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A Review on Application of Global Positioning System in Construction Industry

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Abstract: Construction activity is fraught with many uncertainties such as managing workers, machines, and safeties. Various of strategies have been devised to prevent construction productivity and quality deterioration due to difficulties in managing construction works. This paper discusses the application of GPS technology in the construction industry. Followed by what type of GPS positioning method is used and how well the implementation of GPS technology improves the efficiency and productivity in the construction field. Nowadays, many components of technologies, such as augmented reality, wireless communication, and client–server databases, were used to efficiently control, transfer, and view project data on a mobile with the help of Global Positioning system (GPS) in construction project. In this case, a lot of published studies were looked at, and it was found that GPS can be used to keep track of construction progress, order materials, track construction vehicles, equipment, and workers, and more. So, this paper identifies some possible research where GPS was being implemented in construction industries to improve the efficiency and productivity.

Keywords: GPS, Construction, Construction industry

1. Introduction

Global positioning system (GPS) equiptment can utilize signals from navigational satellites and their widespread are used by millions of people worldwide. It is intended for users in the construction industries, and it delivers real-time information in a simple and easy-to-read manner of position, speed, and projected arrival time of the user's moving vehicles. For civil engineering applications, where the work is frequently carried out in a complicated and hostile atmosphere, making it complicated for staff to perform properly. The potential of GPS to give real-time sub-meter and centimeter-level accuracy at a low cost has manage to change the construction engineering sector dramatically by improvising the productivity and safety of the construction sites. GPS systems are used by construction companies in a variety of applications, including road, building, bridge, and machinery. GPS system consists of an integrated with wireless comunication and data processing computer systems. With the use of the computer display, Global Positioning System (GPS), real-time GPS positioning information (RTLS),

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Global navigation satellite System (GNSS), and other geo positioning technology allow on site data capturing and decision making [1], which helps the operator to determine whether the exact gradient has been attained. It is also used to track the position and utilization of equipment at several sites. By delivering this information to a central location, Geo let contractors to employ their equipment more efficiently. GPS was adopted in constrcution industry as a guiding system for earthmoving machineryin 1990s and implemented in many constructions field.

The important consideration in construction industry is safety, efficiency, and productivity [2]. The construction sector is frequently criticized for their lack of performance in low productivity, waste, and safety issues. Since manpower in domestic construction sites is becoming more and more aging. Various methods have been devised to prevent productivity and quality deterioration of construction due to absence of skilled workers and difficulty in supplying manpower. To overcome this problem the application of GPS technologies is being implemented in many constructions field. This study is focused on determine the implementation of GPS technology in construction industry. Followed by the type of GPS positioning method used and the efficiency and productivity implementing GPS technology in construction field.

2. Literature Review

Chen Kang (2012) mentioned that the application of GPS positioning system technology is rapidly penetrating various fields of engineering measurement, and the advancement of science and technology in high-speed, real-time dynamic GPS (RTK) in the carrier phase ambiguity in the navigation solution has made this technique applicable in engineering measurement. He also mentioned that GPS technology is being applied into many fields in construction industry for example in road design, bridge design, highway design and monitoring.[3]

Amr A. Oloufa (2003) illustrated that utilizing GPS technology and wireless communications in equipment tracking and collision detection in construction project can offer many benefits such as optimizing productivity, safety, and security. He aslo stated that impementing GPS technology can avoid collision between machines. In this paper he pointed out the mechanism and of the GPS-based system in avoiding collision.[4]

Nipesh Pradhananga (2012) demonstrated how GPS data logging technology can be used to track and analyse the use of equipment resources on a construction site. The presented technique contributes novel insights into the analysis of such spatio-temporal data. Applications for construction simulation, job site layout analysis, productivity, and safety analysis were discussed. Specifically, this paper presented several cases with data obtained from continuously tracking resources.[5]

Abdul Rahman ANDOH et al. (2012) demonstrated a software that utilises GPS to dynamically monitor hazards during the building of subway station, delves into construction equipment modelling, and explores conflict risk analysis and management. The author also mentioned program of GPS settings on construction equipment where the GPS receiver and OEM board will be installed on equipments like excavator and cranes.[6]

