The Feasibility of Real Time Location Systems in Construction

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The construction industry is becoming increasingly sophisticated by implementing new computer-based technologies to improve safety, efficiency, accountability, and many other aspects. One new type of technology that is becoming increasingly popular in other labor based industries is real time locating systems. These systems allow for managers to keep accountability of a variety of assets in a manufacturing facility or industrial center. Recent research has shown the benefits and potential uses of these systems on construction jobsites. This paper seeks to analyze the potential for Real Time Location Systems (RTLS) to be used on construction jobsites and compare the different RTLS products that are being offered for use in various industries. The goal is to increase awareness within the construction industry of this technology and to provide interested owners, contractors, and subcontractors the needed information in order to implement RTLS. At this time, RTLS is not widely adopted within the construction industry potentially because the benefits do not yet outweigh the costs. Through better understanding of RTLS products, the Architect, Engineer, and Contractors (AEC) industry may consider this option increasingly feasible on their jobsites.

Key words: RTLS, Tracking, Technology, Safety, Assets

Introduction

The typical construction jobsite contains a plethora of moving components to include materials, tools, equipment, vehicles, and workers. As projects get larger, the management of all these assets becomes more complicated and time consuming for the construction managers who are responsible for the project. Real time locating systems (RTLS) offers a solution for construction managers to more effectively keep track of all components on a jobsite even while offsite. While the use of RTLS is not new to the construction industry, it has not yet been widely adopted. (Soltanmohammadlou et al., 2019) The proposed benefits for RTLS within the construction industry include safety, material storage/locating, equipment tracking, and labor efficiency. Most studies conducted have been focused more heavily on the safety benefits of RTLS within construction.

The use of RTLS in other industries such as manufacturing, mining, and healthcare has been well documented in recent years. Since the purpose of RTLS is to keep accountability of assets, it is clear why it would be common in these industries. (Li et. al, 2015) Industries such as manufacturing utilize asset location information to optimize decision making processes, which increases overall efficiency. (Kelepouris, McFarlane, 2010) Similar advantages of using RTLS are found within other industries as well. While many of the available RTLS systems are focused more on these other industries, they do have capabilities within the construction industry. The feasibility of RTLS in construction relies on various factors such as individual product capabilities, the project size limitations, and of course cost. (Soltanmohammadlou et al., 2019) With a vast array of products available with differing capabilities, this paper aims to explore the various options available and how they could apply to construction in the future.

Fundamentals of RTLS

While there are many different types of technology used to provide RTLS, every system has the same overall purpose of keeping accountability of assets. Different fields or industries use RTLS to keep track of different objects or people, and the technology required to accomplish that can depend on the size or layout of the area. The benefit of keeping track of objects or people also differs depending on the industry and thus some systems are better suited for certain industries. While the type of technology may differ between products, there are many similar components needed such as tags and anchors (or receivers). (Li et. al, 2015).

The basic concept of RTLS is some type of device, typically referred to as a tag, is attached to an asset that is desired to be tracked. The tag attached to an asset then communicates with an anchor that is placed elsewhere on the site, which essentially provides the location of that object on the site to a computer. This information can be viewed by the client whom the service is being provided for on some type of software. The location data is constantly updated to provide a real-time location of the asset being tracked. This would ideally be provided on some type of map, of which the viewer is familiar with, so that they can better understand the location data and utilize the information as needed.

The technology by which this is accomplished differs from product to product. Some examples of the technology used are ultra-wideband (UWB), GPS, WiFi, or Radio-Frequency Identification (RFID). It is important to note that each of these types of technology systems have their strengths and limitations, and thus their applications vary. The ways in which different products use this data can differ greatly depending on the type of service they are trying to provide to the client. Many features as well as the software used to view the information are unique to each individual product.

RTLS in Other Industries

Many other labor-based industries have been successfully using RTLS for years now with many of the same types of technology that can be used in construction. The most prominent industries that utilize RTLS are hospital services, manufacturing, and mining.

Hospitals appear to be one the most prominent of industries utilizing RTLS due to the static parameters of the location in which assets are being tracked. Hospital real-time location systems are designed to identify and locate tagged equipment, personnel, or patients as they move through hospital facilities. According to a 2008 survey of U.S. hospitals, 15% of administrators indicated that their hospitals already had RTLS in place and another 43% expressed their intent to purchase a system within the next two years. (Fisher, Monahan, 2012). Hospitals can use the information gathered to increase safety, efficiency, and other benefits similar to how construction could benefit. It is also clear that this type of technology has a long track record of being used in hospitals and has advanced greatly over the past decade.

