Monitoring of Organizational, Technological and Environmental Solutions in Construction with Blockchain Technologies

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Abstract. The paper considers the relevance of blockchain technology in the field of construction, highlighting that the expansion of information modelling through integration of BIM and blockchain technology opens up new opportunities not only for making beneficial construction agreements, but also for arranging comprehensive monitoring of construction progress. It also argues that the number of blockchains depends on the selected option of devising organizational and technological solutions for any type of construction. The paper offers an example of a specific project with a brief description of the construction technology employed therein and provides an interconnection diagram of organizational, technological and environmental blockchains. Novelty of the paper consists in the fact that it suggests considering technology and work organization blockchains as elements inseparable from environmental blockchains. The theoretic importance of the work stems from the fact that it may serve as the basis for developing the theory and general methodology for creating construction blockchain technology and its integration with BIM technology.

1. Introduction

The overview of scientific publications [1-3] has shown that a lot of research has appeared recently that is focused on the importance of the use of blockchain technology, aside from BIM, to accomplish a sustainable development of the construction industry. According to [2], blockchain technology is a “decentralized accounting book, which records each transaction consummated in the network and known as a block consisting of ciphered data covering the entire history of transactions.” Another paper [3] notes that blockchain should be viewed as “one of the components of digital transformation of the construction industry”. This component must be used in conjunction with BIM technology [1, 2, 4, 5], as the new intelligent digital technologies, to which BIM and blockchain belong, allow construction organizations to gain certain benefits. For instance, according to the results of the research provided in [6], the introduction of blockchain technology in residential construction pegs cost savings at 8.3 % of the total cost of residential development. The author of the paper [7] stresses that the “main task of applying blockchain technology in construction is the reduction (ideally, elimination) of unnecessary expenditure of workforce, as well as technological, material and financial resources.” It is assumed [8] that the use of blockchain technology on the construction site will lead to providing accurate data in construction logs. In the papers [4, 9-11] the authors emphasize that all information accumulated using this technology is transferred to BIM, which is the key innovative
point of its integration with BIM technology and other Internet based applications for a sustainable development of the construction domain.

However, despite the availability of a number of scientific publications, including the papers [12-14], where the benefits of blockchain technology are brought to the forefront, the issues associated with the use of this technology for monitoring technological, organizational, and environmental solutions in construction of buildings and facilities are currently profoundly underexplored. This is why the authors of this paper formulate their main task as exploring the use of this technology for monitoring technological and organizational, as well as environmental solutions in the course of construction.

2. Main text

The analysis of the above-mentioned papers published in scientific magazines and on scientific websites [4, 15, 16] shows that blockchain is a chain of individual information blocks (including database) arranged as a decentralized digital register, where each subsequent block references (relies on) the previous block. The number of blocks, in our view, may depend on the uniqueness of a construction project, the assumed technological, organizational, economic solutions, possible adverse environmental effects of construction, work conditions, etc. The sequence of blocks is strictly established and cannot be altered, because specific tasks are implemented with the use of appropriate information blocks (database), and as these lifecycle stages of a construction project are completed, they become relevant in the respective timeline. As regards spatial layout solutions and design solutions forming part of a construction system, a more effective tool to use at the design stage of the lifecycle of a construction project is either BIM technology or conventional design technology.

Figure 1 shows several fragments of the overall design of a unique object developed with the aid of Revit software.

![Figure 1](image-url)

**Figure 1.** Façade fragments of the Academy of Arts without net-shaped support towers.

The uniqueness of the object (the Academy of Arts building) is explained not only by its unconventional layout, but also by the fact that is planned to be constructed in a mountainous cluster near Sochi. More specifically, the object is going to be placed between the summits of two mountainous formations. The engineering process was predicated on the assumption that the building will be accessible in two ways:

The first way is by two elevators arranged in the center of the two standalone net-shaped metallic towers, which simultaneously serve as the building supports.

The second way is by the suspension cable-stayed footbridge, which connects the summits with the building and is also coupled to the metallic towers.

This way, entrance to the building is provided via the footbridge from the side of the mountain tops and by the high-speed elevators from below. The elevators and the footbridge at the same time play the role of observation sites. Considering that the towers have dedicated sites intended for performing specific academic tasks, interim elevator landings are envisaged to access the practice grounds. The design solutions for the building ensure its safe operation despite the known regional seismic activity.
We should note that another very important task during the engineering phase is the creation of blockchains to keep tally of construction materials.

Respective confidentiality of the project related information, we cannot provide a detailed description of the object just yet (still, it is worth noting that the design of the building was developed under the guidance of a member of the Russian Union of Architects, Associate Professor of the Volgograd State Technical University, Mr. R. H. Ishmametov).

At the first glance, this futuristic building appears extremely complex from the technological and organizational perspectives of the construction process. That said, the global construction practice offers a considerable number of more complex pieces of property, unique in terms of their architectural solutions, which have been built and successfully operated.

Technologies dictate the adoption of organizational solutions of one kind or another. What is blockchain as a means of pinning down organizational and technological solutions? This is, first of all, a database containing data on technologies and work techniques for construction and (or) reconstruction of a particular object. Buildings and facilities that are constructed using standard designs must have individual blockchain technologies, because the selection of a construction technology and work techniques takes into account not only the construction system or construction system flowchart, but also the working conditions on the construction site.

