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Role of automation in construction industries: a review

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Abstract:

Background: Nearly 10% of gross domestic product (GDP) of developing countries, like India, is based on the construction industry. Under the Make-in-India scheme, about $1000 billion investment is expected, for the infrastructure sector in the next few years. The urban infrastructure alone is expected to fetch $ 650 billion investment in the next 20 years. **Purpose:** As embedded system plays a vital role in automation so purpose of the paper is to discuss different methodologies used in automation for construction industries and sites. **Methodology:** In this paper, review of literature has been carried out for concluding the details of different technologies used for the automation of construction sites. Literature review has been categorized and compared on the basis of technologies such as RFID technology based systems, GPS; Zigbee; Bluetooth based systems, RSSI based localization techniques, sensor based monitoring systems, IT & Software based Automation. **Findings:** In today's scenario, automation plays a key role in technology, but its implementation in the construction industry has a big challenge for engineers and managers alike, partly due to at-site safety constraints. **Conclusion:** The paper discusses different methods, that has been suggested for automation of construction industry and compares the existing technologies in literature.

Keywords: Automation, Construction industry, GPS (Global Positioning System), RFID (Radio Frequency Identification Device), RSSI (Received Signal Strength Indicator), Sensor.

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I. Introduction

Although automation offers huge opportunities in the construction industry but its implementation is the greatest challenge for the engineers and management. The use of information technology in automation can ease the handling of data. Robotics provides an effective way of automation in the construction industry; they may increase productivity, speed, and quality of product e.g. a robot “Hadrian” has been designed for brick laying, which can build a house in two days with capability of laying 1000 bricks per hour. Robots can be a part of the construction activity where work is to be performed in dangerous conditions to optimize the operation and improve safety at work. It may be noted that each technology has its own features and challenges, which need to be addressed. The scope for automation is broad in the construction industry, which may include tunnel and bridge construction, new machineries, earthworks, road and building construction, data handling, goods tracking, safety of workers and at construction sites, etc. The advantages of automation include high accuracy, uniform quality, better work in dangerous environment and work efficiency. The Automation includes site monitoring, machine automation, inspection, etc. The gap between research and development (R&D) in automation at universities and actual site requirements is a huge challenge to overcome. In field of construction, many methods for automation have been suggested that are reviewed.

II. RFID Technology based Systems

Jaselskis et al. (2003) developed a Radio Frequency Identification (RIFD) technology-based tool to help contractors and construction industry owners, by collecting and managing data over portable databases. The tool also assists them in communicating various routing and control instructions. This is done with the help of RFID tags/transponder. By this method time to download data to a company’s system is significantly reduced. This also allows the user to mark/flag an item so that the data base entry is not repeated. As these tags are not affected by any kind of weather/lightning changes, they turn out to be more efficient instead of traditional barcodes. RFID is a promising technology as far as material receiving process is considered [2]. Lu et al. (2011) discussed the applications of RFID tag in retail, e-commerce, logistics, research, and security. The RFID technology has greatly changed these sectors, providing them with real time traceability and information visibility. Construction is another sector where RFID can be used as a game-changer. This paper discusses how RFID can be implemented for the management of material, men and machinery [3].

Jang, et al. (2009) argues that the use of sensor technology increases the use of automation and improves data acquisition. Currently, most of the tasks in the construction industry are done manually, especially asset tracking and data management. Technologies, such as RFID and GPS, have not succeeded to impress their value at bigger scales or geography because of their technical limitations. Here the idea of an embedded sensor system is discussed for asset tracking. A detailed explanation of the hardware and software architecture is provided along with experimental data. The system turns out to be more accurate and flexible than previous technologies. Research findings show that a practical deployment of such a

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system is possible [8]. Goodrum, et al. (2006) said, for smooth functioning at a construction site, tool tracking is an important factor. Therefore, they suggested an RFID tag based system for tracking and data base operations. These tags can also be used for tracking all equipment and to build an inventory system [10]. Wang, et al. (2007) proposed a mobile-based construction RFID supply chain management system (M-ConRDSCM) which was tested at a high tech factory building in Taiwan. The biggest advantages of M-ConRDSCM are dynamic operation and management. This study showed a generic system architecture and implementation [17]. Lee, et al. (2011) proposed an RFID-based RTLS (Real Time Location System) for safety management at jobsite. The RTLS provided an accurate and robust performance, despite the hindrances at a construction site. The time of arrival method was adopted as a method for localization and for wireless networking and maintaining signal strength, and the 'Chirp spread' method and the assistant tag methods were adopted. To test the RTLS system, two case studies were done and results showed its potential for improving safety management at a construction site [26]. Kelm, et al. (2013) proposed an RFID tag based logistic management system for construction sites. An RFID based mobile portal was developed, which displayed data and also kept a record. The Personal Protective Equipment (PPE) was used to protect the personnel health and safety. The study presented steps to implement PPE [32]. Fig. 1 shows the components for control and Fig. 2 shows the placement of RFID tag on equipment.

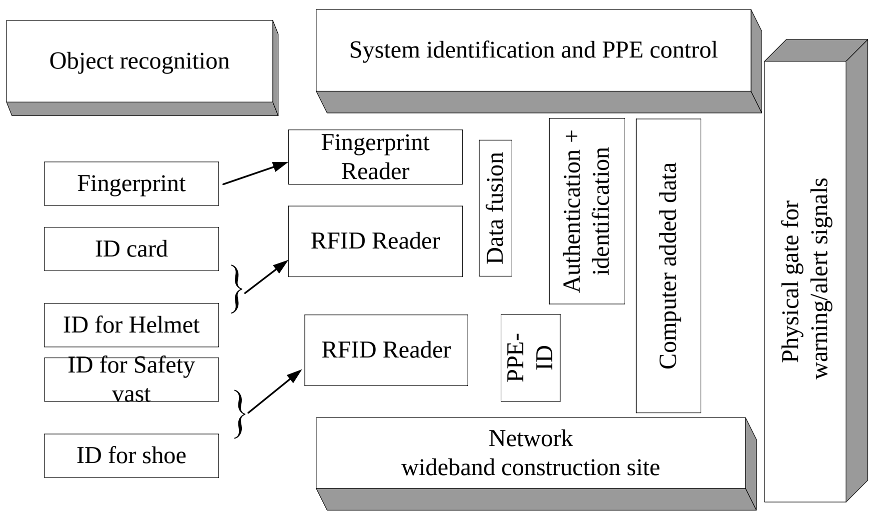

Fig. 1 Components for the control gate [32]

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Fig. 2 RFID tag on personal protective equipment [32]

Schneider (2003) reported on RFID tags and their implementation in the construction industry. RFID tag provides a wireless medium for gathering and storing data. This process helps increase data entry speed and data management efficiency [33]. Lee et al. (2013) developed an RFID-based framework for ILM (Information Lifecycle Management). The ILM framework included key RFID points and types of material to aid material control. This study also showed handling of complex equipment with RFID [34]. Chae et al. (2010) proposed an RFID-based anti-collision system for hydraulic excavators and cranes at construction sites. This system was based on a study on past accidents with heavy equipment. A new approach for tracking with ultra- wideband technology was discussed [45]. Fig. 3 shows the approach towards tracking. Fig. 4 shows the snapshots of the construction sites with actual implementation of the device.

