Improving construction cost prediction through standards and technology

Alan G MUSE, United Kingdom
Mercy T IYORTYER, Nigeria

Key words: construction; ICMS; BIM; cost benchmarking: cost estimating; cost planning; cost prediction

SUMMARY

According to the Construction Intelligence Centre, $2 trillion of construction work is required to satisfy the global demand arising from urbanisation and infrastructure from 2018 to 2022. To deliver smarter living and environmental resilience, while meeting this demand, governments and investors face difficult economic decisions. Attracting the required private sector investment requires greater certainty, accuracy and transparency in cost prediction. How can emerging digital construction technologies, such as BIM, artificial intelligence and blockchain, work with professional international standards like International Construction Measurement Standards (ICMS) to improve the cost prediction of global construction and infrastructure projects?

ICMS (www.icms-coalition.org) was developed collaboratively, by worldwide construction professional bodies, to provide high-level cost reporting standards. It enables consistent and comparable reporting of costs across markets and within markets and is designed to link to local, more detailed standards, where relevant. ICMS was launched in July 2017 and is already in use by investors, end users and professionals around the world: a second edition will be launched in 2019 to cover life cycle costs in addition to capital costs.

At the same time, digital technologies are emerging quickly in construction. BIM not only allows design to be undertaken more efficiently and effectively, but allows the interaction of design and cost, time and operational data. Thus, global professional work standards allow common rules for the collection of data in a BIM environment.

Improved cost prediction hinges not only on the amount of data available, but the pooling of data around similar projects (Skitmore et al, 2006). Similar projects may be classified, at early design stages, by type, floor area and basic attributes. ICMS allows this high-level comparison of data between international markets and therefore acts symbiotically with 5D BIM and improved cost prediction.

This standardised data and technological manipulation will allow more informed and better decisions to be made at each stage of the design and construction process. In turn, this will allow better cost prediction of projects leading to a ‘should cost’ rather than a ‘will cost’ framework.

As construction becomes more global and more complex, international professional construction standards allow professionals to guide technologists and fully utilise and embrace the opportunities that new technologies provide. Every professional dealing with the financial management of construction projects can help to embed the use and adoption of ICMS around the world.

1. INTRODUCTION

Players in the construction industry have continuously sought ways to enhance project performance by reducing project delivery time, increasing productivity and quality and decreasing project cost. Studies have, however, shown that improving project performance is only possible by improving decision-making at each stage of the project life cycle. In turn, decision-making can only be improved by providing the right information, in the right form, at the right time. Hence, developing standards to provide common rules for information is crucial. Of course, we need open data standards at an IT technical level. In addition, however, we also need standards for the professional work processes for those populating the BIM model(s).

Information is like turning on a fire hose. It can quickly overwhelm you. It therefore needs to be defined in accordance with what decisions need to be made at each stage of the project lifecycle. Defining information needs is critical.

Technology needs professional standards - and, in terms of data collection, use of predictive cost data and general relevance, professional standards need technology. So, as BIM advances and the disruptive technologies affect property and construction, the need for international professional standards becomes ever greater.

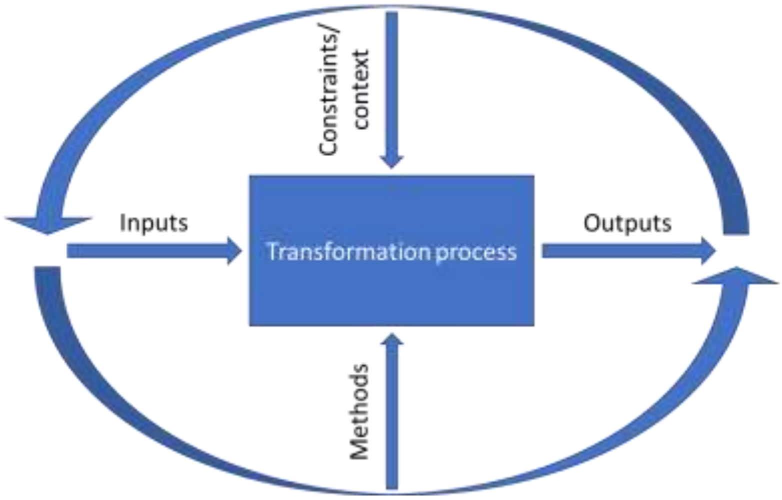
This paper considers how decisions are currently typically made through the project life cycle to predict cost, the technological change that is upon us and how this is likely to develop to support decision-making, the emerging need for unified and harmonized international standards to further improve industry performance. In short, it considers how technology improvements and professional standards together can be transformational.

