

INTENT

Barton Malow partnered with Guardhat and conducted a trial pilot in order to get a better understanding of the safety offerings as well as the many productivity features encompassed in the technology. We knew what tech was in its IIoT devices and what it was supposed to do. We wanted to see how the system performed in the real world and how actual construction workers would react.

This paper is aimed at construction project teams. Even though we partnered with Guardhat and AXAXL and will share our results, this paper is intended to represent the contractor's point of view. A project team that reviews this document will ideally be well equipped to decide whether or not and how to deploy Guardhat.

The intent of this paper is not to decide project priorities or even to evaluate ROI. The system offers safety and productivity use cases, and it's difficult to attach a price tag to the former. For the latter, the ROI metrics captured were limited due to the size of the pilot. However, project teams should be able to read this paper and then decide for themselves whether the use-cases and potential ROI presented here apply to their project and what cost is reasonable for the benefits of those use-cases based on their own budget and priorities.



GUARDHAT IN USE

Special thanks to the project team at the Wayne County Criminal Justice Center for many hours of assistance.

WHAT IS GUARDHAT?

It is easy to think that Guardhat is just about hardhats. **Guardhat is not about hardhats - it's about IIoT** (Industrial Internet of Things). IIoT refers to a system of interrelated, internet connected objects that are able to collect and transfer data over a wireless network without human intervention.

What Guardhat wants to do is use a variety of devices to capture events and conditions, and send that data to its back end system where it can initiate actions. Whether that data comes from a hardhat, a cell phone, a wall mounted device, a clip-on tag, etc., is less important than the data itself.

Use the example of fall detection, for instance. The worker falls, a sensor in a device detects the fall and sends that information back to the central computer through the internet. This is where Guardhat really gets interesting because its back-end system is configurable, meaning the project team gets to pre-decide what happens next. Once the central computer is notified that someone fell, it can alert nearby workers, alert safety personnel via text or email, record the incident automatically into an incident tracking system, or even call for an ambulance.

Now imagine a set of devices jammed with sensors - not just fall detection, but ambient temperature, humidity, noise levels, gas detection, heart rate, etc. Each sensor can have pre-programmed, custom responses to a wide range of events or conditions.

This is why Guardhat is so powerful and such important tech. As such, upfront deployment efforts are needed. You don't just put on your smart hardhat and go back to work. There are a lot of questions to answer first.

- **What should we do with that data?**
- **What events matter?**
- **What should happen when each action is triggered?**
- **Which device supports each particular sensor?**
- **What connectivity is required to make a particular trigger work?**
- **How precisely does the device need to know its location in order to be useful?**
- **Each answer depends on multiple variables.**



THE DEVICES

HC1 COMMUNICATOR

This is the flagship hardhat form factor. It does the most, works the best, and costs the most. It is an ANSI-certified hardhat. It is packed with tech and has a battery. It weighs 1 lb 12 oz. A conventional hardhat weighs 14 oz. Functionality will be discussed later in the “Use-Cases” section.

TA1 TAG

This is a small, clip-on device and what most workers in the pilot wore. It is really just an Android phone in a small form factor. It has a screen and buttons for control and a clip on the back.

RHEA MOBILE APP

This is an Android app that runs inside Guardhat’s system. It was not tested during the pilot.

BIO BAND

Guardhat can also provide a biometric band. It is separate from the other devices and does not provide location on its own. It tracks skin temp, heart rate, and exertion as a percentage. We only tested this device on one day during the pilot, but it seems to hold the potential for better preventative and predictive safety information.

SCC

The Safety Control Center (SCC) is the back-end system and is where a lot of the power of this solution resides. The ability to configure custom responses to events requires more thought and preparation, but allows immediate, prepared responses to critical safety events where speed of action is most important. Plus, it contains the potential to provide insight that could be used to prevent or predict injuries.



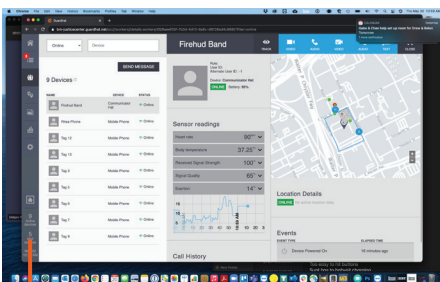
HC1 COMMUNICATOR

The flagship, ANSI-certified hardhat form factor.



TA1 TAG + RHEA MOBILE APP

Similar to an Android phone in a small form factor.