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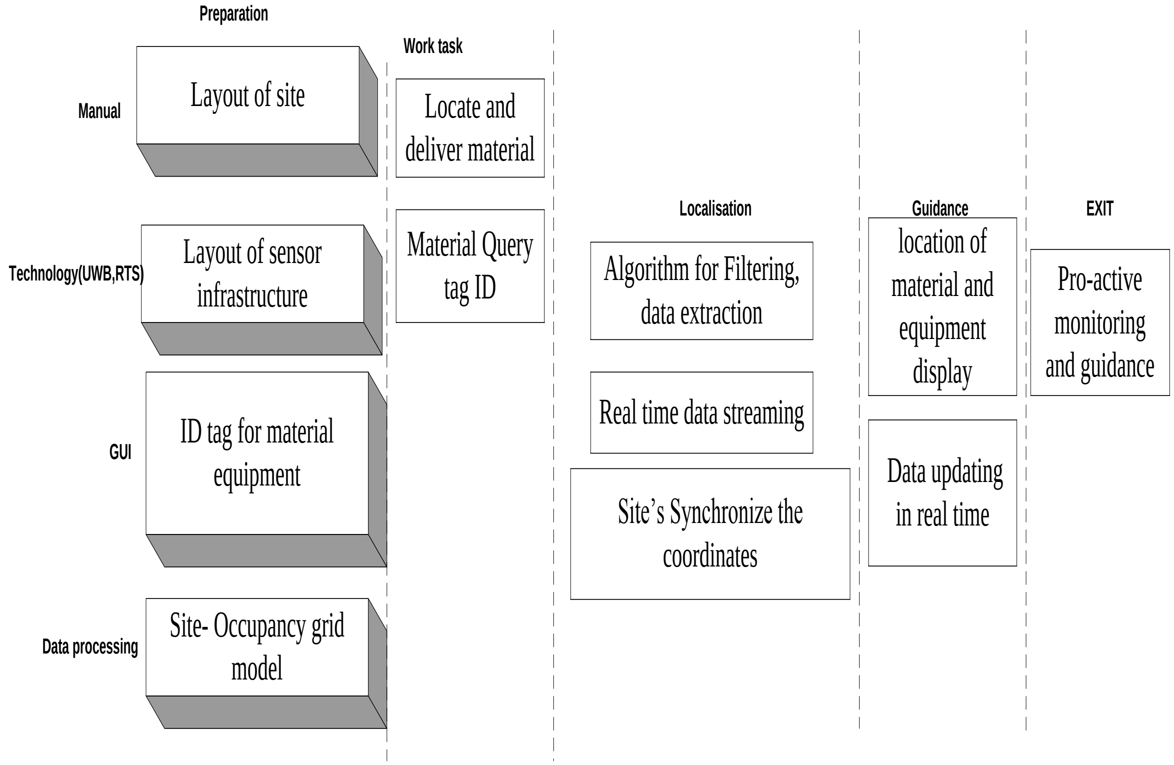

Fig. 3 Tracking with ultra-wideband technology [45]

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Fig. 4 Snapshots of construction site with RFID devices [45]

Costin et al. (2012) designed an RFID-based system to collect and distribute information among workers at the construction site. The system helps advanced decision making capability [52]. Hamalainen et al. (2008) aimed to focus on the requirements of different types of information required to identify its characteristics. An RFID-based tracking system was proposed to collect information which helps collect the status of elements [63]. Lyu et al. (2009) designed an RFID-based Quality Assurance System (QAS) to check product quality. It determined the causes of a problem for collecting and testing data. It collected data from the product line and then determined the ways for improvement and could detect and avoid quality problems more efficiently [55]. Fig. 5 shows a framework for an RFID-based quality assurance system.

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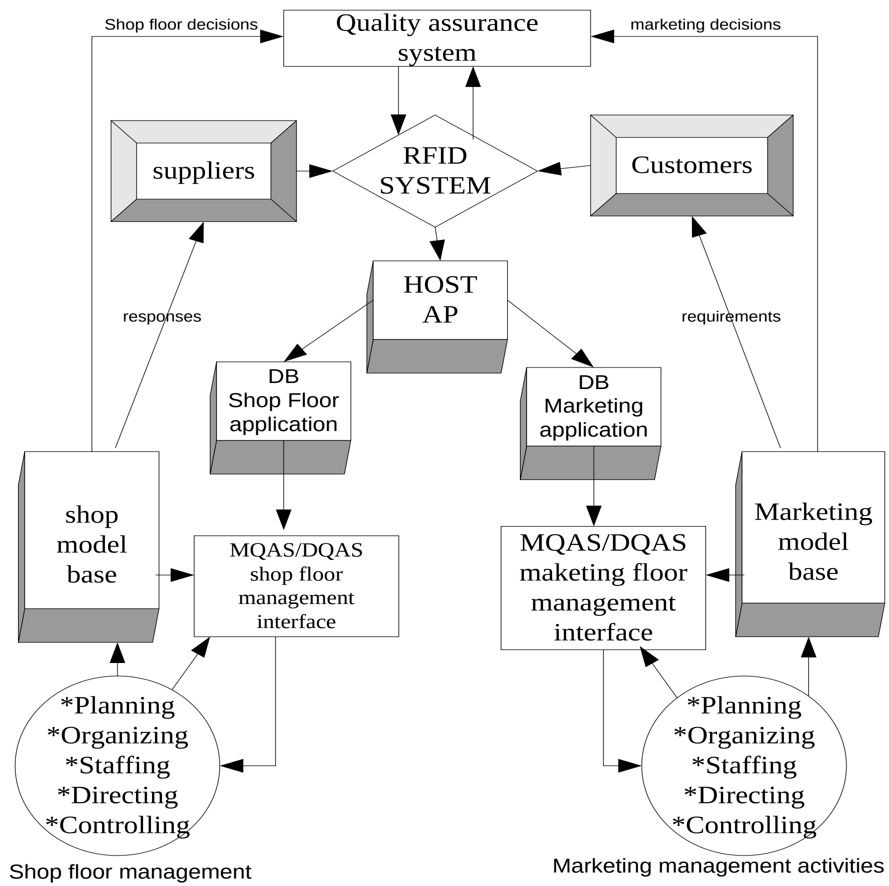

Fig. 5 Framework for RFID-based quality assurance system [55]

Razavi et al. (2012) considered RFID as most vital technology for indoor tracking systems, due to the limitation of GPS in outdoor environment [60]. Fig. 6 shows the various indoor tracking technologies.