2. COST PREDICTION PROCESS

Cost Prediction may be thought of as a process as illustrated in Figure 1.

In order to produce the desired output, the Cost Prediction, input is necessary in the form of data. The method used to transform the data into a Cost Prediction depends on the type of data available. The process must take account of the context of the Project, in other words, the conditions under which the project is to be undertaken such as market conditions, procurement route, location and any constraints which might apply, such as difficult access or noise restrictions. The accuracy of the Cost Prediction depends on the accuracy of the input data, the accuracy of the method adopted to transform the data, and the accuracy with which the impacts of the context and constraints can be quantified.

Figure 1: Cost Prediction Process



Project realisation is a dynamic process that starts with the client's needs and finishes when the project is finally put into operation. The realisation process passes through a number of stages starting with a Business Case setting out the economic, environmental or social justification for the project, passing through a series of design phases from concept to working drawings, and finishing with construction and commissioning.

Figure 2: Project Stages

At each successive phase the data available to quantify the inputs and the impact of the context should become increasingly complete, detailed, and reliable. The process is not linear but iterative, since decisions made earlier in the process may require revising in the light of more accurate or comprehensive information that becomes available later.

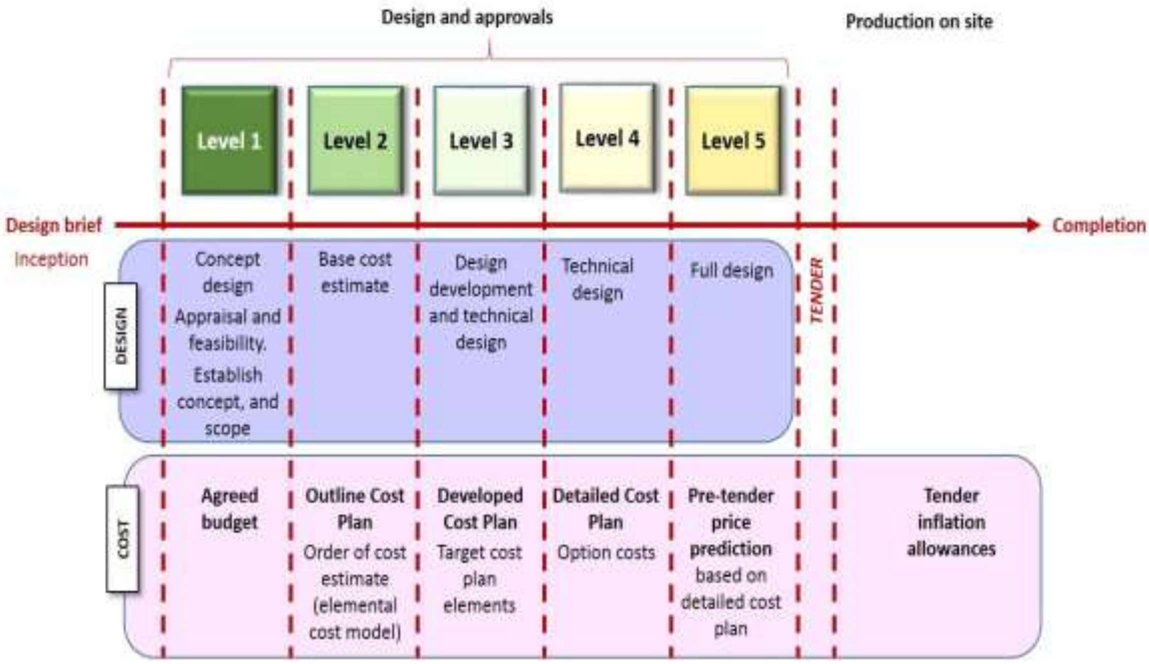
It is therefore clear that the method used to predict costs will change as the amount and reliability of available data changes.

