Trends and Limitations of Current Construction Safety Technologies

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CITC GLOBAL
Construction in the 21st Century

Introduction

The application of new technologies continues to grow in the architecture, engineering, and construction (AEC) industry.

One of the applications of new technologies is to improve construction safety.

The main goal is to provide an additional layer of hazard identification and avoidance at all project phases, from design to construction.

Introduction

- The AEC industry faces numerous obstacles to achieve goals such as reducing costs, increasing productivity and safety, to achieve such goals, ‘innovations’—are needed.

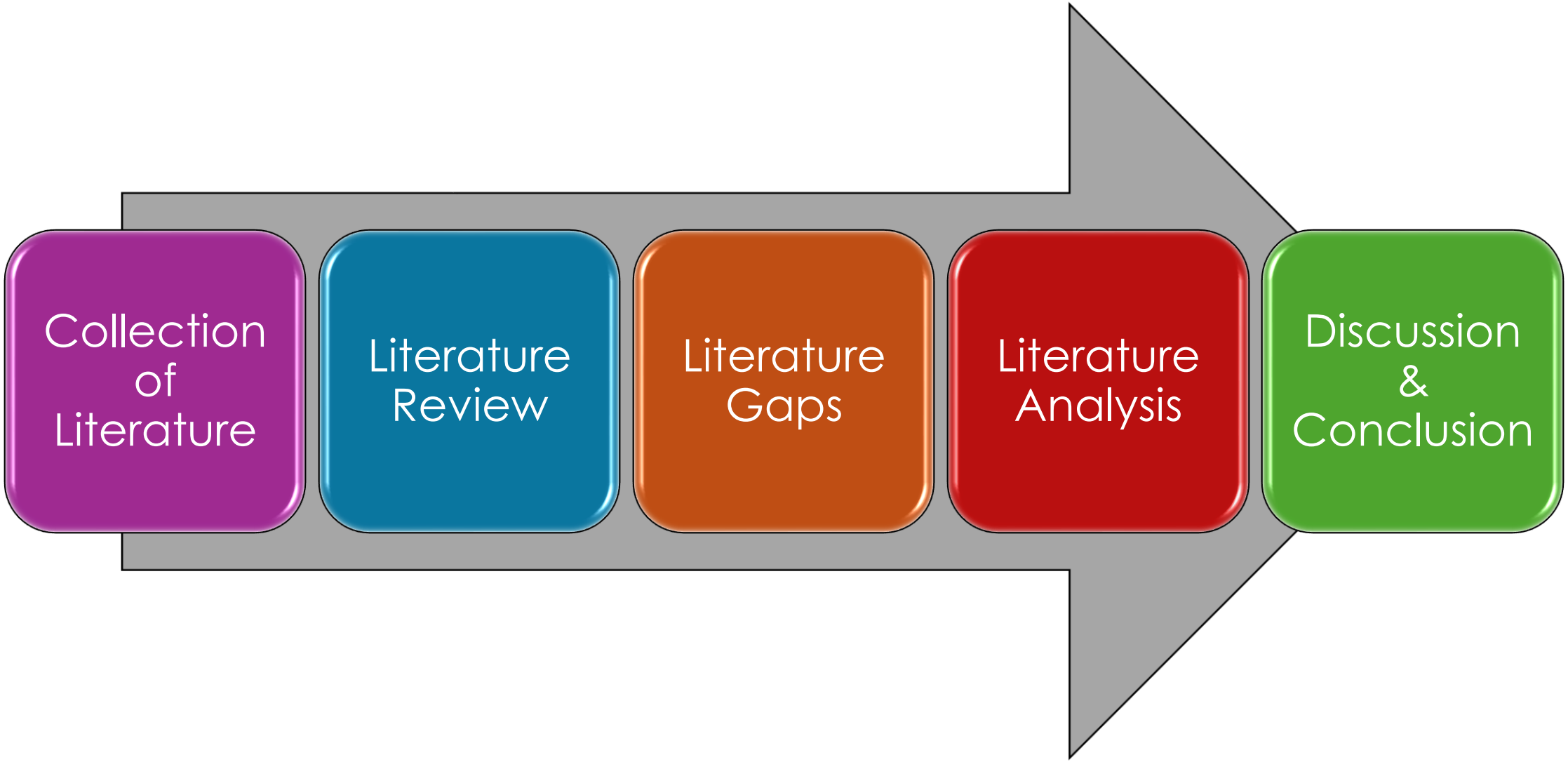
- Innovation is defined as the adoption of ideas, systems, policies, programs, process, products, or services that are new to the adopting organization (Damanpour 1992).

- Construction safety plays and important role in the success of a construction projects, according to the Occupational Safety and Health Administration (OSHA 2014).

- Construction industry accounted for 20.5% or 874 worker fatalities in the U.S.

- lower construction safety means high risk of incidents that leads to injuries and even fatalities, which all will dramatically affect the construction process.

- Construction industry account for more fatal injures than in any other single service industry.


Collection of Literature
Literature Review
Literature Gaps
Literature Analysis
Discussion & Conclusion

- Published articles from 2015 to 2019 were considered for this literature research.

- Articles were collected from various sources:
  - Journal of Construction Engineering and Management.
  - Journal of Management Engineering.
  - Engineering, Construction, and Architecture Management.
  - Automation in Construction.

- Twelve articles were selected to be analyzed for this literature review paper.

- Construction industry is full of safety hazards, even with the implementation of safety regulation and guidelines, construction-safety are frequently violated, which expose workers to incidents of injuries and fatalities.

- Several types of technologies were proposed and developed to improve safety at construction sites, such as:
  - Proximity and safety monitoring technologies.
  - Detection of near mess falls.
  - Detection of hardhats use.
  - Mobile software to improves safety inspection processes
  - Machine learning.
  - eye-tracking technology that would.

The objectives of this study are to:

1. Identify the gaps in literature of construction safety technologies.

2. To identify common limitations and trends in the proposed technologies.

3. Provide future suggestions to cover limitation and gaps.

There are several gaps in the literature of safety technologies:

1. The literature are often limited to an individual type of safety improvement using technologies.

2. Most of the proposed technologies and their performances were mainly tested in laboratories, in addition to a limited number of actual site experiments and participants.

4. No studies have focused or experimented a combination of safety technology sets in order to provide a comprehensive model of construction safety.

5. Proposed technologies were evaluated with neglecting one of the most important factor, the human “user” factor, for example the acceptance and adoption of the proposed technologies.

Literature Analysis

To identify gaps and limitations in the body of knowledge the twelve selected articles were analyzed by the following aspects :

1. Safety phase.
2. Technology type.
3. Data collection methods.
4. Data samples.
5. Technology performance metrics.

Literature Analysis

The author found the best way to group the safety technology is by the safety phase that will be mainly impacted by the proposed technology.

Safety Phases

This phase is related to safety planning before the start of construction phase, it is mainly located in the design phase of the construction projects.

Teo Ai Lin et al. (2017) "*Framework for productivity and safety enhancement system using BIM in Singapore* "

- Developed a conceptual framework of intelligent productivity and safety system (IPASS) to improve safety and productivity by using BIM.

- While the project is submitted for approval the developed (IPASS) can point high risk areas during the design stage, enabling hazard mitigation plans to be applied.

- The proposed framework would allow users to identify and mitigate unsafe designs and their associated risks.
- Which will increase safety before the start of the project by updating the designs accordingly.
- It will help project managers to plan site activities and safety programmers to focus on the higher-risk trades and to priorities hazard mitigation strategies and intervention methods to make effective resource allocation decisions.

Teo Ai Lin et al. (2017) "*Framework for productivity and safety enhancement system using BIM in Singapore* " limitations are:

1. The proposed system depends solely on the use of BIM and the associated levels of details.

2. The proposed (IPASS) uses the same BIM models used for submission to the authorities, but still may require some manual efforts so that IPASS could be used to its maximum capability.

Safety Phases

Safety technologies that alert workers of safety hazards in day to day activities provides an additional layer of protection, but it does not overcome the importance of worker's manual identification of risk and hazards.

Hasanzadeh et al. (2017) *"Measuring the Impacts of Safety Knowledge on Construction Worker's Attentional Allocation and Hazard Detection Using Remote Eye-Tracking Technology "*.

- Studied eye tracking technique to measure worker attention in order to analysis the impacts of safety knowledge (training, work experience, and injury exposure) on workers' attentional allocation.

- The study performed a laboratory experiments on 27 construction workers to record their eye movements while they try to identify safety hazards presented in 35 construction site images.

Hasanzadeh et al. (2017) *"Measuring the Impacts of Safety Knowledge on Construction Worker's Attentional Allocation and Hazard Detection Using Remote Eye-Tracking Technology "*.

- The results shows that practical safety knowledge and judgment on a jobsite requires both interaction and explicit knowledge gained through work experience, injury exposure, and interactive safety training.

- The study shows that eye tracking can be utilized to improve workers' safety-training programs which will yield a safer working environment

Safety Phases

New project management software have eased expedited activity tracking and execution in construction sites by using smart devices such as tables and smart phones in order to interact with site activities.

Zhang et al. (2017) "*Development of a Safety Inspection Framework on Construction Sites Using Mobile Computing*".

- The study developed and provided a mobile application named *iObserver*, the application is mainly used by safety inspectors who can report safety related inspection activities easily using the application.

- The developed application has a lot of features similar to any project management software.

Zhang et al. (2017) "*Development of a Safety Inspection Framework on Construction Sites Using Mobile Computing*".

- The application was developed and evaluated by the industry practitioners, and it resulted in not only eliminating the redundancy in paper-based systems, but also enhanced the coordination and integration of information between safety inspection procedures and other safety management strategies.

