CONSIGLIO NAZIONALE
DEGLI INGEGNERI

ORDINE INGEGNERI CATANIA

SOSTENIBILITA', ETICA, APPROCCIO PRESTAZIONALE PER LA SICUREZZA E LA SALUTE NEI LUOGHI DI LAVORO.
IL CONTRIBUTO DEI PROFESSIONISTI:
PIU' INGEGNERIA, MENO BUROCRAZIA

CATANIA - Piazza Dante

Venerdì 7 ottobre 2022 - ore 8:30

Aula Magna Santo Mazzarino del Monastero dei Benedettini

LE SFIDE DELLA RICERCA PER LA GESTIONE DELLA SICUREZZA NEI CANTIERI

PROF. ING. NATALIA TRAPANI

Prima sessione 09:30 – 11:30
Novità e sviluppi futuri per la salute e la Sicurezza nei Cantieri
Moderatore: **Gaetano Fede**

La sicurezza nei cantieri: questione locale o globale?

ITALIA*	In complesso		Mortali	
Tutti i settori	448.245	8%	1.119	15%
Settore costruzioni	37.256		164	

*Infortuni sul lavoro avvenuti nel periodo 2021 e definiti al 30/04/2022 (INAIL, 2022)

Forza lavoro mondiale impiegata nell'edilizia

circa 7%

Vittime sul lavoro nel settore edile a livello mondiale

30-40% dei casi fatali

Evoluzione dei cantieri

IERI

OGGI

…in altre parti del mondo

https://www.cptcomo.org/sicurezza/foto-cantieri-2/

Evoluzione dei cantieri

Università di Catania

OGGI O DOMANI?

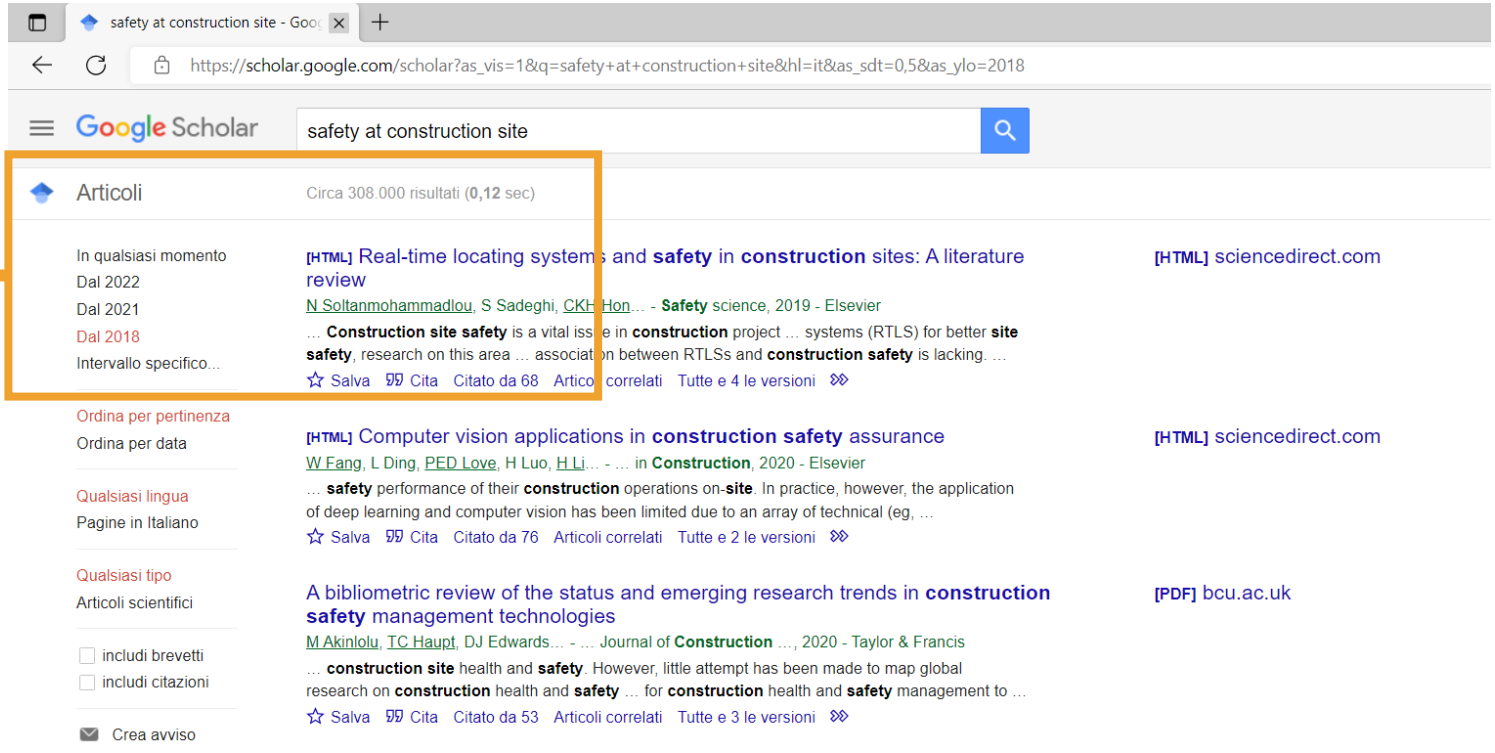
https://www.ip4fvg.it/quando-la-realta-aumentata-entra-nel-cantiere/