The design phase of any construction project is cyclic, repetitive and evolutionary involving designers from various specialist design groups. Design development involves a complex set of decisions that evolve as more information becomes available. It is tempting to describe design and engineering as a neat sequential process, which it is not, it is iterative. Design iteration is the repetition/improvement/modification of design tasks in the light of discovery of new information. The design process requires inputs from many different sources. As a design evolves, more decisions are made that impact production of the design from idea, to project

delivery on site. Iteration is an inherent and unavoidable aspect of any design phase which requires proper planning.
The design process is broken into smaller tasks to reflect design development. Some of the tasks require technical information that is produced as a result of other tasks. The challenge is dependency and interdependency of the design tasks. A lot might be known about the façade, but little known about the foundation design because of the lack of ground investigation.

The 'levels' in Figure 3 are examples of design and cost progressions. These are levels of architectural, engineering and specialist design progression and other 'information' (since they may all progress at different rates), rather than using design stages that are not universally accepted by different markets.

Figure 3: Linking cost prediction and the design sequence



No matter how good the available data and information may be, and no matter how good the method of cost prediction, there will always be an element of uncertainty. This arises from two principal sources. First, there is uncertainty in quantifying the impacts of the social, economic and environmental conditions that will apply during project realisation. For example, it may not be possible to predict with perfect accuracy how many accidents might occur during construction, or how easy it will be to attract labour capable of producing work at the rate and hourly cost assumed in the prediction, or how much time or productivity will be lost due to inclement weather. Second, unit costs can only be based on historical data, and since no two projects are ever identical, if for no other reason than they are necessarily constructed in a different place and context, the unit costs incurred in a project today can never be the same as those incurred yesterday.

In addition to these uncertainties, there are numerous other risks associated with cost prediction ranging from the incidence and impact of design changes, no matter how undesirable these may be, the impact of unforeseen ground conditions or weather conditions, to changes in regulations and government policies. For these reasons and many more, the cost of a project can never be certain until the final account has been agreed. Thus, there is good reason to consider predicting costs probabilistically as is commonplace in the oil and gas industry. However, whilst these methods deserve more research, there are challenges in introducing such an approach in the context of construction, since, presently, comparable and consistent data is difficult to obtain.

3. TECHNOLOGICAL CHANGE

3.1 Building Information Modelling

Technology has become an enormous driver for innovation, existing process, and transforming business in today's construction industry (Kim 2008). BIM and its allied digital technologies and tools provide enormous opportunities for project cost management professionals to dramatically improve the quality, speed, accuracy, value and sophistication of their cost management services and therein ensure their future as key players in the BIM world. This is particularly the case during the design development stages when various design options are being proposed and evaluated. Franz and Messner (2017) have pointed out a a key benefit of BIM, and that is its ability to facilitate the development of detailed information and analysis much earlier in the building process to improve decision making and reduce downstream changes. The ability of the project cost manager to use BIM models and other digital technologies to provide quick and accurate cost prediction throughout the design simulation process provides an enormous opportunity for the profession to play a key leading role in sustainable design and construction development. Muzvimwe (2011) supports this notion and describes the value of the cost manager in being able to simulate and explore various design and construction scenarios for the client in real time through having their cost data and quantities integrally linked in the live BIM model. This certainly raises the value of the cost management service but is dependent on the cost manager having BIM capability/expertise, sharing their cost data in the model and having the experience, expertise and intuition to analyze and critique the information that is being generated by the model.

