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A selective study of Information technologies to improve operations efficiency in construction

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Abstract. Today, information technologies (IT) are used in almost every production industry. While the aspects of IT are well studied and discussed in relevant monographs, articles, web sources, etc., this paper reviews the performance improvement options in the construction industry by leveraging IT. From a wide range of information technologies the author has picked the most relevant solutions, from his point of view, based on several considerations, the most important one being the lack of adequate attention to these technologies specifically in the construction industry. The paper covers the following technologies: Big Data (a smart technology for high-speed processing of huge and diverse data arrays); situation centers (SC) for construction and operations projects (SCs are successfully used in other industries for operating control of sophisticated facilities); data warehouses (DW) for the construction industry (DWs are viewed as a standalone project rather than a supplement to Data Mining or Big Data); operational and dispatch radio communication service (radio communication can ensure instant connectivity between several subscribers); VSAT (a satellite technology for prompt connection of a distant construction site with the 'outer world' when no alternatives are available). The paper briefly presents the essence of each technology, describes the pre-requisites for its use in construction, outlines the key advantages, limits and shortcomings, and lists construction projects where it shall be worthwhile to use a specific technology projects.

1 Introduction

The active adoption of IT is one to the key methods to raise efficiency in almost every production industry. These technologies are rather well known, discussed in relevant monographs, articles and web sources, developed at an active pace and successfully used in practice. However, the introduction of IT in different economy branches and industries is uneven due to a number of reasons including, among others, the specifics of a particular industry (construction in our case). The objective of this paper is to study the state-of-the-art information technology, which are rather successfully used in a number of industries but which use in construction is very limited. Here, the following information technologies are considered: Big Data, situation centers for construction and operations projects; data

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warehouses for the construction industry; operational and dispatch radio communication service; and VSAT.

2 Materials and methods

The Let's start with Big Data [1-3]. Recently, the technology has become such a success that it is referred to now as the 'Big Data phenomenon' [3]. The major achievements are in telecom, banking, retail and a number of other industries. As for construction, from our viewpoint the technology there develops not as actively as it could despite the pre-requisites for successful implementation being in place (for large-scale projects).

First, let's give a brief overview of the key matters related to the Big Data application in large-scale construction projects.

Speaking about the 'Big Data' concept, the most popular 'three V' definition is used where 'Volume' means the data scope, 'Velocity' is about the necessity of fast information processing, and 'Variety' describes the diversity and often encountered scarcity of data structuring.

Extended 'five V', 'seven V' etc. versions are sometimes used instead of 'three V'.

Considering the topic of this paper, let's pick two more components from the extended list: 'Veracity', i.e. reliability, and 'Variability', in other words inconstancy. As for the first 'V' — data scope — the presence of this factor during the construction of a high-riser is evident: besides the huge amount of data directly related to construction activities, it is required to take into consideration the enormous number of environmental, nature protection and other factors.

The second 'V' is necessary because of the great deal of multifaceted data which shall be processed within a rather short time period, that is, at a fast pace, because processing results are needed to solve current tasks which emerge during the high-riser construction.

The third 'V' is about the variety and insufficient structuring of data. Indeed, numerous parameters and factors related to different areas are required during the construction of a high-riser. First of all, these are the parameters directly related to construction activities; then it is required to take into consideration the whole range of factors relevant to the environmental effect of such a large-scale construction project; bear in mind that a high-riser affects the local propagation of radio waves in different wavelength bands (which, in its turn, can impact the operation of some services); and purely aesthetical aspects of a high-riser construction within the surroundings shall be considered as well. The latter remark clearly demonstrates that many factors are weakly structured.

As for the remaining two 'Vs': 'Veracity' for reliability, and 'Variability' for inconstancy, the first one exists because the construction of a high-riser is a quite responsible business from many viewpoints; that's why data review and decision-making shall be based on reliable factors. The necessity to take 'Variability' into consideration has the following explanation: the project is designed for operation during several decades, and some of the reviewed values can substantially change meanwhile.

It is important to stress that the five 'Vs' considered above are no more than the top of the Big Data technology iceberg. First and foremost, the Big Data technology utilizes the Soft Computing methods. These methods are aimed to solve management tasks with scarcely structured objects; the soft computing toolbox uses the fuzzy system technique (fuzzy sets, fuzzy logic, fuzzy regulators), fuzzy neural networks, genetic algorithms, probabilistic reasoning, belief nets. Different soft computing methods can complement each other and are often used together. Moreover, the Big Data technology uses cluster analysis [4], crowd sourcing [5], data fusion and integration, as well as a number of other techniques.

The second part of this paper is the use of situation centers (SCs) during both construction and operation of buildings.

First, let's define the 'situation center' concept in the context of the paper. Ultimately, this is a room (hall or office) with the most advanced telecommunication and interactive communication facilities, convenient data visualization tools for the on-screen display of CCTV video feeds, computer-processed sensor readings and other details. The review of emerging situations and prompt decision making are based on obtained information and interactive communications between meeting attendees (including remote participants) using mobile communication, conference calls, video conferencing, etc. Decision making is based on the active use of smart data processing methods, including the above-mentioned Big Data. Further, the system switches over to the response mode, i.e. a series of actions aimed to implement the adopted decisions. Instructions are sent to front line staff using a complete range of cutting-edge telecommunication tools, including radio communication for instant connectivity, which is significantly faster than cellular communication. Further, the actual progress is monitored in real-time, with the required adjustments to be made interactively, as needed.