SCC - SAFETY CONTROL CENTER

The customizable, back-end system.

WORKER REACTIONS



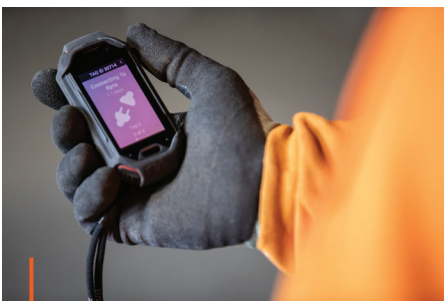
HARDHATS

Extra weight of the hardhat was initially a concern for some workers, but they quickly acclimated.



UNDER BRIM BUTTONS

After 2 - 3 days, workers felt comfortable with button function and location.



TA1 TAGS

Workers responded well to the small, cell-phone-like device.

HARDHATS: There was concern about the extra weight at first, but after a day it didn't bother them. Similarly, there was initial difficulty with the buttons. They are on the underside of the brim; easy to access, but difficult to see. It took 2-3 days to feel comfortable with the functions. The camera is mounted in the center of the brim in front. Some workers felt uncomfortable aiming a camera that was mounted on their forehead. It doesn't have a screen to see what the camera sees. They liked the easily replaceable battery. Even though workers adjusted to the hats, they generally did not like them. They resisted wearing them and preferred their regular hardhats. This resistance was not very strong and wide deployment and firm expectations is likely all it would take to drive consistent use.

TAGS: Workers generally liked the TA1 TAG. The device feels familiar since it is just a cell phone with a touch screen. They struggled a little with where to put it. Some wore it clipped to their vest and others to their pants pockets. Devices on pants or in pockets were more difficult to hear. Some workers would remove and set aside the devices during concrete pours because they worried the devices would be damaged or lost. Secure mounting near the shoulder should address these concerns. Battery life was generally adequate except in situations where the devices could not access LTE and were continually trying to connect. Workers in areas with poor connectivity consistently experienced some devices that died during their shift.

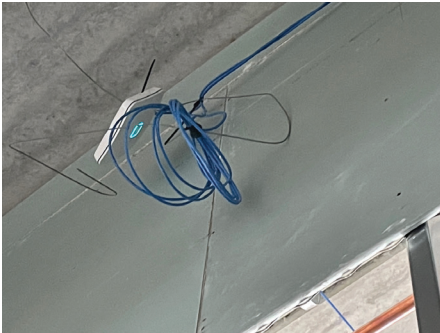
BIG BROTHER: Workers were definitely concerned about being tracked. They did not like it and initially struggled to understand why they were being tracked. They were worried that they were also being listened to and watched through the cameras. Consistent effort was made to address these concerns. The cameras and mics cannot be remotely controlled. Voice and video calls between devices are not stored or available in the SCC. Tracking is anonymous and necessary for finding workers that need assistance. It seemed that resistance to tracking diminished over the course of the pilot.

It is noteworthy that their favorite feature was "push to talk." They did not like that the menu for making calls was anonymous (tag1, tag2, tag3, etc.) but chose to leave that in place rather than have their names visible in the system.

USE: Many of the benefits of the system do not require worker action. The main functions available to workers are communication via voice or video and taking video and photos. They did not take very many photos or videos. They did use the communication via push to talk on an open channel to their team. They liked this, but were somewhat frustrated by delays and connectivity problems. They did not think that communication was reliable or fast enough to replace radios. They might have used the person-to-person communication more if the address book had not been anonymized.

HEARING: Workers complained that the speakers on the tags were not loud enough, especially when devices were clipped on at waist level or in pockets. We tested using bone conduction earphones that leave the ear open. These worked well in terms of sound and battery life. Testers said they could easily hear both ambient sound and sound from the Guardhat tag. Sound from the hardhat was good.

INFRASTRUCTURE



CONNECTIVITY

A Wifi mesh extender is shown in the top image and a Bluetooth sensor below. The Wifi is for connectivity and the Bluetooth tracks location.

In order for the devices to function properly they need two things: location and connectivity. There are different levels of each that have different capabilities and costs. Part of deployment is determining use-cases and making sure the location and connectivity infrastructure will deliver those use-cases.