RICS (2014) contend that BIM provides project cost managers with the opportunity to spend more time on providing knowledge and expertise intensive advice to the project team - the automation of processes such as quantification will substantially reduce time spent on technical processes and will provide more time and the digital tools for higher value-added and more sophisticated cost management services. The value of BIM is growing, this was encapsulated by the chairman of the Associated General Contractors BIM Forum who spoke about the BIM and said "Everyone sees this as the last best chance to remake our industry the way we want it,...It's a huge story that goes well beyond BIM (p. 26). Clients and developers are beginning to advocate for BIM. Developers, designers, builders, and contractors are engaging with the models triggered by BIM. BIM is slowly but surely infiltrating the supply chains to subcontractors, particularly contractors and the trades (Post, 2008),

However, the lack of global standards in relation to BIM measurement creates a range of issues and problems for the cost management profession. The automated quantities generated from the range of software programs utilized in BIM platforms vary widely in terms of format and content. Tremendous benefits could be obtained if international BIM measurement standards were developed by the profession and software authors influenced to adopt these standards.

3.2 Big Data

Big data is revolutionizing 21st century business generally and is opening significant opportunities in the construction industry to deliver better 'value-added' projects more effectively, efficiently and sustainably. Whilst a wide range of definitions have been developed to describe big data, the basic concept is that the rapid development of the internet and digital technologies over the past two decades has meant that what people do is increasingly leaving a digital trace (or data) which can be used and analyze. Big data therefore refers to that enormous amounts of data that can now be collected and the ability to make use of it. The big data trend will continue to grow at a rapid rate as the digital tools required to collect and analyze the data are become more powerful, less expensive, more accessible and easier to use.

Another terminology used is the 'Internet of Things'. Mitchell (2015, p.1) contends that *"the Internet of Things – the linking of physical objects with embedded sensors – is being developed at a breakneck speed. Companies and consumers are now using technology daily to track movements, improve collaboration and customer service to increase productivity at an organizational and personal level. This simultaneously creates massive network effects and opportunities for global industries to shape our lives."*

Whilst slow to embrace the use of big data compared to many other industries, the impact of big data on the construction industry will be enormous. Marr (2016, p.1) notes that *"huge amounts of resources and work go into major construction projects and of course this means that huge volumes of data are generated. Number crunching has always been a big part of construction – a commonly heard phrase is that construction companies are accounting companies which happen to erect buildings. It's an industry where 35% of costs are accounted for by material waste and remedial work. So, counting the cost of every screw could be the difference between delivering on budget and bankrupting an organization (or several organizations) financing a build"*.

Whilst analytics have always been used in the construction, the effective utilization of big data will require more advanced analytics and investigation. *Construction firms are now starting to move into real-time cloud-powered analytics of large and unstructured datasets (which) have the potential to redefine the traditionally fraught relationships between the interested parties* (Marr 2016, p.1).

High level analytics are likely to increasingly drive planning and design strategies as well as post occupancy evaluations. Mitchell (2015, p.1) provides an insight into the future. *"Building-occupant research has long played a critical role in planning for some projects. What's changing is the immediacy and sheer amount of data, and the ease by which it can be collected and analyzed. The retail supermarket sector is emblematic of living, breathing and using data to track customer behavior and applying these metrics to benefit the future design and fit out of stores. Additionally, the rise of mobile devices and social media, coupled with the use of advanced survey tools and interactive mapping apps, has created a powerful conduit through which building teams can capture real-time data on the public — what spaces they like most and least in a given building, where they prefer to hang out on campus, whether they take public transportation or drive to work. With advanced traffic flow simulation programs that allow users to program thousands of avatars with unique behavioral characteristics, building teams can predict—with a much higher degree of certainty—how people will interact with a space layout"*.

4. **INTERNATIONAL CONSTRUCTION MEASUREMENT STANDARDS (ICMS)**

Business practices are increasingly demanding global rules. We have seen this in the accounting arena, with international financial accounting standards, and, with 70% of global wealth in land and property, measurement of space in property and standards in construction cost are prime candidates.