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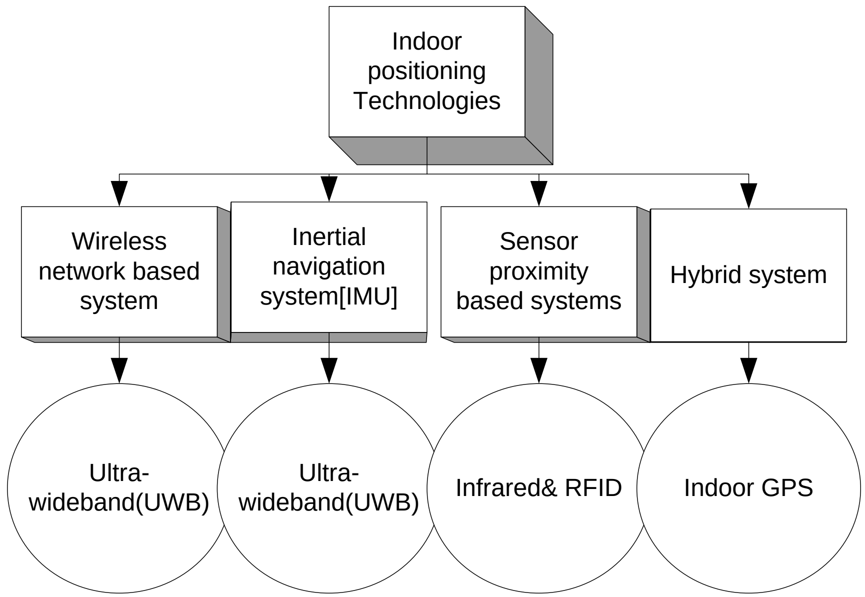

Fig. 6 Indoor tracking technologies [60]

III. GPS, Bluetooth, Zigbee based Systems

Lu et al. (2007) proposed a GPS, bluetooth and DR-based vehicle navigation technology for construction industries in Hong Kong. A solution for tracking and positioning the construction vehicles by integrating GPS with DR (Dead Reckoning), a vehicle navigation technology was proposed. Road-side beacons can be placed to calibrate positioning errors. The beacon uses Bluetooth to communicate with the DR of the vehicle. The real time location of the vehicle can be sent to the control room with SMS [18]. Fig.7 shows the trails at site for the developed system.

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Fig. 7 Snapshots for the trails of developed prototype at site [18]

Wu et al. (2010) proposed an RFID and Zigbee-based network for safety at construction sites. It is required to save lives due to major accidents at construction sites, due to avoidance towards safety. The model was evaluated for safety in a fully functional warehouse, which was like a construction site [19]. Behzadan et al. (2008) proposed a WLAN and GPS based indoor and outdoor tracking system. The key benefits and technical challenges of implementing of model were also discussed. The system was experimented for indoor and outdoor environments to ensure practical implementation [21]. Oloufa et al. (2003) discussed a study on the implementation of differential GPS (DGPS), wireless and web technology for situational awareness. A vehicle tracking and collision prevention system was proposed and a brief summary of the method along with its practical limitations and required augmentation in other technologies was given [22]. Wang et al. (2008) discussed a study on an RFID-based quality inspection and management system (RFID-QIM) to improve data gathering and management. A case study was done in Taiwan in a test lab and feasibility and its implementation was discussed [24]. Fig. 8 shows the RFID-enabled PDA for quality management. Fig. 9 shows a flow chart for the tracking system progress.

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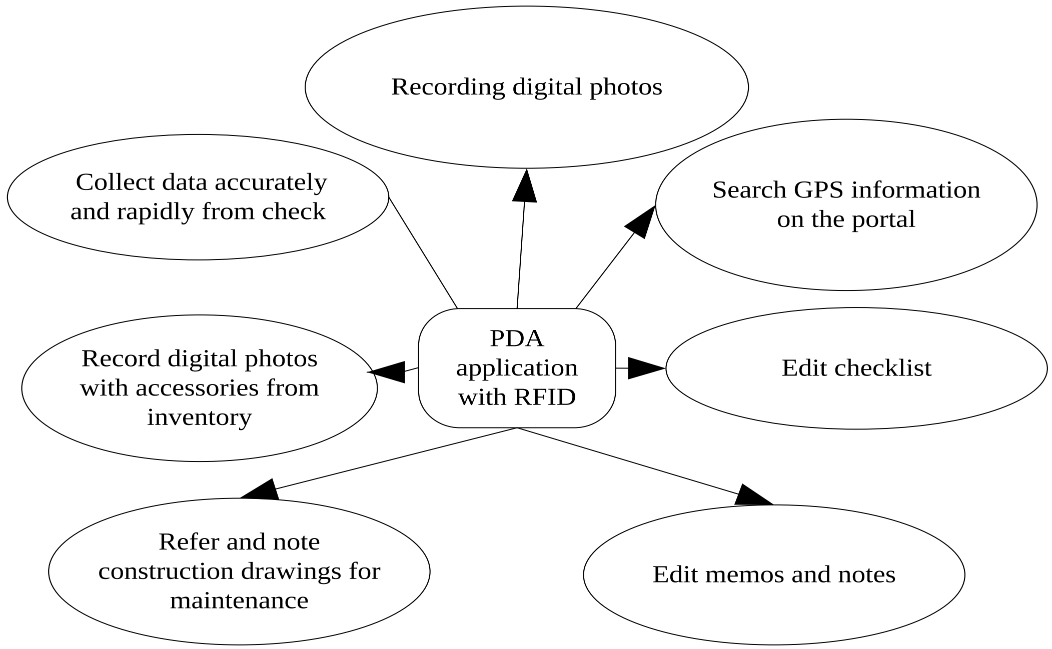

Fig. 8 RFID-enabled PDA for quality management [24]

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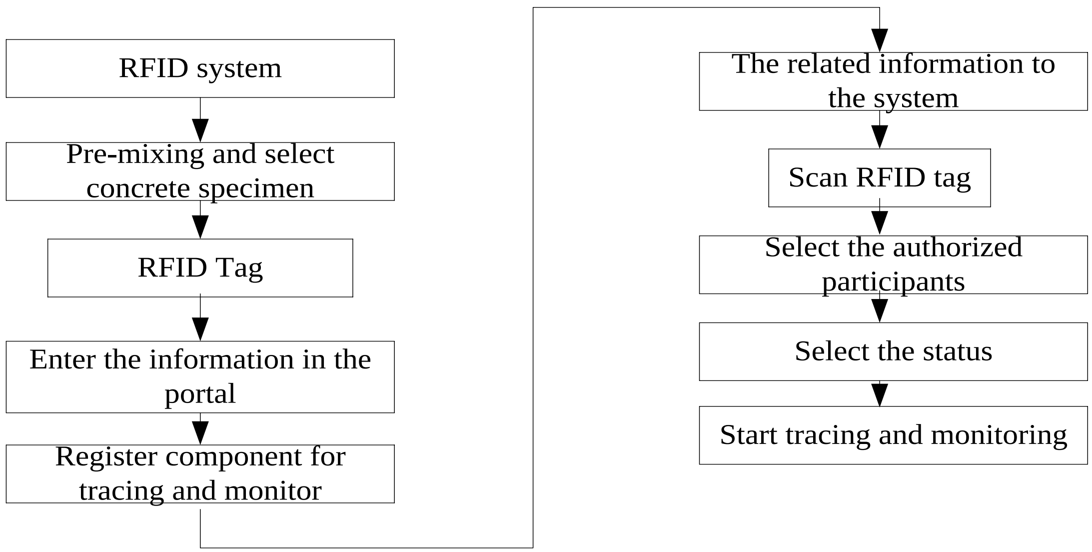

Fig. 9 Flow chart for the tracking system progress [24]

Yang et al. (2012) proposed a study on real-time identification system for accident prevention and improvement of safety at a construction site. A case study was conducted to identify technical requirements for analyzing accident precursors. Results showed a requirement of three tier system, comprising control schematics, inspection and training, and authorized operations. The system was designed by integrating ZigBee wireless sensor network and RFID technology. A database was also created having 15 tables and 54 queries along with required reports and forms. A prototype was designed for mock implementation [27]. Fig. 10 shows the snapshots of real time implementation of the system.

