BIM and QR-codes interaction on a construction site

R S Vasilyev, K Y Losev, A G Cheprasov and D T Bektash
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia
E-mail: rusid80@hotmail.com

Abstract. The study presents the methods of construction site Quick Response Code (QR) codes implementation and gives suggestions to improve routine construction site tasks management. QR-code exchange data technologies are integrated into construction control system based on BIM providing availability of data, security and mutual cooperation on a construction site. The task of the study was to present Internet of Things (IoT) integration solution scheme, a mobile integration for data exchange system via QR-codes, using smartphones to scan and upload data about construction processes, and use "smart scanners" to process and print these codes as tags. These tags are to be attached to construction elements and equipment. It allows to control staff, machine and mechanisms movement, as well as follow up the stages of construction process. As a result, the statistics and advantages of working with smartphones over computers were considered. IoT integration solution scheme is presented. Except basic identification information BIM/QR-code subsystem should contain additional data associated with the Quality Management System (QMS) "quality records" on construction site. The scheme could be used as the basis of Enterprise Resource Planning (ERP) system together with construction control system and QMS within the IoT concept.

1. Introduction
Nowadays, during the construction phase, there are difficulties related to "as-built" project documentation working out and the information transferring between construction participants. Therefore, there is a need to develop subsystem inside of a construction site control system based on the direct participation of workers in the construction sector, as well as improving the interaction between building information modeling (BIM) and Quick Response Code (QR code) technology [1].

A means of improving the interaction between manager staff and construction crews is the simultaneous use of BIM and QR code. When using it together, there is an improvement in employee safety planning and communications. [2].

1.1. QR-code and BIM at the construction site
QR-code is a two-dimensional matrix barcode. Its popularity is due to the ability of a quick read and a larger capacity compared with conventional bar codes of the UPC standard. [3].

BIM is a process based on the use of various intelligent representation of a building model during the life cycle of a building. Architects, civil engineers and other specialists of AECO (Architecture, Engineering, Construction, Operation) sector can improve their efficiency if it is based on BIM technologies equipped with QR codes. [4].
2. Construction Site processes using BIM and QR-Codes

There are 2 tasks for BIM/QR-codes sub-system on a construction site:
1. Verification of construction site staff and non-site personnel associated with the construction project processes.
2. Schematization of the assembly/disassembly/operation of construction materials, assembly elements and equipment (tools and building machines) [5].

2.1. Verification of construction site staff

One of the main subtasks is the lack of real-time knowledge about the skills and levels of construction site staff admission [6]. In order to solve this problem, there is a set of tables (database) that summarizes and makes easy to understand information about a particular employee, which need to know in order to entrust him with a specific task.

The concept is as follows: for each summary sheet of the table, where there will be information about a particular construction participant, an individual QR-code is created, which is the identifier of the worker [7]. This code will be duplicated on the employee's helmet or tag (Figure 1), and when scanning the code from the employee’s clothes on the device that was scanned, the employee’s personal file is opened (Figure 2). The application of this approach allows to instantly learn about the profession, name, qualifications, work permits in certain dangerous conditions of a person [8]. The following is an example of applying the system in practice: Figure 1 shows a personal QR-tag of an employee [9].

![Figure 1](image_url)

**Figure 1.** A tag with a QR code on the helmet and a working tag with a QR Code, attached to the employee’s work uniform.

After scanning the label with a smartphone or tablet, information about the employee is displayed on the screen. From the one hand it could be basic identification information: name of the structure, name of the structural part of the building (to which it refers), level and assembly number of the structure the company from which he works, as well as information about the equipment with which he works. The above can be improved by increasing the QR-code scale on the helmet (Figure 1), as well as by adding an electronic signature and data about current routine employee's duties. However, QR-codes abilities have not been using as "quality records" during construction management on the site. In this case the electronic form could be considered as a "quality record" in terms of Quality Management System (QMS) according with ISO standards 9001 and 9004 series.

The implementation of the QMS is a standard requirement for every construction project taking place in Russia and abroad in recent times.

