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Theoretical Understanding of Indoor/Outdoor Tracking Systems in the Construction Industry

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Abstract: **The construction project manager frequently encounters difficulties tracking the performance or migration of contractor workers on the construction site. Additionally, typical performance data collection methods are complex, costly, and time-consuming. Due to information loops, the construction industry's ability to obtain data on time is hampered. As a result, the tracking strategy attracts researchers supporting the construction industry for a long time. The primary tracking system inventory will be introduced in this study as a powerful tool for decision-makers. The tracking systems demonstrate their value, particularly in the aftermath of the SARS-COV-2 pandemic. It appears as though the only option to track worker performance from site to office quickly is through automated tracking. Eventually, the new technology can help project stakeholders to measure the activity progress quickly and efficiently.**

Keywords: **BIM; Radio-Frequency Identification (RFID); Wireless Fidelity (WI-FI); Bluetooth (BT); Bluetooth Low Energy (BLE); Building Information Modelling (BIM).**

1. INTRODUCTION

The new iconic National Bank of Kuwait (NBK) Headquarters building in the heart of Kuwait City with 300 m tall, covering a total floor area of 127,000 sqm. The tower boasts a distinctive presence among other high-rise buildings in Kuwait with Construction Value (400,000,000 US$). A considerable number of contractors working together in a very crowded city may affect each other. Once the project manager accepts the contractor schedule supplied with the resources, it is very complicated to know precisely where that number of works, on which floor, and what item they are working on. Therefore, if there were a tool to detect each contractor's performance and to know the impact of the contracting companies on each other, it would be exciting, "This is what the Ezzat Hallal - Chief Engineer- The new iconic (NBK) Headquarters' building said in 2018" [1]. This study is aimed to establish a theoretical understanding of the concept of indoor/ outdoor tracking techniques in the construction industry and the barriers limiting its adoption. Traditional workers tracking performance techniques in the construction sector are time-consuming, costly, and a waste of team effort, say industry experts. The information may be linked to an error in reproducing the data, using outdated data, or partiality. The efforts of researchers in this area are beneficial in calling attention to its importance and promoting research.

Moreover, Significant global drivers and construction deficiency indicate how the construction industry needs a paradigm shift. Achieving the global drive need to ensure how the building is constructed effectively. Many governments see that implement technology in construction such as BIM will bridge the gap to respond to this catalyst for change. Using technology in the construction industry is seen as an opportunity to increase the economic performance of the construction by reducing costs and risks while improving performance and productivity and satisfying the environmental drivers.

1.1. THE WORLD GLOBAL DRIVE

Rarely hears about a paradigm change in the construction industry technology around the world. United Nations Environment Programme (UNEP) reported in 2018 that Africa is constructed around 1,324 buildings per day in urban areas. The population is growing at a rate as a world has never experienced before. To facilitate world changes, there must be global drivers. The current global drivers can generally be grouped under three main headings: the same three pillars of sustainability; Social, Climate, and Economic.

- Social Drive:

The world population currently is about 7.6 billion. By 2030 it is estimated to be 8.6 billion, and by 2050, the estimate is 9.8 billion; if the estimate for the year 2050 holds, by 2050, there will be an extra 2.2 billion people on this planet. With more people comes more required space to cope with their needs. Dealing with change demands is the biggest challenge facing every organization today [2&3].

- Environmental Drive:

The National Oceanic and Atmospheric (NOAA) Administration stated that, after the year 2000, the world witnessed the hottest years. In addition, despite current initiatives, global atmospheric CO2 levels are steadily increasing.

- Economical Drive:

The construction industry profit is low due to the competitive nature of the contractors. The average pre-tax profit margins for the ten largest tier (1^{st}) contractor's sites in the UK is -0.5%. In addition, the world's economy is still recovering from the global financial crisis of 2011 and COVID19. However, following research by both the Construction Industry Institute (CII) and the Building Smart Alliance (BSA), potentially, over half (50%) of the project's cost can be attributed to non-value-adding efforts or waste in resources and materials [4].

