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Development and application of smart construction objects and management system for an efficient and cost-effective safety management

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Supplementary Materials:

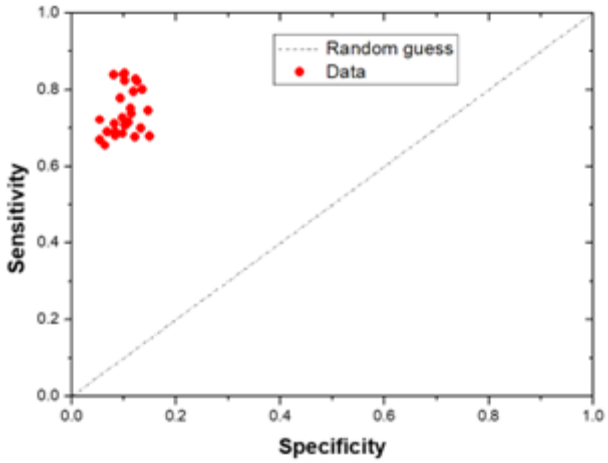


Figure S1. Image processing for the fire detection (b) Receiver operation characteristics.

Citation: Lee, J.; Shin, D.P.; Park, S.H.; Byon, C. Development and Application of Smart Construction Objects and Management System for an Efficient and Cost-Effective Safety Management. *Buildings* **2023**, *13*, 1383. https://doi.org/10.3390/buildings13061383

Academic Editor: Rafiq Muhammad Choudhry

Received: 7 April 2023
Revised: 13 May 2023
Accepted: 23 May 2023
Published: 26 May 2023

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Table S1. Structural stability test items and results.

Classification	Test method	Result (/criteria)	Decision
Real-time monitoring of on-site worker number	Monitored with 20 beacons (workers) for the workers in the tunnel	20/20	Passed
Number of controllable workers	Check the maximum distance per one tunnel information scanner (standard: 100m)	100 m /100 m	Passed
Communication stability	Converted into a statistical percentage after 100 measurements.	100%/99%	Passed
Accuracy in location monitoring	Using one tunnel information scanner and 10 beacons, check the accuracy of positioning the beacon	100%/99%	Passed
Success rate of reaching process safety management information	Test and check transmission/reception status using 1 tunnel scanner and mobile	Communication quality	Passed

Table S2. Overview of user interface for the smart construction system.

Classification	Menu items					
Monitoring		**Worker status**	**Worker location**	**Equipment inspection status**	**Status of inspection of vulnerable sites**	**Information of construction sites**
Sensing and analysis	Detection of worker location	Real-time location	Access control by zone			
	Sensing	Oxygen	CO_2	CO	Temperature/ humidity	Hydrogen sulfide
	Image analysis	Face recognition	Heart rate abnormality detection	Behavior recognition	Fire detection	
Management of resources	Worker	Dispatch management	Education management	Beacon allocation management	Employment status	Service status
	Equipment	Equipment registration management	Check before using NFC	Today's inspection result	Equipment status	
	Vulnerable site	Vulnerable site registration management	NFC daily inspection	Check payment	Safety checklist	Inspection record
	Nonconformity	Management of nonconforming registration	Vulnerable places incongruity	Equipment nonconformity	Inspection and action history	
Disaster management		SOS emergency bell	Individual report in case of disaster	Accident reporting system	Rapid report	Agency for emergency
Reporting management		Work start report	Work completion report	Complaint report	Disaster management resources	
Organization and HR management		Construction site management	Company management	User management		

Table S3. Comparison of implemented functions of various smart safety platforms (Rarely implemented: X; Implemented in part: △; Implemented with high degree: O).

	Ref. A		Ref. B		Ref. C		Present	
	PC	Mobile	PC	Mobile	PC	Mobile	PC	Mobile
Worker management	X	X	△	X	O	X	O	O
Risk evaluation	O	X	O	△	O	△	O	O
Change management	X	X	X	X	X	X	O	O
Heavy equipment management	△	X	△	X	△	X	O	O
Heavy equipment work plan	X	X	X	X	X	X	O	O
Permit to work (general)	X	X	X	X	X	X	O	O

Permit to work (important)	X	X	△	X	X	X	O	O
Danger daily inspection	O	X	△	X	O	X	O	O
Risk zone inspection	X	X	△	X	X	X	O	O
Risk zone access management	X	X	X	X	X	X	O	O
Work performance	△	X	△	X	△	X	O	O
Safety training (basic)	O	X	△	X	O	X	O	O
Safety training (special)	X	X	X	X	△	X	O	O
Tool box meeting	X	X	X	X	X	X	O	O
Non-conformity management	X	X	X	X	X	X	O	O
Dashboard	X	X	△	X	X	X	O	O
Notice	O	X	△	X	O	X	O	O
IoT device interworking	X	X	△	X	X	X	O	O