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A review on the impact of information and communication technology in civil engineering practice

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Abstract. Information and Communication Technology is playing a vital role in virtually almost every field of human operation such as education sector, medical field, banking sector, agricultural sector, field of engineering and more. Information and Communication Technology has substantially eased operations in several fields and has helped to save resources in the likes of labor, cost and time. It has also helped to drastically increase the speed at which work is done. This paper reviews the impact of information and communication technology in civil engineering practice and examines operations such as the construction industry, road transportation industry, engineering education, structural engineering, energy efficient buildings, building preservation and engineering design. Information and Communication Technology is seen to be very relevant for sustainability in civil engineering practices across literature.

Keywords: Engineering, Civil Engineering, Information and Communication Technology, Impact

1. Introduction

The role of information and communication technology (ICT) in our immediate society cannot be downplayed. Information and communication technology has played vital roles in several spheres of life and has brought about ease and advancements in many of human operations. Among the important contribution of ICT is cost reduction [1]. There is always a substantial and cumulative cost reduction benefit of application of ICT in a particular field. The use of ICT has also been known for its efficiency in time management. The application of ICT in any field of operation can substantially reduce the normal time with a wide gap such as usual operation that would have taken months, weeks or hours without the application of ICT. Among many fields of human operations where ICT has been of evident impact are telecommunication industry, design and construction industry and banking industry, the education sector and more. ICT has continued to find its place in almost or all aspects of man's operations. ICT has remained relevant to both developed countries and developing countries of the world. It has introduced advancements in the economy of nations and hence, its roles cannot be done without. Among the nations of the world where ICT has had great contribution, Nigeria as a country is not left out [1]. In Nigeria, ICT has contributed immensely in the area of her education, design and construction industry, road sector, education, telecommunication and many more [1],[2]. This paper presents a review of some applications of ICT in some sectors in civil engineering practice. These sectors include the construction industry, road transportation industry, education sector, engineering design, building preservation, energy efficient buildings and structural engineering.

2. ICT in Civil Engineering Practice

The role of ICT in some fields of operations in Civil Engineering practice are as related in this section

2.1. ICT in the Construction Industry

The use of ICT in the construction industry has witnessed a continuous increase over the years, being that it has continued to gain acceptance in operations across this industry. The introduction of ICT in the construction industry has made it possible to model projects in a virtual environment ahead of the physical environment. The possibility of having projects modelled ahead of construction has improved communications between construction team members and has enabled stakeholders to have a clear grasp of what to expect even before the project is implemented on site from start to finish. Nevertheless, despite the wide acceptance of the engagement of ICT in this industry, stakeholders in construction projects still face certain challenges in the aspect of communication especially when their projects reach the phase of implementation [3]. According to [4], Some of these communication challenges can be traced to gaps in the integration between what had been designed and what is been implemented in the production process. Other challenges being encountered by stakeholders in the use of ICT in construction are problems of relating technical content adequately, the ideal environment for the operation of the technology, several collaborations between stakeholders both on the site and off the site. Most of these challenges are due to the fact that the construction industry is predominantly on site and a good way to tackle these challenges will be to ensure the conveyance of the right information to the right place at the right time and a good understanding of the impact of the ICTs on different phases of a project is very important to help address communication challenges faced by stakeholders.