Heng Li et al. (2005), presented a study on applying integrated Global Position System (GPS) technology to reduce construction waste and improving construction efficiency. A prototype study is created using an automatic data capture system, such as a barcoding system, for the management of construction materials and equipment (M&E) on-site with the help of GPS and GIS. This paper then present the suggested GPS and GIS system's conceptual model, as well as its logical system design and esecution. Potential requirements and further applications are discussed as well.[7]

Deng Hui (2012), presented that GPS positioning Technology have been design and implemented in high-rise building construction to meet the completion requirement time, improving the accuracy and efficiency. He futher mentioned that GPS positioning technology, especially its implementation in high-

rise building, has gained constant improvement in the aspects of theoritical study, technique of implementation, signal reception mode, signal processing, and software development.[8]

Ronald Anderegg (2008) enlightened the idea about GPS based compaction technology in construction and mentioned in asphalt and soil compaction, GPS-based compaction technology with tamdem and single drum rollers makes compaction machines easier to use in practise.[9]

Yufeng Zhu et al. (2012), discussed the application of GPS technology positioning in mattresses lying under the water of marine navigational matters project and hull dolosse installment localization and the seabed, the island wall monitoring. He also mentioned that the advent of GPS measurement technology created a new high-tech method for marine surveying since the emergence of GPS technology, the measurement mode realized the leap from points and lines measurements to surface measurements.[10]

Seungwoo Han et al. (2006), estimated GPS implementation improves productivity in earthmoving opeartions. He pointed out that the GPS-based system can increase productivity by 21.74% compared to conventional method. The productivity of GPS-based system was estimated by implementing GPS system in earthmoving machines. It was proved that GPS-based system is more effeicient compared to conventional method due to functions of the GPS-based system, such as reduce reworking, faster response, soil volume checking and stakeless operations.[11]

Yassine Zein et al. (2018), proposed a mechatronic system which work with Global positioning system (GPS) to memorize a route to avoid obstacles and detect bumps. For further confirmation, they conducted an experiment using a small-scale car which equipped with proposed mechatronic system which work with GPS. The proposed autonomous vehicle proved that with the help of GPS and other sensory system it can be applied to machinery in construction industry in the future.[12]

Ma zhanwu (2020), conducted a study on GPS positioning and discussed the specific application of mechanical positioning technology in the civil engineering measurement process, to provide corresponding reference for the popularization and application of GPS positioning technology. He also mentioned that to promote the development and application of GPS positioning technology in civil engineering, relevant researchers must strengthen positioning technology research and innovation in accordance with the current state of GPS positioning technology application and improve the application effect of GPS positioning. Only in this way will we be able to broaden the use of GPS positioning technology in a variety of disciplines and encourage the advancement of civil engineering measuring technology in my nation.[13]

Hepi Hapsari Handayani et al. (2015), conducted a study to monitor the deflection of Suramadu bridge. GPS systems were used to monitor the deflection of the bridge by kinemetic method. The author mentioned that Continuous data recording from the GPS satellites, using ground-based receivers androbust telemetry, can be used for monitoring the health of engineered structures, and can thereby be useful for assessing the public safety aspects of civil, structural, and earthquake engineering which proved the GPS-based system can be implemented in construction industry.[14]

Jiang Siyi et al. (2013), descrided the application of GPS in highway measurement and pointed out the error of GPS implementation in highway survey and revealed how to decrease error to enhance measurement accuracy and expand the scope of GPS applications. Through the study cases the author mentioned that GPS control survey on highway engineering has great prospects for development and GPS can reduce the labour work strenght and workload, improve work efficiency than conventional method.[15]

Siyi Jiang (2014), introduced that the GPS technology in brigde construction to achieve high accuracy request of bridge axis lofting. The author also mentioned that because of GPS systems rapid speed, high precision, all-weather capability, low cost, high degree of automation, and lack of

topographical limits, GPS technology is widely used in a variety of measuring applications. And, as it evolves and improves, it is increasingly displacing certain conventional standards.[16]

Nipesh Pradhananga et al. (2012), presented an automated GPS-based to assess the productivity of construction equipment. Analysis methods and rules for monitoring productivity using GPS-based system in construction equipment operation were also discussed. The author also proposed a software that analyze and visualize important parameters in creating realistic simulation models. Later, the author mentioned that this research aids construction project managers in decision making for planning work tasks, hazard identification, and worker training by providing realistic and real-time project equipment operation information.[17]

Implementation of GPS-based systems in construction field in which the studies have been done by the researchers in the above litarature review are summarized in the table below for better understanding.