Zhang et al. (2017) "*Development of a Safety Inspection Framework on Construction Sites Using Mobile Computing*" limitations are:

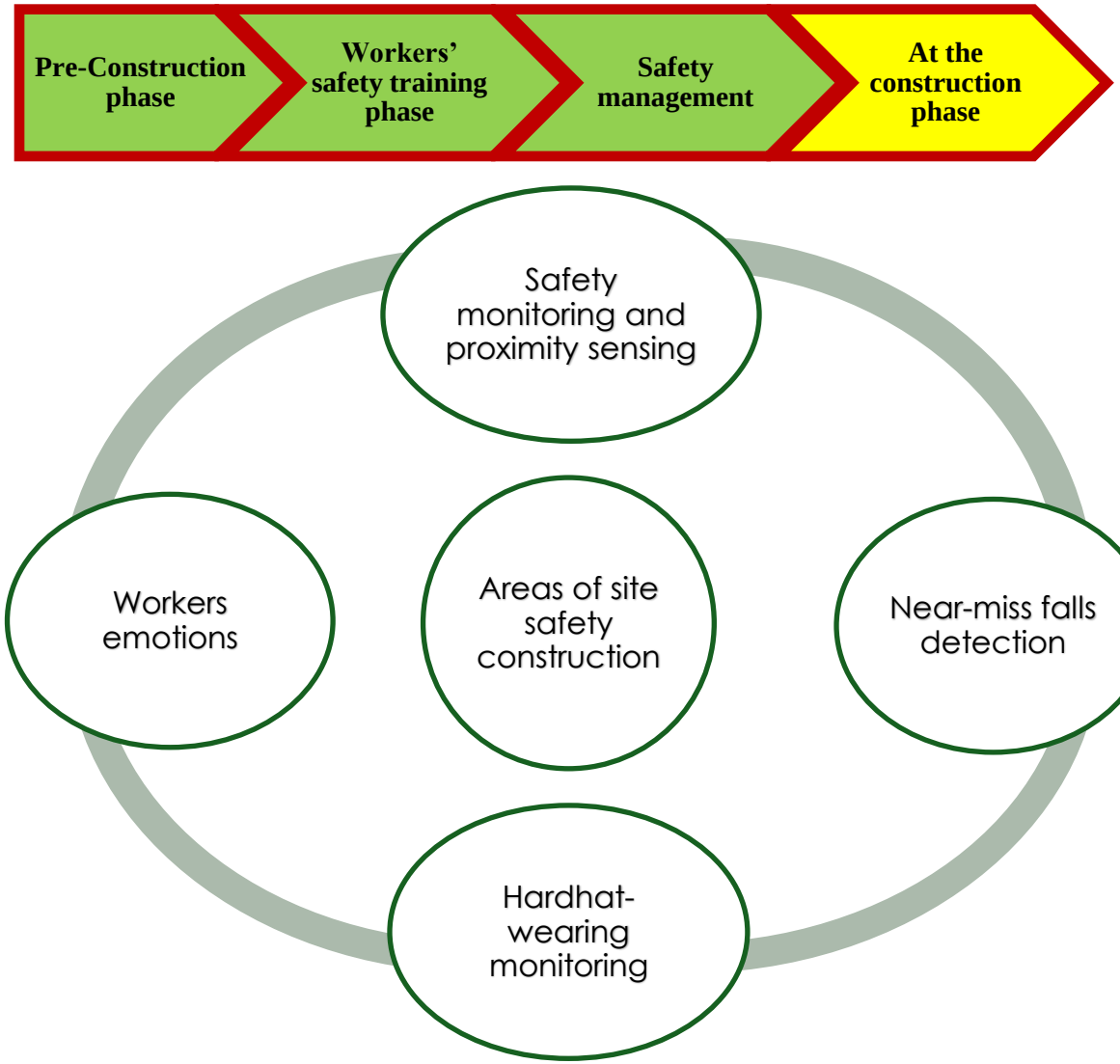
- The limited functionality and the availability of data base for each project, the developed application was a prototype that has one construction task, hence for real world use, hundreds of tasks need to be added and updated regularly, which will require scientific and automated data-mining approaches.

- In addition to the need of safety information data base to capture results from the analysis of collected inspection data.

Safety Phases

Most of the selected articles are related to new technological innovations in construction safety that deals with ongoing construction activities at project site.

- From the selected twelve articles, six articles discussed technology related to “At the Construction” phase.
- The author found four main areas of site constructions presented that researchers are trying to improve throughout the use of new technologies.



#	Safety Area	Paper Title	Author(s)
1	Safety monitoring and proximity sensing	Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors	Park, J., Kim, K., and Cho, Y. K. (2017)
2		Performance Test of Wireless Technologies for Personnel and Equipment Proximity Sensing in Work Zones	Park, J., Marks, E., Cho, Y. K., and Suryanto, W. (2016)
3	Near-miss falls detection	Using Smartphones to Detect and Identify Construction Worker's Near-Miss Falls Based on ANN	Zhang, M., Cao, T., and Zhao, X.
4		Artificial Neural Network-Based Slip-Trip Classifier Using Smart Sensor for Construction Workplace	Lim, T.-K., Park, S.-M., Lee, H.-C., and Lee, D.-E.
5	Hardhat-wearing monitoring	Real-Time Alarming, Monitoring, and Locating for Non-Hard-Hat Use in Construction	Zhang, H., Yan, X., Li, H., Jin, R., and Fu, H.
6		Hardhat-Wearing Detection for Enhancing On-Site Safety of Construction Workers	Park, M.-W., Elsafty, N., and Zhu, Z.
7	Workers emotions	Measuring Workers' Emotional State during Construction Tasks Using Wearable EEG	Hwang, S., Jebelli, H., Choi, B., Choi, M., and Lee, S.

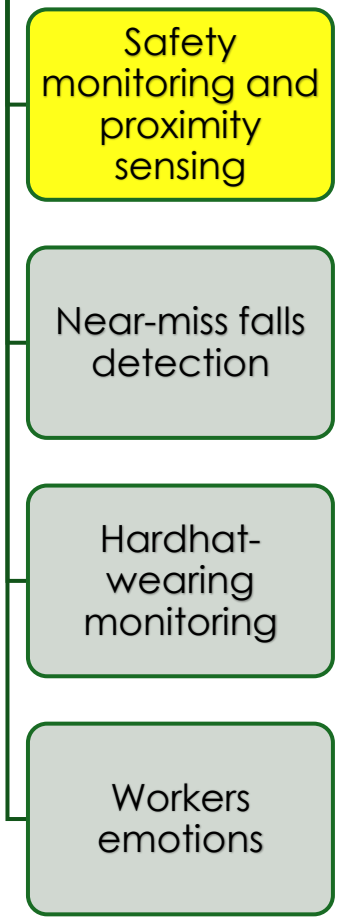
Safety monitoring and proximity sensing
Near-miss falls detection
Hardhat-wearing monitoring
Workers emotions

1

"Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors"(Park et al. 2017).

- The study created and evaluate a new low-cost automated safety monitoring system to assist in the construction-safety monitoring process.

- The system relies on BLE sensors, which are cheap, reliable and available, also it relies on cloud communication platform and the main component is BIM -building information model (BIM)-based hazard identification.



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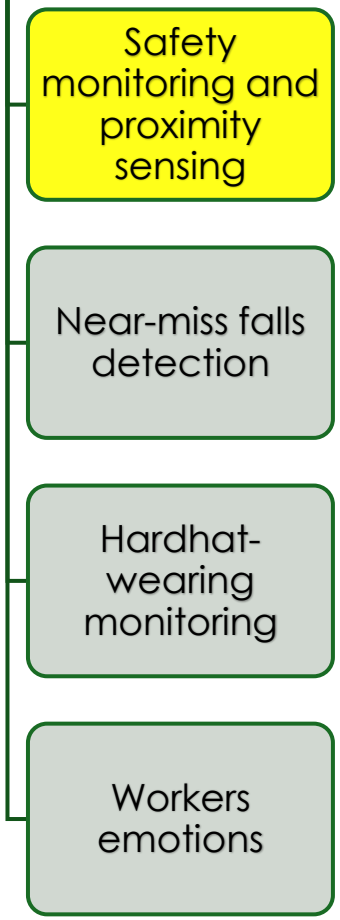
"Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors" (Park et al. 2017)

- The study utilize automatic identification of hazard areas using BIM based automatic identification, this means that BIM needs to be fully updated and needs to be in line with construction activities.

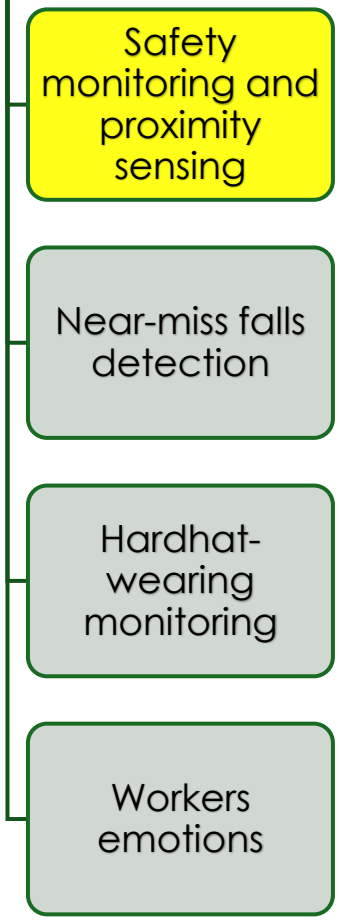
- Some hazards can't be identified using BIM that means safety inspectors should provide their inputs to cover what the automated BIM identification had missed,



1

"Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors" (Park et al. 2017)

- The location of workers at the site are located by BLE beacons all around the site, and smart phones that connects to those BLEs. When a worker enters a per-defined unsafe zone the work will get a real time alert as well as alerts for related safety personnel throughout the cloud.
- This way of using BIM is more superior in identification hazards due to its indoor capabilities compared to others other systems ultra-wide band-UWB, GPS, RFID, etc.