It should be stressed that, considering the substantial cost of SC implementation, these centers are justified for large-scale tasks. There are two groups of such tasks in construction: The first one is the construction of major sites like building campuses, high-risers, etc. The second task refers to the operation of large-scale construction facilities. Here the advantages of SCs become especially evident in complicated and force-majeure situations.

It should be mentioned that the use of SCs in the first and second case has its own specifics. In the first case where SCs are used during the construction process, the major part of telecom equipment, hardware and specialized software becomes unnecessary when the construction is finished. In the second case, such hardware and software are in use during the entire building lifecycle. There are two ways to increase the economic return on funds invested in creating a SC for the first case: set up a suite of hardware and software tools for a SC so that the equipment can be moved to another construction site without major losses. The second way is to customize the equipment to fit operation purposes, i.e. set up a SC to operate a building campus based on the existing construction-focused SC.

The next area of IT that can be effectively used in construction is Data Warehouse (DW). In the context of this paper, this means a subject-oriented information database developed and intended specifically for reporting, business analysis, and decision making support in the construction industry.

Data warehouses are based on the following principles:

- Problem-solving and subject-oriented focus (in our case the focus area is construction). Data are combined by categories and stored according to the matters they describe rather than the applications they use.
- Integrated approach. The data are combined so as to satisfy all requirements of the key objective of construction in general rather that its one and only function.
- Zero adjustment. Data are not born in DW: in other words, they arrive from external sources, with no adjustment or deletion.
- Time-dependence. DW data can only be precise and accurate if they are linked to a certain time period or moment. This aspect is especially important for a construction project because of a number of parameters which describe the construction project change over time.

Then, the following point can be raised: earlier the paper mentioned the effectiveness of the Big Data use in construction. However, this technology follows and develops the Data Mining technology which, in its own turn, is built on the basis of DW. The difference lies in the fact that here this is a matter of a separate use case, i.e. the creation of a subject-oriented Data Warehouse to be used in construction. Data related to construction and/or operation of a city or city district are imported to this DW in a structured form. Over time, the amount of data in DW grows, and the value of relevant information increases. Project can be financed differently: from a regional budget, via private funding, etc. The effect of such project can be viewed from two different angles: The first is the increased project construction and operation quality through the utilization of DW-sourced information in smart data processing tools (Big Data, Data Mining). The second gain is revenues from the DW-sourced information sale to third-party organizations engaged in different construction activities: marketing, design, construction, operation, etc.

Another solution to improve performance during construction and operation is the use of operational and dispatch radio communication.

The practical implementation of this solution shall allow to [6-8]:

- support the control and management of construction processes, such as delivery of materials, erection of structures, vehicles and staff movement within the construction site, etc.,
- ensure safety of production personnel in dangerous zones, emergency and extraordinary situations,
- connect remote construction areas with a single radio communication network,
- control the movement of staff and machinery within the construction site,
- establish own secure radio communication channels to transmit confidential voice data.

Also, the major and often decisive advantage of radio communication compared to cellular communication is that it supports almost instant connectivity (vs. a gap of several seconds needed to establish cellular connection).

Another significant advantage is that radio communication does not depend on cellular coverage. This does not mean that conventional mobile communication shall be abandoned. Rather, some categories of workers shall be equipped with both types of hand-held devices: portable radio and smartphone. Ideally, communication shall be supported by both devices, each having its own advantages: for smartphone this is the expanded functionality, for portable radio this is the instant and zero-fee connection. However, an opposite scenario is possible as well, where both of the devices fail to support communication. Thus, the most critical areas of major construction sites must receive appropriate monitoring and practical measures applied to ensure at least one communication link stays live and has enough redundancy. Also, the supply of additional receivers/transmitters to arrange radio communication will likely be much easier and cheaper when compared to the support of cellular communication through mobile operators.

The so-called 'scrambling' was meant with reference to secure radio communication channels for the transmission of confidential voice data. Scrambling is the encryption of source signal aimed to conceal message content from unwanted persons. This method is principally different from cryptography, which is a more common encryption method. Scrambling is utilized for other purposes, such as telephony, radio signal transmission, and satellite communication, and employs techniques being quite different from cryptography. They include the adding of specific components to source signal, alteration of important signal parts to complicate source signal restoration, etc.

In conclusion of this topic, it should be noted that all statements related to the use of radio communication specifically in construction are equally true for the use of this communication method in the operation of major facilities.

The considerations presented above mostly deal with the construction and operation of major facilities. Below we shall look at an information technology for rather small construction projects on remote and undeveloped sites (or initial construction stages as part of bigger sites). A typical case of this kind is the construction of a building for a timber business or a research station. In Russia with its huge territories, the option of satellite communication should be always kept in mind. Quite likely, this solution can be useful in other countries as well.