Table 1: Literature summary of GPS in Construction industry

No	Author	Year	Application field
1	Cheng Kang	2012	Structural Health Monitoring
2	Amr A. Oloufa	2003	Construction Automation
3	Nipesh Pradhananga	2012	Construction Automation
4	Abdul Rahman ANDOH et al	2012	Construction Site Management
5	Heng Li et al	2005	Construction waste management and efficiency
6	Deng Hui	2012	Construction structural monitoring
7	Ronald Anderegg	2008	Construction equiment
8	Yufeng Zhu et al.	2012	Marine construction
9	Seungwoo Han et al.	2006	Smart construction equipment
10	Yassine Zein et al.	2018	Construction Automation
11	Ma zhanwu	2020	Civil engineering survey
12	Hepi Hapsari Handayani et al.	2015	Structural health monitoring
13	Jiang Siyi et al	2014	Highway survey
14	Siyi Jiang	2014	Structural monitoring
15	Nipesh Pradhananga et al.	2012	Construction site management

3. Framework of GPS application in construction

3.1 Overview of GPS

The Global Positioning System (GPS) is a satellite-based navigation system that uses a network from satellites that circling the Earth. The three segments of a typical GPS system are space constellation, control ground monitoring station, and user equipment. To perform measuring operation using GPS technology, three components of coordinating works are necessary. In space segment, the GPS satellite constellation consists of 24 satellites, where 21 of them are operational and the three remaining satellites are spares. The 6 space orbits will divide the 24 satellites equitably throughout operation to make sure that the satellite in each area operates normally in the plane. GPS ground control station's monitoring system is made up of ground monitoring stations. The main purpose of a ground monitoring station in GPS positioning is to observe and measure the relevant data of GPS satellites according to different monitoring stations, as well as to check the parameter of orbiting satellite to complete the statistical calculation of the parameter difference. Third the GPS positioning system users employ equipment. GPS users utilize variety of equipment, including GPS receiver data processors, processing software, and other terminal data devices. The GPS can accurately capture each satellite signal at various altitudes and the satellite signal to be measured, as well as track the positioning satellite's actual running track, process, exchange, and expand the tracked satellite signal, and then use

the relevant information. The processing programme completes the calculation of baseline of the GPS network adjustments and analyses and processes the data in depth (Ma zhanwu, 2020).

