"The role of education for Civil Engineers in the implementation of the SDGs"

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DIGITAL CONSTRUCTION: CHALLENGES FOR CIVIL ENGINEERS

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ABSTRACT

Predicting the impact of current technological trends is a speculative and error-prone exercise. Nevertheless, digital transformations in the Construction sector are already sufficiently established to allow for some predictions about future impacts and challenges for Engineers and other Construction professionals. These transformations transcend the most obvious technologies, many of which are adapted from other areas of activity, and include less visible aspects such as the development of technical specifications and standards or the training of new professionals. This article begins with a very brief historical perspective on the process of digitisation in construction, comparing some of the current challenges with those encountered when similar technological transformations occurred in other sectors of activity. Standards, education, and training are discussed as factors that help explain an uptake in the interest for digital construction and present new challenges and opportunities for Civil Engineers.

1. DIGITAL CONSTRUCTION: "THE FUTURE"?

Digitisation is a long-standing aim for the Construction Industry, which has been described thoroughly in the literature for decades. It is also an elusive goal since continuous technological development, and the existence of previous comparable initiatives from other areas of the economy have long inspired generations of Civil Engineers who wish to automate construction tasks or otherwise improve information management. Current examples of trending digital solutions [1] are often the result of adapting long-existing technology. For example, Laser scanning emerged in the 1960s, Building Information Modelling (BIM) was initially developed during the 1970s to the 1990s, or more recently, Digital Twins were

described for the first time in the early 21st century. Even other technologies which are often associated with Industry 4.0, such as sensors or Artificial Intelligence, have a long history of application in various sectors, including Construction.

Over the past twenty years, several studies and opinion articles have sought to estimate the importance of digital technologies in the Construction sector, comparing it (often unflatteringly) with other areas of activity [1-3]. Some studies have suggested a relationship between productivity and the degree of diffusion of these technologies [4-6], underlining the growing gap between Construction and the rest of the economy for over half a century. Given the Construction Industry's global economic and social relevance, increasing productivity and reducing waste in this field through technological upgrading and innovation is critical in achieving the 2030 United Nations Sustainable Development Goals (SDG), particularly SDG 8 [7].

1.1. The productivity paradox

Despite continued technological development, productivity in the sector (measured by Gross Added Value per hour of work) still lags behind that of the economy as a whole. In this regard, it should be noted that the economic and social impact of a technology often occurs years or even decades after its invention. Even innovations that are now central to the economy have required a favourable context for their effect to be clear – to the point of rendering obsolete the technologies that preceded them.

For example, the economies of scale, the obvious changes in our consumption habits, and even the organisation of many coastal cities that resulted from the widespread use of shipping containers only occurred decades after Malcom McLean introduced them in 1956 [8]. It was necessary to wait for standardised solutions, and the construction of appropriate vessels and port facilities.

The electric motor and computers also motivated the perplexity of contemporary observers, who noticed the gap between the perceptible pace of innovation and the delay in achieving productivity gains [9]. If in 1987, economist Robert Solow observed that "the computer age was everywhere except for the productivity statistics" [10], computer networks and the Internet, as well as the gradual adaptation of companies, altered this reality significantly during the following decades. Indeed, the feasibility of a new disruptive technology often depends on the context in which it is adopted, and may require compatible technical and organisational solutions.

Considering that digitisation is a decades-old transformative process, it is important to reflect on the causes of the growing interest in this field from researchers, educators, and construction professionals. Recent innovations have increased interest in digital construction, enabling the greater dissemination of these technologies. The following section describes some of these advances that create a more favourable context for the productive adoption of information technologies in construction.

2. DEMANDS FOR NEW SKILLS AND RULES

The development of digital models of buildings and infrastructure that share many characteristics with their physical counterparts is arguably the main result of the ongoing digitisation process. While the most critical hardware and software components for creating digital models have been available for over two decades (with continuous improvements since then), some less visible requirements have only more recently seen significant developments [11]. Indeed, the productive adoption of digital models requires standard workflows and skilled human resources, as described in the following paragraphs.

2.1. Standards

The pioneering adoption of BIM in countries such as the United Kingdom has resulted in national rules, which have influenced the international standards that followed them. The ISO 19650 series, published from the end of 2018, describes what a BIM model is, how it can be organised and what role actors play in different stages of the construction lifecycle [12]. Other, even more recent standards describe how to specify information requirements, thus enabling contracts for BIM services based on standard rules. Specifications are available for geometrical and non-geometrical requirements for model elements, for relationships between these elements, among many other aspects. These rules are very general, so their adaptation to national standards, legislation, or even those frequently cited but insufficiently defined "rules of good practice" will require further effort from interested parties in each country.