First of all, it shall be noted that here we refer to the use of satellite communication, specifically geostationary satellites. The key advantage of this communication method is the opportunity to establish prompt connectivity between the construction site and other business units which can be hundreds or even thousands miles away. The major reason to arrange this type of communication is that there are no communication facilities across the area where construction activities are commenced, and the use of other connectivity options is either impossible, commercially unreasonable, or requires too much time. Afterwards, various scenarios are available: to route a wire line (for instance, fiber optic), set up cellular communication, leave everything 'as is', that is, retain satellite communication, or carry out the complete dismantling.

The layout of a remote construction site connection to a company's HQ office via a satellite communication channel is shown in the Figure 1.

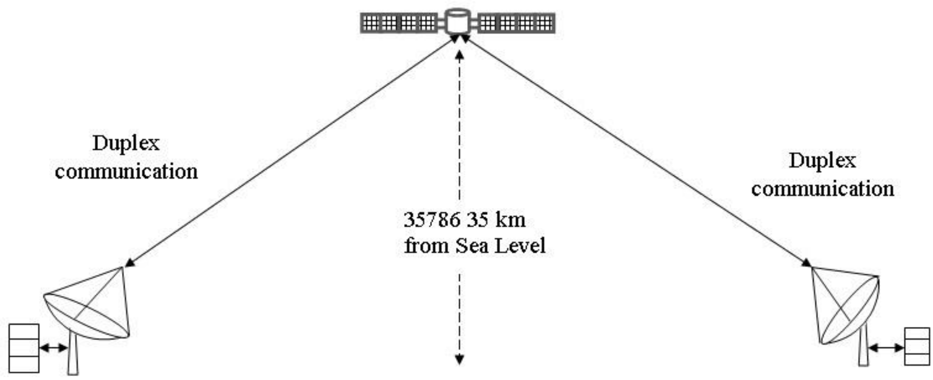

Fig. 1. The layout of a remote construction site connection to a company's HQ office via a satellite communication channel.

This figure specifically shows that satellite communication runs in the duplex mode, i.e. with the two-way data exchange: data goes from a satellite and then goes back via the satellite. There is also an asymmetrical mode of a satellite channel operation (mostly used to establish Internet connection at country houses). In the asymmetrical mode, the satellite channel is only used to receive data, while requests are transmitted via a regular wired channel.

Here is a brief overview of this technology: Currently, the VSAT (Very Small Aperture Terminal) technology is used as a solution for geostationary satellites. According to international classification, VSATs are satellite stations with antennas up to 2.5 meters; often the antennas are approx. 1.2 meters. VSATs comprise the following two major parts: external unit (antenna and receiver/transmitter) and internal unit (to convert information in a format suitable for telephones, computers etc.). Internet speed for VSATs can reach 18 Mbps [9].

There are ambitious plans to cover the whole world with inexpensive satellite Internet [9]; however, we adhere to a more tempered view. Satellite communication services have been available for over 20 years and throughout this time they have not managed to provide any significant competition to other types of communication, remaining a rather narrow segment, which is, as viewed by this article, construction in remote areas and specific conditions. However, this type of communication should not be underestimated due to mere one simple reason: it can ensure prompt connection of a distant construction site with the 'outer world' when no alternatives are available.

3 Conclusions

A wide range of information technologies is currently used to increase the performance of operations in various industries. The paper presents the solutions which, according to the author, receive inadequate consideration specifically in construction.

First, there is Big Data, a new and extremely perspective smart data processing technology that supports high-speed processing of huge volumes of diverse and loosely structured data. This technology integrates its predecessors' achievements in smart data processing and offers new innovative solutions. The paper stresses that all prerequisites for the successful implementation of this technology exist in the construction and operation of facilities, but only in the case of large-scale projects: building campuses, high-risers, etc. Otherwise, the utilization of Big Data is not justified economically.

Second, it is proposed to use situation centers (SCs) as part of large-scale construction. The key requirements to a situation center for construction management are outlined as follows: a separate room, smart information processing tools, appropriate telecommunication facilities, various visualization tools, including a large screen for interactive communication between experts, review of emerging situations, prompt decision making and actions. It is noted that SCs can be also used to operate large construction facilities.

Construction-focused subject-oriented Data Warehouses (DW) are proposed as yet another tool to increase the efficiency of construction. Specifically, DWs are viewed as a standalone project rather than an accompanying tool for Data Mining or Big Data. DW-stored information becomes increasingly valuable as DWs are populated with practical data. The effect of such project can be viewed from two different angles: the first one is the increased quality of construction, the second gain is revenues from DW-sourced information being marketed to third-party organizations.

Another solution to improve performance during construction and operation is the use of operational and dispatch radio communication. The paper outlines areas where this communication method can be used in construction and specifies its key advantage, i.e. near-instant establishment of connection without reliance on third-party providers (cellular operators).

The VSAT technology based on geostationary satellite communication is considered as yet another solution. The sphere where this technology can be utilized is construction in remote areas and specific conditions. This technology can be used for prompt connection of a construction site with the 'outer world' when no alternatives are available.

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