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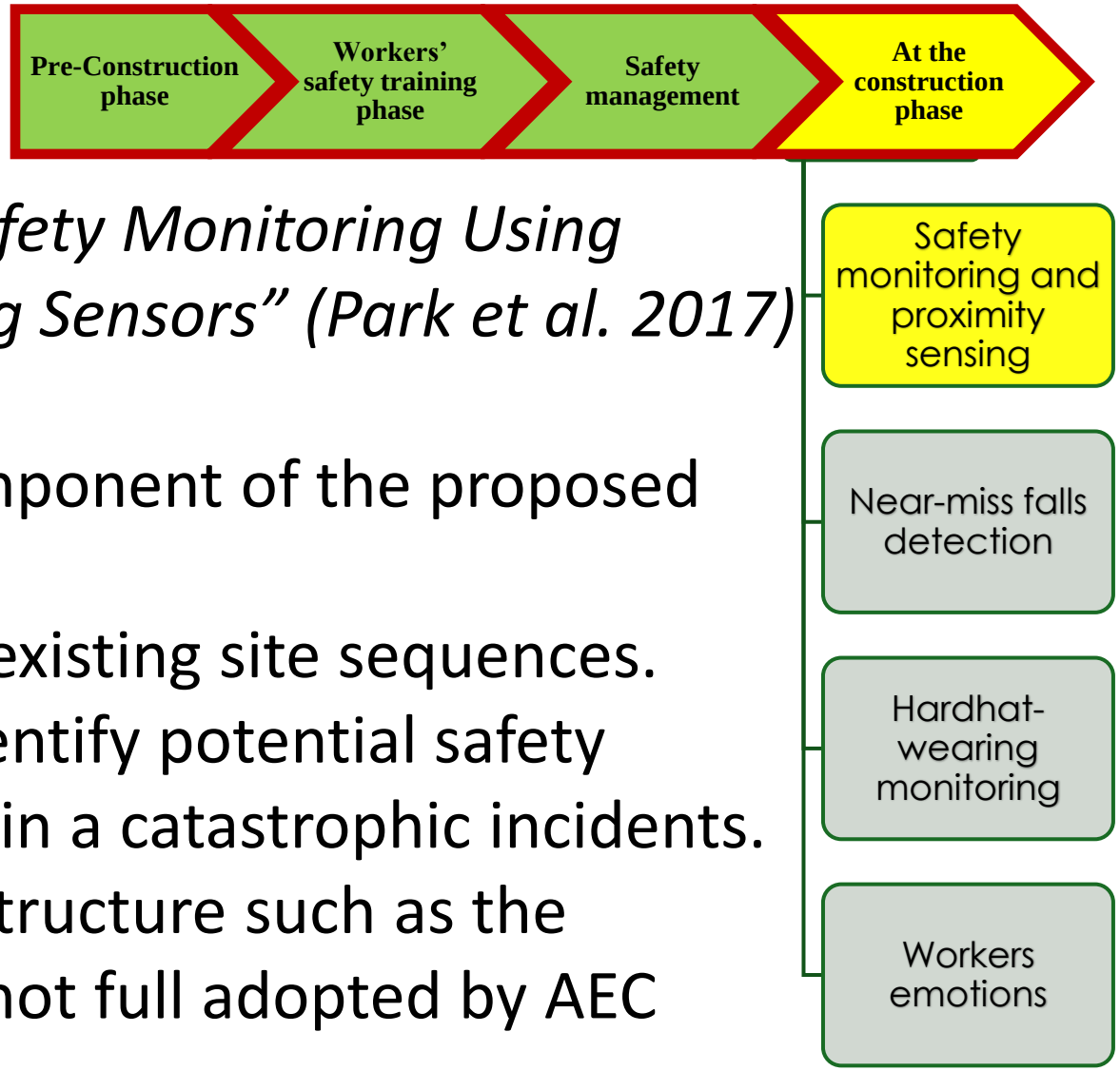

"Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors" (Park et al. 2017)

- The limitation is related to the main component of the proposed system which is BIM:
  1. The need of fully updated BIM with existing site sequences.
  2. The reliance on manual efforts to identify potential safety hazards, any human error will result in a catastrophic incidents.
  3. The need for heavy, expensive infrastructure such as the availability of BIM, while BIM is still not full adopted by AEC industry.

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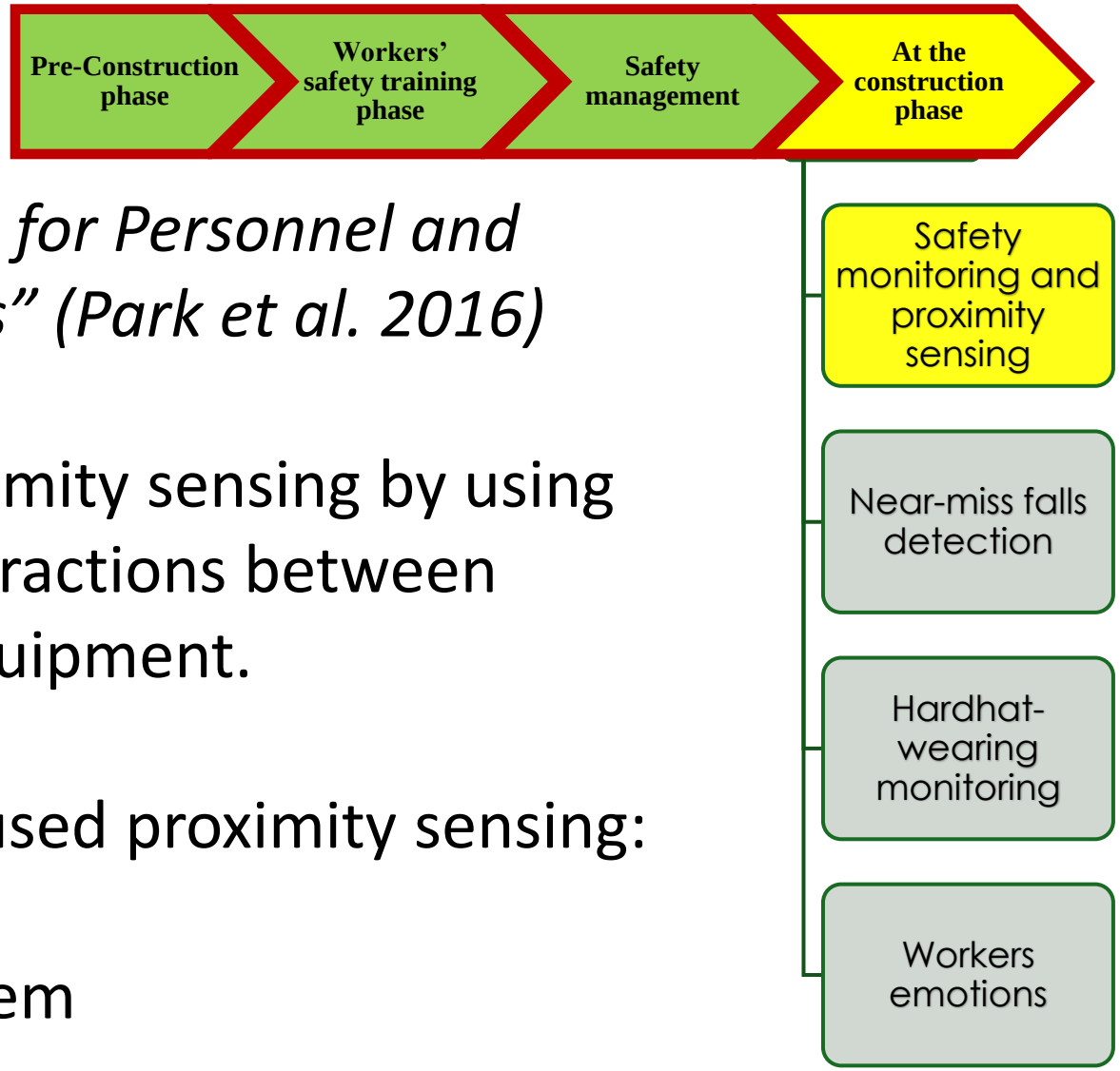
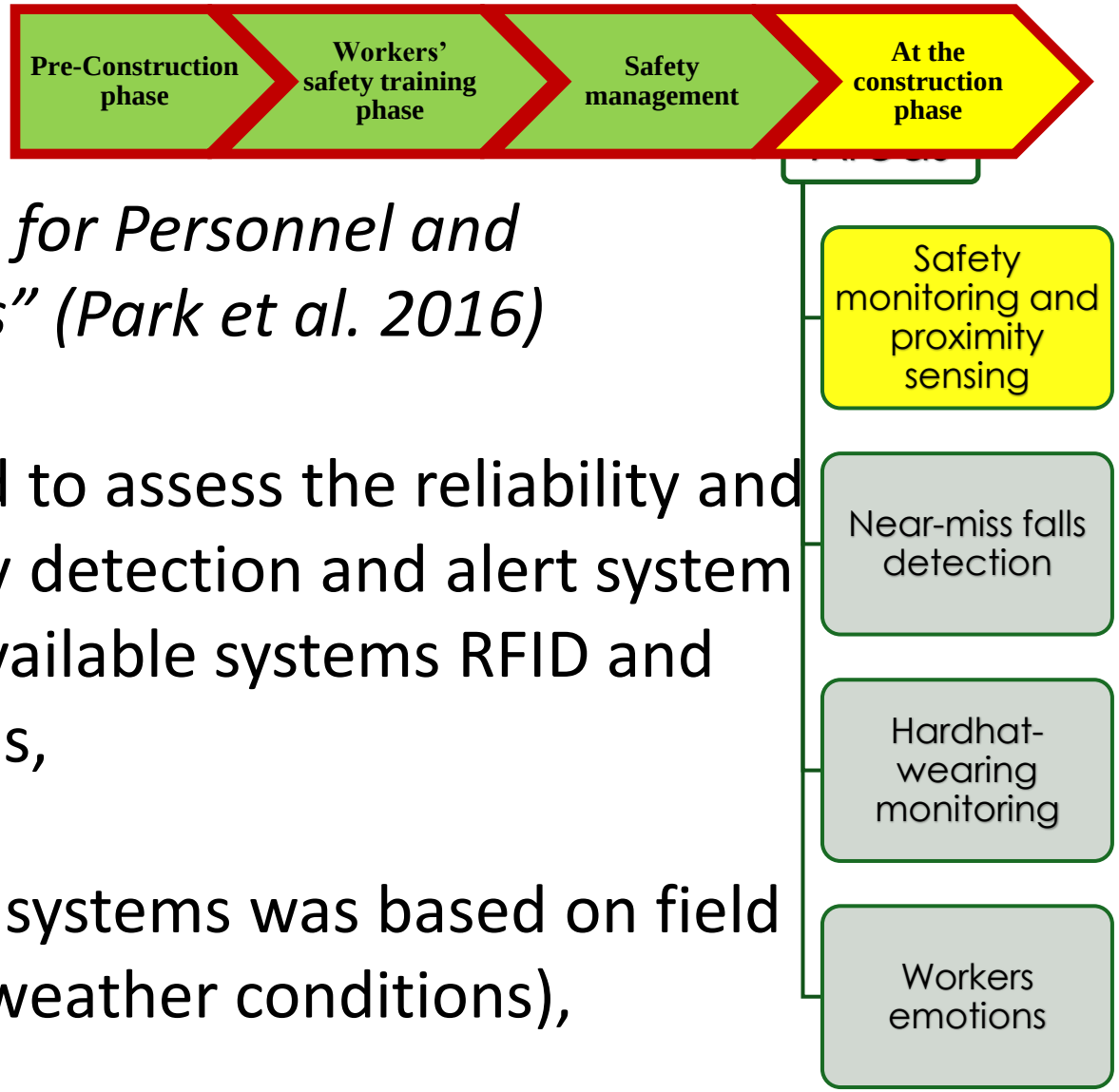


"Performance Test of Wireless Technologies for Personnel and Equipment Proximity Sensing in Work Zones" (Park et al. 2016)

- The study developed a new way of proximity sensing by using Bluetooth technology regarding the interactions between pedestrian workers and construction equipment.

