

Supplementary Material

Table S1. Summarized literature review characteristics of the 51 included papers reporting BIM applications in occupational health and safety.

Literature Source	Country	Building Type	Data Sources	Hazards	Solution Type	Building Model	Linked Technologies	Phases	Users of Solution	Beneficiaries of Solution	Facilitating factors for adoption	Barriers
Alizadehsalehi et al. (2020).	Turkey, USA	Not specified	Experience, Safety Guidelines & Industry Reports, Measurements	Not specified	Site Layout & Task Planning Real-Time Monitoring	4D BIM	Drones	Construction Planning, Construction Execution	Designer, construction manager, safety manager	Construction workers	Integrated project team structures	Increased upfront resource needs Technological immaturity Regulatory boundaries
Arslan, et al. 2019	France	Not specified	Measurements	Intrusions & Near-Misses	Site Layout & Task Planning Real-Time Monitoring	3D BIM	Bluetooth Beacons	Construction Planning, Construction Execution	Safety manager, construction manager	Construction workers	N/A	N/A
Arslan, et al 2019b	France	Not specified	Measurements	Intrusions & Near-Misses	Real-Time Monitoring	3D BIM	Bluetooth Beacons	Construction Execution	Safety manager, construction manager	Construction workers	N/A	Isolated use cases Static information in BIM
Arslan, et al. 2014	Pakistan, USA	Not specified	Measurements	Health Damages	Real-Time Monitoring	3D BIM	IoT Sensors	Construction Execution	Safety manager, construction manager	Construction workers	High degree of software interoperability Use of established BIM software	Limited user-friendliness
Brosque et al. 2021	USA, Norway	Commercial	Others	Health Damages	Task Performance by Robots	3D BIM	Robots	Design, Construction Planning, Construction Execution	Robotic start-up, construction manager, subcontractor	Construction workers	Extension of BIM use cases Innovation mindset	Resistance to change Need for organizational changes Increased upfront resource needs High quality

Requirements for BIM												requirements for BIM
Author	Country	Project Type	Source of Information	Information Type	Application	BIM Level	Other Technologies	Application Phase	Responsible Party	Target Group	Other Factors	Findings
Choe and Leite, 2017	Korea, USA	Commercial	Experience Historical Data	Not specified	Site Layout & Task Planning	4D BIM	-	Construction Planning, Construction Execution	Safety manager	Construction workers		Static information in BIM Lack of technical skills
Cortés-Pérez et al. 2020	Spain	Not specified	Safety Guidelines & Industry Reports	Not specified	Site Layout & Task Planning	3D BIM	-	Construction Planning	Safety manager	Construction workers	Use of established BIM software Use of established standards Regulatory obligations	Lack of technical skills
Costin et al. 2015	USA	Other (hospital)	Measurements	Intrusions & Near-Misses	Real-Time Monitoring	3D BIM	RFID	Construction Execution	Safety manager	Construction workers	N/A	Integrity concerns
Deng et al. 2019	China	Residential	Experience	Falling Struck-By	Design for Safety Safety Training Site Layout & Task Planning	4D BIM	-	Construction Planning	Safety manager	Construction workers	High degree of software interoperability	N/A
Ding et al. 2016	China, UK	Commercial	Historical Data	Not specified	Safety Training Site Layout & Task Planning	4D BIM	-	Construction Planning, Construction Execution	Safety manager	Construction workers	N/A	Lack of technical skills Human intervention needed for quality assurance

Fang et al. 2016	USA	Commercial	Measurements	Intrusions & Near-Misses	Real-Time Monitoring	3D BIM	RFID	Construction Execution	Safety manager	Construction workers	Complementary IT infrastructure	Technological immaturity, Need for complementary infrastructure
Getuli et al. 2020a	Italy	Commercial	Worker Characteristics Others	Not specified	Safety Training Site Layout & Task Planning	4D BIM	Virtual Reality	Construction Planning	Construction manager, safety manager	Construction workers	High user-friendliness Low implementation costs Accessibility of technology	Lack of technical skills Lack of evaluation metrics
Getuli et al. 2020b	Italy, Israel	Commercial	Experience Worker Characteristics Others	Not specified	Safety Training Site Layout & Task Planning	4D BIM	Virtual Reality	Construction Planning	Construction manager, safety manager	Construction workers	High user-friendliness	Lack of technical skills Limited transferability of training situations to real world
Golovina et al. 2016	Germany, USA	Not specified	Measurements	Struck-By Intrusions & Near-Misses	Site Layout & Task Planning	3D BIM	GPS	Construction Planning, Construction Execution	Safety manager	Construction workers	N/A	Technological immaturity Static information in BIM
Hossain et al. 2018	Singapore	Commercial	Experience	Not specified	Design for Safety Site Layout & Task Planning	4D BIM	-	Design, Construction Planning, Construction Execution, Operation	Designer, safety manager	Construction workers, maintenance workers	N/A	N/A
Jin et al 2017	China, USA, Canada	Not specified	Safety Guidelines & Industry Reports Historical Data	Falling Caught-In/Between Situations	Equipment & Temporary Structures	3D BIM	-	Construction Planning	Designer, safety manager	Construction workers	N/A	N/A
Jin et al. 2019	USA	Other (kindergarten)	Experience	Not specified	Design for Safety	4D BIM	-	Design, Construction Planning	Designer, engineer, construction manager	Construction workers	Integrated project team structures	Limited scope of hazard recognition