Manufacturing is another industry that utilizes RTLS in a number of ways. The overall goal of using such a system in manufacturing is to increase efficiency and ultimately save time, due to the fact that employees spend significant amounts of time searching for misplaced assets (Kelepouris, McFarlane, 2010). Manufacturing typically is contained in a facility which is static in its size and layout. Assets within that facility can thus be tracked effectively once the proper RTLS hardware is in place. Due to the large quantities of various materials used in the manufacturing industry, it is beneficial to have the ability to track down materials in a timely manner.

RTLS in Construction

While the use of RTLS in Construction has not been widely adopted, there has been research conducted on the topic. These different studies have evaluated the different types of RTLS technologies that can be used, the various types of applications in construction, the benefits, as well as the limitations. The most researched application for RTLS is for safety benefits on construction jobsites.

Li et al. (2015) provide a systematic review of the use of RTLS technologies in the construction industry. In their paper, they identify the different types of RTLS technologies that have been used in other industries and construction. These technologies include: RFID, GPS, ultra-wideband (UWB), wireless local area network (WLAN), ultrasound, and infrared. It is noted that each of these types of technology have their benefits, and some are more applicable than others on a construction jobsite depending on the environment. They also acknowledge that there are two important factors affecting the choice of RTLS in construction projects which are cost and deployment. Since there are only a few studies which have considered the cost involved, it is difficult for the industry to adopt RTLS. (Li et al., 2015). In a brief discussion on the benefits of RTLS they highlight the potential to track the location of materials which can result in time and cost savings. While this paper provides a great overview of the potential technologies, there is a lack of research on specific products which real companies offer.

Soltanmohammadlou et al. (2019), researched the utilization of RTLS in construction with a focus on the safety management. They found that the occurrence of many direct immediate causes of accidents can be prevented by proper monitoring of site conditions. They also acknowledge that it would be impossible to monitor the whole site in real time without utilizing advanced technologies. Their research included a total of 75 relevant papers that were identified to be addressing construction safety and RTLS simultaneously. Using this information they were able to tabulate the common uses for RTLS relating to safety. The results are: 41% did not mention accident types, 34% mentioned collision accidents, 9% mentioned fall accidents, 6% health problems, 4% struck-by falling, 3% gas explosion, and 3% near-miss. (Soltanmohammadlou et al., 2019) Additionally, the most common research topics for these publications was Workers, Workers and Equipment, Behavior-based safety, safety alert and warning, and collision tracking. The consensus between these many research papers is that RTLS can aid in safety management on construction jobsites.

Huang et al. (2020) researched the use of Bluetooth low energy (BLE) RTLS, where they conducted a case study on the subject. Previous research showed that RFID has too low of accuracy for safety management on construction sites. They also acknowledge previous research that revealed both UWB and GPS are extremely accurate for safety applications but tend to be more expensive since they typically require timing cables to synchronize data across the site. Using BLE in their case study, they were able to determine distances between workers and equipment and generate alerts within 1 second when they were in dangerous proximity. Exact location of both workers and equipment could also be seen in real time at any point in time. BLE is just one of the technologies that can provide accurate positioning in a large site, and thus it is important to look at all of the available options and their availability for construction application.

Methodology

The objective of this research is as follows:

- To gauge the availability for RTLS technology for construction purposes and the interest in companies to provide for the construction industry
- To compare the capabilities of the available full service RTLS products offered for construction purposes
- To explore the costs of different RTLS systems to help determine the feasibility for their use on construction projects

A descriptive survey was conducted in order to gather data on various products that are being offered by different companies. The RTLS companies were gathered through a simple google search of "RTLS construction" and the top 9 companies in the results were used in this research. The companies are headquartered in various locations around the world. An initial email was sent to each company to gauge their interest in participating in the survey. The survey was then forwarded to the companies that were willing to participate in the survey. The survey was conducted on google forms and consisted of 17 questions which are contained in Appendix A.

Results

Availability of RTLS Technology for Construction Purposes

There were 9 different companies that were selected based off the initial online search for RTLS technologies that offer services for construction. There appears to be a lot of different RTLS technologies that are advertised online for a variety of purposes. Construction does not appear to be the top sector for many of these companies, but some put more focus on it than others. Of 9 companies contacted concerning their available RTLS services, 5 responded to the online survey and answered all of the questions.