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Fig. 10 Snapshot of the real time implementation of the system [27]

Skibniewski et al. (2007) designed a Zigbee and ultrasonic device based hybrid system to automate the tracking system known as AMTRACK. A prototype was developed for the system to check its feasibility [46]. Beyh et al. (2004) discussed a study on different modes of communication between workers at the construction sites, including walkie-talkie, telephony, etc. It also discussed challenges and constraints to implement these modules [53].

Sung et al. (2011) introduced a ZigBee based embedded system to enhance industrial safety quality. This system included weight grading, electrical sensing, energy monitoring, length filtering etc. [54].

Wireless motes have been designed for construction sites and equipment monitoring. Table 1 shows a comparison of wireless motes with respect to the mode of connection with controller for e.g. I2C, SPI, USART, GPIO, ADC and DAC

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Table 1: Comparison of wireless motes w.r.t mode of connection with the controller (I2C, SPI, USART, GPIO, ADC and DAC)

NAME	Release	I2C/TWI	SPI	USART	GPIO	USB	ADC(bit)	DAC(bit)
ANT	2006	-	1	1	22	-	8*10	-
Wisense	2014	1	1	1	24	-	8*10	-
AquisGrain	2004	1	1	2	53	-	8*10	-
Arduino-BT	2008	1	2	1	23	-	14*10	-
AS-XM 1000	2011	2	2	2	48	-	8*12	12
ssAVRaven	2008	1	3	2	32	-	8*10	-
AWAIRS1	1999	-	-	-	26	-	4	-
BEAN	2004	-	2	2	48	-	8*12	12
B-PART	2014	2	2	2	19	1	8*12	-
BSN nodeV2	2004	-	2	2	48	-	8*12	-
BT Node	-	1	1	2	53	-	8*10	-
CIT Sensor node	2004	2	2	1	40-44	-	8*10	-
DOT	2001	1	1	2	32	-	8*10	-
DSRPN	2006	-	-	3	64	-	3*32	-
Egs	2010	-	-	-	-	-	NA	-
EPIC mote	2008	1	1	2	32	-	2*32	-
Firefly	2012	1	3	2	54	-	8*8/4*16	-
ExES	-	-	2	2	48	-	8*12	12
Imote1	2003	-	-	-	-	-	NA	-
Imote2	2005	2	1	3	NA	-	NA	-
Mica	2002	1	1	2	53	-	8*10	-
Mica2	2003	1	1	2	53	-	8*10	-
Mica2 dot	2003	1	1	2	53	-	8*10	-
MicaZ	2004	1	1	2	53	-	8*10	-
Micromote	1999	1	1	2	32	-	8*10	-
Sensor node	2009	1	2	2	48	-	8*12	12

Shimmer	2006	1	2	2	48	-	8*12	12
Shimmer3	2008	1	2	2	48	-	8*12	12
S mote	2007	-	1	1	21	-	2*8/1*16	-
Sunpot	2007	1	1	1	32	2	16	
T mote/telos	2004	-	2	2	48		8*12	
T node	2009	1	1	2	53		2*16	
Ubimote2	-	2	2	2	48		8*10	12
WASPmote	2011	1	3	2	54		16*10	
Wismote mini	2012	1	1	1	38		8*10	
Zigbit ZDM-A1281	2007	1	3	2	54	-	2*8	
ZN1	2006	-	-	1	-		16*10	16
Hnode	2016	1	2	2	48		8*12	12
.NOW	2012	1	1	2	13	-	3*12	
TUT WSN	2006	1	1	1	25		13*10	

IV. RSSI-based localization techniques

Woo et al. (2011) explained the need of some form of tracking for material, men, and machinery during indoor construction operations, e.g. tunnels, residential projects. Due to systematic limitations of GPS, this study demonstrated the use of Wi-Fi as an alternative way of tracking in indoor operations. The system was based on RSSI (Received Signal Strength Indication) which was integrated with access points for transmitting data. Experiments conducted at a shield tunnel in Guangzhou, China, showed the reliability of the system. Results showed accurate readings with an error margin of 5 m, and proved the utility of system as an approximate tracking system for labor. This system can also be used to track vehicles and materials at a construction site [5]. Fig.11 shows the safety helmet with RFID tag.

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Fig. 11 Safety helmet with RFID tag [5]

Luo et al. (2011) presented a study on testing of the accuracy of RSSI system and its implementation algorithms. It showed that the MinMax algorithm had better accuracy than the other algorithms. The average error was 1.2 m with a beacon density $0.186/m^2$. The Ring Overlapping algorithm is the easiest to implement. The k-nearest algorithm has been the most used algorithm, which has been explored by other researchers. But the beacon sensitivity is a hindrance to its full-scale implementation [11]. Table 2 shows the characteristics of different RSSI based localization techniques.

Table 2: Characteristics of different RSSI-based localization techniques [46]

S.N	Technique	Design approach	Technology	Testbed	Location(ft)
1	Eco-location	Constrained based approach applied on the ordered sequence of raw RSSI data	MICA2	26*49 ft indoor	10
2	Probability Grid	Probabilistic RSSI values are used to estimate the one hop distance in a grid	MICA2	410*410 ft outdoor	66

3	RADAR	RSSI fingerprint map	802.11b	42.9*21.8 m	15
4	Mote track	RSSI fingerprint map	MICA2	18751 ft^2	13
5	LEASE	Online fingerprinting and signal propagation model	802.11b	225*144 ft	15
6	Bayesian indoor positioning system	Learning based	802.11b	225*144 ft	20
7	Stochastic indoor location system	Optimal positing of the given number of cluster heads with respect to the location detection performance	NA	NA	NA
8	Monte carlo localization	Learning based with signal strength map	802.11b	NA	7.2
9	Nibble	Bayesian networks	802.11b	224*96 ft Indoor	20

V. Sensor based Monitoring Systems

Jang et al. (2008) demonstrated a study on the use of wireless sensor technology for monitoring the construction site. The process is split into three stages. The first stage involves the programming of a wireless hardware for the transmission of data from the sensors. This is done by programming the sensors using a proprietary. In the second stage, the signals are transferred wirelessly with JAVA back-end. This application deciphers the information and stores it into a data base. The data base is structured so that the end user can retrieve the data with ease. In the third stage, the user mines the data form the database using a web based application. This study shows the impact and feasibility of wireless systems in construction [4]. Akinci et al. (2006) said that defects are costly and time-consuming at construction sites. Current methods to counter defects are not efficient and cannot adequately tackle them. Sensor technology and project modeling have made it possible to have an active quality and testing control at a construction site. The study gives a brief outline of the process of acquiring design information and updating it, identifying goals for inspection and planning sections, data acquisition and analysis and, management of defects and their detection [6]. Fig. 12 shows the sensor-based quality control model.