Global standards also enable better project decision-making using BIM, as described above, to be more consistently applied in different markets, leading to greater capability for benchmarking and greater transparency.

Governments, clients and end users increasingly want to compare and contrast the cost of construction projects on an international basis. Surveys carried out by RICS (BCIS) in 2009 and the European Council of Construction Economists of cost consultants in 40 countries have shown that:

- approximately 50% of countries did not claim any published standard elemental classification of building parts
- in the absence of locally agreed standards, professionals frequently adopt 'foreign' standards or ad hoc in-house developed standards
- there is no common way of expressing cost per m2, both in terms of the cost definition and the floor area
- there are many countries where the quality of cost information and data classification falls short of what local professionals might wish.

BCIS concluded in its survey: *"Although there are countries with quite complete cost related standards and information sources, there appear to be many more where the quality of published guidance and cost information falls short of what local professionals might wish.*"

Accordingly, construction professional bodies from around the world met at the beginning of June 2015 at the International Monetary Fund in Washington DC to launch the International

Construction Measurement Standards (ICMS). The ICMS Coalition was established by non-profit organizations representing professionals in more than 140 countries. Collectively, the group aims aimed to harmonize cost, classification and measurement definitions to enhance comparability, consistency, statistics, and benchmarking of capital projects. Inevitably, the coalition will continue to grow as further professional organizations come forward. Industry corporations, contractors and key government stakeholders are encouraged to contribute to, and lead adoption of, the new international framework in their capital markets. This is the first time these professions have come together in this way to develop unifying standards that reflect and enhance the increasingly international construction market.

ICMS creates (a framework for) a standard system to classify and cost construction projects. To understand what is included in the 'cost' and what is not, for building and civil engineering projects (works) that will allow cost comparisons to be made on a like-for- like basis across countries. To allow Governments and international bodies compare the costs of construction of building and civil engineering projects (works) so that:

- national costs can be benchmarked;
- the causes of differences in costs can be identified;
- properly informed decisions on the location of construction projects can be made; and
- The relative performance of the construction industry in different countries can be determined.

ICMS are essential global classifications to allow more consistent international use of BIM models. In turn, this will lead to better collection of data for both space and cost prediction and, ultimately, machine learning. As With BIM, big data and Smart Cities begin to merge as concepts standard classifications will assume an even more important role.

ICMS will provide a scalable solution. Most comparisons of construction industry performance require that construction costs be converted to a common base. Existing mechanisms for such conversions produce unreliable results. A proposed method for producing industry-specific conversion factors was tested using a single building type. The lack of a consistent and reliable cost conversion mechanism for comparing construction costs internationally has been acknowledged (Best, 2007; Walsh and Sawhney, 2002, 2005; Blake et al., 2004; Stapel, 2002) and it has been demonstrated (Best and Langston, 2006a, 2006b) that the use of different conversion factors in comparative studies can produce quite contradictory outcomes.

5. SYNTHESIS: HOW DO ICMS AND NEW TECHNOLOGIES IMPROVE COST PREDICTION?

Decision-making in construction projects involves the management of multiple interrelated components such as quality, space, time, and cost. Uncertainty associated with each of these parameters, and the evolving relationships between them within the constraints of time, cost and space are at the root of complexity in project management. Accounting for this complexity is critical to effectively plan for contingencies and test the usefulness of alternative decision-making strategies. However, predicting the consequences resulting from such complex behaviour is difficult as they are often emerging within dynamic contexts.

A simple way to avoid making the wrong decisions at the wrong time is by establishing a series of project gateways at which the project team compile information describing the project as it stands, the client assesses that information and either asks for changes or approves it and gives instructions to progress to the next stage.

At each of these stages, certain aspects of the project may be 'frozen' and change control procedures introduced for those aspects. For example, at the end of the concept design stage, the project brief may be 'frozen'. Freezing the project brief means that it can only be changed with the explicit agreement of the client, and then only when the cost implications and the disruption of the change have been evaluated and accepted, and the change recorded.