All this information needs to be collected in a PDF document, which can be saved and sent by e-mail or messenger. All information is displayed in electronic form (Figure 2). The QR-code can contain 7089 digits, 4296 numbers and letters, 2953 bytes of the binary code and 1817 hieroglyphs [10]. Therefore, individual links can be embed to PDF documents that will be stored in the cloud, or the direct storage on the Web portal.
Figure 2. A data sheet that displays construction staff basic information.

2.2. Schematization of the assembly / disassembly / operation of the material, tool, equipment, temporary structures

The next aspect of work optimization is associated with the depiction of operational procedures, construction processes using easy-to-understand schemes [11]. It is proposed to sketch the necessary actions in the form of a simple scheme for understanding.

A form designed to meet the requirements of simplicity and schematization can improve communication skills and simplify the understanding of the processes of construction and installation works by an engineer and construction worker at a construction site [11]. By applying a label with a QR-code to a technical element, processing object or next to it, any worker can display on his smartphone or tablet all the information contained in a certain form [12]. In the example presented in Figure 3 below, the tag was fixed on a building element (a wall under finishing) [13].

Figure 3. Tag with QR-code on the design element

The presence of computer equipment during construction and installation works is a sign of an engineer. But the requirement for an engineer to participate in all types of construction and installation works is excessive. There are a large number of construction and installation works where the participation of highly specialized personnel is not required. For example, work on the preparation of the base of the Foundation slab, most finishing works and others. But the QMS requires the creation of quality records for each stage of the work related to a construction process. Moreover, it is necessary to monitor the actually performed amount of work within the planned work. This task can be solved using the BIM/QR-codes technology.
Three ways to use technology as follows:

1. Marking and sequential reading of a QR-code from site staff helmets and uniform containing the basic identification information and information associated with quality records within the QMS on construction site.

2. Marking and sequential reading of a QR-code on construction equipment.

3. Marking and sequential reading of the QR-code in the premises with an indication of the volume of work performed and following it.

In order to use these methods of reading QR-codes, it needs to introduce communication inside BIM/QR-codes interaction sub system.

3. Improving the interaction between BIM objects and QR Code technology

To improve the interaction between building processes and data processing technologies using QR-Codes, the third task for BIM/QR-codes sub-system on a construction site should be described. It is positioning of building structures and equipment. With a significant spread of QR-codes on a construction site, one should determine the location of a human, equipment or any classified entity. This task has to be divided into two components:

- The classic use of familiar navigation services to determine the location of an object.
- Positioning indoors, which can already be built, relative to individual elements of the building, for example, elements of the frame, roof and floors.

It helps the employee to determine which construction element is in front of or behind and then display it in a graphical representation [15].

Typical GPS location scanning using a mobile phone can be replaced by encoding small building elements, as well as parts of a mobile equipment complex. The idea is that with the help of a smartphone or tablet, an employee can recognize a QR-code and automatically receive the necessary operational information on the device in a default fixed-document format (pdf/xps/djvu) and send via messenger or mail. Such a scheme completely eliminates coordinate data from the storage system, and also solves the dilemma of accuracy when positioning in premises. The main purpose of the encoding is automatic identification, i.e. the ability to quick and efficient reading such information on the device. BIM/QR-Codes technology allows to encode the maximum number of characters in a single code, decrypt a partially damaged QR tag, and does not require special equipment (such as complex linear codes or three-dimensional codes) to read a tag. A black-and-white printer is enough to print a QR-code, and the mark is determined using a digital camera integrated into the device.

Figure 4 shows a diagram of the exchange of data on the location of an object through a workstation and a database that is uploaded and located on the Internet. Currently, a computer with installed software for processing and generating a QR-code and a printing device are used as a workstation. [16].