A slight majority of the companies that responded stated that their system is commonly used in construction, as shown in figure 1. 3 of them said that their system is commonly used for construction. The other 2 respondents said that their system is not commonly used for construction. There was quite a range in experience between these companies in how much they have worked within the construction industry. One company has only had approximately 3 projects that had used their RTLS technology, and also responded that they do not commonly work in construction. The second company had slightly more experience in construction, having been on 10 construction projects. Company 3 has used their system on approximately 150 constrution projects, which showed construction was a much larger priorty for this company. Company 4 did not have an exact number of past construction projects to provide, but noted that their second largest customer is in construction. The 5th company has not used their services on any construction projects.

The companies that do not commonly use their systems for construction were asked about their interest in expanding into the construction industry. Company 4 responded that they plan to expand into the industry. Company 1 did not respond to this question, but they did state elsewhere that they have used their system on approximately 3 construction projects in the past. It is unclear whether or not they plan to increase their presence in the construction industry.

Within the construction industry there are many different types of projects that have different requirements due to the environment. Company 3, which has the most experience in the construction industry, indicated that their product primarily can be used on large commercial and heavy industrial construction. Company 2 stated that their system can be used on highway, tunnel, and high rise construction projects. Company 5 stated that their system can be used on all types of construction projects, but suggested that major RF (Radio Frequency) shielding may occur on certain projects which could cause interferance with the system. However, they do have some deployment tactics that can be used to reduce these effects. Company 1, has used their system on warehouse construction projects.

The majority of the companies stressed the importance that all of their systems can also be used in industries other than construction, which for most of these companies comprises a majority of their business. The most popular industries appear to be mining, manufacturing, healthcare/hospitals, and oil/gas. Company 5 stated that their system can be used anywhere that requires location or data services. The four other companies directly stated that their system can be used in mining, with company 4 stating that mining is their primary industry. Three of the five companies reported that manufacturing is another industry that their system can be used in. Healthcare or hospitals was indicated as another industry by three of the five companies. Oil and gas is another industry that was reported by two of the five companies.

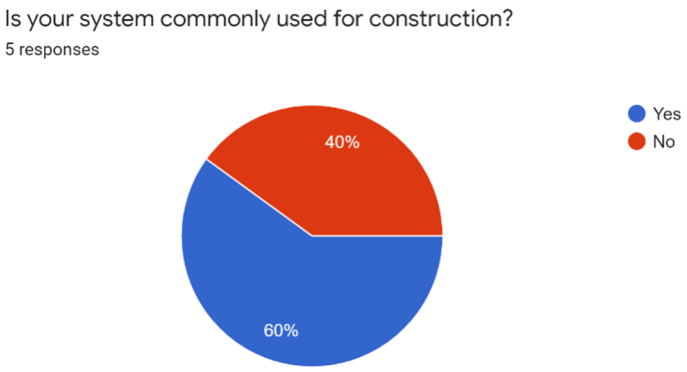

Figure 1

Comparison of RTLS Product Capabilities

Li et al. (2015) researched the primary strengths and weaknesses of the many types of RTLS systems that can be utilized in construction. Many of those same types of technologies are utilized by the companies discussed in this research. The type of technology utilized by each company influences the capabilities of the individual products. Three of the five companies utilize ultra-wideband (UWB) technology, which appears to be the most common. While company 4 uses UWB, they also use Bluetooth, Ultra High Frequency, and GPS technologies for their products. Company 3 uses a 900 mhz Radio Frequency technology for their product. Company 5 primarily uses active RFID Bluetooth, but also uses WiFi, GPS, PoLTE, and cell ID for their RTLS product.

The different RTLS products also have a variety of purposes, which can play a role in selection by a construction manager, which Table 1 details below. The primary intended purpose for a majority of these products seems to be to provide real-time location data. The way that a customer utilizes this data is ultimately up to them, but it is seen that some common cases are efficiency, productivity, and safety concerns. Collision avoidance can also be considered a type of safety measure, making safety the highest mentioned use for these products by the companies themselves.