- Several advantages compared to other used proximity sensing:
  1. Lower required infrastructure
  2. lower overall cost for the whole system
  3. Good signal continuity and coverage.

2



"Performance Test of Wireless Technologies for Personnel and Equipment Proximity Sensing in Work Zones" (Park et al. 2016)

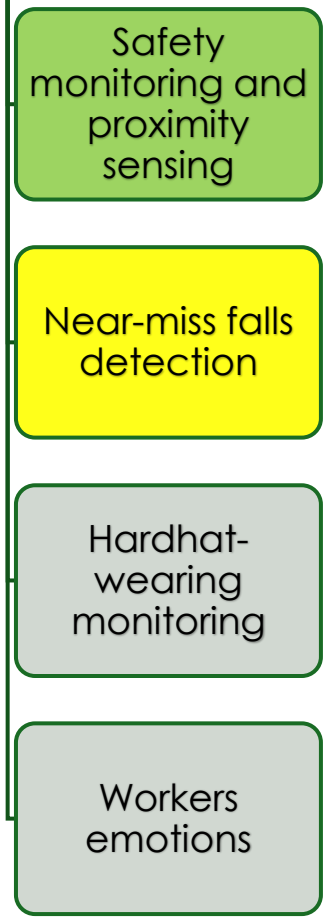
- Several experiments that were designed to assess the reliability and effectiveness of the Bluetooth proximity detection and alert system compared to other two commercially available systems RFID and magnetic field proximity sensing systems,

- Performance evaluation between three systems was based on field experiments (in open area and normal weather conditions),

"Using Smartphones to Detect and Identify Construction Worker's Near-Miss Falls Based on ANN" (Zhang et al. 2019), & "Artificial Neural Network-Based Slip-Trip Classifier Using Smart Sensor for Construction Workplace" (Lim et al. 2016).

- The study explored the potential use and feasibility of integrating smartphones and artificial neural network (ANN) to measure near-miss falls, which can be measured by triaxial accelerometers embedded in smartphones.

- The study provides a new perspective for measuring the relationship between near-miss falls and fall accidents quantitatively.



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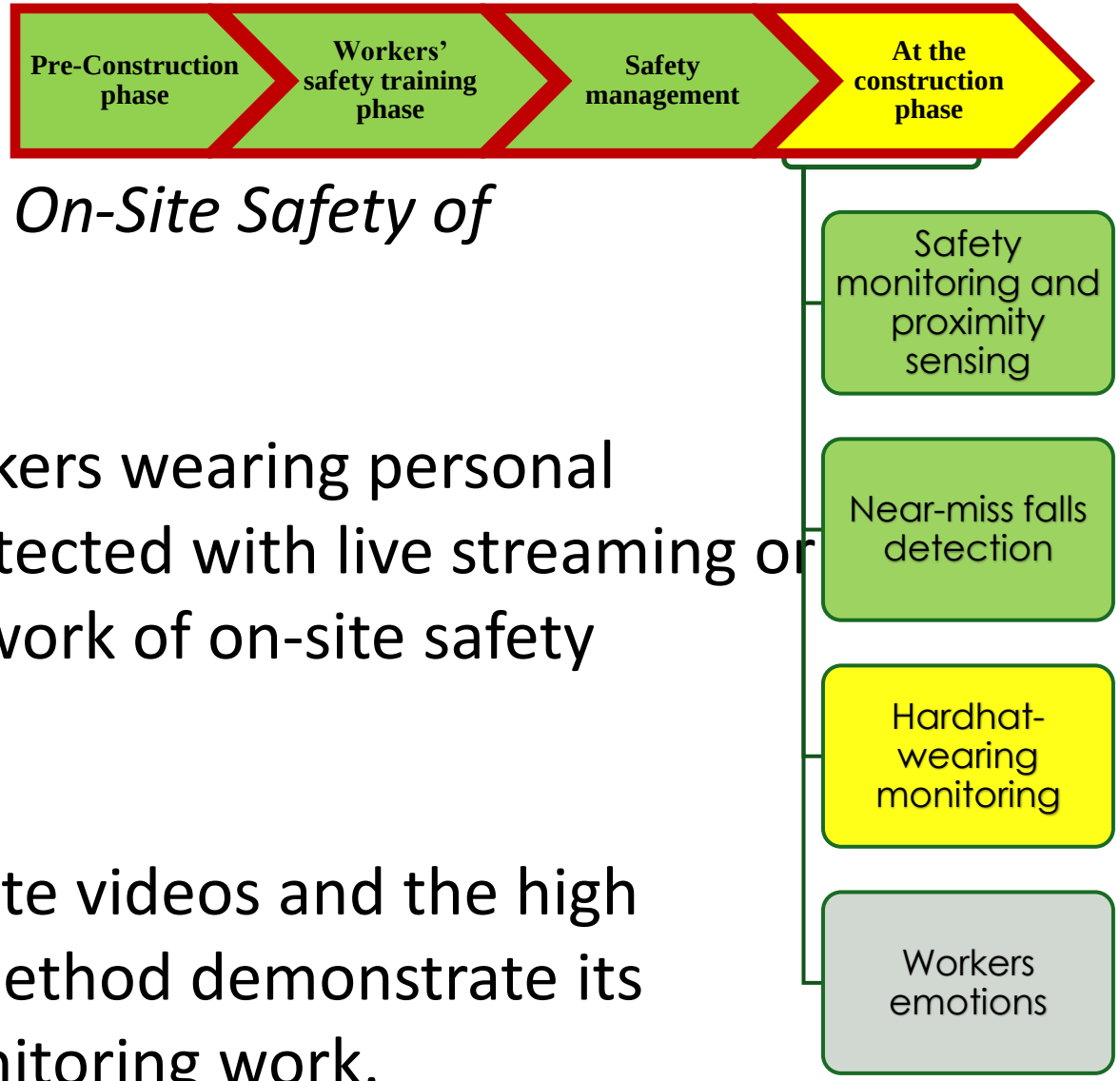

"*Hardhat-Wearing Detection for Enhancing On-Site Safety of Construction Workers*" (Park et al. 2015).

- The study evaluated if construction workers wearing personal protective equipment (PPE) could be detected with live streaming or time-lapse videos, in order to facilitate work of on-site safety inspectors.

- The method has been tested with real site videos and the high safety alert precision and recall of the method demonstrate its potential to facilitate the site safety monitoring work.