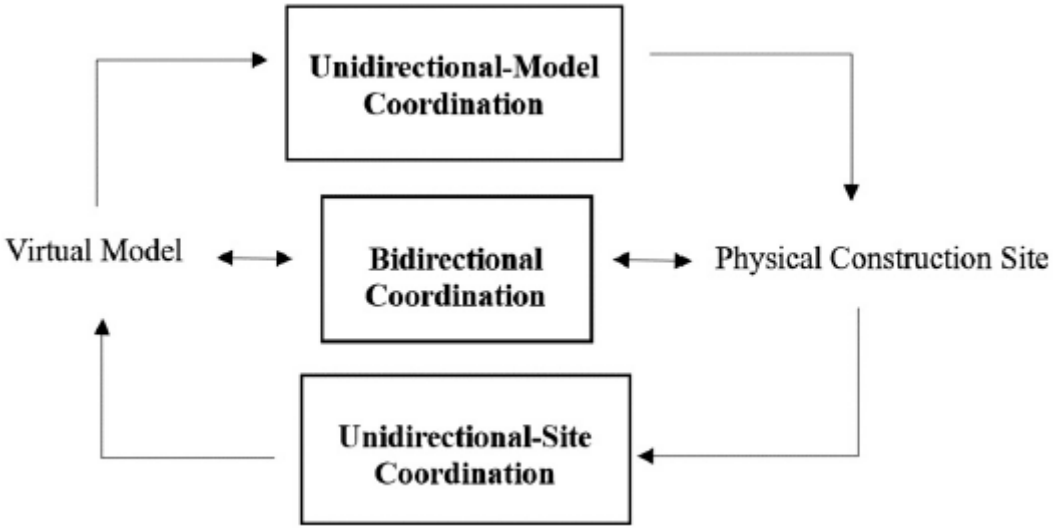

Figure 1. Unidirectional and Bidirectional Information Communication Flow. Source: [3]

[3] related the four different types of information flow in the use of ICT in construction projects as related in the figure 1. These information flows are undirectional-model coordination, unidirectional-site coordination, non-automated bidirectional coordination and automated bidirectional coordination. Most recent research works have focused us exploring the use of ICT in the facilitation of unidirectional-model mode of communication [5],[6].

2.1.1. Potential implementation of technologies in the construction industry

The following are the potential implementation of technologies in the construction industry:

i. An important area for the implementation of technology in communication in the construction industry is exploring Radio Frequency Identification. This is very vital to help manage supply chain in the construction, quality control, adequate tracking of resources and inventory and life cycle

management of the project. This implementation is necessary for cost reduction and time resource saving [7], [8].

ii. 3D laser scanning is a necessary area for exploration in the construction industry. Areas where the 3D scanning has been engaged in previous times are quality control process, concrete casting, surveying process, alignment of highway and paving operations [9].

iii. Robotics technology implementation in the construction industry is another field that is gaining exploration. This has facilitated safety and security monitoring on site. It has also facilitated on-site image capturing and 3-D modelling [10].

iv. Wireless connection technology implementation in the construction industry is one area of technology that has facilitated quality real-time data flow, information exchange and effective distant communication within the shortest time possible [11].

v. Mobile computing technology implementation in the construction industry has facilitated management of operations on site, monitoring on site and information sharing [12].

vi. Quick response codes and NFC technology implementation in the construction industry have enhanced operations in the area of material tracking on site, accounting and purchasing, recording keeping of used materials and controls in documentation [13].

2.2. ICT in the Transportation Industry

Among the many impacts of the implementation of ICT in the road transportation industry is the high level of safety it brought on-board. ICT in road transportation industry has substantially reduced loss of lives and properties due to clashes between vehicles on the road. A way that this has been made possible is through invention of traffic and warning lights that coordinates and communicates efficiently in navigations on the road to help avoid vehicular collisions. Though much funding might be required to setup these technologies in the required places in a city, the benefit outweighs the cost [14].

2.3. ICT in Education Sector

According to [15], the use of ICT in teaching civil engineering related courses has gained wide acceptance worldwide over the past few years. It has created a departure from immaterial imagination to a realistic visual perception for students across the learning classrooms. Years before now, dictation of lecture materials in classrooms by teachers was the approach, ICT has been able to bridge this gap such that technology implementation has made it possible for teachers to project their lecture materials thereby saving time and easing communications in the classrooms. Implementation of technology in the learning environment has also introduced the use of several computer applications such Microsoft Office, Microsoft PowerPoint, Google Talk, Skye, Microsoft Outlook and Adobe PDF Reader. These applications have made learning and teaching process very easy. The implementation of technology in the education sector such as the introduction of E-learning platform has also made distant learning and exchange in learning activities possible [16].

2.4. ICT in Engineering Design

Several years back, design in engineering takes a very long time. The duration for the design of a mini project such as a residential building in Civil Engineering could take up to a month for analysis and design of all the structural members of the structure. Time resource in design of structures used to be a major challenge especially when engineers are faced with complexity of high-rise structures which could take months or even years before completion if approached manually. The developments of different computer aided design application over the past few years have helped to make design in engineering an easy task. These design applications are also very helpful in by-passing the usual human errors that could arise from manual design approach [17], [18]. It can greatly enhance structural quality right from the design stage [19]. With the use of design applications, designs of structures that would usually take weeks, months or even years could now be modelled, analysed, and designed within few hours.

Some of the well-known and well engage design application in the market are AutoCAD, Orion design software, ETABS, SAFE, SAP2000, Autodesk Revit, CAD RC, STAAD Pro and RISA [15].