Table 1

	Type of Technology	**Primary Intended Purpose**
Company 1	UWB	Indoor Location, Collision Avoidance
Company 2	UWB	Real-time location. Use cases are efficiency management and safety.
Company 3	900 Mhz Radio Frequency	Real-time location data to improve productivity, worker safety, and site risk.
Company 4	UWB, Bluetooth, UHF, GPS	Safety
Company 5	RFID, Bluetooth, WiFi, GPS, PoLTE, Cell ID	Real time location services

RTLS systems are heavily reliant on being able to attach a trackable device, often referred to as a tag, to the asset that needs to be tracked. There are a variety of assets that can be tracked by different RTLS products, as shown in figure 2. All five companies indicated that their RTLS systems can be used for both workers and equipment, which appear to be the most common of assets to track on a construction jobsite. Two of the five companies responded that their systems can be used to track materials. Two companies mentioned that vehicles can be tracked as well, which can fall similarly under the equipment category. Company 5 stated that "If you can stick a tag to something, and ensure there's a backhaul connection available for the tag, we can tell you where the tag is." Therefore, it is practicable to track a wide variety of assets using their product, which may be applicable to many of the other products although not specified.

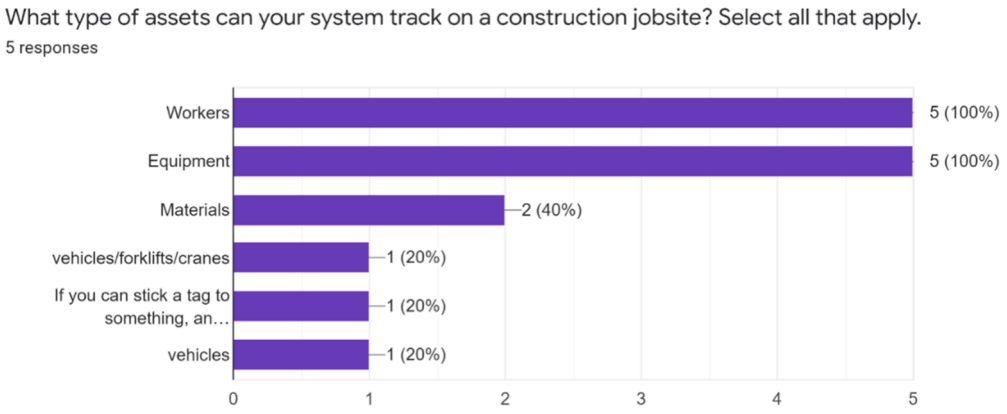

Figure 2

While there are key differences in the hardware used between products, there are also some variations in the software used to view location data. Companies were asked about four different aspects relating to the software capabilities of their RTLS systems, as shown in table 2. The first consideration is whether the product offers any type of software dashboard at all. All five of the companies in this paper do have some type of software dashboard, but the complexity of that software is not analyzed here. Three of the five companies also do provide a mobile application. A mobile application provides a convenient means for construction managers to access the information at any time or in any location. For a system to also be truly considered an RTLS it must be able to provide location data that can be viewed in real-time. Information that cannot be displayed in real-time is not as useful for the intended purposes. All five of the systems in this research allow the user to view the information in real-time. The final feature that is included in this research is the ability for these RTLS to be integrated with a Building Information Modeling (BIM) application to show location data on virtual building models. This is a feature that allows for construction managers to fully understand locations in correlation to the actual jobsite, which changes drastically over the course of project. Only two of the five companies state that their systems can be integrated with BIM applications.

Table 2

	Software Dashboard	**Mobile Application**	**Real-time data**	**BIM Integration**
Company 1	Yes	No	Yes	No
Company 2	Yes	Yes	Yes	Yes
Company 3	Yes	Yes	Yes	No
Company 4	Yes	Yes	Yes	Yes
Company 5	Yes	No	Yes	No

RTLS Product Costs

There are several different factors to consider in the cost for using an RTLS product on a construction jobsite. The different devices necessary for a complete RTLS system is the first part to consider. Each of these individual components also carry a cost to purchase by the customer but is typically property of the customer at that point and can be used on different projects. As with many software products, there are often monthly or yearly subscription fees which must be paid for the use of the system on a specific project.

Many of the components required for an operational system are similar between the different products that are offered. However, there are of course some minor differences between products depending on the type of technology that is being utilized. The basic components that each of the system requires is the trackable tags, which are attached to the asset to be tracked, and the "anchors," which are the access points that track the tags. Some of the systems require different tags depending on the type of asset being track such as a vehicle instead of a worker. Company 1 states that their product in some cases may require a type of internet connection or 4G service. Company 2 product also requires the use of both anchors and gateways to complete their system in addition to the tags.