The sheets themselves on which such tags are printed have to be isolated from external influences (rain, snow, strong wind). Such tags can easily be lost. To avoid this, we will add to our scheme (Figure 4) the mobile integration of QR-code processing, then we can use our database in a smartphone through a separate web service, or an application for mobile platform. To use a more advanced Data Base Mobile Service (DBMS) for data processing, one needs a tablet type device with system requirements that correspond to the above software. In result, it might be most convenient to use an application for a mobile device or the site, which will be adapted for a smartphone. This suggestion is denoted by red colour arrows on the Figure 4. Wi-Fi will be used as a signal source, or if it is absent, then 3G, LTE or similar type connection.
In addition to mobile integration, there is also the integration of the IoT, which will allow to transfer all the main work through the application to a special scanner-printer ("smart scanner"), which is connected to the smartphone via radio frequency signal (e.g. Bluetooth), and an operator can directly set certain input data through the application into the phone and print a tag (sticker) with a QR-code directly from the abovementioned device. It is proposed to apply the IoT concept to this scheme. The scanner-printer becomes a “smart” device and a network node at the same time. The "smart scanner" is directly connected with the server, is engaged in the processing of input data and sends output data to the application in the form of reports. The modified scheme is shown in Figure 5.

In this case, the application uses connection to the "smart scanner" and sends input data in accordance with construction process tasks, as well as data about building elements to generate a QR-code in the device and immediately print a tag with the code, in order to fix it on any classified entity or to mark premises under construction. QR-code tags attached to elements, equipment (tools or machines), staff uniform or premises can be immediately read [16]. A construction crew, arriving at the place of work implementation, reads tags using a camera integrated into the device. Then this label is decrypted and sends a request to the server with parameters that allow to accurately identify these entities and fix its association with current construction process by place and time [17]. If there are no
collisions, such information is processed through the server and a command is sent to the device to print a tag (sticker) with a QR-code. This option is quite simple and does not require data input from a smartphone. [18].

4. Results

According to «Scanova» blog [19] the construction industry in the world will increase from 4.8 trillion US dollars. The main problems encountered at the construction site are:

- Lack of communication between managers of the project and construction staff.
- The safety of workers on a construction site.

British construction company Laing O’Rourke uses QR-codes to mark their design drawings. When scanning a QR-code in their drawing, they go to an external website that is connected to a document management system. Here the user gets detailed information about the drawings. When using a smartphone to scan and enlarge QR images, image processing and uploading information to a document management system could be carried out much faster [19]. Statistics of the benefits of using smartphones over personal computers for 2014-2017 shown in Figure 6.

![Figure 6. Smartphone usage statistics over personal computers](image)

For the «Internet of Things», statistics were considered for 2015-2025 for an increase in the use of devices in both the construction and household sectors. By 2022, according to statistics (Figure 7), an almost twofold increase in the use of devices adapted for Internet of Things is expected, which will affect the potential growth of such technologies in the construction industry (Figure 7).
5. Discussion

In addition to detecting statistics on the use of mobile devices, an increase in the QR-code on helmets and workwear items can bring a good result, which will increase the distance from the camera for scanning and image recognition.

The use of badges or waterproof stickers instead of badges with QR-codes will prevent the loss of badges. A complete rejection of printers for printing QR tags will reduce the cost of printing and attaching sheets with codes for building structures.

Using a native application for a smartphone, when developing a user-friendly interface, will increase the influx of workers who are used to dealing with the simplest and most understandable actions for working with electronic devices[21].

6. Conclusions

1. The use of BIM/QR-code subsystem in other countries brings improvements in the interaction of construction project participants on different levels. It increases the quality of decision making in the field of "as-built" documentation issuing and increasing the level of security and mutual understanding at the construction site.

2. The integration solution scheme is presented on the base of the IoT approach. It illustrates the practical use of the suggested monitoring subsystem, which characterized by the synergistic use of IT-tools, QR-codes and BIM technology.

3. BIM/QR-code subsystem information should contain not only basic identification information but additional information associated with the QMS "quality records" on construction site.

4. The subsystem should be designed to be focused on a universal IoT device («smart scanner»).

5. It is assumed that the most of the building or equipment elements in the Construction site control system will be equipped with visual QR tags, and the system will be mobile integrated and all the images will be processed preferably by mobile devices.

6. The statistics and advantages of working with smartphones over computers were considered. The scheme could be used as the basis of Enterprise Resource Planning (ERP) system together with construction control system and QMS within the IoT concept.