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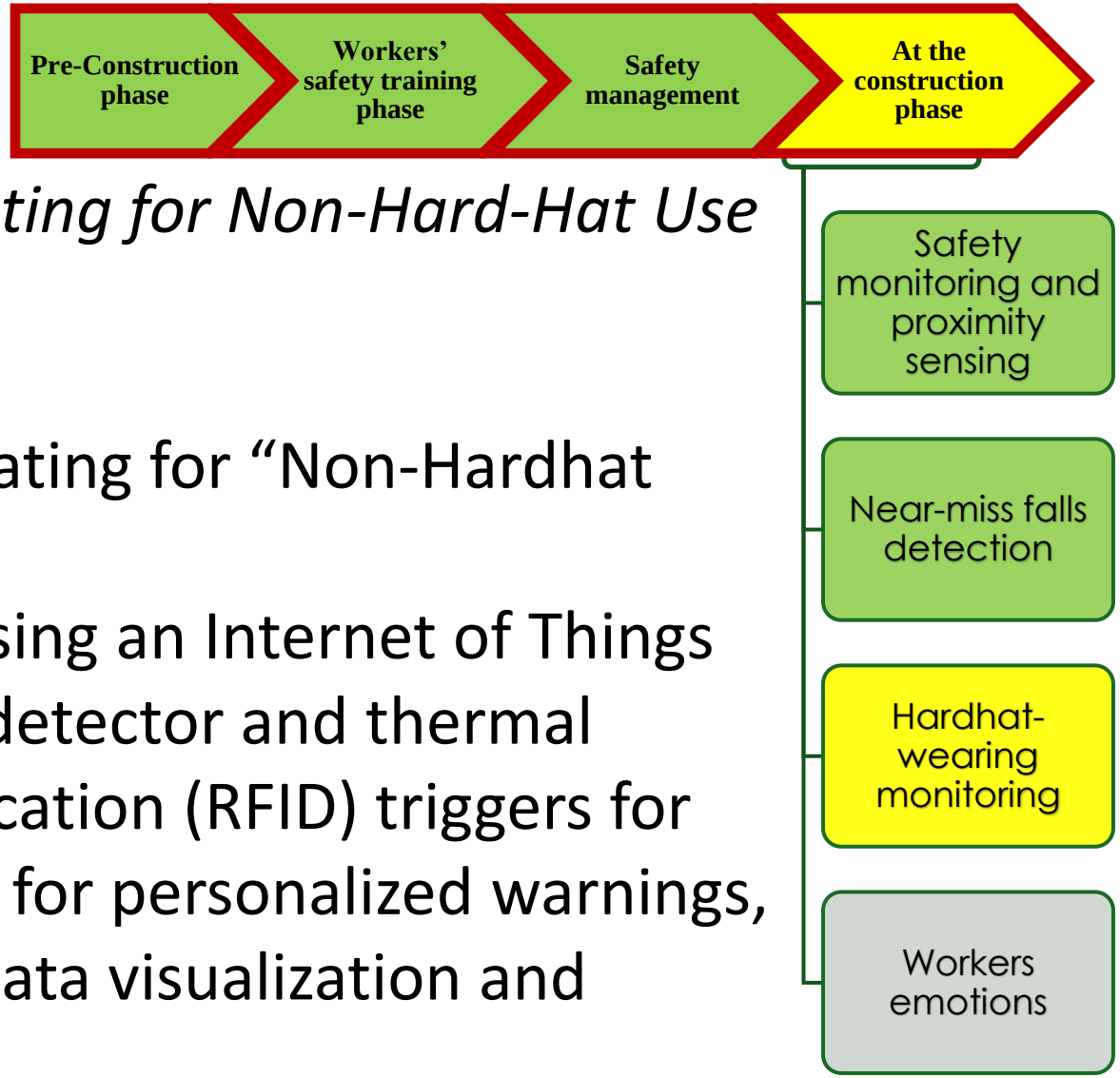
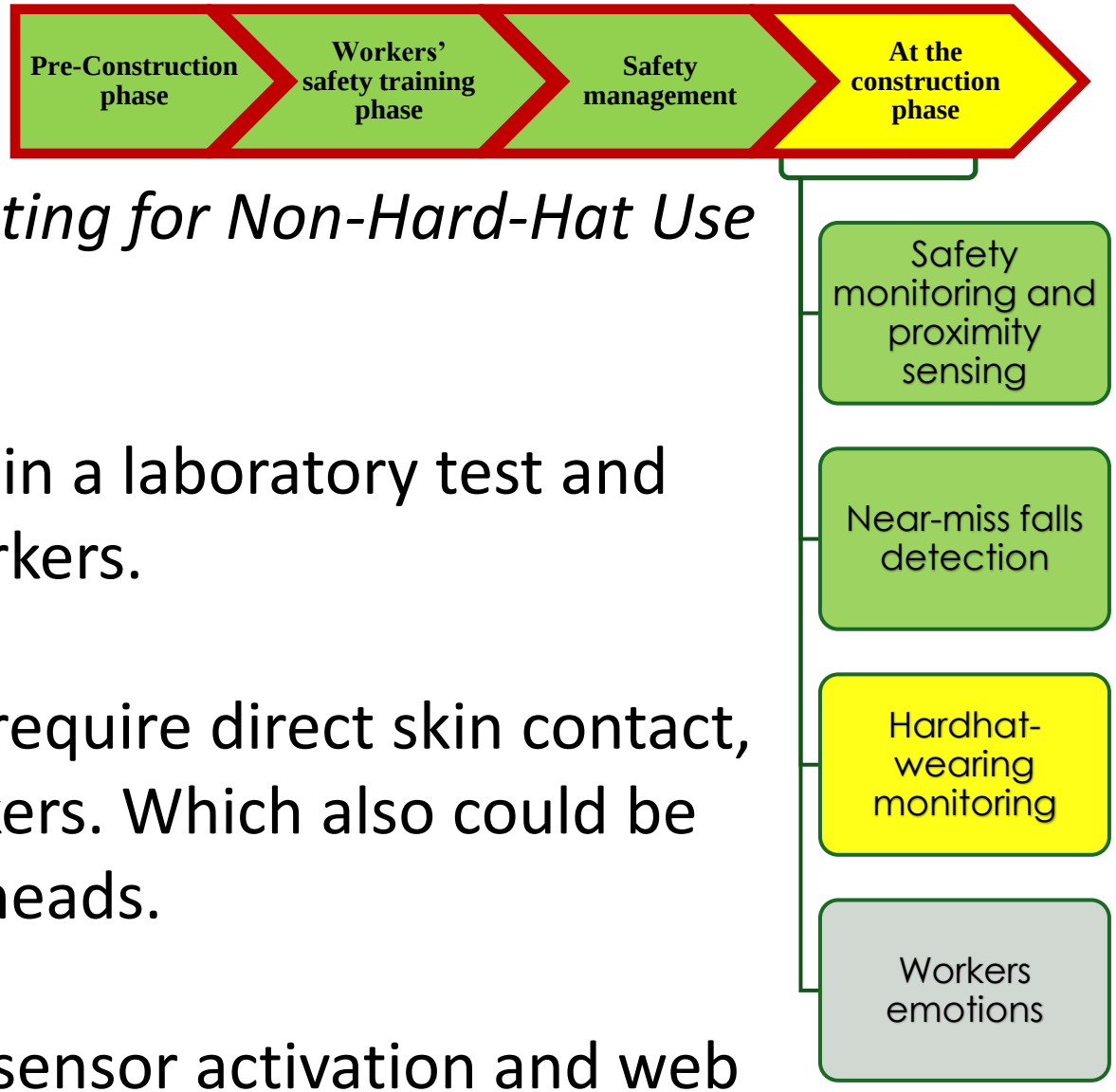


"*Real-Time Alarming, Monitoring, and Locating for Non-Hard-Hat Use in Construction*" (Zhang et al. 2019).

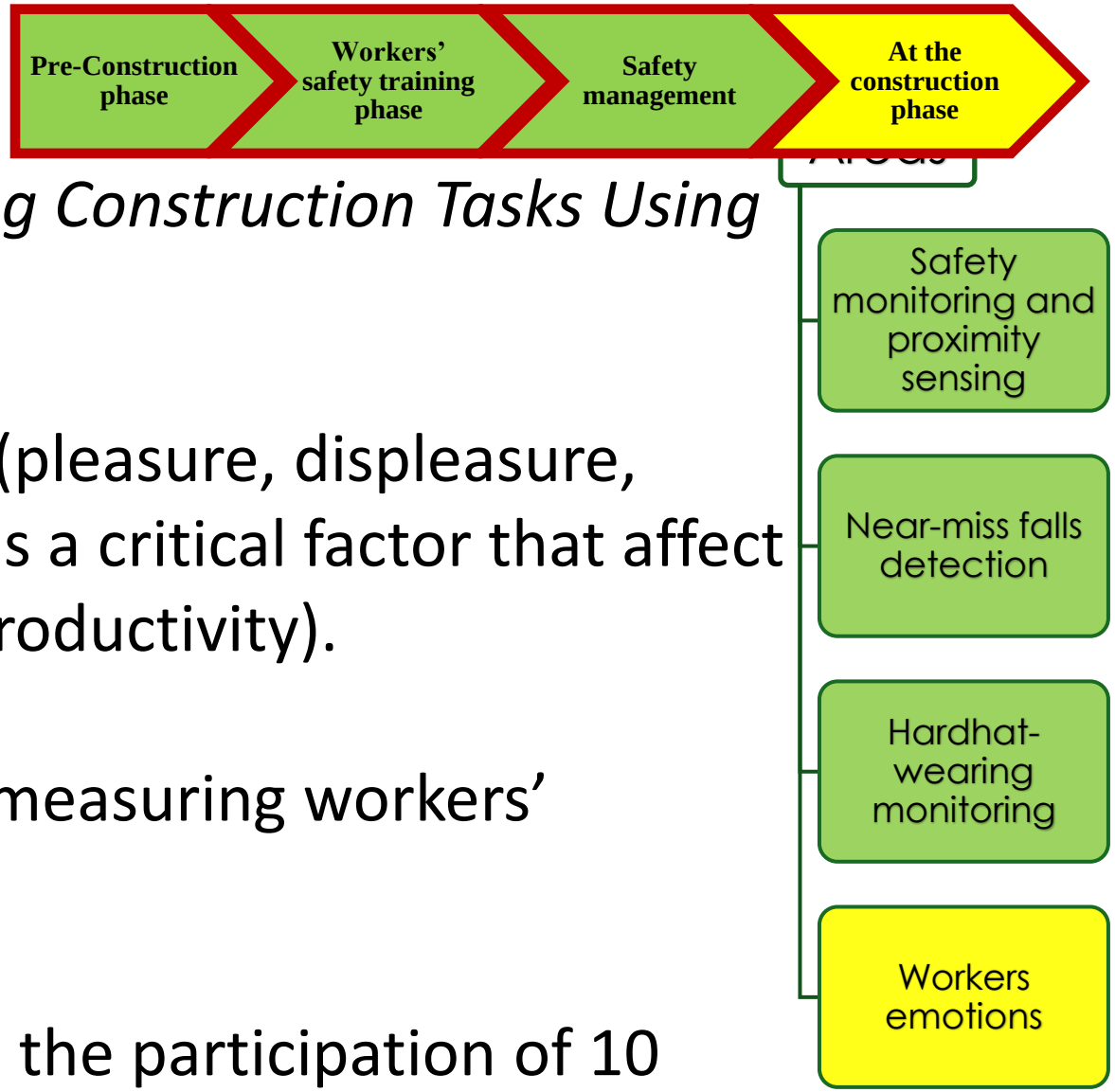
- Real-time alarming, monitoring, and locating for "Non-Hardhat Use" NHU
- A smart hard-hat system is developed using an Internet of Things (IoT), a hard hat with an infrared beam detector and thermal infrared sensor, radio-frequency identification (RFID) triggers for locating NHU, a smartphone application for personalized warnings, a web application and cloud server for data visualization and alarms for managers.