The cost of the individual components of each system is a major portion of the entire cost, which is heavily dependent on the scale of the project. Many of the companies in this research indicated that their cost information is non-disclosable information. Two of the five companies did provide

approximate component costs, which provides a basis for a possible estimate of costs. Company 1 stated the approximate cost of each of their devices is $100. This cost applies to both the anchors and the trackable tags. Company 2 provided a cost range of $75-$125 per tag, $250-$700 per anchor, and $600-$800 per gateway. Company 2 also noted that the cost of these components will depend on the project size/scale. Along with the individual component costs, there are the subscription fees that must be included in overall cost to implement. Many of these companies state that these subscription costs will depend on the size of the project along with other factors. Company 1 directly stated that the subscription fees for their system is 20% of the device costs per year with a 3 year contract. Company 4 gives the option to select a one off payment so that the system would be the property of the customer.

The overall costs of implementing any of these RTLS products on a construction jobsite is going to strongly depend on the scope and the scale of the project. It appears that the cost of tags may be relatively the same price between several products, averaging out to $100 per tag. The number of assets needing to be tracked on the jobsite will directly influence the cost of the tags for the project. The amount of required anchors or gateways will also depend on the amount of assets being tracked as well as the area needing to be covered. In the case of company 1, the system subscription costs are a direct percentage of the overall cost, and therefore also dependent on the amount of assets or size of the project. Another consideration in overall implementation costs is the cost of energy needed to power these systems, which is not covered in this research.

Conclusion

Analysis

It seems that many of the available RTLS products currently are more focused on industries other than construction, such as: mining, healthcare, and manufacturing. The RTLS products in this paper do have some experience within the construction, or at least expressed interest to expand into construction. The lack of experience in the construction industry for many of these companies offering RTLS may be due to the lack of knowledge about the products by construction managers. However, the technology is available for those within the construction industry who see the value. For those interested in utilizing RTLS on a construction jobsite, it may be important to consider the experience and capabilities of the company within the construction industry.

While UWB appears to be the most common type of technology being used for RTLS, it is important to note that many companies are successfully using other types of technology to accomplish the same goals. Regardless of the type of technology being used, all the companies in this paper are capable of providing real time location data. Use cases for RTLS are primarily for safety, efficiency, or productivity. All of these products can be used to track equipment, workers, and vehicles on a construction jobsite. The primary focus may differ between products, and thus a construction manager's reasons for using RTLS may impact the decision on which product to use. There are also other features that may make certain RTLS products more feasible than others. Each of these products do offer some type of software interface to view the data, but only 60% have a mobile application and only 40% can integrate their data with BIM applications. These are features that would be key for construction managers to have in order to make these products more convenient.

Most of these RTLS products consist of the same components, but cost can differ. Unfortunately many of these companies could not provide this cost information. Based off the companies that did provide cost information, it is apparent that cost will be dependent on the scope and size of the project. Tags average around $100, which will be needed for each individual asset to be tracked through the system. This price could increase quickly on larger projects. Other components such as anchors and gateways are required based on the size of the project and density of items being tracked and thus increase along with the costs of the tags. Service subscription may be a percentage of overall cost, or some products may offer a one off payment to own the system.

Future Research

While there are a variety of RTLS systems available for the construction industry, it is unclear how much these systems cost to implement on a construction job. A cost-based case study would be beneficial to understand the true costs of implementing an RTLS product on a construction jobsite. An analysis of the strengths and weaknesses of the different types of technology these products use could also be beneficial to understanding which are most applicable to construction.

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Appendix A

1. What is the primary intended purpose of your system?
2. Is your system commonly used for construction?
    a. If not, does your company plan to expand into the industry?
3. What type of construction jobsites can the system be used on?
4. What are the project size limitations?
5. What type of assets can your system track on a construction jobsite?
6. What other industries can this system be used for?
7. What type of technology does your system use to track assets?
8. Is there a software user interface or dashboard offered with the system?
9. Do you offer a mobile application?
10. Can information be viewed in real time?
11. Does the system integrate with other BIM applications to show locations on virtual building models?
    a. If yes, which applications?
12. What components are required for your system to be operational on a job site?
13. What is the approximate cost of each of the individual components?
14. What are the monthly/yearly subscription fees for the use of the system?
15. Approximately how many construction projects has the system been used on?