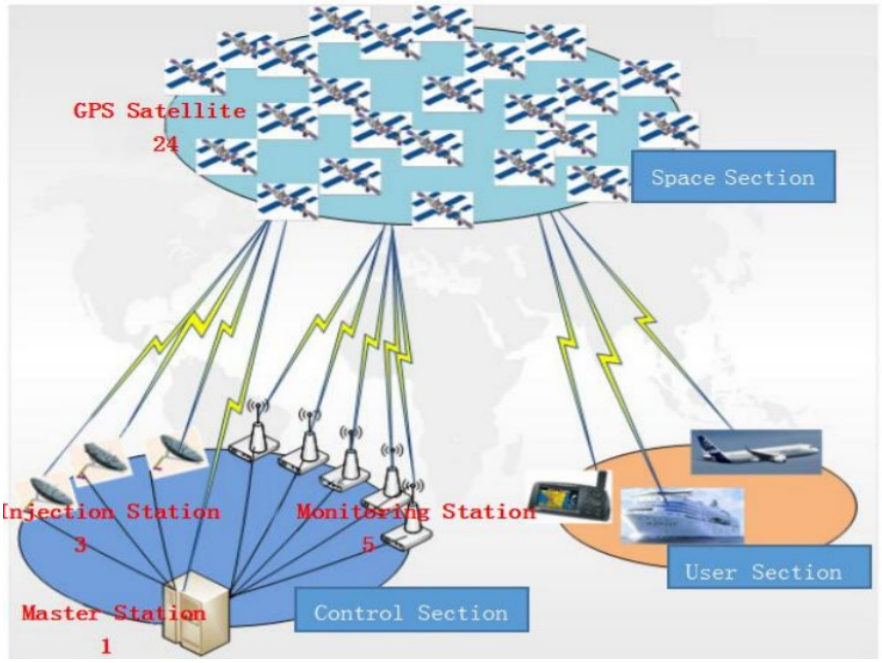

Figure 1: Example of GPS composition system

3.2 Advantage of GPS Positioning Technology

GPS positioning technology has a high level of precision, and its use can assure data measurement accuracy. The GPS system's static mapping inaccuracy can be adjusted to within millimeters in the civilian category of GPS positioning technology, where there are minimal interference elements in the measuring environment, the error can be significantly decreased, and the measurement data's dependability can be considerably enhanced. GPS can considerably increase the efficiency of surveying and mapping operations, and the measuring technique is very easy, which may improve the GPS positioning technology's operation impact and assure the technology's application advantage. The GPS system can wrap the whole globe and cover 98 percent of the land area. The external environment has little influence on the GPS locating technology throughout the measuring procedure. Furthermore, due to the wide range of applications for GPS positioning technology, the cost of the application process can be effectively controlled, and the economic benefit of positioning technology application can be increased (Ma zhanwu, 2020).

3.3 GPS Application in Construction Industry

Application of GPS technology varies in many fields such as emergency location, public safety, vehicle tracking, automobile navigation, control survey, vehicle automation, and in construction fields. Prior to researh and development on single application of GPS technology, it will deliver high-efficiecy and cost-effective solution to construction sector. Also, GPS technology was used to provide decision making with internal capability for rapid and effective site characterization, which is a common application of technology in construction field such as bridge engineering, road or highway construction, high-rise buildings, and construction automation to monitor, control, manage the site in terms of efficiency, productivity, and safety.

3.3.1 Bridge engineering

Bridge engineering surveys can substantailly benefit from the application of GPS. In an actual construction process, the calculation for each construction link can be determined, also GPS

measurement technology are used in elevation measurement in inspection of cross-river and measuring work, allowing to improvise the efficiency, and making sure the data is corect in bridge construction. Using GPS positioning technology to acquire matching engineering geological data prior to the building of a bridge project has a beneficial impact on the bridge project's design level and can give scientific direction for later bridge construction.

3.3.2 Road and Highway Construction

GPS technology has high precision, strong adaptability to the environment, but it is also environmentally friendly, and it can be used to measure terrain obstacles, serious and complex hydrological conditions, or major projects, such as the construction of a high-grade road in a mountainous area. GPS has the potential to minimize the amount of work in the field and offers a high measurement efficiency, a high level of automation, and is inexpensive. The roadway measuring model is considerably simplified by GPS-RTK technology. Route, bridge, and tunnel surveys employ GPS-RTK technology, which allows for real-time three-dimensional coordinate location, direct field real-time measurement, lofting, and piling point measuring, considerably simplifying the highway measurement mode.

One of the applications of GPS in road or highway construction is lift-thickness in pavement construction. Because lift-thickness can impact pavement durability and long-term performance, monitoring it is a key quality control technique in pavement construction. Lift-thickness control enables for more effective attainment of desired density levels (Liu et al., 2016). A proposed combining laser scanner with RTK-GPS was used to measure and monitoe the lift thickness. The thickness variance may be computed, and locations where the thickness falls short of the requirement can be detected. This technique is capable of continually and automatically monitoring and regulating lift thickness. (Liu et al., 2018) [18].