https://www.linde-mh.it/it/

© Andre van Delft

https://bim.acca.it/bim-e-sicurezza-in-cantiere/

La ricerca (bibliografica)



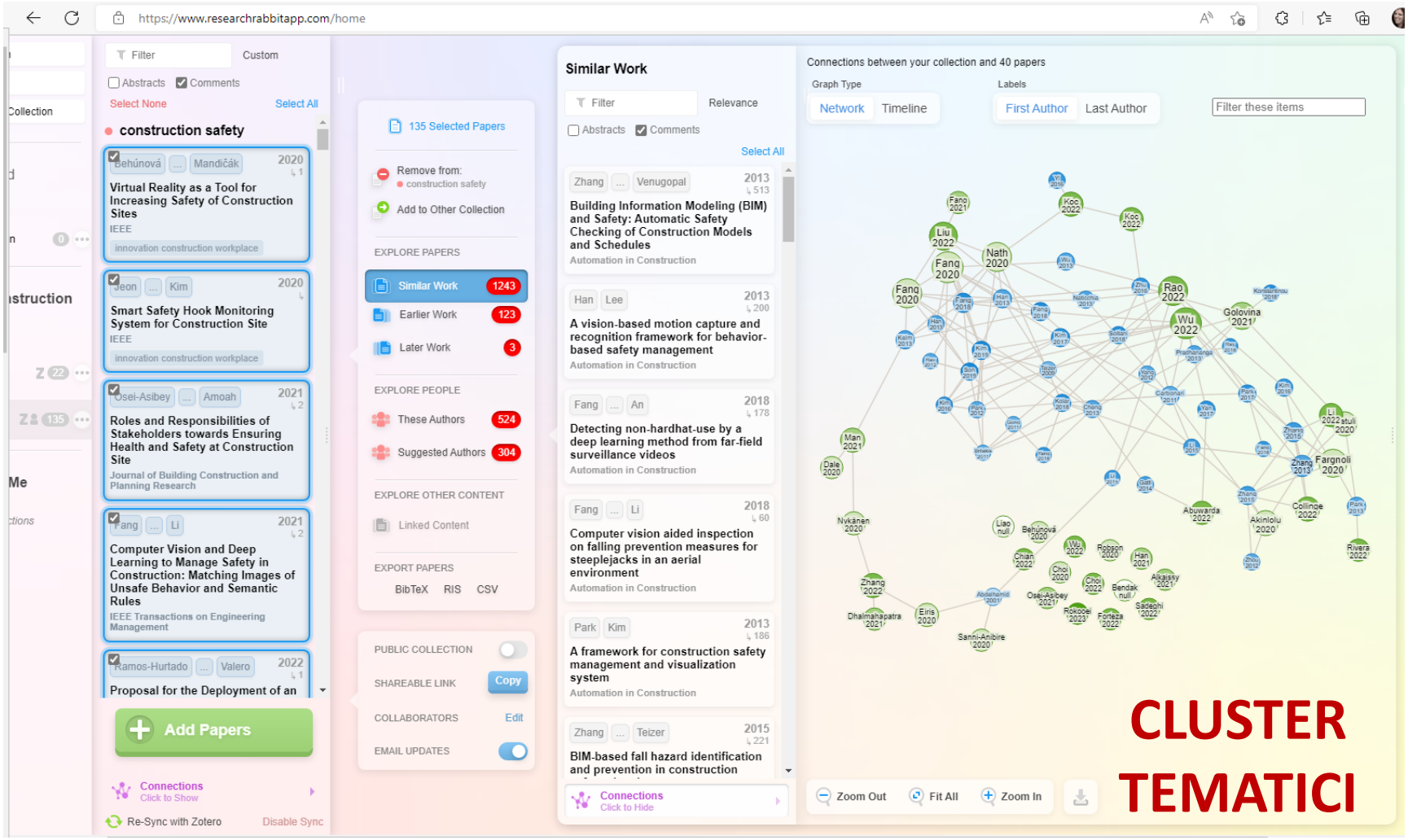
circa 308.000 risultati

dal 2018

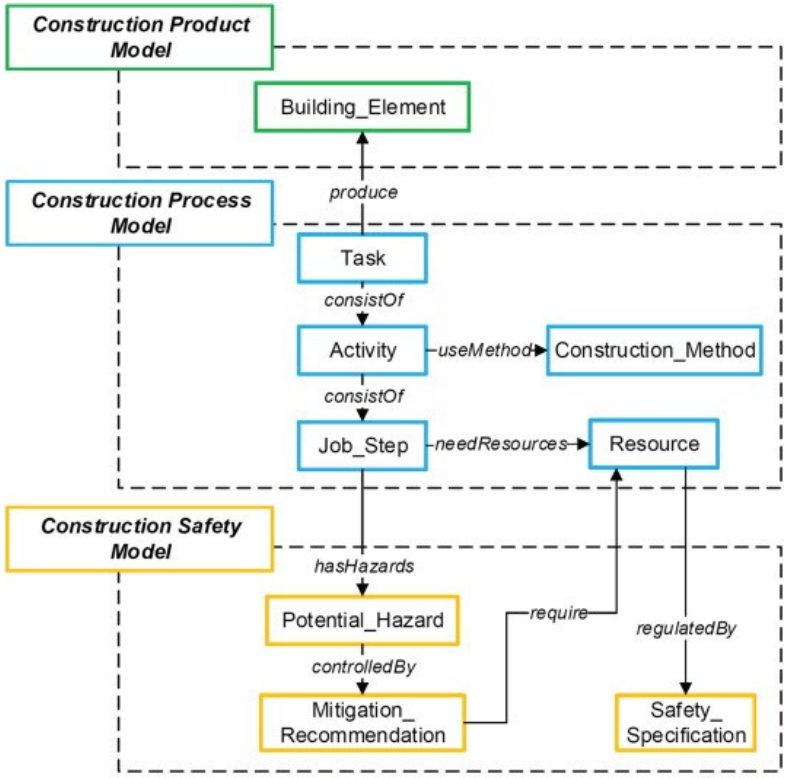
Journals

- Journal of Construction Engineering and Management
- Safety Science
- Automation in Construction
- Accident Analysis and Prevention
- Journal of Safety Research
- Journal of Management in Engineering
- Journal of Building Construction and Planning Research
- Journal of Occupational Health Psychology
