A large crawler crane and multiple truck cranes were used to accomplish the high-precision installation of complex steel components.

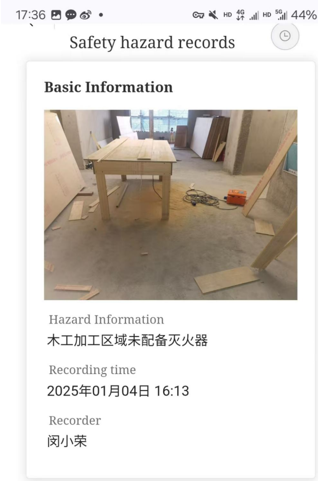




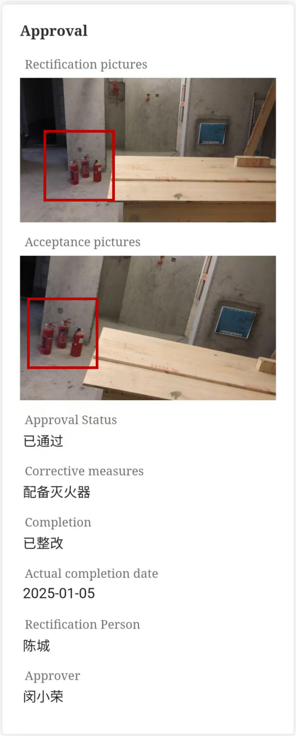
4. Applications and Conclusions

Agents: Hazard management based on agents enables comprehensive data collection and analysis of safety management behaviors from various personnel.





The woodworking processing area is not equipped with a fire extinguisher.



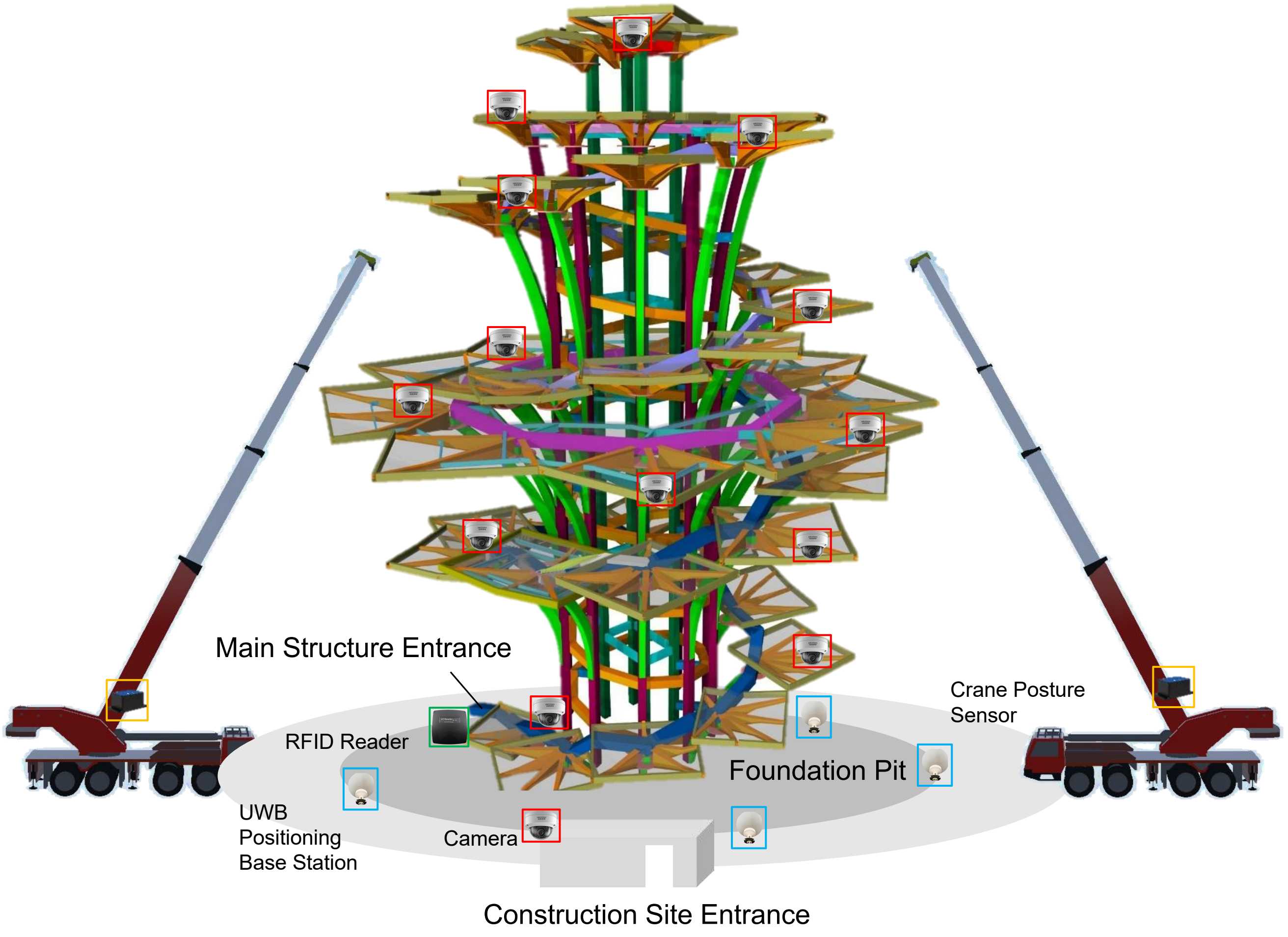
Hazard Traceability: Record the responsible units and individuals for hazards, along with corrective measures and images, to facilitate managers in reviewing the project's historical risks.