Beyond engineering designs that translate into engineering drawings, ICT has recently advanced into virtual environment design. This is the design that brings the project into a virtual environment such that

stakeholders in a project can actively interact with the project in a virtual reality before it is implemented on the site. Through this new development, it becomes easy for clients to make adjustment and express their interests or dissatisfactions with a part or some parts of the project before it is built. Hence, a building that exists in a physical environment can be modelled in a virtual environment with same representations [20].

2.5. ICT in Building Preservation

According to [21], building degradation process is a known to be a major threat to wooden stilt buildings across the world. Inadequacy in spatial planning approach, conditions of waterfront settlement, and inability for protection and enhancement of the features of the buildings are some of the contributing factors to the vulnerability of the buildings. Nevertheless, there have been developments with cases of preservation of like-buildings such as the preservation of rorbu; a structure temporarily built to shelter fishermen, preservation of the carrelets in the Gironde estuary and the Scottish Crannog Centre Despite. Through the introduction of ICT in building preservation, evaluation methods have been very instrumental in conservation buildings in many homes in the United Kingdom and other countries. Use of ICT has greatly helped in structural damage assessment [22], [23] & [24]. Some of these methods are Home Condition Report, 2004, NEN 2767 (the Netherlands), Grille d'evaluation de la degradation de l'habitat, 2011, Inspeccion Tecnica de Edificios, 2011, MAEC, 2006 and MANR, 2007. Although the aforementioned methods of evaluation do not put into consideration the features and information type to be gathered, they have helped in advancing body of knowledge towards the achievement of better results. Knowledge from the aforementioned evaluation methods have contributed immensely to the development of ICT diagnostic method of evaluating and focusing on wooden stilt-houses [25].

2.6. Implementation of ICT in Energy Efficient Buildings

Based on study, the building sector is said to be the sector with the highest consumption of energy of other sectors. The building sector is also known for the emission of CO_2 up to an approximate of 40% of total consumption. According to [26], by 2030, the total energy that is being emitted in the building sector would have been substantially reduced by 30% through the engagement of new high technology and extensive research. According to [26], the most of the energy consumption in a building is during its usage life and this is about 80%. Hence, to reduce the energy consumption in any building, it is necessary that the reduction exercised is focused on the operational cycle such as an improvement on the access windows, the ventilation system of the building, and thermic features by insulation. Another way to cause reduction in energy consumptions in building is to appreciate the exploration of ICT in the building sector [27]. Though [26] related that energy consumption by 2030 would have reduced by 30%, the International Panel on Climate Change related that reduction in energy consumption would be greater than 30% by 2030 through ICT solutions. In line with the International Panel on Climate Change, some specialists believe that ICT would not only bring about a greater that 30% reduction as related by the International Panel on Climate Change, rather the reduction would range from 50% to 80%. According to [28], an experimental study of an ICT monitoring system installed in a building immediately recorded more than 30% energy consumption reduction. Though the percentage reduction dropped afterwards. Hence, these present ICT to be a potential solution to substantial energy consumption reduction in the building sector [29].

2.7. ICT in Structural Engineering

In the recent years, ICT began to gain attention in its application in Civil Engineering and especially structural engineering. Apart from improved design and enhanced energy efficiency, another area that the use of ICT has greatly improved activities in the built environment sector is in the area of structural health monitoring. It has been very useful in predicting risks of seismic activities and for averting the hazards of building collapse [30]. This discovery had been through the use of smartphones designed with sensors that can efficiently carryout structural health monitoring (SHM). These smartphones are also designed with in-built batteries and units that serve as processor. The structural health monitoring operation is basically focused on assessing damages in a structure and to assess the degree of safety of the structure. Many researchers have continued to work tirelessly to device means to upgrade on the

present SHM system due to challenges such as high cost of sensors, high cost of maintenance, high cost of installation, high power consumption, wireless communication issues, cabling issues and more. Some of these challenges have directed line of thoughts towards the use of smartphones as potential upgrade over the previous SHM systems. The figure 2 relates one of the first studies carried out by [31] on the use of smartphones in structural engineering as SHM system.