- International Journal of Occupational Safety and Ergonomics
- Advanced Engineering Informatics
- …

La ricerca (bibliografica)

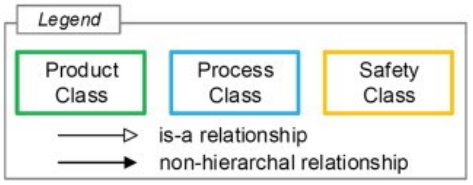


Cluster 1: Progettazione e tecnologie digitali

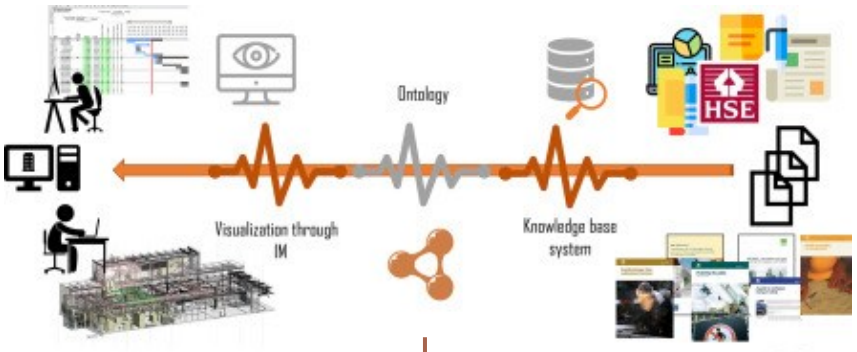


Construction Safety ontology

Zhang et al. (2015)



Non tutti i BIM forniscono suggerimenti sulla sicurezza o consentono una valutazione obiettiva dei livelli di rischio



Collinge et al. (2022)

Safety in Design (SiD)/Prevention through Design (PtD)