LOCATION

The resolution levels are GPS (<30 meters), WiFi, Bluetooth (zones), UWB (<1 meter). These cost more as they get more accurate. The only way to determine what you need is to first address use-cases. For example, if you want to be able to locate a worker in distress, how much accuracy do you need? In some situations, maybe on a large site, GPS would be sufficient. On a dense, loud site with many rooms and levels, GPS might not be sufficient to find that worker quickly. If you want to evacuate a floor of a building Bluetooth might be the right choice. It is inexpensive and would tell you if a worker was on a floor or not. If you want to detect when a forklift is about to back over a worker and alert the worker and the operator, you would need UWB to be accurate enough for that to work. An important factor to keep in mind about location is that UWB is by far the most accurate, but is very expensive and only works with the hardhats at this time. The Hardhat is just one form factor for UWB. There are other options for workers to track UWB with the included infrastructure.

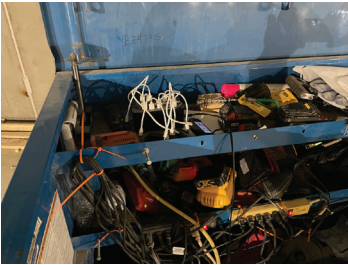
CONNECTIVITY

The second arm of infrastructure is connectivity. Whether you are locating a worker, communicating, or checking ambient noise levels, the information has to be able to access the internet/network and ultimately the SCC before it is actionable. The devices can store data, but it doesn't get back to the system until they can connect. The easiest and cheapest solution is to use LTE. All of the devices support LTE and Guardhat can use whichever major carrier has the strongest signal on your site. However, if you have poor reception with all carriers or if what you are building interferes with the cellular signal, things get more difficult and expensive. Again, this goes back to use-cases. If workers are taking photos for the record and those photos don't get uploaded until they enter an area with a strong signal, maybe that is OK. But if a worker falls or presses SOS and needs immediate assistance and there is poor connectivity and no other devices around, that is a bigger problem. It is necessary to consider each use case as it relates to accuracy of location, quality of connectivity, and which device(s) is in use.

The pilot project consisted of very dense walls and ceilings, so we installed a WiFi mesh system on 2 floors to improve connectivity. The solution needs a stable internet connection to ensure real time visibility. Connectivity was still not great. The system was a bit in the way and was even disconnected by workers at one point.

LOGISTICS

Another consideration is the physical management of the devices. They need to be charged at night and checked out the next day. During the pilot, we assigned devices to individuals to minimize potential COVID-19 exposure from sharing devices. This did not work well. Workers tended to not plug in their devices consistently and grabbed them indiscriminately in the morning. One of the foremen ended up doing most of the



DEVICE MANAGEMENT

Charging and assigning devices proved a challenge for the site team during the pilot.

charging. We tried moving the charging from the trailer to a gang box. This did not work well. The cords were a mess and the charging box got unplugged.

Guardhat supports using badges to check out devices. This would solve the assignment problem, but any successful deployment is going to need to figure out how to ensure that devices are charged and worn. From our experience on the pilot, it seems that a dedicated person responsible for daily charging and checking in and out would be needed for reliable results. There was also some concern about dust in the charge ports, but Guardhat provided small port plugs that solved that problem.

USE-CASES

Remember that each use-case requires certain capabilities to work. First, choose use-cases and then make sure the location tracking, connectivity, and devices all support the selected use-cases.

FALLS

If a worker falls and needs attention, Guardhat could save their life. The system alerts anyone on the SCC (Safety Control Center), anyone nearby, and anyone else pre-programmed. This immediate alert paired with location means help is on its way and knows where to go. Fall detection is extremely reliable in the hardhat and was in BETA at the time of the pilot for the tags, but in our testing the tags were also reliable. We got a few false positives from the tags, but better than no alert at all. Users have the ability to silence fall alerts if no assistance is needed.

SOS

The SOS feature allows a worker to call for help. This function is also potentially lifesaving, especially in loud environments or for solo workers who might otherwise have trouble getting help.

COMMUNICATION

The SCC, hardhats, and tags all have communication functionality. It is simple to make voice or video calls between any of these. There was some use of these features on the pilot, but workers preferred the push to talk feature.

PUSH TO TALK

The system allows for multiple channels with configured groups. For example, on the pilot, Channel 1 was the entire group and Channel 2 was an individual crew. This feature suffered from connectivity issues. It was not fast enough or reliable enough to replace the radios worn by foremen, but the rest of the crew used it quite a bit. Having workers wearing the devices get a feature that they benefited from and enjoyed helped with adoption. The improved communication and also provided some efficiencies. If speed and reliability of connection could be improved enough, this might be able to replace all or some of the radios used currently. Replacing expensive radios would provide a cost savings to pay for the Guardhat system and provide many more features than just communication. In any case, the enhanced communication should provide productivity and safety benefits.