Khan et al. 2020	Korea	Commercial	Safety Guidelines & Industry Reports	Fires & Explosions	Learning & Documentatio n Site Layout & Task Planning	3D BIM	Blockchain	Constructio n Planning, Constructio n Execution	Safety manager	Construction workers, safety inspector	N/A	N/A
Kim et al. 2015	Korea	Residential	Historical Data	Not specified	Learning & Documentatio n Site Layout & Task Planning	3D BIM	-	Constructio n Planning, Constructio n Execution	Safety manager	Construction workers	High degree of software interoperability	High degree of manual work Limited scope of hazard recognition
Kim, et al. 2016	USA, Korea	Other (university)	Measurements Others	Intrusions & Near- Misses	Site Layout & Task Planning	4D BIM	RFID	Constructio n Planning, Constructio n Execution	Safety manager	Construction workers	N/A	Lack of evaluation metrics Technological immaturity
Kim et al. 2020	Korea	Commercial	Safety Guidelines & Industry Reports Historical Data	Falling	Site Layout & Task Planning	3D BIM	-	Design, Constructio n Planning	Architect, safety manager	Construction workers	Use of other technologies to overcome BIM- inherent limitations	Limited input data Lack of evaluation metrics Static information in BIM
Kim et al. 2015	USA, Korea	Other (water park, fabrication facility), residential (multifamily house)	Others	Falling Caught- In/Betwee n Situations	Equipment & Temporary Structures	4D BIM	-	Constructio n Planning	Designer, safety manager	Construction workers	N/A	N/A
Kim et al. 2016	USA	Commercial	Experience	Falling Caught- In/Betwee n Situations	Equipment & Temporary Structures	4D BIM	-	Constructio n Planning	Safety manager, construction manager	Construction workers, safety inspector	N/A	High degree of manual work Limited scope of hazard recognition Isolated use cases Limited input data

Kim and Teizer, 2014	USA	Other (hospital)	Experience Safety Guidelines & Industry Reports	Falling Caught-In/Between Situations	Equipment & Temporary Structures	4D BIM	-	Construction Planning	Architect, engineer, construction manager	Construction workers	Use of other technologies to overcome BIM-inherent limitations	Static information in BIM Limited scope of hazard recognition Limited input data
Lee et al. 2019	China, Taiwan	Residential	Experience Academic Literature	Not specified	Equipment & Temporary Structures	3D BIM	-	Construction Planning	Safety manager	Construction workers	N/A	N/A
Lee et al. 2020	Korea	Not specified	Safety Guidelines & Industry Reports Academic Literature	Falling Struck-By Caught-In/Between Situations	Site Layout & Task Planning	3D BIM	-	Design	Designer	Construction workers	N/A	Regulatory boundaries Limited input data Lack of evaluation metrics
Li et al. 2015	Hong Kong, Australia	Residential	Experience Historical Data Measurements	Falling Struck-By	Safety Training Real-Time Monitoring	3D BIM	-	Construction Execution	Safety manager	Construction workers, maintenance workers	N/A	Limited scope of hazard recognition
Liu et al. 2020	USA	Residential	Safety Guidelines & Industry Reports Measurements	Falling	Site Layout & Task Planning Real-Time Monitoring	3D BIM	Indoor Positioning System	Construction Execution	Safety manager	Construction workers	N/A	N/A
Liu et al. 2020	China	Others (stadium)	Measurements	Caught-In/Between Situations Intrusions & Near-Misses Fires & Explosions	Real-Time Monitoring	3D BIM	IoT Sensors	Operation	Safety manager	Building occupants	Extension of BIM use cases	N/A

Melzner et al. 2013	Germany , USA	Commercial	Safety Guidelines & Industry Reports	Falling	Equipment & Temporary Structures	3D BIM	-	Constructio n Planning	Safety manager	Construction workers	N/A	High degree of manual work Static information in BIM Limited scope of hazard recognition
Mirahadi et al. 2013	Canada	Commercial	Safety Guidelines & Industry Reports	Fires & Explosions	Design for Safety	3D BIM	-	Design	Designer	Building occupants, maintenance workers	High degree of software interoperability	N/A
Park et al. 2013	Korea	Commercial	Safety Guidelines & Industry Reports Historical Data Others	Not specified	Learning & Documentation Safety Training Site Layout & Task Planning Real-Time Monitoring	3D BIM	RFID, Augmented Reality	Constructio n Planning, Constructio n Execution	Safety manager	Construction workers	High user-friendliness High degree of software interoperability	Lack of technical skills Limited depth of hazard recognition Technological immaturity
Park et al. 2017	USA	Not specified	Experience Measurements	Intrusions & Near-Misses	Real-Time Monitoring	3D BIM	Bluetooth Beacons	Constructio n Execution	Construction manager	Construction workers	N/A	N/A
Pham et al. 2020	Korea	Residential	Safety Guidelines & Industry Reports	Falling	Site Layout & Task Planning	4D BIM	-	Constructio n Planning	Safety manager, construction manager	Construction workers	N/A	Human intervention needed for quality assurance, Limited input data, Regulatory boundaries, Limited depth of hazard recognition
Qi et al. 2014	USA	Not specified	Experience	Falling	Design for Safety	3D BIM	-	Design, Constructio n Planning	Designer	Construction workers	N/A	Limited depth of hazard recognition