	Scenario Scenario 1: Floor with openings (150 < x < 3000)		Risk Fall: From open edge	Construction Scope In situ concrete
	Building Element Slab	Element Location High-Level: Near Opening	Associated Activity Install construction	Risk Factor Physical: Opening
	Eliminate	Reduce	Control by subsequent design	Inform
Preliminary Design	Replace all openings required in floor slabs with precast service openings.	Cast in mesh in openings to reduce risk of person falling through.	Group small floor openings together to create one large opening.	Engage Strucutral Engineer with Architects to assist in design of handrail and guard elements.
	Avoid holes - consider alternatives to achieve design purposes.	Reduce hole sizes.	Locate floor openings away from passageways, work areas, & structure perimeter.	Engage with contractors and temp. works at appointment.
Detail Design	Avoid low walls in circulation areas.	Avoid trap hazards near openings.	Design permanent grating in opening to be installed when opening is created during construction.	Identify covering strong enough to support any loads likely to be placed on it - fix in position to prevent accidental dislodgment.
	Avoid hidden alcoves and offsets.		Specify guardrail systems around floor openings except at the entrance to stairways.	
Pre construction	Avoid risk of objects falling from holes/openings on workers below.	Provide requisite guardrails and toe boards at all slab openings.	Provide warning markings and/or colour change.	Inform contractor to design-in permanent cast-in sockets around floor openings to enable early installation of railings.
			Provide protective grate to support weight of person over opening.	Identify safe working load (SWL) of temporary covers in slab floor and specify fixings.
			Use safety nests fixed directly below the opening.	
Site work, Temp works, Change control	Securely fix cover with adequate safe working load (SWL) over opening with fixings requiring tool.	Ensure work is carried out only when weather conditions do not jeopardise the health and safety of workers.	Provide safe lighting levels, including access and depression.	Inform Site team of any activities when covers or guardrails need to be removed.
	Impact protective measures regularly.		Consider indicating pathways and adding tie-offs.	Site team required to highlight and report any changes on iste affecting the design.
			Every temporary floor opening shall be constantly attended by someone.	Contractor should identify all remaining opening/edges and check the selected permanent safety measures.

Fig. 5. Risk scenario and associated treatment prompt matrix.

Cluster 1: Progettazione e tecnologie digitali

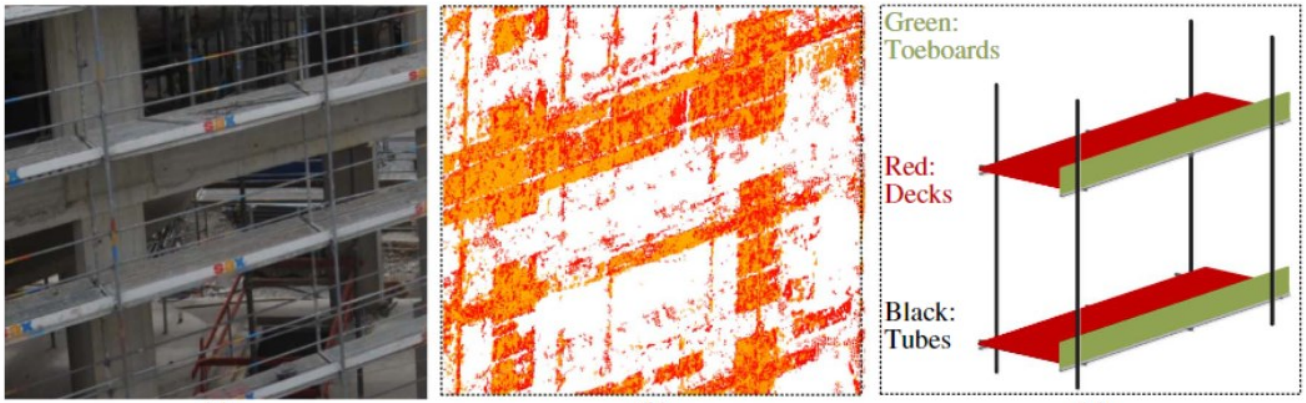


Fig. 1. (a) Image scene of scaffolds. (b) Photogrammetric point cloud generated. (c) Expected model of reconstruction.

Xu et al. (2022)

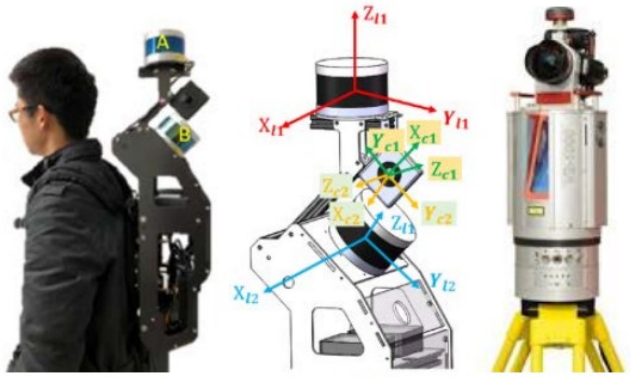


Figure 1. (a) The XBeibao II Multi-sensor system. (b) Multi-sensor coordinates system. (c) Riegl VZ-1000.