2



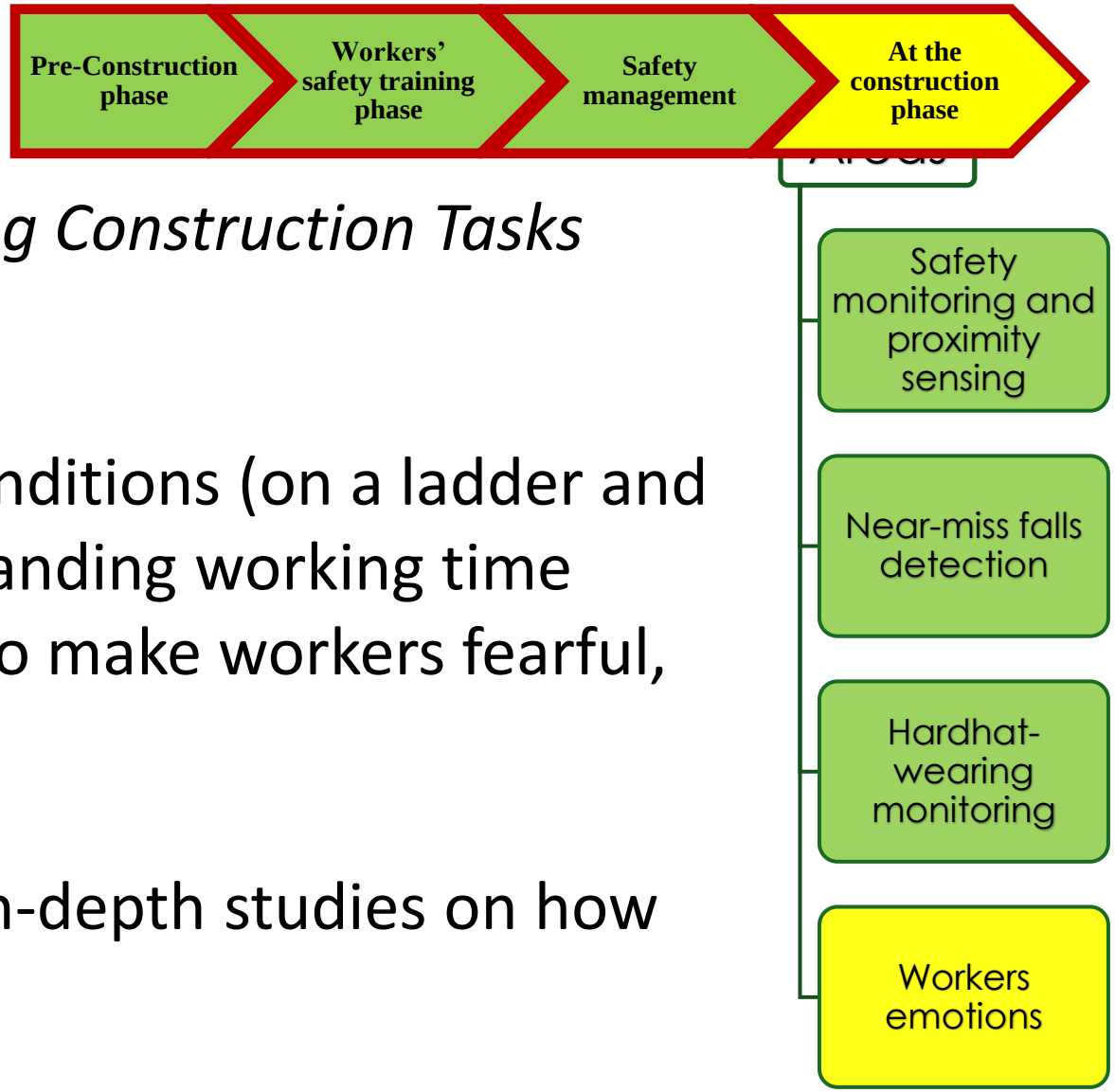
"*Real-Time Alarming, Monitoring, and Locating for Non-Hard-Hat Use in Construction*" (Zhang et al. 2019).

- The system performance was evaluated in a laboratory test and validated in a field application by 19 workers.
- Sensor based NHU inspection methods require direct skin contact, which would be uncomfortable for workers. Which also could be deceived by objects other than human heads.
- Trigger errors and time delays between sensor activation and web or smartphone app alerts.



"Measuring Workers' Emotional State during Construction Tasks Using Wearable EEG" (Hwang et al. 2018).

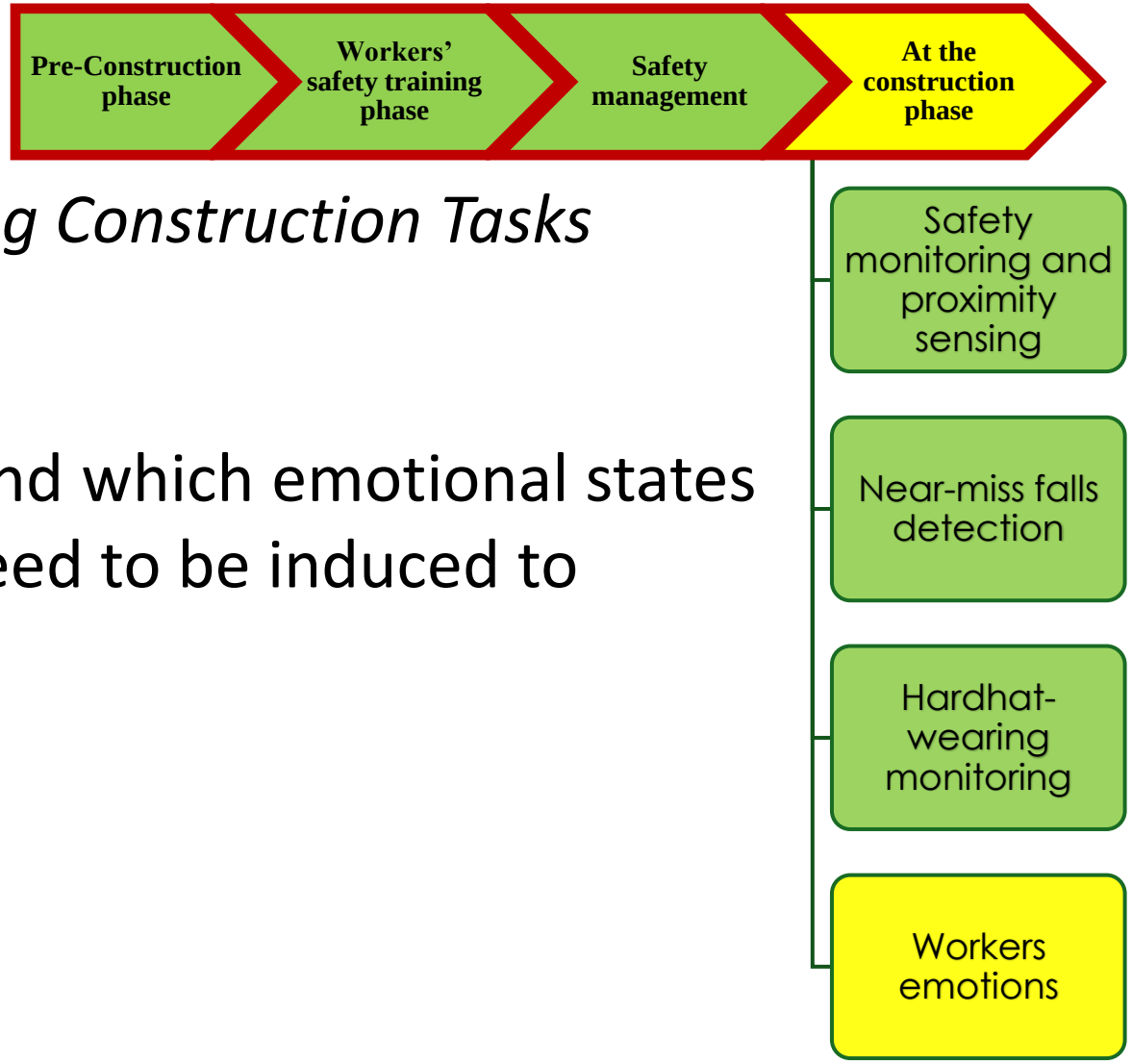
- Construction workers' emotional states (pleasure, displeasure, excitement, and relaxation) are known as a critical factor that affect their performance (safety, health, and productivity).
- The study investigated the feasibility of measuring workers' emotions using a wearable EEG sensor.
- It preformed real field test that included the participation of 10 workers.



"Measuring Workers' Emotional State during Construction Tasks Using Wearable EEG" (Hwang et al. 2018).

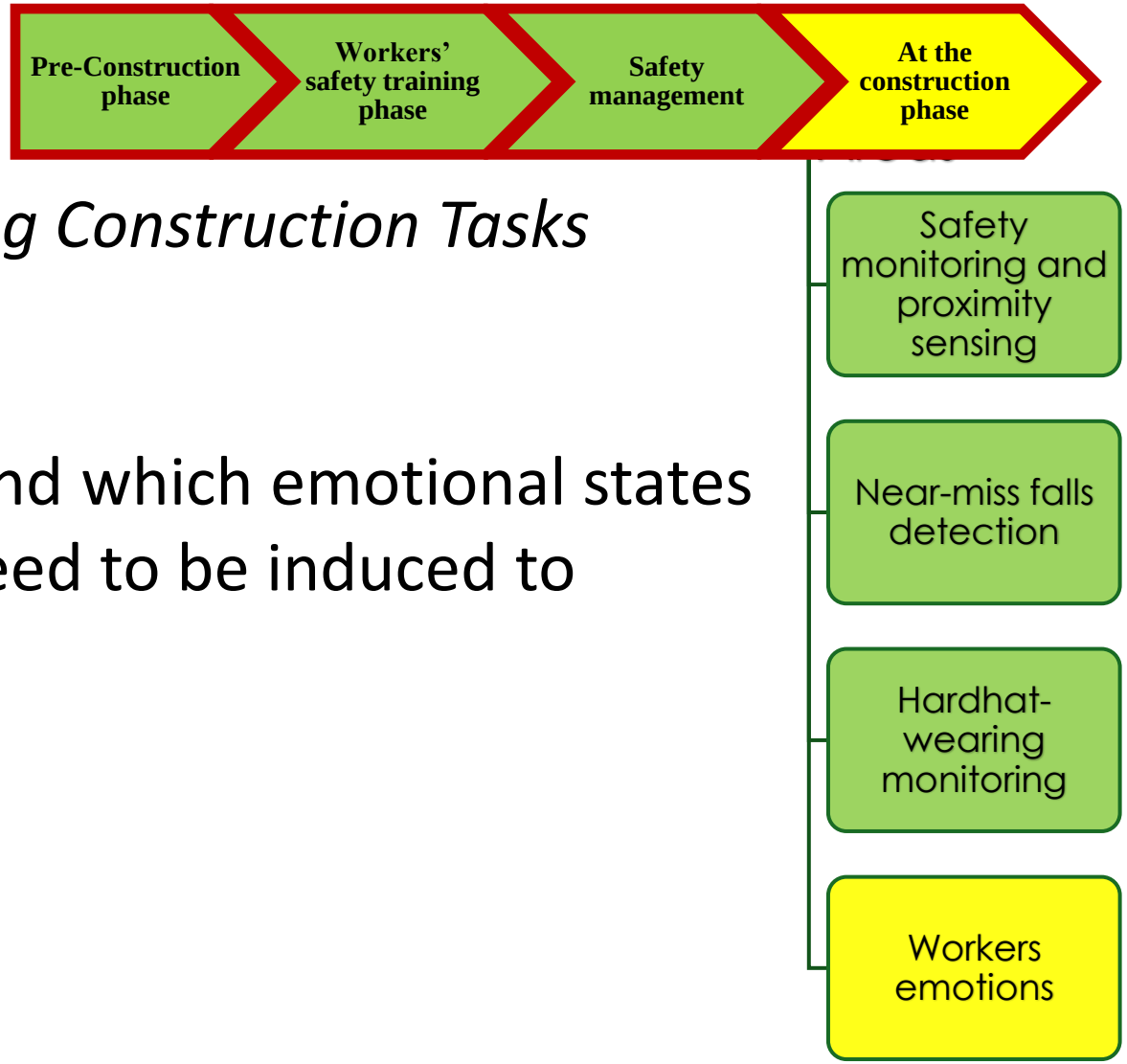
- The results showed that unsafe work conditions (on a ladder and in a confined space) and physically demanding working time (working 2 h without resting) are likely to make workers fearful, frustrated, and/or depressed