2.2. Education and training

Human resources with adequate training and experience are another critical requirement for companies moving towards digital work processes. Topics such as BIM or Digital Twins were only formally included in the curricula of most Civil Engineering courses a few years ago. As a current example, the two largest Civil Engineering Masters degrees in Portugal offer optional BIM and digital technologies courses to first-year students [13, 14]. No specific courses on BIM are offered in Civil Engineering bachelor degrees in these universities. Hence, many students continue to graduate with no experience with BIM tools and, more critically, with no knowledge about standard digital construction processes or rules that are applied around the world, often compulsorily.

Thus, although this reality is changing as the offer of graduate and undergraduate training in the field of digital construction increases, technicians with knowledge and experience in this area remain scarce. This shortage of professionals may prove to be an obstacle to the adoption of new work processes.

2.3. New professional roles

Also within the scope of human resources, digitisation creates new roles and transforms existing ones. Although their names vary, these roles can be grouped in three main categories [15]: Operational (often model development, requiring expertise with specific IT tools), Development (requiring programming skills), and Management (responsible for integrating BIM at the level of a work team, a company, or a project).

This wide variety of possible roles and related skills within each of these categories is largely compatible with the functional organisation of most construction companies. Still, the transition towards digital construction processes requires a suitable approach from Higher Education Institutions when preparing students for future careers. Indeed, as each type of role demands different levels of understanding about the underlying work processes, digital construction topics should be included at different points in a Civil Engineering curriculum and should preferably be integrated within existing Curriculum Units instead of compressing Operational, Managerial and Strategic issues into a single module.

Companies must identify existing skills and available human, hardware, and software resources, and prepare accordingly for the expected changes in workflows. In Portugal, the number of companies that have already started this journey has increased sharply. Still, many others are yet to take the first steps, even knowing that the use of BIM in many countries is already mandatory in public works.

2.4. Construction owners

Construction owners will have a key role to play in the transition towards digital processes. The proper definition of information requirements before contracting BIM services can make the difference between receiving a valuable digital asset or a model of no use for the intended purposes. A BIM model can be used to obtain quantities automatically, perform different types of simulations, support Facilities Managenent, or many other common tasks, but only if it has been prepared for this.

Thus, if construction owners can fail by under-specifying information requirements, they may also err by over-specifying requirements in the procurement phase. Adding successive layers of information to a model results in a very significant increase in preparation and management costs. The risk of unnecessary requirements in procurement processes may be compounded if, for example, the construction owners simply transcribe information requirements from one project to the next without critically assessing the value of each option.

Thus, construction owners, particularly public entities, should prepare themselves to hire and receive digital models. While the number of consultants available to support BIM implementation in companies or individual projects is increasing, construction owners must strive to develop their own skills in this area.

3. CONCLUSIONS

Digital Construction is by no means a novelty, but several factors contribute to an increased awareness of the importance of adopting digital solutions in the construction industry. Although the hardware and software needed to conduct surveys, prepare models, or conduct simulations have been available for years or decades, the construction sector has only recently had access to suitable standards and human resources.

In many countries, BIM use is already mandatory in public works. This requirement will likely spread to more countries, particularly in Europe. Even in regions where legislation does not

impose BIM use, construction owners who recognise the value of digital assets increasingly demand it.

Digitisation provides significant opportunities and challenges for Civil Engineers. New roles are emerging, which require technical and management skills that have only recently been introduced to many Civil Engineering courses. Although students are often keen to develop modelling skills, these are not required for all new digital processes. Software Development and Information Management skills are also increasingly valuable skills. Project Managers must also accommodate this growing variety of profiles within work teams.

Technology is evolving to lower barriers for Civil Engineers. Immersive Virtual and Augmented Reality interfaces provide easy access to complex 3D building models, and Visual Programming Languages allow many tasks to be automated without steep learning curves.

It is almost a truism to say that there are no good projects without good construction owners, and digitisation gives these agents an even more central role. Owners, and in particular public entities, should be prepared to procure and manage digital models. They are responsible for defining the objectives of digital processes, without which the usefulness of information models is compromised. The adequate development of information requirements is a particularly critical task for owners when hiring BIM services.

Reducing wasted effort and increasing productivity are common goals for all entities that transition towards digitisation. Following the past example of other activities, achieving this purpose depends on a coordinated effort of the construction sector, including companies, public entities and higher education institutions.

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