Droni (Rotary-wing):

- capacità di volo verticale, che facilita decolli e atterraggi
- capacità di volo stazionario, che consente di volare in spazi ristretti e attorno agli ostacoli

3D mapping and positioning of indoor environments. SLAM-based indoor mobile laser scanning systems (IMLS) (Wang et al., 2019)

Cluster 2: Sensori e sistemi di monitoraggio

Rao et al. (2022)

Real-time Construction Site Monitoring

Sensing construction environment

- **Mapping Sensors**
  - Laser scanners
  - RGB cameras
  - Depth cameras
  - Ground penetrating radar
  - Sensor integration
- **Positioning and Communication Sensors**
  - Tracking devices
  - Inertial Measurement Units
  - Global Navigation Satellite Systems
  - Short-range Communication technologies
  - Long-range Communication technologies
- **Sensor Platforms**
  - Stationary
  - Handheld
  - Equipment-mounted
  - Wearable
  - Trolley
  - Unmanned Ground Vehicles
  - Unmanned Aerial Vehicles

Real-time monitoring methodologies

- **Scene Understanding**
  - Classification
  - Object detection
  - Segmentation
- **Positioning Methods**
  - Proximity
  - Triangulation & trilateration
  - Fingerprinting
  - Dead reckoning
  - Visual positioning
- **Tracking Methods**
  - Active tracking
  - Passive tracking

Case studies of construction site monitoring

- Construction environments (static and dynamic)
- Monitoring workers (behaviour and physiology)
- Hazardous situations

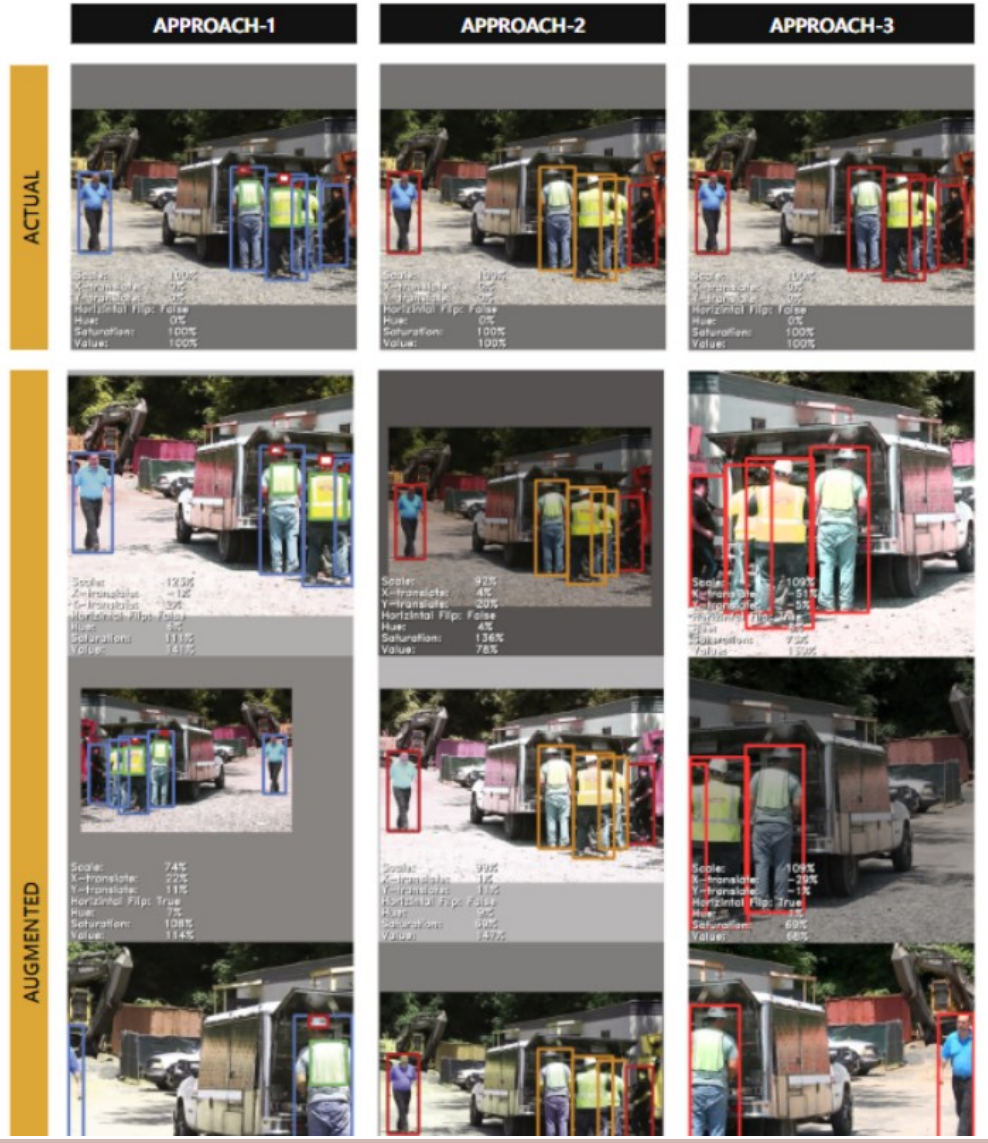
(Moselhi et al., 2020)