Hazard management process: Each hazard must be approved by the supervisor after rectification before being entered into the safety database. Otherwise, it will be returned to the person responsible for rectification for rework, ensuring that every corrective action is effectively implemented.

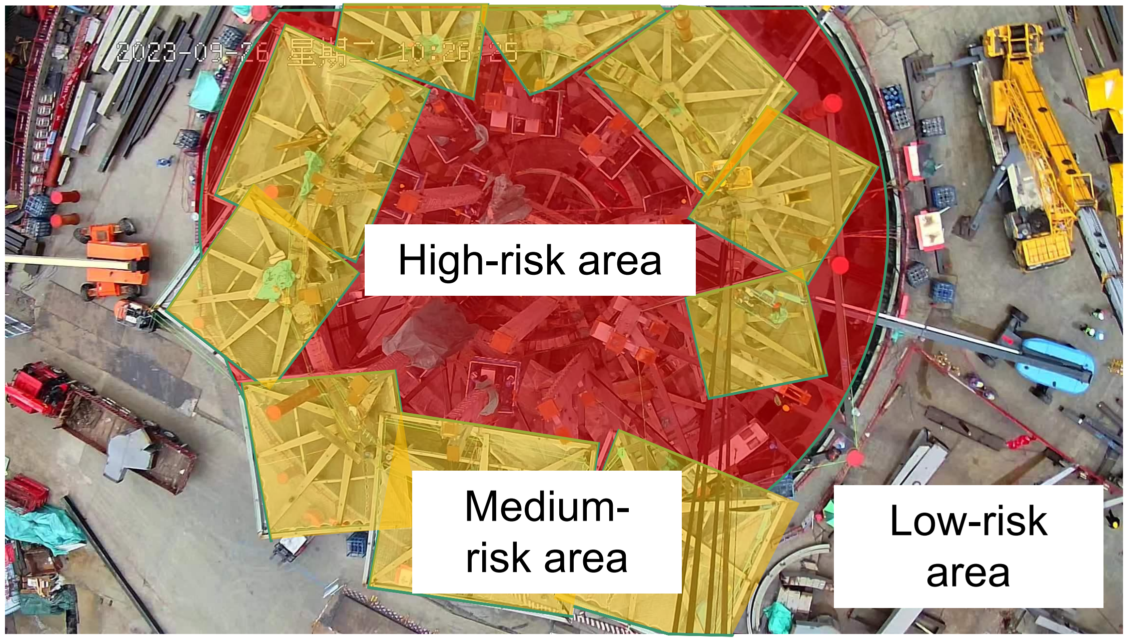
Safety Data Sources: On-site Multi-source Data Collection