- The outcome of this study is to enable in-depth studies on how the emotions affect work performance.



"Measuring Workers' Emotional State during Construction Tasks Using Wearable EEG" (Hwang et al. 2018).

- Such efforts will help to better understand which emotional states of workers are the most effective and need to be induced to achieve desired work performances.

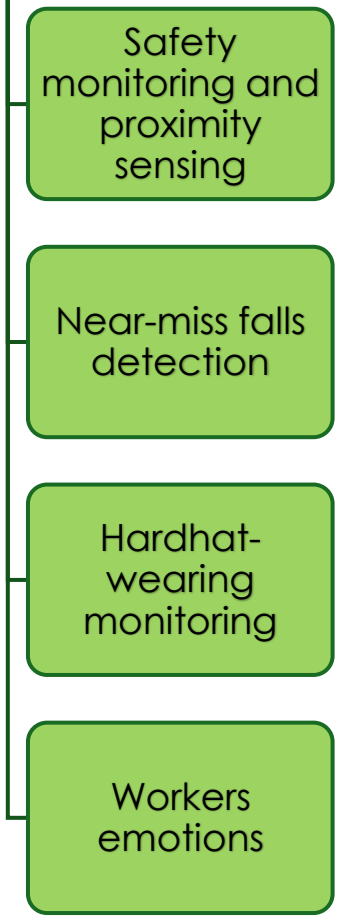


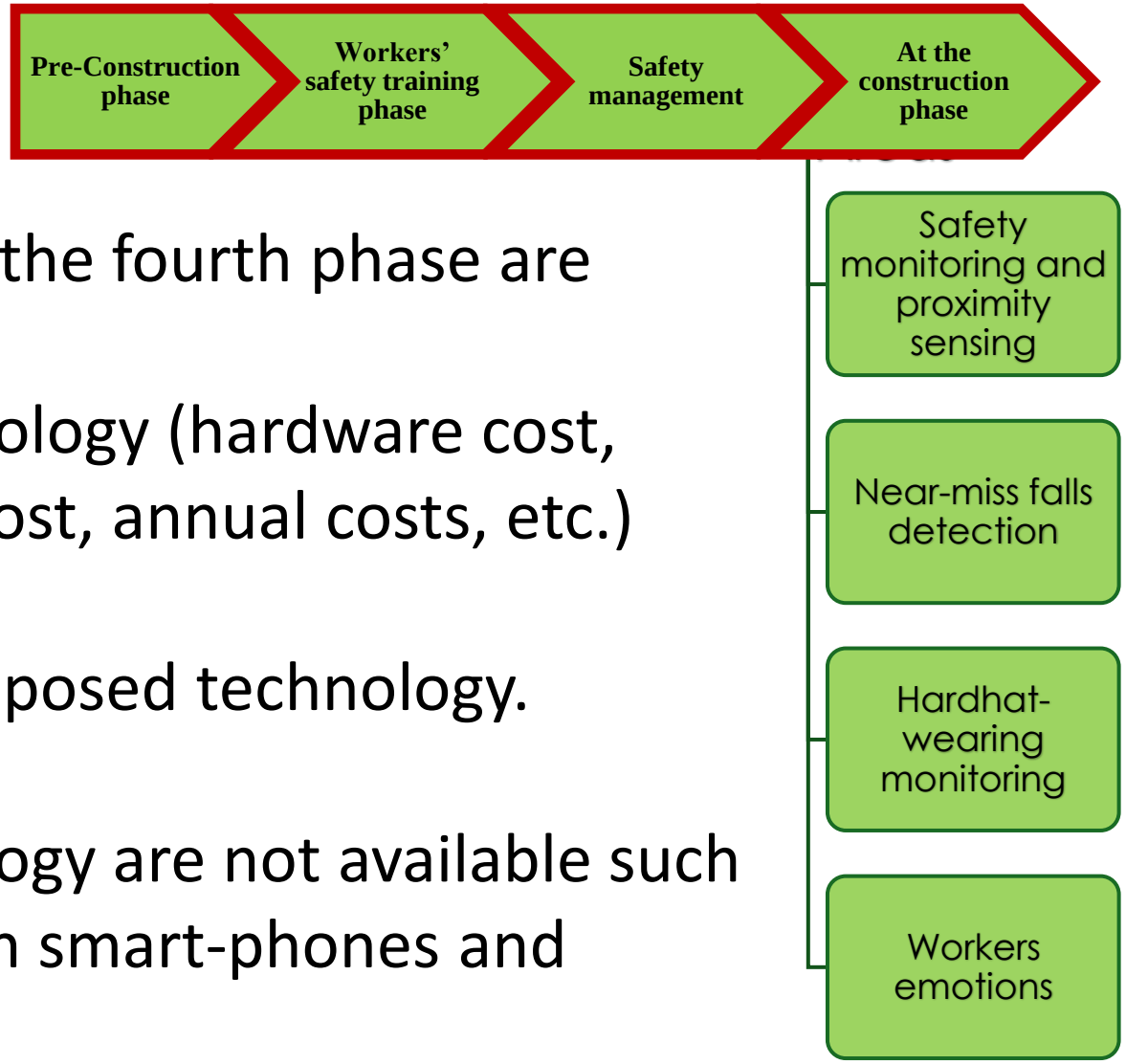
"Measuring Workers' Emotional State during Construction Tasks Using Wearable EEG" (Hwang et al. 2018).

- Such efforts will help to better understand which emotional states of workers are the most effective and need to be induced to achieve desired work performances.

One of the objectives of this review paper is to identify common limitation for the proposed safety technologies, with reference to:

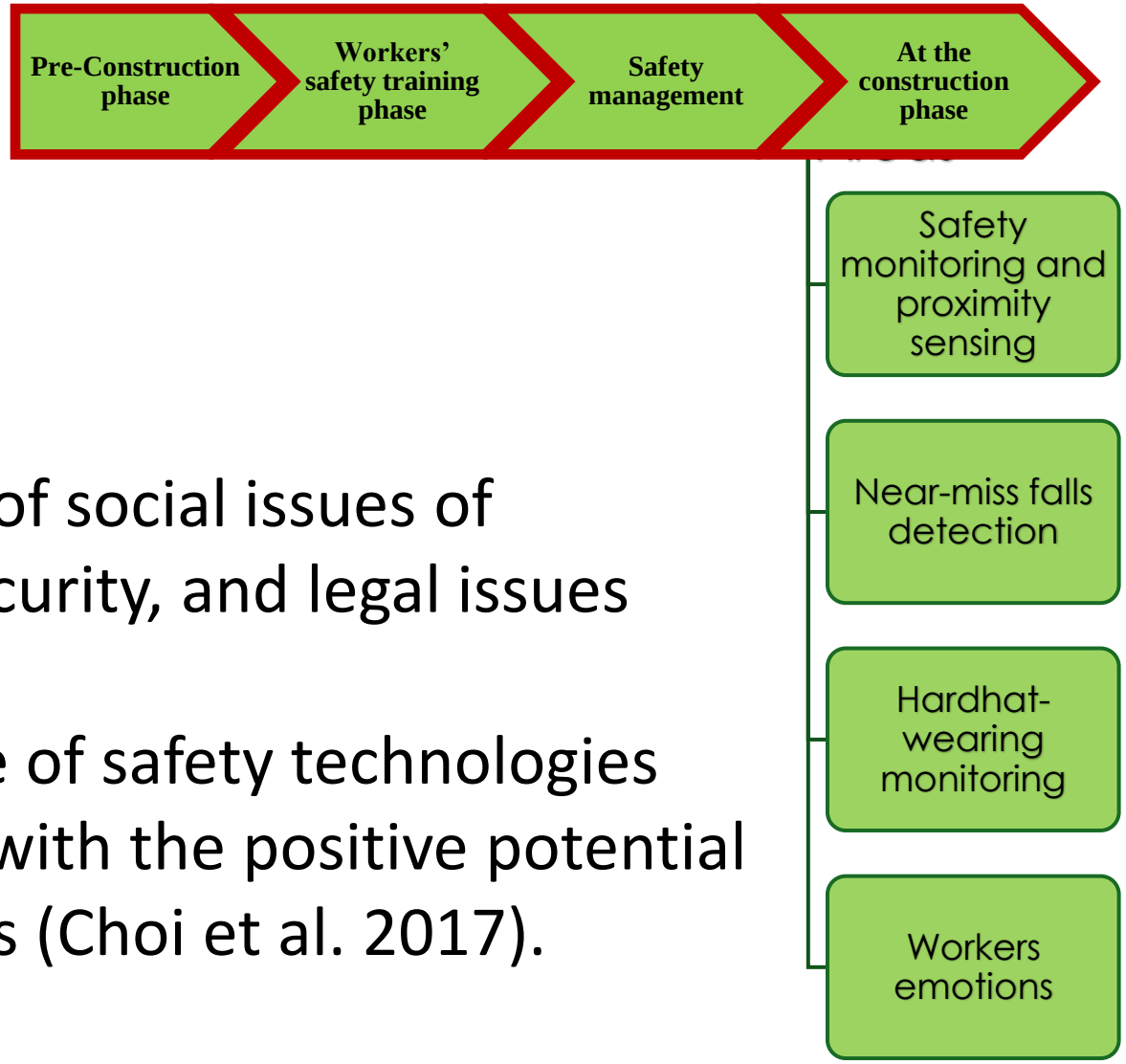
- Safety phases:
  - The main limitation for the first three phases is the heavy reliance on the diffusion of other technologies such as the diffusion of BIM , and regulations that may be tied to architectures and engineers, such regulations and laws that forces the implementation of safety technologies in order to design a safer construction environment.