Type	Integrated RS System	Capabilities	Limitations	Refs.
Positioning systems integration with other sensory data	GPS + Barcode	(1) Relatively low cost (mainly goes for GPS receiver); barcode: Label ~ $0.1, Reader ~ $100–500 and GPS: Receiver ~ $200 Satellite signal free (2) High level of standardization and reliability (3) More scalable for projects of varying sizes (4) Straight forward implementation	(1) Need for free access to space for GPS system which makes it unsuitable for interior environment (2) Limitation of barcode tags in differentiating between items of the same kind (3) Not fully automated approach	[5,22,23]
	GPS + RFID	(1) Easier material identification due to non-line-of sight capability of the RFID tags (2) Providing both identification and localization data simultaneously	(1) The need for free access to space for GPS system (2) A large number of RFID readers are required which increases the cost; RFID Tag ~ $1–50 and RFID Reader ~ $1k–5k (3) Boundary constraint limitations in cluttered environments	[7,24]
	Sensor-aided GPS (SA-GPS)	(1) Stability to be used in various construction operations (2) Real-time tracking and reporting capabilities (3) Not sensitive to the ambient environment (4) Having both location/action recognition capabilities (5) Providing continuous update of the location estimates	(1) Obstacles associated with data fusion, coordination, processing, and reduction of data to produce meaningful conclusions (2) Requiring relatively more time for post processing (3) Drift inherent to sensors (4) Initialization and calibration difficulties	[26,44–47]
RFID integration with other sensory data	RFID + WSN	(1) Make it possible for tags to communicate with each other (2) Facilitating the negotiation of RFID readers together (3) Increased positioning accuracy (4) Decreased energy consumption in comparison with an individual WSN [1] system	(1) Sensor does not provide any power until tag is not in the radio frequency field to communicate with reader (2) Reading range decreases as the system starts using energy	[26,29,48,49]

Cluster 3: Internet of Things & Data Analytics

identificazione dei rischi, monitoraggio delle condizioni di salute e della sicurezza e le ispezioni, utilizzo di dispositivi di protezione individuale innovativi

- Computer vision
- Deep learning
- Transfer learning
- Image dataset
- Real-time object detection



(Moselhi et al., 2020)

Cluster 3: Internet of Things & Data Analytics

Smart PPE (= Personal Protective Equipment = DPI)

Table 1
Safety performance metrics for construction safety and health hazards.

	Construction site hazards		Metrics
	Safety hazards	Health hazards	
Physiological monitoring	Slips, trips, and falls from height.	Stress, heat, cold, strain injuries (carpal tunnel syndrome, back injuries), skin diseases (absorption), cuts (injection), breathing or respiratory diseases, toxic gases.	Heart rate, heart rate variability, respiratory rate, body posture, body speed, body acceleration, body rotation and orientation, angular velocity, blood oxygen, blood pressure, body temperature, activity level, calories burn, and walking steps.
Environmental sensing	Slips, trips, fire and explosions.	Chemicals (paints, asbestos, solvents, chlorine), molds, noise, heat, cold, radiation, vibration, toxic gases.	Ambient temperature, ambient pressure, humidity, noise level, light intensity, air quality.
Proximity detection	Caught-in or -between, Struck-by moving vehicle or equipment, electrocution.	Chemicals (paints, asbestos, solvents, chlorine), molds, noise, heat, cold, radiation, vibration, toxic gases.	Object detection, navigation, distance measurement, and proximity detection.
Location tracking	Caught-in or -between, struck-by, confined spaces, cave in, electrocution.	Hazardous chemicals (paints, asbestos, solvents, chlorine), molds, noise, heat, cold, radiation, vibration.	Worker location tracking, materials tracking, and vehicle/equipment location tracking.