In addition to the previous global drives, one crucial difference between the construction industry and others is that "no prototypes" are tried or tested before being built or manufacturing. This is a burden on the construction industry, which has not developed since only time. Prototype modeling was able the design and construction team to determine project shape when they best understood how the shape would impact the structure, the site, the budget, and the construction schedule. The American Institute of Architects (AIA) define the Integrated Project Delivery (IPD) as a project delivery method that participates systems, business, structures, people, and practices into a procedure that collaboratively connects the talents and insights of all project members to enhance project results, increase value to the owner, decrease waste, and maximize efficiency through the project lifecycle [5]. Significant global drivers and construction deficiency indicate how the construction industry needs a paradigm shift. Achieving the global drive need to ensure how the building is constructed effectively. Many governments see that implement technology in construction such as BIM will bridge the gap to respond to this catalyst for change. Using technology in the construction industry is seen as an opportunity to increase the economic performance of the construction by reducing costs and risks while improving performance and productivity and satisfying the environmental drivers.

2. TRACKING TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

2.1. Introduction

Time theft is an adversary lurking in the depths of the construction industry. The chairman of Robert Half International in New York said stealing time would take $160 billion in corporate profits through 1985 while hurting the ability of many companies to operate correctly. In 1985 Half conducted a survey and stated shocking results. According to Half, the average office labor steals 4.5 hours a week from employers, while the average manufacturing labor steals just under 4 hours. The labor wastes time in various ways, including arriving late and leaving early; socializing; conducting personal business; faking illness and wasting sick leave; indulging in long lunches and coffee breaks; working at a slow pace to force overtime conditions; and sleeping on the job. Agree Merrill Douglass with Half study, the Grandville Time Management Centre president.

Douglass stated that up to 50% of labor work is wasted in most companies. "Science Research Associates and Booz, Allen & Hamilton Inc. have conducted studies that have found that about 45% of the workday is wasted. That is more than 3.5 hours a day" [6].

In the beginning, the apparent solution to this issue may seem to provide construction sites with supervisors. Usually, supervisors are paid higher than those who manage them because of their qualifications and experience to keep the team on track, and they have proven that they can be trusted. Supervisor's tasks often seem endless, so when they have to perform non-essential and time-consuming tasks like making sure every employee is actually where their timecard indicates throughout the day, they are left out of the more pressing matters. It also limits its ability to manage multiple projects in different locations simultaneously. Technology can provide a solution to track or monitor labor or site activities. Whether technology solutions simplify back-office operations or provide real-time visibility into a job site, their role is often to drive efficiencies in the construction lifecycle. Accurate monitoring technology of onsite construction operations can bring immediate awareness and corrective action for the project. Some monitoring approaches will detect and track outdoor site activities based on video or image analysis. Others were starting to use the GPS (Global Positioning System) and UWB (Ultra-Wide Band) [7]. Also, some of them using Wireless Fidelity (WIFI), and others use Bluetooth for tracking the objects. Park and Brilakis, in 2012, present a fusion of tracking and detection, which enables automated initialization of tracking and enhances accuracy [8].

2.2. Background Subtraction Method

Some monitoring approaches will detect and track site activities based on video or image analysis. Gong and Caldas, in 2011, evaluate the three most widely tested background subtraction methods (Mixtures of Gaussian, Codebook-based, and Bayesian model-based methods). Gong and Caldas conclude that the Codebook based method and Bayesian model-based method outperform the Mixtures of Gaussian. Chi and Cladas, in 2011, adopt background subtraction to segment moving objects and classify the workers, backhoes, and loaders by several dimensional features [9]. Notable that the background subtraction is only applicable in a mounted camera and requires updating strategy to reflect the change in the background. Since motion is the primary factor, background subtraction does not detect fixed or still objects such as trucks or excavators [10].