3.3.3 High-rise building

GPS monitoring in high-rise building used to monitor settlements, thermal expansion, and other long-period displacement patterns in structures (Yi et al, 2010)[19]. RTK technology has advanced rapidly in structural health monitoring since the solution of GPS Ambiguity Resolution on the Fly (SHM). The reference station operates in RTK mode as a stationary checkpoint whose 3D coordinates were previously obtained using the traditional static GPS method, and it continuously records the difference between its known position and the position computed from satellite data (Yi et al., 2012)[20]. The observed discrepancies which are due to satellite technical faults and, more importantly, reduced atmospheric delays. The mistakes are then sent to the rover through an ultrahigh-frequency radio set (or another data transmission mechanism like as fiber-optic connection or a high-speed internet link). This error information is used by the rover, which is the GPS receiver whose position is being monitored, to enhance its accuracy. The precise location of the rover station may be established using this method. The overall concept of GPS placement on a high-rise structure is shown in Figure 2.

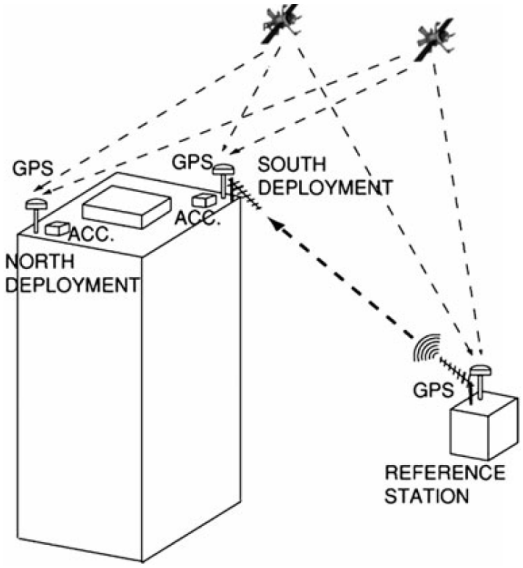

Figure 2: General schematic of the GPS deployment on a high-rise structure

3.4 Construction Automation

Construction automation is a machine-centered construction industrial technique for bringing robotic system to the construction industry. The scope of construction automation has been expanded to encompass information modelling and digitalization since the idea of Industry 4.0 was launched. According to some academics, "construction automation" refers to the combination of computer-aided design and robot-based worksite technology for the purpose of streamlining overall processes. Several of them, have begun to use the phrase "digital fabrication" as a synonym for "construction automation," particularly when discussing bespoke building construction.

3.5 Type of GPS Positioning Method

In engineering survey there are three major GPS measuring methods utilized, which are A Static GPS Baseline is a technique used to determine accurate coordinates for survey points, Real-Time Kinematic or RTK Observations are like baseline methods in that they are used to measure distances between a base station and a second receiver and Continuously Operating Reference Stations, or CORS operate using the same principles as the other measurement techniques described. The table below shows each reviewed paper and the type of GPS positioning used or mentioned by the author.

Table 2: Literature summary of type of GPS positioning method used

No	Title	RTK	Static
1	Application of GPS and Remote Sensing Image Technology in Construction Monitoring of Road and Bridge.	✓	✓
2	Situational awareness of construction equipment using GPS, wireless and web technologies.	✓	
3	Automatic spatio-temporal analysis of construction site equipment operations using GPS data.		✓
4	A Framework of RFID and GPS for Tracking Construction Site Dynamics	✓	
5	Application of integrated GPS and GIS technology for reducing construction waste and improving construction efficiency.	✓	✓
6	The Design and Implementation of High-rise Building Construction Based on GPS Positioning Technology.	✓	✓
7	3D-Construction Applications III GPS-based Compaction Technology.	✓	

8	Discussion on the Application of GPS Using in Marine Construction Survey.	✓	
9	Simulatiom analysis of productivity variation by global positioning system (GPS) implementation in earthmoving operation.	✓	
10	GPS tracking system for autonomous vehicles.	✓	✓
11	Application of GPS Positioning Technology in Civil Engineering Survey.	✓	✓
12	Preliminary study of bridge deformation monitoring using GPS and CRP (case study: Suramadu Bridge).		✓
13	GPS application in highway survey.	✓	✓
14	Discussion on the application of GPS technology in bridge construction plane control net and in survey of bridge axis lofting.		✓
15	GPS- Based Framework Towards More Realistic and Real-Time Construction Equipment Operation Simulation.	✓	

4. Analysis and Discussion

4.1 GPS implementation in construction field

As reviewed in most of the reviewed literature, the majoriy of research presented a conceptual framework or case study that utilised to validate the viability of various projects. The construction industry is a huge industry, but it is very reserved in adopting new technologies which is GPS and huge amount of field in which GPS-based system can be implemented. There are many fields which uses GPS to bring a change in the construction industry.