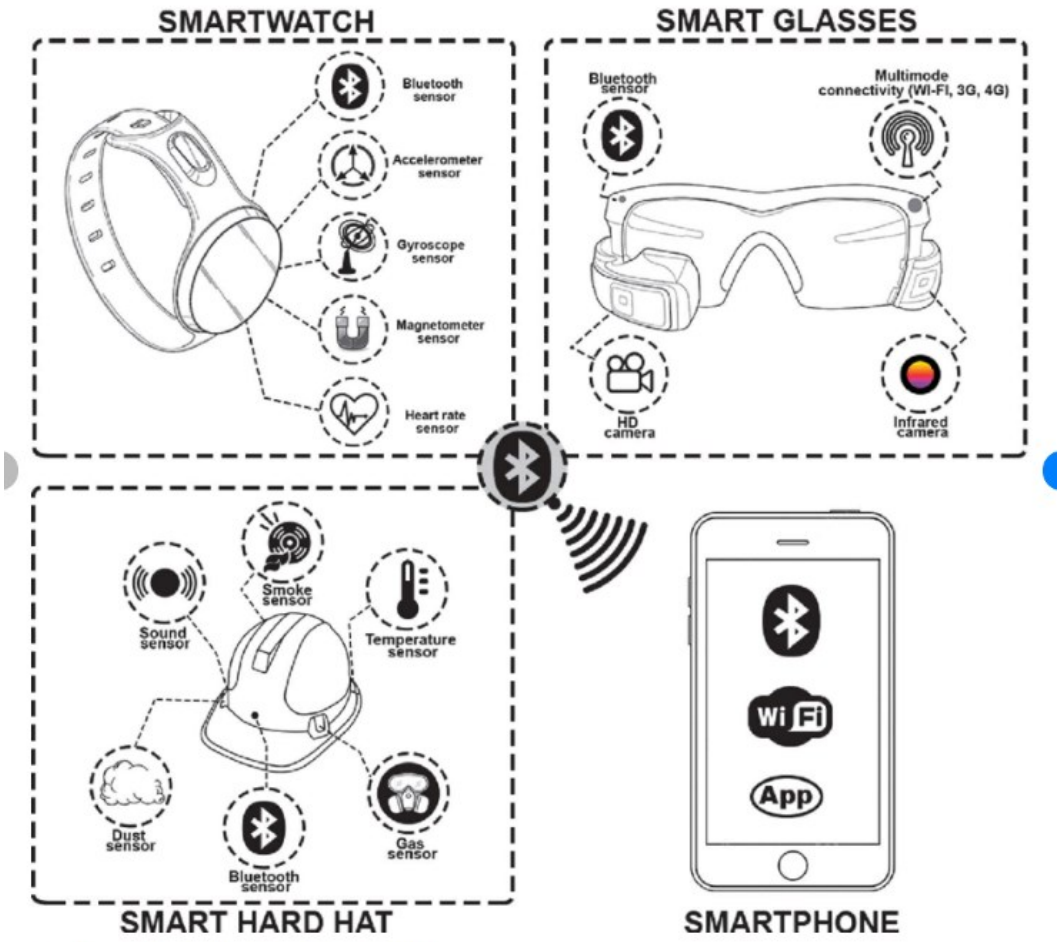
Table 2
Sensors and systems for monitoring common construction safety and health hazards.

Construction Site hazards	Metrics	Sensing technology
Falls from height	Body posture	Gyroscope, accelerometer, magnetometer
Slips and trips	Body posture, body speed, body rotation and orientation	Gyroscope, accelerometer
Stress	Heart rate, blood pressure, respiratory rate	ECG/EKG, infrared, radar
Heat or cold	Body temperature	Thermistor
Fire and explosions	Smoke and fire detection	Infrared
Noise	Noise level	Noise sensor
Caught-in or -between	Proximity detection	RFID, UWB, infrared, radar, Bluetooth
Struck-by object	Proximity detection, location tracking	RFID, UWB, infrared, radar, Bluetooth, GPS
Electrocution	Proximity detection, location tracking	RFID, infrared, radar, Bluetooth, GPS, RFID, UWB
Cave in	Location tracking	GPS, RFID, UWB

(Awolusi et al., 2018)

Cluster 3: Internet of Things & Data Analytics

Smart PPE (= Personal Protective Equipment)



Smart technology and sensor upgrades in PPE

Although such new technologies promise greater safety and comfort for workers, there are still many obstacles that need to be overcome to ensure their successful use https://osha.europa.eu/en/publications/smart-personal-protective-equipment-intelligent-protection-future

(Adjiski et al., 2019)

Cluster 4: Robot

Utilizzo di robot nelle costruzioni:

- sostituire i lavoratori nella gestione di carichi pesanti
- evitare il ricorso a lavoratori in ambienti pericolosi (es. gallerie, spazi confinati)
- Rilevare posture adottate dal lavoratore e guidarlo nelle azioni tramite esoskeleton

(Li & Ng, 2017)

Programma Nazionale per la Ricerca 2021-2027 GRANDI AMBITI DI RICERCA E INNOVAZIONE

Articolazione 4. Robotica per la salute e sicurezza 4.0 (TRL >3)

Priorità di ricerca: …Sistemi robotici per la salute, la sicurezza e il benessere lavorativo.