2.3. Object Shape Features Method

Another general approach for construction activity detection is utilizing object shape features that usually use machine learning technology. The object shape feature begins with collecting image samples of various conditions and then adding each shape’s feature descriptor. Similarly, some research like M. Park and I. Brilakis [8] starts using motion, shape, and color features to detect construction workers wearing safety vests. This algorithm first locates the workers using the background subtraction and HOG-based classifier, then distinguishes construction workers based on the color histograms trained with k-Nearest Neighbours. Accordingly, this method can detect the safety vest-wearing and facilitate onsite safety monitoring

2.4. Automated Tracking

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2.4.1. Global Positioning Systems (GPS)

Numerous businesses, including navigation, transportation, manufacturing, and logistics, rely on location tracking technologies. While Global Positioning Systems (GPS) have been widely accepted for outdoor localization, no robust solution has been developed for general use in the inside setting. In stark contrast, numerous industries have demonstrated an increase in demand for indoor localization [11].

2.4.2. Inertial Navigation Systems (INS)

INS-based solutions determine the user’s location by utilizing inertial measurement sensors such as accelerometers and gyroscopes. This approach is entirely self-contained, requiring just a sensor device carried by the tracked individual. Since position estimations are derived from acceleration measurements via a double integration, this technique suffers from a significant distance-related drifting fault [12].

2.4.3. Ultra-Wide Band (UWB)

UWB is a location tracking technology that enables precise location tracking. Compared to RFID, it sends data over a much wider bandwidth, making it less susceptible to signal interference and more capable of passing through walls. While UWB-based localization technology has the potential to attain centimeter-level accuracy, numerous investigations have demonstrated that the UWB system’s accuracy is heavily dependent on a clear line of sight between readers and tracked subjects. Additionally, the primary disadvantage of UWB is its high hardware cost, which is approximately $140 per square meter, making it an expensive tool [13].

2.4.4. Business Smartphones

However, K. Tabata et al., 2016 started using business smartphones as indoor positioning technology instead of special positioning devices. In this study, labors smartphones were designed to measure worker behavior continuously for a long time. However, the workers raised some faults regarding using the smartphone for tracking, such as battery consumption became faster than before; the smartphone was heated because an application runs on during working hours, which is critical [14].

2.4.5. Laser-Scanner

Others use a dedicated facilities attempted method by estimating office workers moving behavior and face-to-face communication using laser-scanner [15].

2.4.6. WLAN-Based

WLAN-based is primarily dependent on the capability of the current WLAN infrastructure. As a result, it is one of the most cost-effective solutions for localization.

2.4.7. Radio Frequency Identification (RFID)

Numerous contractors in the United States utilize RFID technology offered by the program to track labor on more than 30 construction sites. RFID is similar to barcoding, which is applied to a tag or label and read by a device that retains the data. The RFID system is composed of two components: a chip (Tag) that stores and processes data and collects energy from the RFID reader’s interrogating radio waves, and an antenna that receives and transmits a signal and is powered locally (via a battery) and capable of operating hundreds of meters away from the RFID reader. Since RFID tags can be placed in clothing and personal goods and attached to persons, the possibility of reading personally identifiable information without authorization has created grave privacy issues.

In 2007, Ergen and Akinci used RFID to track and fix the tag in the labor hats. RFID was different from traditional barcodes where the tags do not need to be within the RFID reader’s line of sight and cloud be embedded in the tracked object. The tags vary in many aspects: operational life, size, data storage capacity, power source, memory type, data transfer rates, frequency, reading range, and cost [16]. IDTechEx Research has examined the RFID business for 19 years and forecasts that the total RFID market will reach $11.0 billion in 2018, increasing to $13.4 billion in 2022. IDTechEx anticipates selling 16.4 billion tags in 2018, up from 15.0 billion in 2017 [17].

2.4.8. Wi-Fi - Based

Wi-Fi is a seminal technological development of the modern era. Wi-Fi can be used on the construction site since it enables devices to connect to the internet without the necessity of physical wires. Wi-Fi can cover short and large distances and is relatively straightforward to use. The primary downside of Wi-Fi is that its range is uncontrollable and that it consumes a lot of power for a portable device. That is why it is included in many popular gadgets.

2.4.9. Bluetooth

Bluetooth is short-range wireless communication technology, like Wi-Fi, that transmits data via radio waves. Whereas that wireless protocol can operate semi-permanent networks across great distances, Bluetooth is often more constrained and personal. The primary downside of using it for labor tracking is that it requires all workers to connect to obtain their address, which has unfavorable repercussions for controlling random labor entrance compatibility scheduling. Additionally, it is not as energy efficient as a portable device.