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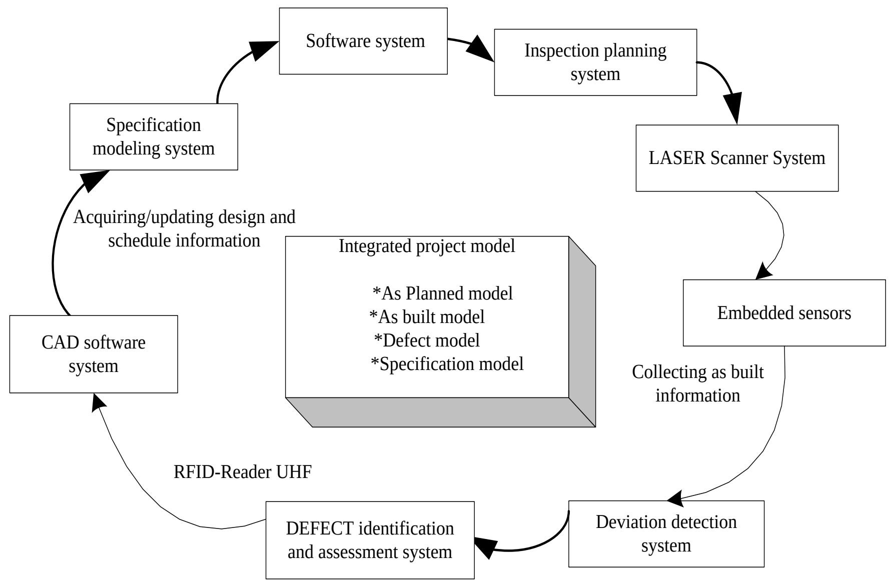

Fig. 12 Sensor-based quality control model [6]

Fig. 13 shows the steps to implement the framework of sensor based quality control.

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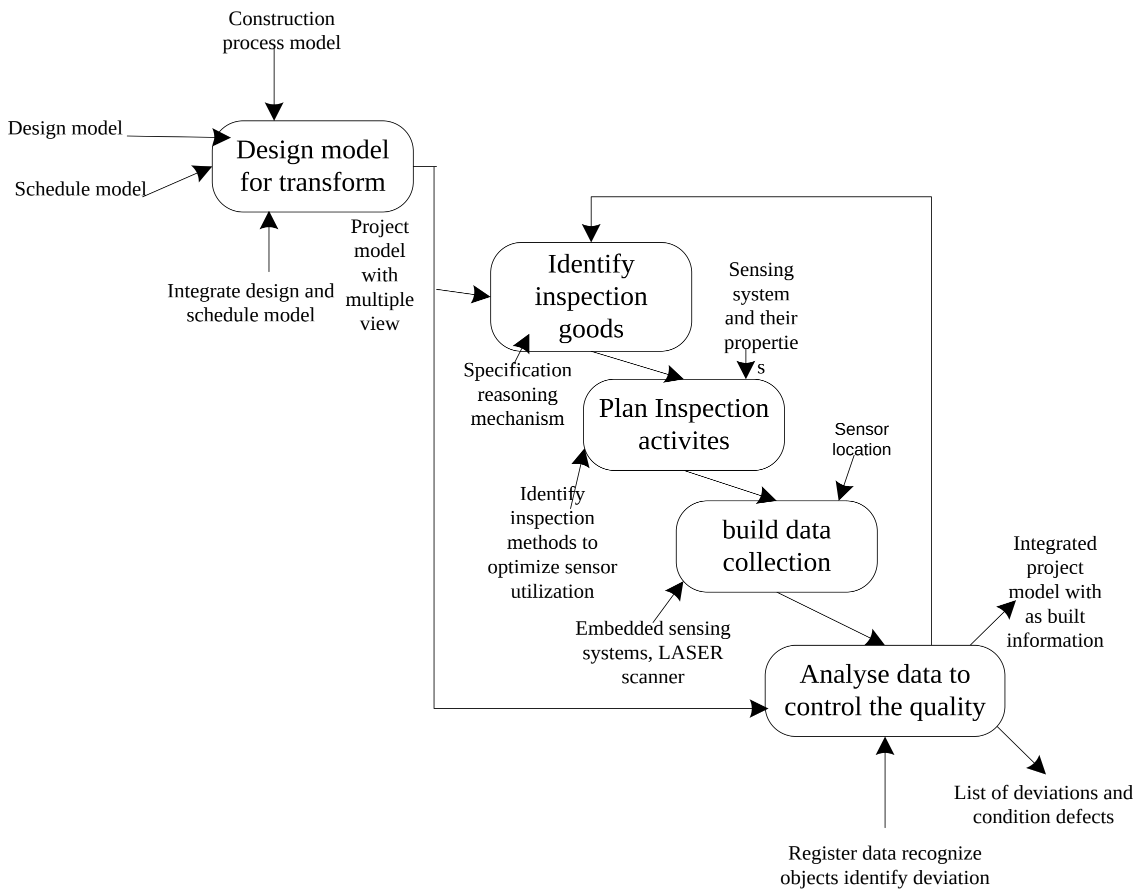

Fig. 13 Framework of sensor-based quality control [6]

Joshua et al. (2010) discussed an accelerometer-based study of the activity of mason to classify it in instructed and uninstructed modes. Classification of activities is done on the basis of data collected from accelerometer segment [49].

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VI. IT & Software based Automation

Wang et al. (2002) developed an experimental network that can integrate a Building-cum-Facility Management system over the internet. It is an open control network developed using embedded web server, PC web server, and DCOM (Distributed Component Object Model) technology. Three strategies were presented to establish a link between the BMS local network via Internet/LAN/Intranet [1]. Lee et al. (2006) discussed a way to embed the domain expertise into models of buildings as parametric modeling. The growth in IT allows the application of a sophisticated modelling software for designing, modelling and fabricating buildings. Implementation of such a system requires knowledge of domain and semantics. This study shows the extent to which a software could be used for Building Information Modelling (BIM). It focuses on the use as BOB or Building Object Behavior, to develop this software for designing, sharing and validating parametric objects [7]. Fig. 14 shows the concept of human robot cooperation.

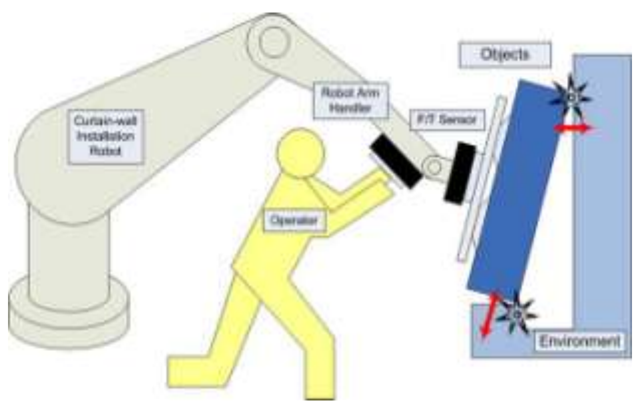

Fig. 14 Concept of human-robot cooperation [7]