If we look at the design of the above building (see figure 1), we can easily discern the use of several work organization techniques. For instance, the net-shaped metallic towers configured as standalone high-rise structures can be erected using two methods:

The first method is bottom-up construction, where erection is carried out tier-on-tier, from the lower to the upper grades (denoted as “CT 1”, i.e. option 1 of construction technology). From the organizational point of view, it is important here to correctly identify the necessary erecting mechanisms. Normally, these are self-lifting cranes, all-purpose suspension type self-lifting cranes, movable crane (davits). If construction is performed using prefabricated sections (units), the first mechanisms to be used are caterpillar and wheel-mounted cranes of a sufficient lifting capacity. Further, as the vertical erection continues, lifting gear will include mechanisms selected according to the hook elevation and lean-to equipment as well as air carries (helicopters), which are used both for transportation and installation of individual ready-to-install sections of the net-shaped metallic towers.

The second method is top-down construction. One (the first) tier is built with the conventional method, after which the upper tiers are erected on the partially completed tower and moved cyclically upward, with the lower tier structures assembled alongside their upward extension (denoted as “CT 1”). This way, the first-built tier becomes the top section of the completed tower. The organizational and technological solutions assumed for top-down construction provide for the use of the same lifting gear as for bottom-up construction.

Then, the upper part of the building can be erected on the available supports (completed towers) to accommodate classrooms, conference and event halls, exhibition pavilions etc.

Here, too, several erection options can be considered: installation of the metallic ring with simultaneous erection of the suspension cable-stayed footbridge, installation of the metallic carcass of the domes etc. The technology described above is shown in figure 2.
Figure 2 shows the two methods of erecting the support towers: bottom-up and top-down construction. The final decision should be made after making the appropriate calculations as part of the environmental and economic justification.

The following sequence of works can be viewed as an alternative option of erection technology. First, one each tier (on each section) of both towers is erected on the ground using the conventional erection method. Upon the first tier, the carcass of the upper (main) part of the building is erected as shown in figure 1. Then, the lower tiers (sections) of the support towers are synchronically erected with the use of the top-down construction method. Along with the erection of the support towers, the carcass of the upper part of the building is being simultaneously extended to the design height. This part can be followed by the arrangement of the translucent covering of the domes, internal installation, finishing and other works in the upper part of the building, together with the footbridge installation works. Fittingly, this option will employ quite different organizational and technological solutions, which are always required to be justified based on the economic and environmental criteria.

The various options of implementing organizational and technological solutions in the construction of buildings and facilities [17] generally predetermines the number of blockchains (databases) required for the technology and work organization aspects.

Multipath organizational and technological solutions in construction lay the groundwork for developing various blockchains by future contractor organizations. The client, when making a construction agreement, can select the most efficient option with minimal expenditure of workforce, technological, material and financial resources and ultimately reduced environmental consequences.

Theoretically, the creation of blockchain technology as applied to the construction field, proves fairly simple, but is seldom used as the global construction practice shows.

Thereby, blockchain technology is an ingenious tool lending itself well to monitoring the flow processes on the construction site. After selecting the optimal construction technology and the method of organizing the erection works (out of the range suggested by the general contractor), the client can finally enter into a construction agreement.

The erection stage of construction deployed on the construction site also includes all types of quality control with simultaneous completion of construction logs and issuance of all acceptance certificates for concealed works, as-built diagrams and other documents making part of the overall as-built construction dossier.
In carrying out the construction processes, their actual environmental impact can be determined. Considering the immense negative effects of construction on the Earth’s geosphere shell, it is necessary to instrumentally assess, in the course of each construction process, the amount of noxious emissions (especially from operating machines and mechanisms) and document the measurement results in the respective reports. As such, blockchains covering the technology and work organization should be viewed as elements inseparable from environmental blockchains. Novelty of this study consists in identifying continuity of the paradigm of organizational, technological and environmental blockchains.

Figure 3 schematically shows the interconnection between organizational, technological, and environmental blockchains by the example of the above-described building of the Academy of Arts, where the ‘1’ to ‘n’ series conventionally indicate the number of construction process flows and the sequence of their completion.

![Figure 3. Interconnection diagram of organizational, technological, and environmental blockchains by the example of a specific construction project.](image)

The above diagram also delineates the processes of obtaining the necessary documents to draw up the as-built documentation to be completed alongside the erection of the building.

3. Conclusion

Expansion of information modeling through integration of BIM and blockchain technology opens up new opportunities not only for making beneficial agreements for property construction, but also for monitoring the performance of various construction works. The adoption of this technology allows organizations not only to cut down unnecessary expenditure of material, technological, and financial resources, but also to mitigate adverse environmental impact of each particular construction process. The more complex a construction project is in terms of its organizational and technological solutions, the more efficient becomes the use of blockchain technology.

The number of blockchains (databases) depends on the multipath arrangement of such organizational and technological solutions in a construction project.

Novelty of this paper consists in considering blockchains for organizational, technological, and environmental solutions as inseparable elements of building information modeling.

The theoretic importance of this paper is explained by the fact that it can be used as the basis for developing the theory and general methodology of creating blockchain technology for construction
and its integration with BIM technology, the importance of which has been explored by one of the authors of this paper (S G Abramyan) in other studies.

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