Riaz et al. 2014	Pakistan, USA	Not specified	Safety Guidelines & Industry Reports Academic Literature	Caught-In/Between Situations	Real-Time Monitoring	3D BIM	IoT Sensors	Construction Execution, Operation	Safety manager, construction manager	Construction workers	Complementary IT infrastructure	Increased upfront resource needs Lack of technical skills Need for complementary infrastructure Resistance to change Technological immaturity
Shen et al. 2016	USA	Others (university building)	Historical Data	Intrusions & Near-Misses	Learning & Documentation	3D BIM	-	Construction Execution	Safety manager	Construction workers	N/A	Limited input data High degree of manual work
Sun and Turkan, 2020	USA	Other (night club)	Historical Data	Fires & Explosions	Design for Safety	3D BIM	-	Design	Architect	Building occupants	Access to as-built drawings and usage characteristics	Technological immaturity
Wang et al. 2015	USA, Germany	Not specified	Experience Safety Guidelines & Industry Reports Measurements	Struck-By Caught-In/Between Situations	Site Layout & Task Planning Equipment & Temporary Structures	3D BIM	Point Cloud Scanning	Construction Planning	Construction manager, safety manager, subcontractor	Construction workers	N/A	N/A
Wang et al. 2015	Taiwan	Others (research institute)	Safety Guidelines & Industry Reports	Fires & Explosions	Design for Safety Safety Training Site Layout & Task Planning Equipment & Temporary Structures	3D BIM	-	Design, Operation	Designer, facility manager	Maintenance workers	N/A	N/A
Wetzel and Thabet, 2016	USA	Not specified	Experience Safety Guidelines & Industry Reports	Not specified	Learning & Documentation	3D BIM	-	Operation	Facility manager	Maintenance workers	N/A	N/A

Academic Literature												
Wetzel and Thabet, 2015	USA	Not specified	Experience	Not specified	Learning & Documentation	3D BIM	-	Operation	Facility manager	Maintenance workers	N/A	N/A
Wetzel and Thabet, 2018	USA	Not specified	Experience	Falling Struck-By Health Damages	Learning & Documentation	3D BIM	-	Design, Construction Execution, Operation	Construction manager	Maintenance workers	Use of established BIM software	High degree of manual work
Yi et al 2014	China, Spain	Not specified	Others	Not specified	Site Layout & Task Planning	4D BIM	-	Construction Planning	Safety manager	Construction workers	N/A	N/A
Yuan et al 2019	China, USA	Not specified	Academic literature	Not specified	Design for Safety Learning & Documentation	4D BIM	-	Design	Designer, architect, engineer	Construction workers	N/A	N/A
Zhang et al. 2015	USA, Australia, Germany	Not specified	Experience	Not specified	Learning & Documentation	Not specified	-	Construction Planning	Safety manager	Construction workers	N/A	N/A
Zhang et al. 2015	USA, Finland, Germany	Office, residential	Experience Safety Guidelines & Industry Reports	Falling	Site Layout & Task Planning	4D BIM	-	Construction Planning, Construction Execution	Safety manager, construction manager	Construction workers	N/A	High quality requirements for BIM Human intervention needed for quality assurance
Zhang et al. 2013	USA, Korea	Not specified	Experience Safety Guidelines &	Falling	Site Layout & Task Planning	4D BIM	-	Construction Planning, Construction Execution	Engineer, construction manager,	Construction workers	N/A	N/A

Author	Country	Project Type	Data Source		Data Type			Application	Participants				Limitations
			Industry Reports	Other	Experience	Not specified	Task Planning		Architect	Construction workers	Integrated project team structures, complementary IT infrastructure		
Tran et al. 2021	Korea	Other (school)	Experience Historical Data	Not specified	Site Layout & Task Planning	4D BIM	-	Construction Planning	Architect, engineer, construction manager, subcontractor, supplier	Construction workers	Integrated project team structures, complementary IT infrastructure	Limited scope of hazard recognition Static information in BIM	
Lu et al. 2021	China	Residential	Historical Data	Not specified	Design for Safety	3D BIM	-	Design	Architect, engineer	Construction workers	Integrated project team structures	Limited depth of hazard recognition	
Liu et al. 2021	China	Commercial	Experience, Measurements, Academic Literature	Struck-By	Real-Time Monitoring	3D BIM	IoT Sensors	Construction Execution	Construction manager	Construction workers	N/A	Limited input data Human intervention needed for quality assurance	