Chen et al. (2002) presented the idea of an IRP (incentive reward program). The IRP is a reward based program which rewards the workers if they do not waste any construction material. Materials are tracked using Bar-code. An experiment was conducted at a residential project in Hong Kong and results showed a reduction in construction waste and superior quality, which otherwise had to be reworked. Major issues in regard to application of the IRP technology were also discussed [9]. Jang, Won-Suk et al. (2009) discussed a study about a framework for a tracking and monitoring system for construction site. A low cot Zigbee based tracking system was proposed to improve the accuracy [12]. Sriprasert et al. (2003) proposed a multi constraint planning system for construction sites. The approach was to design a support system to make

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integrated decisions to enhance the productivity and lower the risk at construction sites [13]. Halfawy et al. (2005) aimed to design an integrated system for information and knowledge of building about its deteriorate. The BIM module and case based reasoning is used to collect the information. The new approach is known as BKM (building knowledge modelling) [14]. Motawa et al. (2013) introduced new project modelling, to reduce the cost and time for architecture/engineering/construction (AEC) project. The basic idea of modelling is to exchange information among different disciplines. A smart AEC object was discussed which is capable of acting according to behavioral aspects [15]. Chen et al. (2011) presents a framework that comprises two platforms one is application model and the other is technical model. The application model studies construction personnel, construction information and construction sites and the interactions between entities. The technical model states a structure to the software designer about its functionality in different environments [16]. Cheung et al. (2004) showed the implementation of PPMS (Project Performance Monitoring System) in order to automate the control of the construction project. Parameters like people, cost, time, quality, health and safety, environment, client satisfaction, and communication are included in PPMS. For each of these parameters, performance measuring systems are established. The process uses Internet and database systems for automation. PPMS can help the project control and management units to monitor and assess project performance [20]. Fig. 15 shows a framework for the project performance monitoring system.

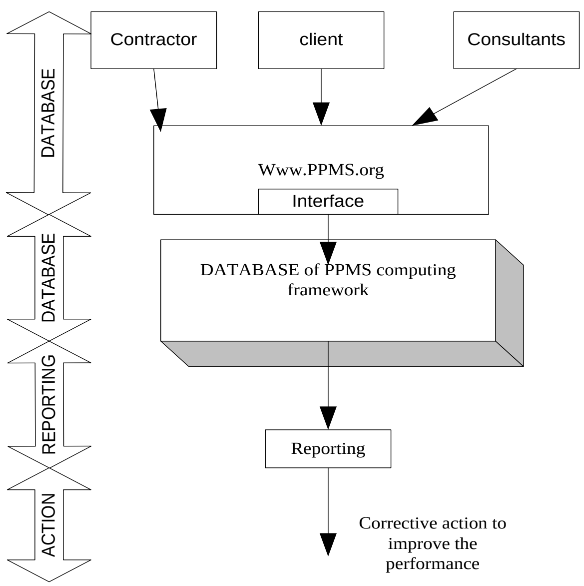

Fig. 15 Framework for Project Performance Monitoring System [20]

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Bowden et al. (2006) showed the study about case studies on construction processes. A scenario was presented to the industry professionals and their feedback is taken. This feedback was used to assess the feasibility of new models in conventional construction projects. It examined the visionary ideas and talked about their implementation, their effects on automation, human resources and impact on knowledge management systems [23]. Sacks et al. (2010) described the "KanBIM" a construction management system and its implementation. The requirement and challenges to implement this system were also discussed. Implementation of this system requires maintenance of work flow stability, negotiation and communication between teams, lean production planning and effective process control and visualization of flow. The system is expected to enhance work flow and reduce waste by providing the visualization of both process and product [25]. Park et al. (2011) suggested a vision based trackers to track a large scale construction site. As the application of vision trackers are limited to 2D coordinates, the use of stereo cameras is proposed to convert 2D pixels to 3D metric coordinates. This method has been tested and implemented on a construction site [28]. Zhou et al. (2012) explored the relationship between construction safety and digital design techniques. There have been advancements in the field of safety in the construction phase, but there are a very few tools as far as designing construction safety is considered. This study also raises concerns regarding mindless use of technology [29]. It is about the framework for human error awareness training (HEAT) to analyze accidents caused due to human errors at construction sites. A new safety approach was also proposed based on error analysis [30]. Garrett et al. (2009) proposed a web and open source platform based system to gather information and manage its flow for construction industries. It is required for implementing the supply chain management in a better manner for construction [31]. Vogel-Heuser (2014) discussed the challenges in the software development. He concludes that many challenges emerge from the circumstances at various points of the life cycle of the automated system [35]. Boukamp et al. (2007) said the quality of a construction project depends on the specification of construction material. In this study a method was devised for automating the tabulation of these specifications to support quality and inspection control. This automatic identification of specifications and automatic extraction of the requirements according to the specifications can support and enable automation of tasks [36]. Irizarry et al. (2013) focused on an IT based model to enhance the integration process of construction supply chain management (CSCM). It combined building information modelling and geographic information systems into a unique system to keep the track of supply chain and to ensure the material delivery. Results showed the combined GIS-BIM model which controls the availability of resources, material flow and visual representation of supply chain [37]. Fig.16 shows a framework for construction supply chain.

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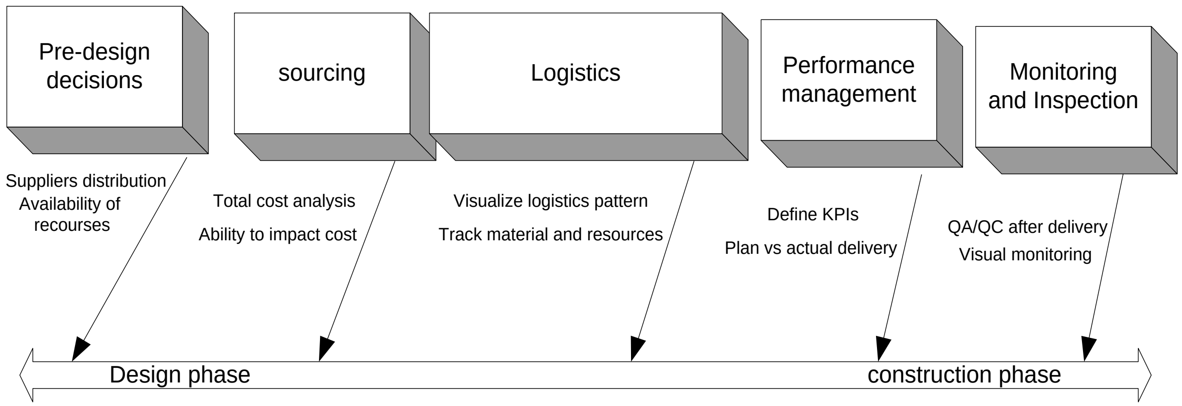

Fig.16 Framework for construction supply chain [37]

Skibniewski et al. (2009) presented a new tracking architecture by combining radio frequency (RF) and Ultrasound (UF) signals for construction sites. Simulation results showed the accuracy in the performance. This approach gave the vital guidelines for the exploration of software and hardware design [38]. The project aim was to reduce conflicts on the construction site and project delays by sharing information and by connecting participants. Tserng et al. (2009) proposed an integrated system by combining the technologies such as personal digital assistant (PDA), bar scanning which is very effective and convenient for information flow. The study showed the results for barcode enabled PDA called the mobile construction supply chain management (m-conSCM) system [39]. Rezgui et al. (2010) discussed the role of knowledge management (KM) in AEC industry. Three generations of KM were identified and discussed. These three generations were knowledge sharing, knowledge nurturing, and value creation, respectively [40]. Aziz et al. (2006) reviewed different technologies implemented to provide data and services to construction sites. It also discussed the synergy between these technologies which makes it possible for web support to mobile workers [41].