Impatto atteso: EU2: Riduzione del rischio di malattie professionali e infortuni sul lavoro;

TRL: Tecnology Readiness Level (TRL = 4 Validazione in laboratorio del concetto)

Cluster 5: Safety Climate & Perfomance

Dimension	Description
Management commitment to safety	Refers to how effective top management members are in ensuring that safety is a priority in their organization
Supervisory safety response	Refers to how responsible first-line leaders are regarding the implementation of organizational safety procedures during day-to-day activities
Safety rules and procedures	Refers to the degree to which workers believe and follow their organization's safety rules and procedures to prevent accidents/incidents
Communication	Refers to how members of both top management and front line workers communicate health and safety issues, and how openly managers receive feedback from workers about their safety and health concerns
Worker involvement	Refers to the degree to which workers receive encouragement from the upper management to participate in safety procedures and the extent to which they are invited to be a part of policy creation
Training	Refers to the amount of safety education and instruction that workers receive during their work
Risk-taking behavior	Refers to the degree of risk that workers are willing to take to complete tasks while violating safety regulations in the organization
Workload pressure	Refers to the amount of work that lead workers to perform work unsafely

impatto sulle safety performance dei lavoratori

(Alruqi et al., 2018)

CONSIGLIO NAZIONALE
DEGLI INGEGNERI

Università
di Catania

La vera sfida è…

…la collaborazione tra imprese, professionisti, organismi di controllo e università

LE SFIDE DELLA RICERCA PER LA GESTIONE DELLA SICUREZZA NEI CANTIERI

PROF. ING. NATALIA TRAPANI

Prima sessione 09:30 – 11:30
Novità e sviluppi futuri per la salute e la Sicurezza nei Cantieri
Moderatore: **Gaetano Fede**

Bibliografia

Collinge, W.H., Farghaly, K., Mosleh, M.H., Manu, P., Cheung, C.M., Osorio-Sandoval, C.A. (2022) BIM-based construction safety risk library, Automation in Construction, 141, 104391 https://doi.org/10.1016/j.autcon.2022.104391

S. Zhang, F. Boukamp, J. Teizer (2015) Ontology-based semantic modeling of construction safety knowledge: towards automated safety planning for job hazard analysis (JHA), Automation in Construction, 52, pp. 29-41 https://doi.org/10.1016/j.autcon.2015.02.005

Z. Jin, J. Gambatese, D. Liu, V. Dharmapalan (2019) Using 4D BIM to assess construction risks during the design phase, Eng. Constr. Archit. Manag. 26 (11), 2637–2654 https://doi.org/10.1108/ECAM-09-2018-0379

Rao, A.S.; Radanovic, M.; Liu, Y.G.; Hu, S.; Fang, Y.; Khoshelham, K.; Palaniswami, M.; Ngo, T. (2022) Real-time monitoring of construction sites: Sensors, methods, and applications. Automation in Construction, 136, 104099. https://doi.org/10.1016/j.autcon.2021.104099

Y. Xu, S. Tuttas, L. Hoegner, U. Stilla (2018) Reconstruction of scaffolds from a photogrammetric point cloud of construction sites using a novel 3D local feature descriptor, Auto. Construct., 85 (2018), pp. 76-95 https://doi.org/ 10.1016/j.autcon.2017.09.014

Bibliografia

O. Moselhi, H. Bardareh, Z. Zhu (2020) Automated data acquisition in construction with remote sensing technologies, Applied Science, 10 (8), p. 2846 https://doi.org/10.3390/app10082846

Li, R.Y.M., Ng, D.P.L. (2018). Wearable Robotics, Industrial Robots and Construction Worker's Safety and Health. In: Chen, J. (eds) Advances in Human Factors in Robots and Unmanned Systems. AHFE 2017. Advances in Intelligent Systems and Computing, vol 595. Springer, Cham. https://doi.org/10.1007/978-3-319-60384-1_4

I. Awolusi, E. Marks, M. Hallowell (2018) Wearable technology for personalized construction safety monitoring and trending: review of applicable devices Autom. Constr., 85 (2018), pp. 96-106, 10.1016/j.autcon.2017.10.010

Adjiski, V., Despodov, Z., Mirakovski, D. i Serafimovski, D. (2019). SYSTEM ARCHITECTURE TO BRING SMART PERSONAL PROTECTIVE EQUIPMENT WEARABLES AND SENSORS TO TRANSFORM SAFETY AT WORK IN THE UNDERGROUND MINING INDUSTRY. Rudarsko-geološko-naftni zbornik, 34 (1), 37-44. https://doi.org/10.17794/rgn.2019.1.4

W.M. Alruqi, M.R. Hallowell, U. TecheraSafety climate dimensions and their relationship to construction safety performance: a meta-analytic review. Saf Sci, 109 (2018), pp. 166-173, 10.1016/j.ssci.2018.05.019