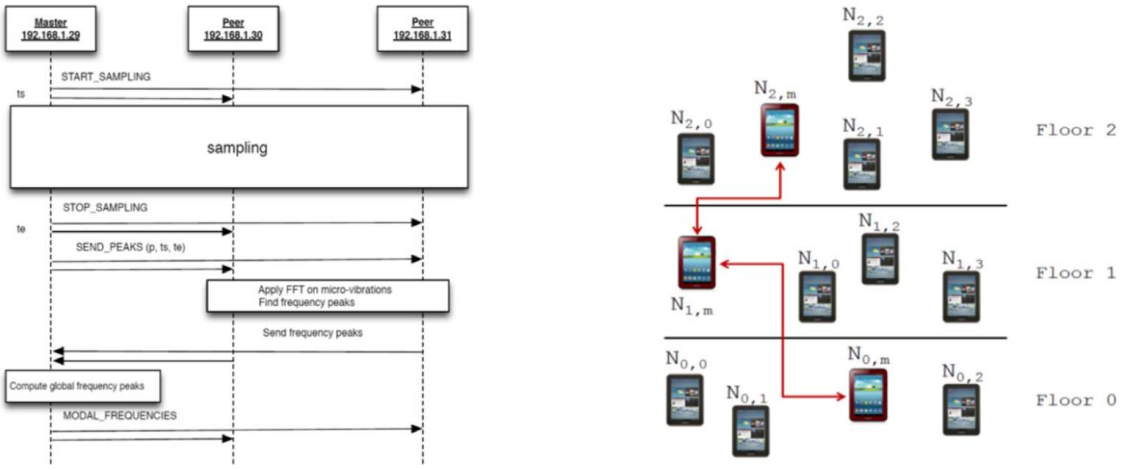

Figure 2. Smart Monitor System (a) sequence diagram (b) deployment across 3 floors [32].

In the design of smartphones to serve as SHM systems, one of the the core features put into consideration is the frequency peak-picking attribute. The smartphone SHM system locates the highest frequency by first assessing the natural frequencies and applies the peak frequency on the time series through the recorded accelerations in three axes. Another in-built feature of the smartphones designed to serve as SHM system is its tolerance for faults in its communication protocol. The master node in the figure 2 is the is that on the ith floor. As an upgrade on the smartphone SHM system approach, [33] proposed a Cloud-SHM approach using smartphone. Different from the three levels in the previous SHM system of [31], the proposed Cloud-SHM has 6 levels of framework.

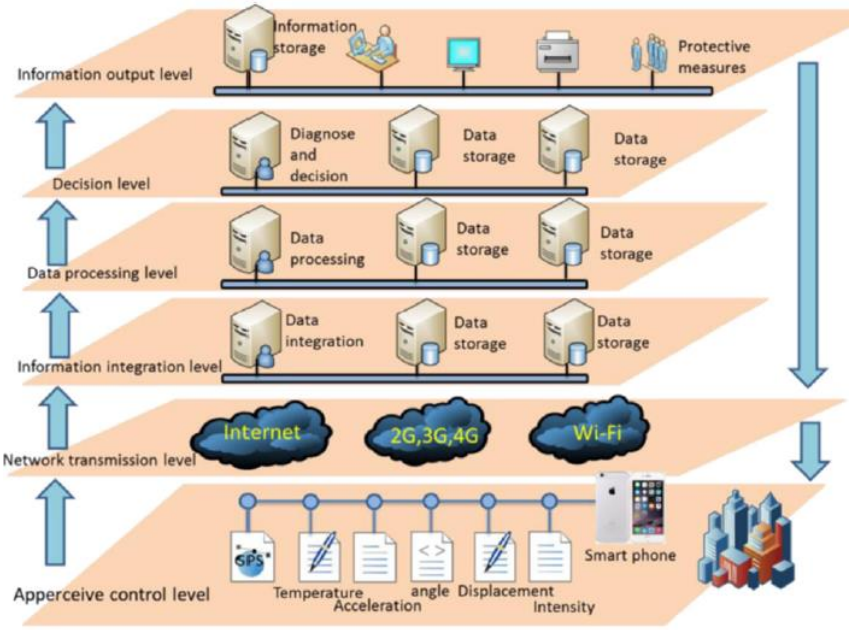

Figure 3. Framework of the Cloud-SHM based on smartphone [32]

The Cloud-SHM based smartphone's platform drew it base from Orion-CC, an application that is capable of acquiring data, analyse data and have the same uploaded to the cloud for the purpose of storing. It is linked up to a website specially designed with other features built with the Cloud-SHM based smartphone are ability to make decision, ability to generate output for the information, ability to process data, ability to transmit network, ability to integrate information and an apperceive control level.

3. Conclusion

The application of Information Communication Technology is very vital to achieve cost reduction, operational time reduction, safety, and more in civil engineering practices. Hence, ICT remains relevant to the field of civil engineering and engineering at large.

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