Three Major On-site Data Sources:

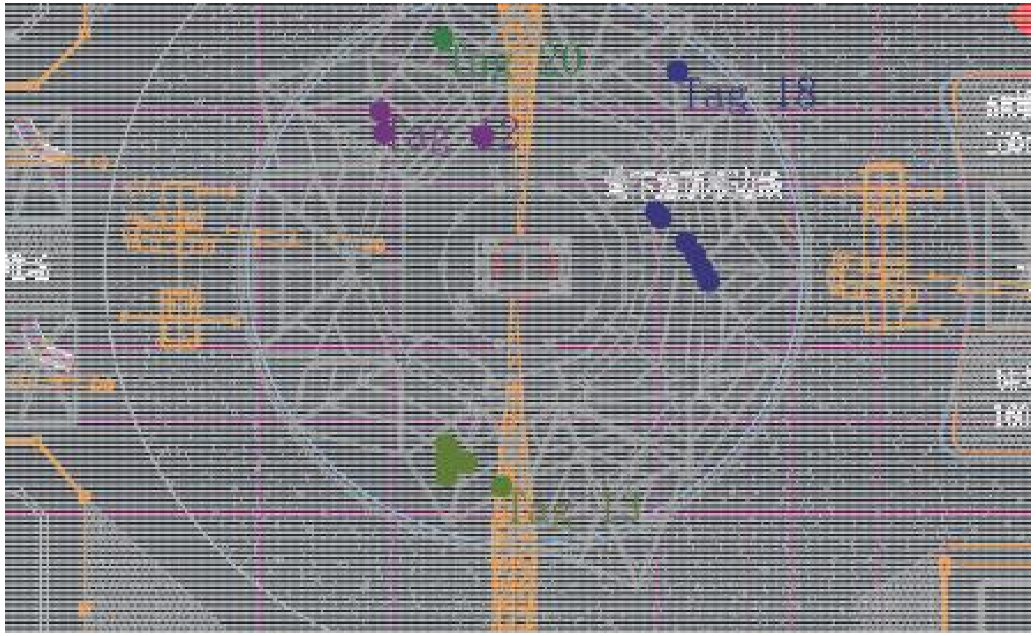
- **A total of 14 CCTV Cameras** are deployed, fully covering the middle-level work platforms and most ground areas.
- **UWB positioning base stations** are used for real-time positioning of various personnel, materials, and machinery elements.
- **RFID positioning** assists in identifying worker identities.
- **Crane sensor groups** are used to monitor the safety status of lifting operations.



Labor positioning and risk management: The worker positioning algorithm can identify the spatiotemporal risks of workers with high real-time and high accuracy, with a positioning accuracy of **20 cm,** an update frequency of **2 seconds**, and the ability to simultaneously locate **50 people.**