PHOTOS AND VIDEO



PHOTO + VIDEO

Each devices can capture photos and video, which are automatically stored in the SCC.

Each device has the ability to capture photos and video, which are automatically stored in the SCC. It would be a benefit to have crews capture imagery, especially if those photos could be used to evaluate progress or feed something like SMARTVID.io or StructionSite. However, workers took very few photos or videos. They can't see what they took if they are wearing the hat.. The photos are only viewable on the SCC. Change management terminology can be added here so the workers are told what they are supposed to use media capture.

ENVIRONMENTAL MONITORING

The current hardhat will monitor humidity, temperature, noise, and pressure. The pressure sensor helps determine altitude/level. The noise, temperature, and humidity sensors could be useful for configurable alerts. For example, if a worker is above a certain noise level or temperature for a certain number of minutes, the system can alert the worker and the foreman. This type of data is also potentially useful in the aggregate. It would be interesting to correlate ambient temperature to injuries, for example. However, there is no way currently to compare ambient conditions to productivity. This would require some way to accurately measure productivity in this system or another. Also be aware that those sensors are only in the hardhats, and are not in the tags.

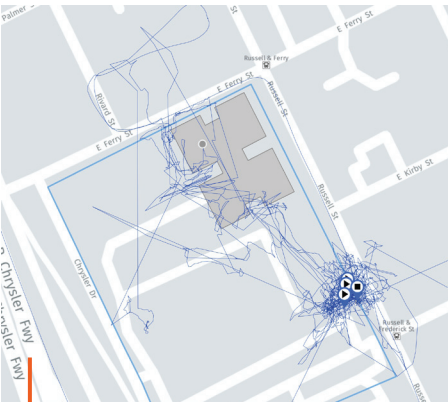
LOCATION TRACKING

Obviously, location tracking results depend on the location tracking tech deployed. In this pilot, we used LTE/GPS on the site and installed Bluetooth beacons on two floors for testing. The location tracking is vital for SOS and emergency response, and worked well for those applications. We were hoping to get useful location information as it related to productivity, but did not find a way to use the location data in the SCC. GPS provided jerky scribbles for location and since there is no tie to the schedule, it just showed us that workers were mostly at the trailer or in the building which we pretty much already knew. If location indoors is needed, more beacons will need to be installed. For the pilot we used a smaller number of beacons to show the location in the floor and that it's possible to show location in a building. In the SCC, locations can be tracked to the evacuation zone or mustering site.

There is also a heat map view that shows the amount of time spent in different areas, but it is no more accurate than the blue squiggles and has to be viewed one person at a time. There is interesting potential here, but some standard reports or even machine learning coupled with UWB (more accurate location tracking) will probably be needed to find the value in this data.

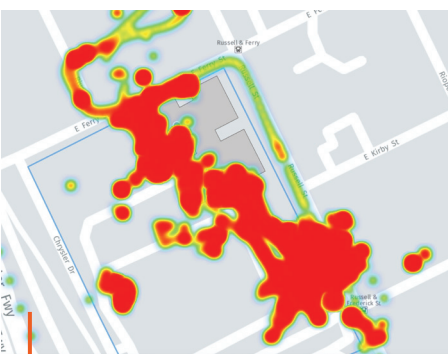
PPE COMPLIANCE

The hardhat can provide configurable warnings when it is not worn. The amount of time before the warning can be set and it is even possible to set blackout zones where the hat does not detect not-worn events (break rooms/bathrooms). The action that follows a non-worn event is also configurable. For example, a worker that removes their hardhat for more than 2 minutes could receive an audible warning and then 2 minutes after that, the system could notify their supervisor.



LOCATION TRACKING

This feature, which is vital for SOS and emergency response, worked well in the pilot.



HEAT MAPPING

Indicates the amount of time team members spent in various locations.



HUMAN CONDITIONS AND VITALS MONITORING

Tracking more than ambient temperature, humidity, pressure, and noise requires the Biometric Band. Use of the band would provide worker-by-worker data and would correlate more accurately to health incidents. For example, the device would much more accurately indicate heat stress. It could even be configured to detect a heart attack and directly contact EMS. The stress meter on the band provides percentage of exertion. These three sensors seem useful in preventing or predicting safety incidents.