Hajian et al. (2009) discussed the challenges to implement data acquiring techniques in architecture, engineering and construction (AEC) industry. To improve the low productivity of industries an integrated system for information management was proposed [42]. Navon et al. (2007) explained the need for proper information in time and challenges for controlling the information. An automated data collection (ADC) was proposed to address this issue [44]. Fig. 17 shows the performance control cycle. Fig. 18 shows the material and management control module [44].

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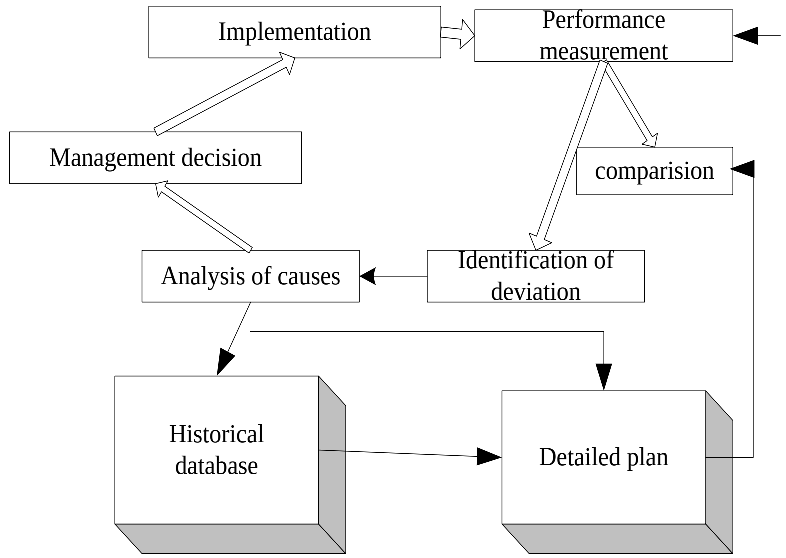

Fig. 17 Performance control cycle [44]

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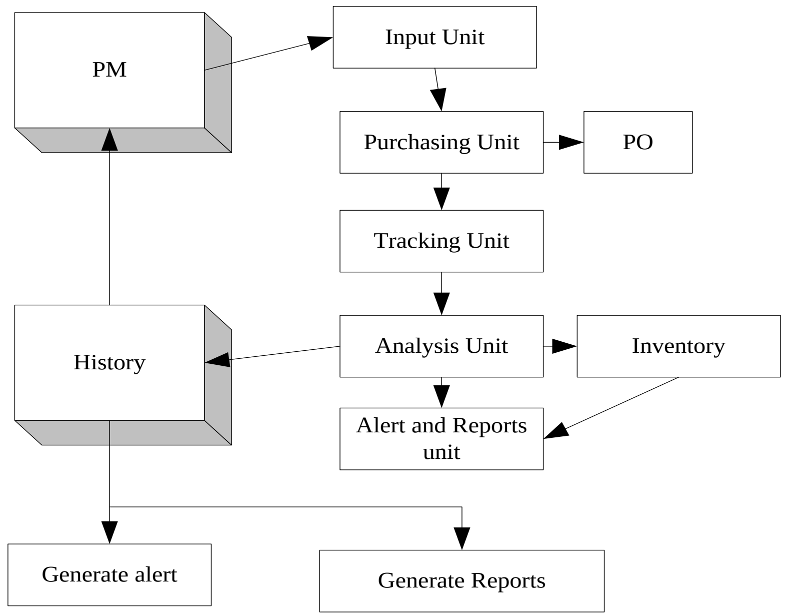

Fig. 18 Material and management control module [44]

Song et al. (2012) proposed a simulation model to automate the look ahead scheduling for the field operations. The system showed more accurate scheduling on the basis of captured data by tracking sensors [47]. Sacks et al. (2010) proposed a new framework to improve the potential synergies during planning of the lean and IBM strategies in the construction industry. The framework suggested the degree of validity between functionality interactions [48]. Brilakis et al. (2011) proposed a vision based tracking system for construction sites to track the material and personnel. The system enhances the safety and productivity at the site [50]. Teizer et al. (2013) proposed a novel method to train ironworker for steel tasks. The framework was designed on the basis of feedback and study on returns [51].

Wei et al. (2012) designed a combined software and hardware system for a 3-d wireless sensor network, for controlling construction systems. The sensor node has been developed to meet the specifications of this wirelessly network system for construction industries [57]. Fig. 19 shows the tinyOS protocol.

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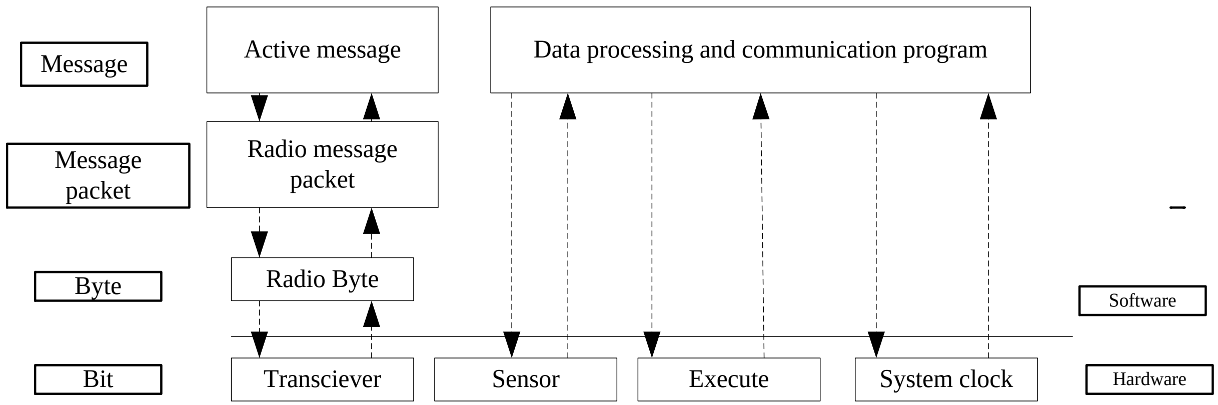

Fig. 19 Protocol stack of tinyOS [57]

Saidi et al. (2008) reviewed automation of construction industries for a span of ten to twenty years. The study presented a summary of the development business, which included the categories of construction, and the typical construction projects. It also discussed some of the economic aspects of imposing AI in construction, and there are examples of robots from varied construction applications [58]. Tibaut et al. (2016) explained a study on automated manufacturing systems for construction industries. It showed that due to technical advancement in interchangeable framework and architecture during last 10 years, there was more maturity of product and process model [59]. Gatti et al. (2014) designed a Physiological Status Monitors (PMS) system for workers, as it affects their safety at construction sites. Measurements from two PMS's were taken to study the performance at rest and then at motion [61]. Vahdatikhaki et al. (2014) proposed a fine tune simulation model for a tracking system for earthmoving projects. The new framework consisted of a method for a multi-step data processing that takes equipment-specific geometric and operational features into consideration to improve the quality of location data and enhance the accuracy of the equipment. The proposed framework was found to increase the quality of near real-time simulation and capture the finest details of excavator and truck motions [62]. Sacks et al. (2013) designed a virtual environment for construction sites, to train the crew involved which helps understand the difficulties in the production management [64]. Venugopal et al. (2010) presented a theoretical concept to track resource location at construction sites. An ultra-wideband technology was proposed for the tracking system [65]. Fig. 20 shows the UWB tags at construction resources [65]

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Fig. 20 UWB tags at on construction resources [65]

Cheung et al. (2004) proposed a study on single performance monitoring system for different categories of project measurement. This may reduce the problem of data handling and incompatibility with different software [20]. Table 3 shows a comparison between wireless motes w.r.t their features.