One of the fields that GPS technology is being implemented is Bridge and road construction. GPS technology has distinct advantage such as high accuracy, presicion and adaptability in design and monitoring roads and bridges. The continuous data receiving technology of GPS are also very suitable for monitoring health of the structure such as high-rise building. Since GPS can measure accurately the dynamic deflection of the structure at sub-centimeter tomilimeter level, these provide a great opportunity to monitor the desplacement and deflection of high-rise building, in real time.

Another field that GPS is utilised is construction automation. Automation machine is one of the challenging applications which require precise accuracy in the open field but since Real time kinematic GPS can provide real time positioning at centimeter level, this gives a huge benefit in tracking, transmiting and sharing information to machines. The implementation of RTK-GPS can amplify the functionality of the construction equipment especially in bad weather condition and harzardous site. GPS also can be used for collision detection; this technique is great for avoiding head-on accidents.

GPS Tracking technology can be also implemented to manage materials and tool on constrcution site. Construction site is a rough, active, and complicated with huge number of resources and variety of activities such as movement related with heavy equipment and tools which takes upto 50-60% of total cost and space on the project. It's vital for project planning, control, and management to be able to precisely identify, monitor, and track site dynamics, as well as communicate information to the office in a timely manner (Abdul Rahman ANDOH et al, 2012). However, with the GPS tracking technology system it was possible to manage materials and tool on construction site by using the acquired real time information.

4.2 Type of GPS Positioning Method Used

There are 3 type of GPS positioning method which are rapid static positioning technique, stop and go technique and Real time kinematic technique. According the the journal and article reviewed, the most used method is Rapid Static positioning and Real time kinematic (RTK) positioning. Figure below

show the GPS positioning method used in each construction field in construction industry from the reviewed paper.

Figure 3: Frequency of GPS positining Method used

From the graph above, according to the journal and conference paper reviewed the majority application of Real time kinematic technique was being implemented in Construction automation and rapid static positining is in structural monitoring. Real time kinematic is being implemented in construction automation frequently because in construction automatian RTK positioning can provide real time and consistent GPS positioning which can enhance its functionality and provide centimeter level accuracy and high-performance output. Rapid static positioning more applied in structural monitoring such as high-rise buildings, bridge and road monitoring is because these engineering structures can be monitored using static technique for example in settlement, long-period displacement and thermal expansion which does not require real time measurement.

4.3 Efficiency and Productivity of Implementing GPS System

Application of GPS-based system in construction industry has brought improving in terms efficiency and productivity compared to conventional construction method especially in structural monitoring, construction automation, construction survey and site management. GPS system also reduced the workload and improve the efficiency and reduce the workload of field logging in highway survey (siyi Jiang et al, 2014) and it is known that implementing GPS-based measurement in road and bridge survey has improved the efficiency for 3 time more than traditional method. In construction management and decision-making implementing GPS has help engineers to aid in planning work task, hazard identification and real-time information on equipment operation more efficeintly as mentioned by (Seungwoo han et al, 2006) GPS-based system can increase productivity by 21.74 % in terms of cost saving compared to consventional method.

5. Conclusion

The objective of this study has been achieved through analysis and paper reviews from many journals and conference papers. The outcome of this research shows that the GPS positioning system is being implemented in many construction fields, even though the application is still in early stage, through the study above we can see that implementing GPS in construction industry has many great successes for development. GPS positioning is being implemented in many construction fields such as road, bridge, and high-rise buildings and been showing a good improvement in efficincy and productivity compared to conventional method used in construction. The application of GPS will be more beneficial in construction industry if researchers strengthen their research and inovation of GPS

technology according to the current norm of the application. Only in this way we will be able to expand the usage of GPS in various fields and promote further development of GPS technology through out the construction industry.

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