LONE WORKER

The safety features of the hats and tags are even more vital for isolated workers. The ability to call for help or even receive help when unconscious after a fall could save a worker's life. Make sure to consider connectivity when relying on those safety features. If the device can't send a signal, it can't call for help.



GEOFENCING

Robust geofencing features including evacuation, muster zones, and restricted areas can be built into the system.

GEOFENCING

The SCC has tools to set up geofences. Blackout zones are areas where workers disappear from the system (bathrooms, etc.). Evacuation and muster zones (evaluated next in this use-case list). Restricted areas can be set up to keep some or all workers out of an area. These are powerful features, but require a plan to be used well. It would be impractical to capture every area that was restricted due to overhead loads, curing concrete, etc. no matter how short the restriction. A project team would need to decide what types of dangers and how long they would be in a certain area and who would be responsible to mark these areas in the system to leverage this capability. Fortunately, it is possible to set durations in the system so that restricted areas expire and don't need to be manually removed.

EVACUATION

Evacuation and muster areas are a particular use of geofencing. Using this feature, it is possible to evacuate some or all workers from some or all areas. The system audibly tells everyone to evacuate and tells them again when they reach the muster zone. This removes the need to count heads. This is powerful and worked well in testing. Keep in mind that any individual with poor connectivity or a dead battery is at risk. It is possible in the system to see where they were last, but not whether they safely evacuated.

LIGHTNING

Evacuations are rare, but more common is the need to take cover from lightning. Guardhat provides a faster, more efficient way to warn workers of weather events. It is possible to use geofences or even just audible warnings when needed.

ATTENDANCE AND TIME TRACKING

If devices could be reliably charged and worn, the system could replace other methods of tracking time. This could remove the burden of supervisors that currently track time or remove the cost of RFID systems that track time. The potential savings here could help offset the cost of the Guardhat system.

TIME AND MOTION STUDIES

The system as tested in the pilot was not useful for time and motion studies. We intend to try testing this use-case with a UWB (more accurate location tracking) infrastructure on a future project.

COLLISION AVOIDANCE

We were not able to test this use-case on the pilot because it requires the accuracy of UWB tracking to protect workers from being struck by equipment. This might be an important use-case on some projects.

REMOTE ASSISTANCE

It is very easy for a worker to initiate a voice or video call to the SCC and ask questions while showing the SCC user what they are looking at in real time. There were also opportunities for the foreman to contact someone in a particular location to see what they were working on. It is not a goal to have foremen just sit at their computers, but for occasional use and time sensitive requests it proved useful to be able to handle some requests remotely. Workers did not contact safety or project management via SCC. To leverage remote assistance on the pilot required giving SCC access at the foreman level.

SCC (SAFETY CONTROL CENTER)

For the pilot, we gave control center access to on site safety, a Project Engineer and a Foreman. This seems to be a good mix. The Safety Professional was often not at their desk but could check their iPad for any alerts. The Project Engineer was mostly in front of their computer, which is ideal for responding to urgent issues. The crew Foreman was mostly not at their desk, but as mentioned in "Remote Assistance," was able to address some questions/issues remotely by having the SCC at their desk. One nuance to keep in mind is that if a worker with a tag wants to voice or video call the SCC, they can choose from a menu, but hat wearers will be directed to SCC operators in a pre-prioritized list.

POSSIBLE PROJECT CRITERIA

- Guardhat might be a good solution for any project, but included here is a list of criteria that can make it an exceptionally good resource:
- Large sites where communication and locating others is especially difficult because of long distances
- Projects where extreme temperatures are a concern
- Congested sites where it might be difficult to locate a worker
- Sites with good cellular signal
- Projects where workers will be isolated

CONCLUSIONS / RECOMMENDATIONS

What makes Guardhat interesting is how flexible and configurable it is. It is not a simple tool that does one or two things - it is a system that can do many things. The safety features are important, but to justify the cost and effort we need to leverage multiple use-cases. Selection of use-cases should drive use of the system and all choices about devices and infrastructure. This is cutting edge tech and therefore project teams should not expect plug and play ease-of-use. There is some work required to get everything working properly, pre-configure actions, get teams to cooperate with something new, and keep everything going once set up.

The reason to take on this extra work is that IIoT on jobsites is an inevitability. The Guardhat system in its current form provides solid benefits, especially in terms of safety and communication. Deploying now, while the tech is emerging, allows us to be ahead of the curve and also help shape the IIoT jobsites of the future.