Table 3: Comparison of wireless motes w.r.t features (architecture, controller used, clock frequency, operating system and connectivity)

NAME	Manufacturer	Release	Architecture	Controller used	Clock frequency	Operating system	Connectivity
ANT	Dynastream Innovation Inc	2006	RISC	TI MSP30F1232	8MHz	Ant	Nordic semiconductor NRF24AP1
Wisense	Wisense	2014	RISC	TI MSP430	8/16MHz	NA	TI-CC1101

	Technologies						
AquisGrain	Philips research	2004	AVR	Atmel Atmega128L	8MHz	NA	Chipcon CC2420
Arduino-BT	Arduino	2008	AVR	Atmel Atmega128L	20MHz	Arduino IDE/JAVA	802.11
AS-XM 1000	Advanticsys	2011	RISC	TIMSP430F2618	16MHz	Tiny OS(V2.X)	Chipcon CC2420
AVRaven	Atmel	2008	AVR	Atmel Atmega1284P	4-20MHz	Atmel studio	Atmel AT86RF220
AWAIRS1	Rockwell	1999	ARMV4	Intel strong ARMSA-1100	59-206MHz	MicroC /OS	Conexant systems RDSSS9M
BEAN	Universidade fedral de minas gerais	2004	RISC	TI MSP430F149	8MHz	YATOS	Chipcon cc1000
B-PART	TECO/KIT	2014	8051	8951 on BluegigaBLE112	32MHz	BGscript	CC2540
BSN nodeV2	Imperial college London	2004	RISC	TI-MSP430F149	8MHz	BSNOS	CC2520
BT Node	BTnode	NA	AVR	Atmel Atmega128L	8MHz	NA	ChipconCC1000
CIT Sensor node	Cork institute of technology	2004	NA	Microcip PIC16F877	20MHz	NA	Nordic semicondutor
DOT	University of California	2001	AVR	Atmega163	8MHz	NA	RF monoliths-TR1000
DSRPN	Chinse academy of science	2006	ARM	TI-OMP5912/TM320C55X	192/200MHz	NA	NA
Egs	Harbin institute of technology	2010	ARMV7-M	cortexM3	96MHz	TinyOS(V2.1)	Chipcon CC2520
EPIC mote	University of	2008	RISC	TIMSP430F1611	8mHz	NA	Chipcon

	California, Barkley						CC2520
Firefly	Nanork/carregie mellon University	2012	AVR	Atmel ATMEGA1281	7.3728MHz	NanoRK RTOS	Chipcon CC2420
ExES	University of Twente	NA	RISC	TI MSP430F149	5MHz	PEEROS	RF monolithic TR1001
Imote1	Intel	2003	ARM7TDMT	Zcevo ZV4002	12-48MHz	Zeevo ZV4002	NA
Imote2	crossbow	2005	ARM V5te	IntelPXA271X	13-416MHz	NA	NA
Mica	University of califoria, berkely	2002	AVR	Atmega128L	8MHz	802.11b	RF monolithic
Mica2	MEMSIC	2003	AVR	Atmega128L	8MHz	NA	Chipcon CC1000
Mica2 dot	University of califoria, berkely	2003	AVR	Atmega128L	8MHz	NA	Chipcon CC1000
MicaZ	MEMSIC	2004	AVR	Atmega128L	8MHz	NA	Chipcon CC1000
Micromote	University of califoria, berkely	1999	RISC	AT90S8535	8MHz	NA	RF monolithic
Sensor node	Genetlab	2009	RISC	TIMSP430F1611	8MHz	NA	Chipcon2420
shimmer	Intel	2006	RISC	TIMSP430F1611	8MHz	TinyOS V2.x	Chipcon2420
Shimmer3	Shimmer	2008	RISC	NA	8MHz	MitsumiWMLC46N	NA
S mote	Yonsei University Korea	2007	NA	TIMSP430F1611	32MHz	NA	NA

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Sunpot	Oracle	2007	ARM VT	TI/chipcon CC2430	180MHz	RETOS	Chipcon2430
T mote/telos	University of califoria	2004	RISC	TI Msp430F149	8MHz	JAVAJ2ME	Chipcon2420
T node	Sownet Technologies	2009	RISC	ATmega128L	8MHz	SOWNET	CC1000
Ubimote2	CDAC	NA	NA	TI MSP430F2618	16MHz	SDCC	CC2520
WASPmote	Libelium	2011	AVR	Atega128	14.7456MHz	Libelium	NA
Wismote mini	Arago Systems	2012	2012	Atmega128 RFA2	16 MHz	V4.0	Atmel atmega128RF
Zigbit ZDM-A1281	Meshnetics	2007	2007	Atmega128	4MHz	Zigbit development kit	Atmel AT86RF2300
ZN1	Hitachi	2006	NA	RenesasH8S/2218	4-24MHz	NA	Chipcon 2420
Hnode	University of Iran	2016	NA	Atmega128	8-16MHz	MitsumiWMLC46N	ESP8266 and NRF2410 module
.NOW	The samraksh company	2012	RISC	ARM32bit Cortex M3	8-48MHz	NA	NA
TUT WSN	Tampere university of technology	2006	RISC	Microchip PIC18LF4620	10MHz	NA	Nordic semiconductor NRF905

VII. Conclusion

In this paper, the extensive automation technologies are studied for construction sites and industries. Robotics technology can be used to automate the heavy equipment and to monitor the construction site. In this context, RFID techniques are found a good solution with RSSI localization techniques. The RFID based RTLS (Real Time Location System) for safety management is proposed in literature. The RFID technology based logistic management systems are also proposed for construction sites. GPS, Bluetooth, Zigbee based Systems are also used for outdoor and indoor tracking, in which, Zigbee is integrated with RFID for better performance. Wireless motes have been designed for construction sites for equipment monitoring. Present study compares the wireless motes with respect to electronic mode of connection with controller e.g. I2C, SPI, USART, GPIO, ADC and DAC. It is concluded that the sensor based monitoring systems are good solutions for monitoring at construction sites. The sensors are used to avoid major disasters due to the negligence of defects. Comparison for wireless motes w.r.t features (architecture, controller used, clock frequency, operating system and connectivity). It is also concluded that although a lot of efforts have been made yet there are some technical gaps due to which actual implementation of proposed systems is difficult at actual sites. It may be due to safety concern and risk of failure of the automated devices. It needs a lot of accurate calculations and safety as a parameter to be considered by developers. Literature shows the scope of embedded system based automation in the construction industry.

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