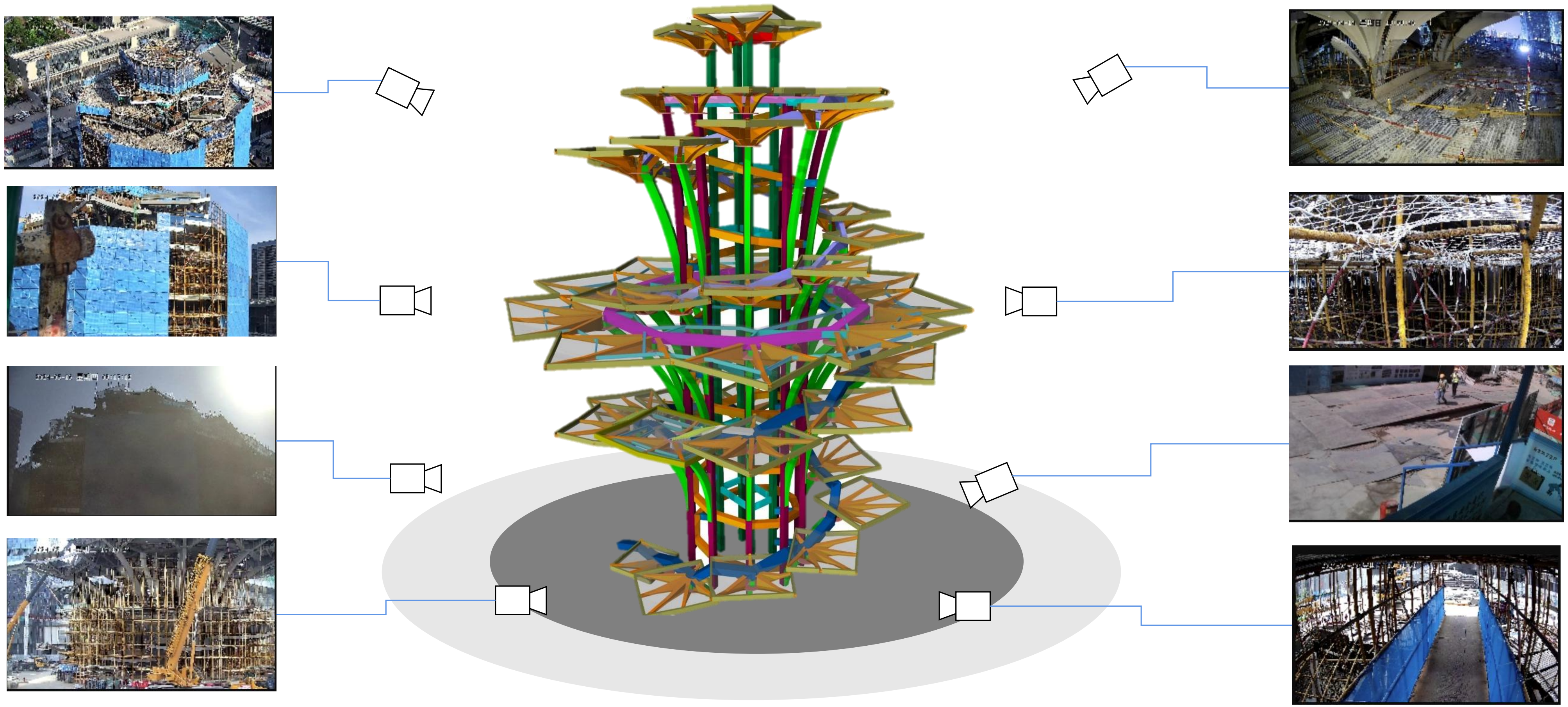
Dividing different risk areas



Real-time monitoring of the number of people in risk areas

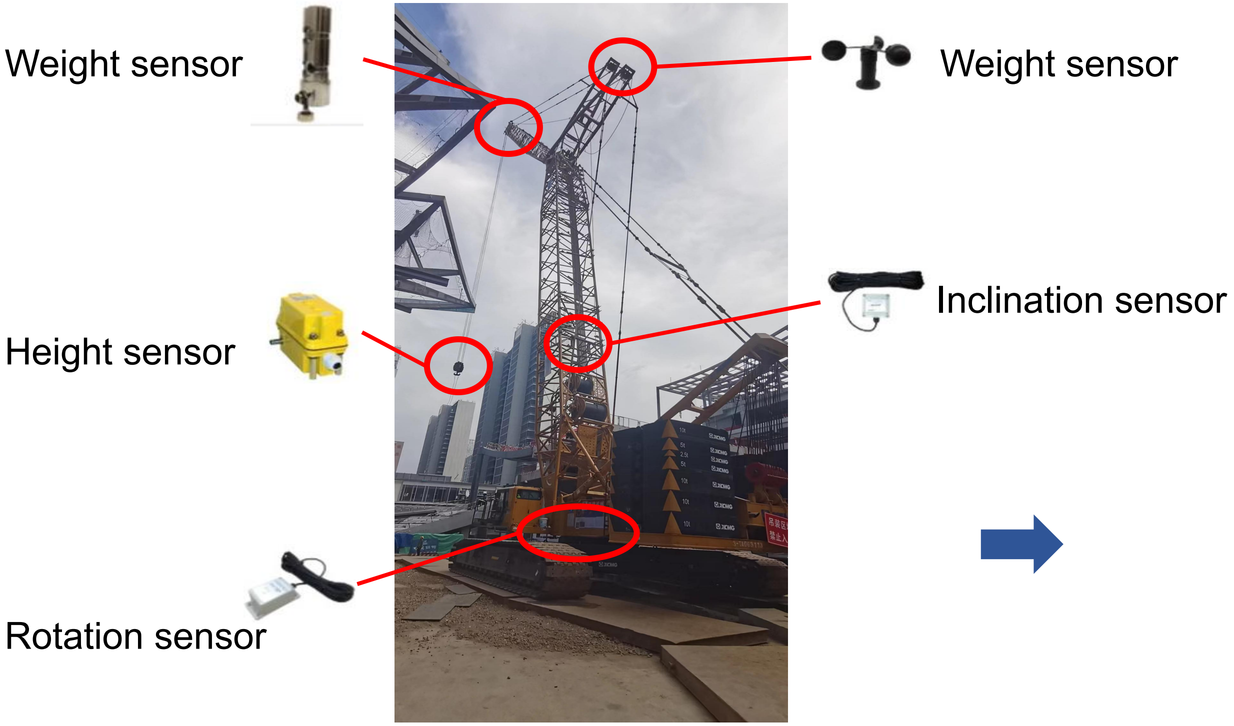
4. Applications and Conclusions

Unsafe behavior monitoring: Camera deployment on-site, with an **80% coverage rate in key areas.** It can identify two main types of unsafe behaviors—improper PPE wearing and dangerous actions. The **accuracy rate is 95%**, and it can scan up to **20 times per second**.

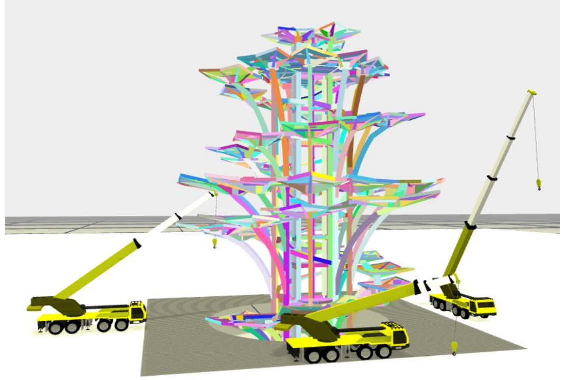


4. Applications and Conclusions

Mechanical state monitoring: The algorithm can accurately acquire the main operating parameters of on-site lifting machinery and identify unsafe operations. It provides round-the-clock monitoring with an **update frequency of 0.5 seconds** and is capable of simultaneously monitoring **4 mobile cranes**.



Digital Twin Platform



Crane Unsafe Condition Checklist

Unsafe Condition	Sensing Equipment	Sensing Method	Sensing Period
Unsafe Lifting	Wind Speed Sensor	Lifting in High Winds	During Crane Operation
	Weight Sensor	Overweight Lifting	
	Tilt Sensor	Inclined Lifting	

Unsafe environment monitoring: Multimodal large models can identify environmental risks in eight scenarios, including lifting operations, scaffolding, work at height, and fire safety.

Debris in escape passages

Ground debris

Missing hoardings

Missing warning lines

Smart monitoring detected missing edge protection during work at height. (17:03)

The aerial work platform in the image lacks edge protection. For high-altitude operations, the work platform must be equipped with complete edge protection measures to prevent workers from accidental falling from the platform.