2.4.10. Bluetooth Low Energy (BLE)

Low-energy Bluetooth BLE, formerly known as (Bluetooth Smart), was introduced in 2011 as Bluetooth version 4.0. It is a wireless local area network technology developed and pushed by the Bluetooth Special Interest Group for novel healthcare, fitness, beacons, security, and home entertainment applications [18]. The primary distinction between BLE and RFID is that beacons utilize Bluetooth Low Energy (BLE) technology, which is extremely energy efficient and has a very long read range. Due to the energy-efficient characteristics of BLE technology, beacons have a more fantastic read range than active RFID. BLE proximity data is significantly more accurate than Wi-Fi data but not quite as exact as Bluetooth data. BLE wireless connections have a maximum range of 30 meters, but Wi-Fi connections have a more fantastic range.

Additionally, the distinction between Bluetooth Minimal Energy and traditional Bluetooth is in sleep mode, which results in low power usage. With BLE's low power consumption, apps can run for four to five years on a tiny battery. The most significant enhancement to BLE 4.0 is significantly lower power consumption, and this may be accomplished by streamlining the protocol and allowing devices to minimize connection intervals when not needed. BLE enables sensors to transfer data wirelessly without the use of USB converters, cables, cellular, or Wi-Fi connections. Bluetooth is one of the least expensive and most widespread IoT technologies available. Other tracking instruments suggest a problem with the gadgets' accuracy or excessive battery consumption. It appears that BLE technology can solve the tracking issues associated with conventional indoor positioning sensors.

2.5. Automated Tracking and BIM

Fig. 1 illustrates the ISO19650 concept for the information management cycle. ISO19650 defines BIM as "the use of a shared digital representation of an asset to facilitate all project processes to form a reliable base for decisions." ISO represents the BIM maturity in stages rather than levels in PAS1192, and there are layers for the elements (Standards Layer, Technology Layer, Information Layer, and Business Layers). Stage 2 maturity is also identified as "BIM according to the ISO 19650," where a mixture of manual and automated information management processes generates a federated information model that supports automated data collection.