- Limitations of proposed technologies in the fourth phase are

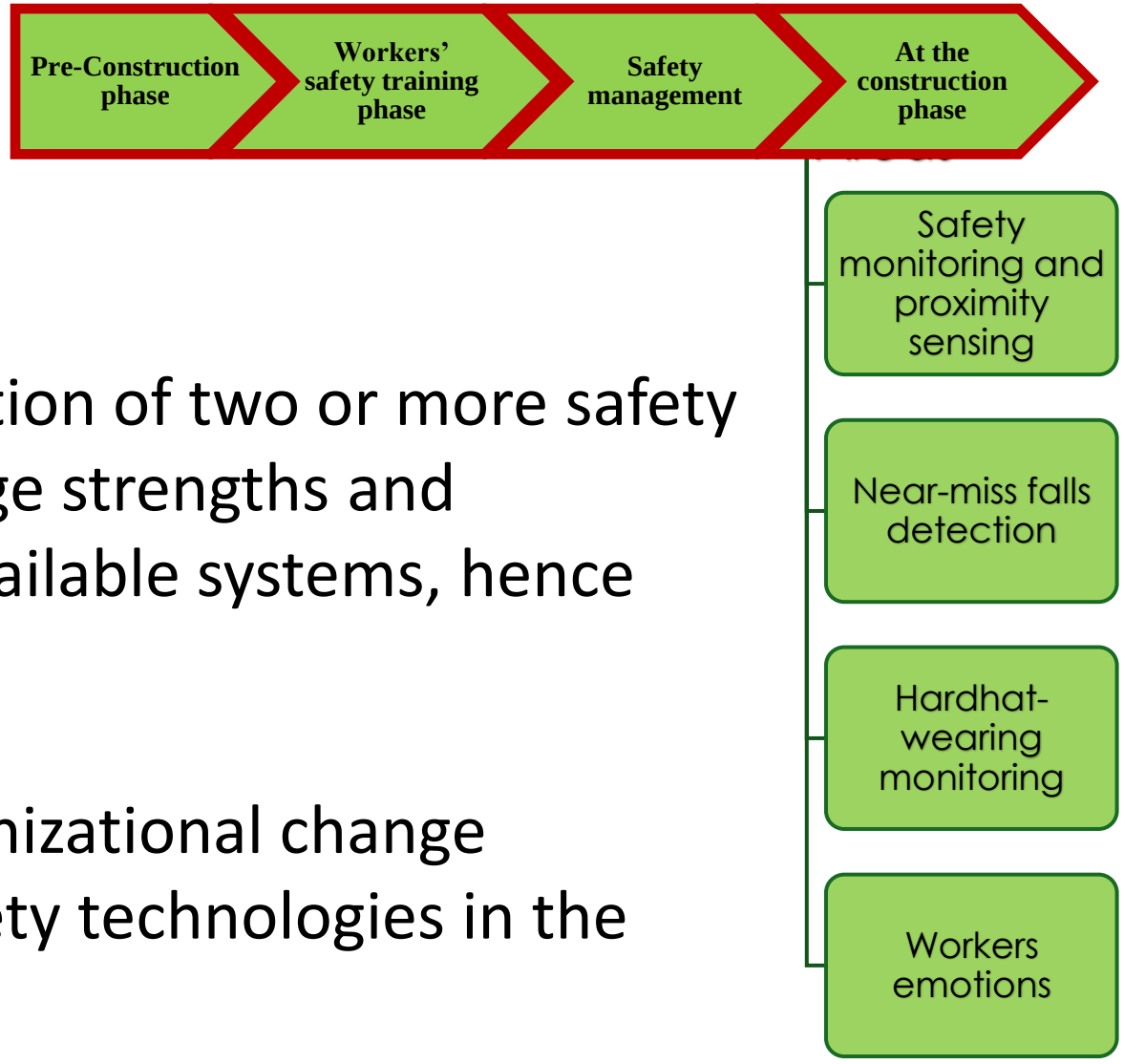
  - The feasibility of the proposed technology (hardware cost, implementation cost, maintenance cost, annual costs, etc.)
  - Performance and accuracy of the proposed technology.
  - Special projects where some technology are not available such are internet connections wi-fi or even smart-phones and cameras



- Other limitations:

  - Limited research studied the impact of social issues of wearable systems include privacy, security, and legal issues

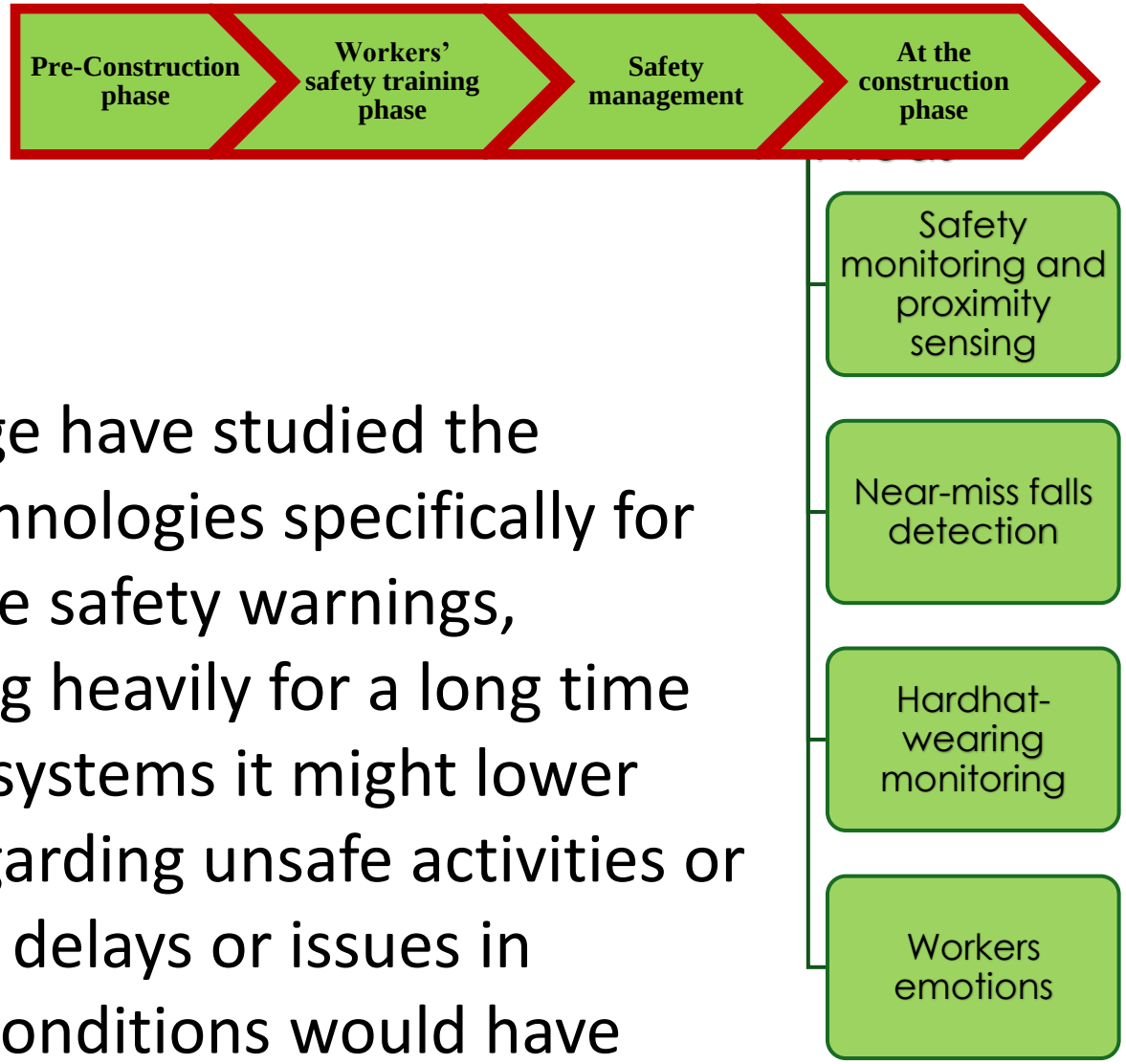
  - little is known about user acceptance of safety technologies such as wearable technologies even with the positive potential and functionality of that technologies (Choi et al. 2017).



- Other limitations:

  - No researches proposing the integration of two or more safety systems in order to effectively manage strengths and weakness of new or commercially available systems, hence achieving complementary benefits.

  - No studies have focused on the organizational change management aspect of adopting safety technologies in the construction industry.



- Other limitations:

  - No research to the authors knowledge have studied the implications of long use of safety technologies specifically for on-site wearable systems that provide safety warnings,
    - For example, when workers relying heavily for a long time on sensing and automated alerts systems it might lower their attention and judgments regarding unsafe activities or conditions, which means that any delays or issues in automated deduction of unsafe conditions would have higher levels of risks.

Thank you for your attention