Fine-tuned multi-modal large language model

On-site image

What non-compliant phenomena with safety standards exist in the high-altitude operation in the image?

Hazard analysis request

LCB Assessment and Improvement: Achieving an enhancement of LCB at all levels, resulting in a 51% decrease in safety hazards.

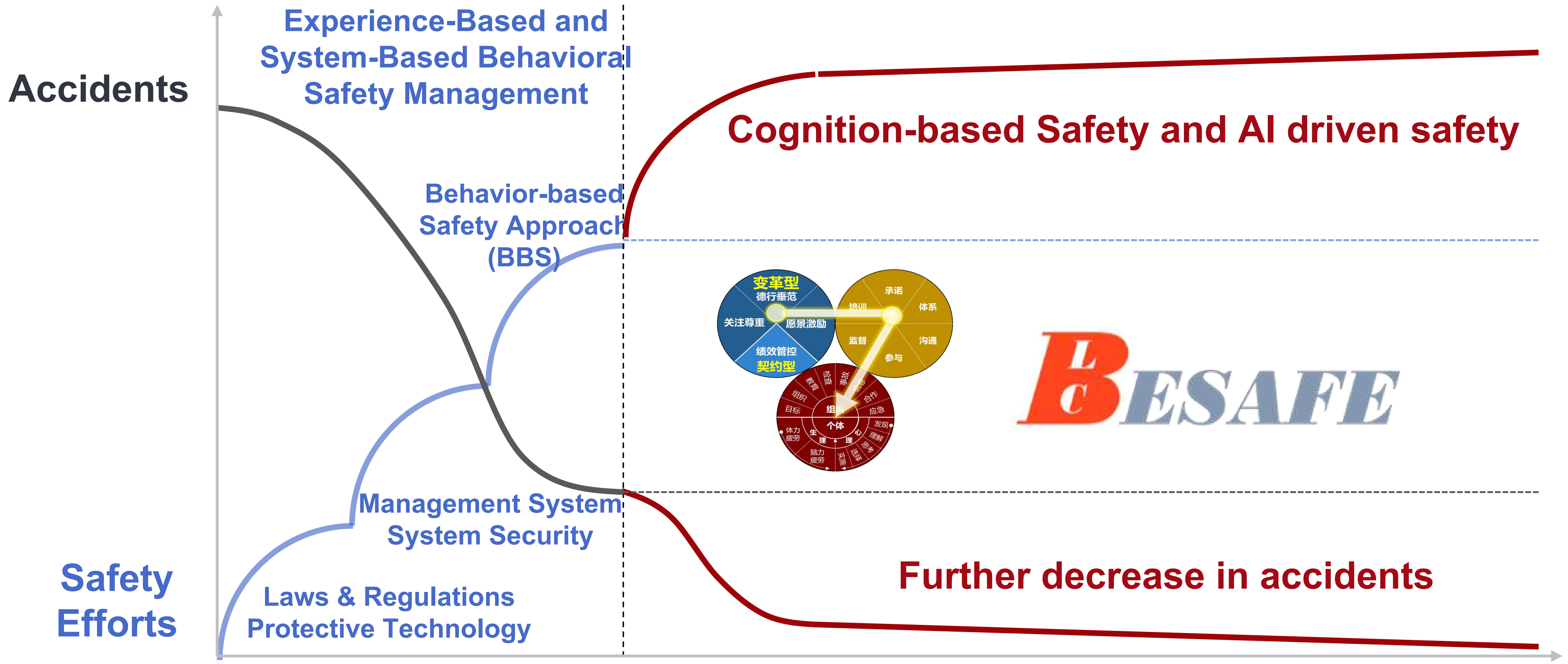
BESAFE AI Agents are now implemented in 2 airport projects:

BESAFE

Hefei Xinqiao Airport Project

Jinan Yaoqiang Airport Project

4. Applications and Conclusions



谢谢！ THANK YOU！

方东平 教授 Prof. Dongping Fang

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