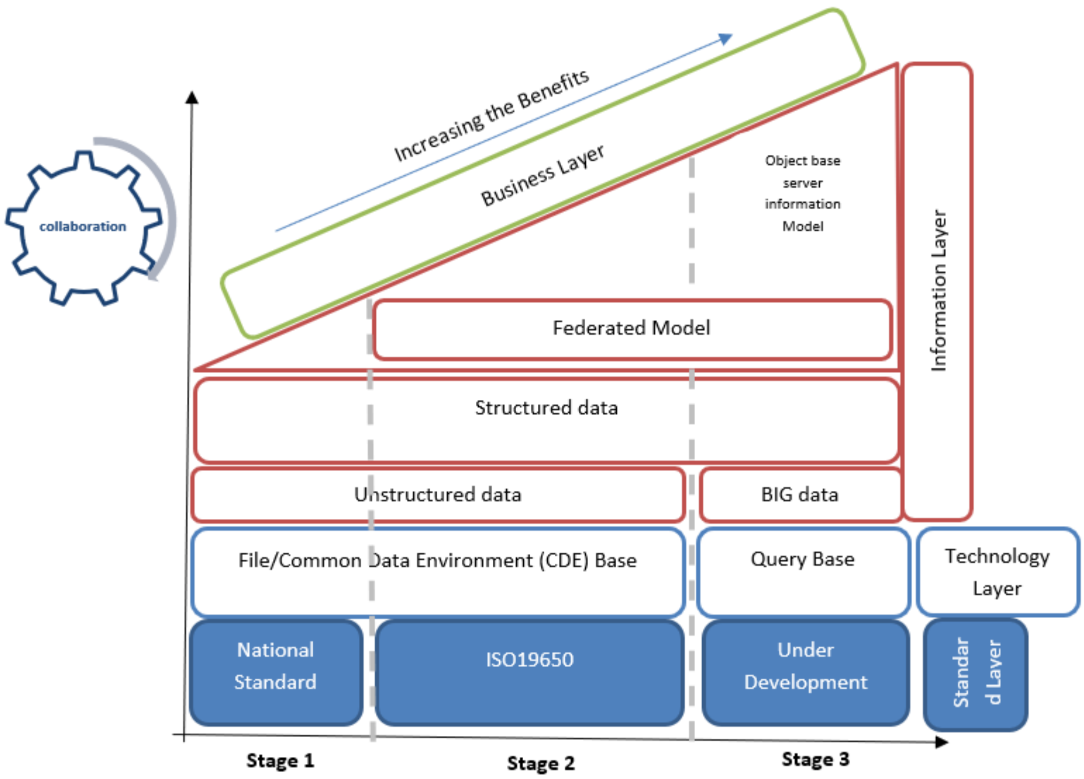

Fig 1: Error! No text of specified style in document. The BIM maturity stages according to ISO19650.

Radio-frequency identification (RFID), building information modeling (BIM), and, more recently, combining the two technologies have seen rapid development and adoption throughout the construction industry's history. However, only a cursory examination of the existing state of affairs and development trajectory of such RFID-enabled building information modeling systems has been conducted. Practitioners would benefit from advice for selecting systems that better fulfill their Construction Engineering and Management (CEM) requirements, particularly given the proliferation of RFID, BIM, and information linkage technologies in use today [19].

Several efforts from researchers focused on integrated systems using various tracking technologies. For example, the Y. Fang et al. study considers integrating RFID and BIM with utilizing a cart with four large antennas for tracking [20]. Y. Zhuang et al. in 2016 have been exploring a combination of support vector fingerprinting and Kalman filtering to improved tracking methodology [21].

S. Taneja et al., in 2016, developed procedures to generate navigation models from Industry Foundation Classes (IFC), used an Inertial Measurement Units (IMU) and Ekahau Wi-Fi sensor for relative and absolute tracking [24]. M. Neges et al in 2014 used IMU with graphic makers to improve the quality of indoor navigation using a highly complex way [22]. N. Li and B. Becerik-Gerber in 2014 proposed a BIM-integrated system with Radio Frequency (RF) beacons [23].

In addition to the above, one approach tries to solve the drift problem on the positioning estimate through alternative sensor measurements. B. Jiang et al. in 2014 used a hybrid-tracking system where a line detection routine on camera images was used to correct drift in gyroscope measurements [25]. J. Park et al. integrates BLE, motion sensors using mobile and BIM together. J. Park algorithm takes advantage of building to enhance the accuracy of location estimation. J. Park extracted data from a BIM model then export it to an XML file after that imported into the mobile system, which is a highly complex process. J. Park's integration method allows the system to collect and control data from multiple sources to enhance the tracking performance.

2.6. Conclusion

With RFID detection as a tracking mechanism through gates set on rooms and each worker carrying a compatible ID (RFID Card), no reliable activity detection is possible, which means that workers can move between zones by manually identifying themselves at specific gated entrances. On the other hand, some approaches using wireless fidelity (WIFI) by installing router modules with portable devices but this technique suffering from high power consumption for a portable device. Moreover, WIFI gives an incontrollable range for field radius. Using BLUETOOTH in tracking but worker's modules should connect to get their address, which would yield undesirable consequences in controlling timing for random workers entrance Compatibility. Add to that, and it is not so power-efficient for a portable device. Based on the last, it is recommended to use Bluetooth Low Energy (BLE) technology. Modules are installed in the zone center and tag workers' hits according to their disciplines or use. BLE will give a limited helpful range allow broadcasting ID without connecting and without worker interaction. A large number of articles and modules were written in order to track building activities through the use of a web-based or portal.

Furthermore, fewer concentrated on data visualization for indoor activities [26]. Adding dynamic data to BIM models, such as existing conditions, sensor measurements, control signals, etc., can help owners analyze building operations and maintenance, which can help them make decisions. Finally, the hybrid BLE with BIM technology has been selected as the best tracking engine based on the study and expert survey.

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