References

[1] Ho Y T, Feng C W, Hajdu M and Skibniewski M 2013 An information-flow-based organisational framework to streamline the process of employing BIM within construction
projects Proc. Int. Conf. on Creative Construction (Budapest) July 2013, pp 6-9
[2] Zhenzhong H, Jianping Z and Ziying D 2008 Modeling of construction processes and safety analysis based on the information model of the building and 4D technology (Tsinghua Science and Technology) pp 266–272
[3] Babic N S, Podbreznik P and Rebol D 2010 Integration of production and construction resources using BIM (Automation in construction, Elsevier) pp 539–543
[4] Harty C, Throssell D, Jeffrey H and Stagg M 2010 Implementing Building Information Modelling: a case study of the Barts and the London hospitals Proc. the 13th Int. Conf. on Computing in Civil and Building Engineering (Nottingham) Paper 93
[5] Liu Y, Yang J and Liu M 2008 QR code recognition using mobile phones Proc. Int. Conf. on Control and Decision (CCDC2008) (Yantai, Shandong, China) (Piscataway: IEEE) pp 203–206
[6] Kovalyov A I 2016 QR-codes. Its characteristics and use. Young scientist (Moscow: Molodoj ucheny) https://moluch.ru/archive/114/29398/) 10 pp 56–59
[7] Succar B, Sher W and Williams A 2013 Automation in Construction 35 pp 174-189
[8] Gulghane A A and Khandve P V 2015 Management of construction materials and control of construction waste in construction industry Intern. J. of Eng. Res. and App.s 5(4) pp 59-64
[9] Trani M L, Bossi B, Cassano M and Todaro D 2012 BIM and QR Code. A synergic application in construction site management Proc. Int. Conf. on Creative Construction (CC2014) (Procedia Engineering) 85 pp 520-528
[10] Wong A K D, Wong F K W and Nadeem A 2010 Attributes of Building Information Modelling Implementations in Various Countries Architectural Engineering and Design Management Special Issue: Integrated Design and Delivery Solutions 6(4) pp 288-302
[11] Qianyu J 2014 Exploring the concept of QR Code and the benefits of using QR Code for companies (Lapland University of Applied Science. School of Business and Culture Degree. Programme in Business Information Technology) Preprint: LAPIN AMK 2014
[12] 7 things you should know about QR Codes 2016 (EDUCAUSE Learning Initiative) Preprint: /2009/2/eli7046-pdf.pdf
[13] Liu H, Darabi H, Banerjee P and Liu J 2007 Survey of wireless indoor positioning techniques and systems (IEEE Transactions on Systems, Man, and Cybernetics - Part C: Applications and Reviews) 37(6) pp 1067–1080
[14] Mertens D 2009 Transformative research and evaluation. (New York: The Guilford Press. Mewomo, M.C. & Maritz, M.J.) (Journal of Construction, South Africa) 8(3) pp 8-13
[15] Braun V and Clarke V 2006 Using thematic analysis in psychology Qualitative Research in Psychology 3 pp 77–10
[16] Namiot D, Sneps-Snegpe M and Skokov O Context-aware QR-codes 2013 Preprint arXiv:13077597
[17] The building and construction materials sector, challenges and opportunities. (TheConstruction Industry Development Board 2007) (CIDB) pp 1–40
[18] Namiot D and Sneps-Snegpe M 2013 Internet of Things, Smart Spaces, and Next Generation Networking (Berlin: Geofence and Network Proximity, Springer) pp 117–127
[19] Thanh N C and Thanh L T 2015 The interconnection between interpretivist paradigm and qualitative methods in education (American Journal of Educational Science) 1(2), pp 24-27
[20] Demir S, Kaynak R and Demir K A 2015 Usage level and future intent of use of quick response (QR) codes for mobile marketing among college students in Turkey Proc. the 3rd Int. Conf. on Leadership, Technology and Innovation Management (Istanbul, November 2013) ed. C Zehir et al (Procedia - Social and Behavioral Sciences vol. 181) pp 405–413
[21] Wibowo M A, Elizar Sholeh M N and Adjie H S 2016 Supply chain management strategy for recycled materials to support sustainable construction Sustainable Civil Engineering Structures and Construction Material 171 pp 185-190