By adopting a process of progressively reviewing and approving aspects of the project based upon the level and detail of information available, it moves forward in a controlled way. If this strategy is not adopted, the client and project team can lose focus, uncertain of what has been decided and what has not and unable to make progress. There can also be 'scope creep' where instructions are given without a proper assessment of whether the instructed work is included in existing fees, whether it has been authorized, or whether it is a sensible use of the clients funds.

Building Information Modelling (BIM) is a very broad term that describes the process of creating and managing digital information about a building or other facility (such as a bridge, highway, tunnel and so on). It can substantially aid this staged decision-making process.

To ensure projects are properly validated and controlled as they develop, data is extracted from the evolving building information model and submitted to the client at key milestones. This submission of data is described as a 'data drop' or 'information exchange'.

Generally, data drops are aligned to the project stages described above, and the information required reflects the level of development that the project should have reached by that stage. This might be considered analogous a stage report on a conventional project.

The nature of data drops should be set out in a set of requirements at the beginning of a project. These requirements may be considered to sit alongside the project brief. Whilst the project brief defines the nature of the built asset that the employer wishes to procure, the requirements define information about the built asset that the employer wishes to procure to ensure that the design is developed in accordance with their needs and that they are able to operate the completed development effectively and efficiently.

Data drops are likely to include:

- Models (Industry Foundation Classes (IFC) models and native project information models).

- Data structures (such as COBie files and schedules).
- Reports (typically PDF's, although native files can be more useable).

The client will check the data in terms of compliance with the requirements, compliance with the brief, space, cost and so on before deciding whether the project should proceed to the next stage.

The timing and exact requirements for data drops will vary with the nature of the project and the needs of the client, however, typically it includes the following stages:

1. Brief.
2. Concept.
3. Definition.
4. Design.
5. Build & commission.
6. Handover & closeout.
7. Operation & in use.

There may also be information exchanges within the supply chain, which may be more frequent than employer information exchanges.

6. CONCLUSION

Effective cost prediction is critical to the successful delivery of a project especially as it can enhance decision making at the early stages and throughout the project life cycle. It enhances planning, saves cost and time with a resultant impact on the project.

Global construction cost reporting classifications (ICMS) are enabling improvements in the cost prediction process through standardized data collection and reporting. In turn, technological developments are enabling the capacity to store, analyze and share greater amounts of cost data to identify trends, differences and improve probabilistic cost estimating and cost planning. Taken together, these developments will be transformational in predicting cost and managing risk.

Cost prediction, including benchmarking, estimating and cost planning, can be improved by better data that can be analyzed into relevant pools of information for the project in question. Similarly with sufficient detail, systems of differences can be identified which allow key differences in size, complexity, specification and performance outcomes to be compared and adjusted.

Consequently, for all construction stakeholders to benefit from these developments, it is key that ICMS is endorsed, adopted and used alongside relevant construction technologies by the Profession, Clients, Governments and Non-governmental organizations.

REFERENCES

1. Building Team Views Technological Tools as Best Chance For Change. By: Post, Nadine M., ENR: Engineering News-Record, 08919526, 12/1/2008, Vol. 261, Issue 17
2. Franz, B., Messner, J., Evaulating the Impact of BIM on Project Performance (2017) in Computer Integrated Research Program – White Paper 1
3. Kim C. Kim H., Han S H., Kim C., Kim M K., Park S H. Developing a technology roadmap for construction R&D through interdisciplinary research efforts, Journal of Automation in Construction 18 (2009) 330-337
4. H. Kim, S.H. Han, M.K. Kim, Computing as reflected in the technology roadmap for center for technology fusion, Journal of Computing in Civil Engineering 22 (2) (2008) 69–70
5. Langston, C. and Best, R. (2005) 'Using the Big Mac Index for comparing construction costs internationally', in proceedings of QUT Research Week 2005, Queensland University of Technology, July 4-5.
6. Marr, B., Big Data in Practice: How 45 Successful Companies Used Big Data Analytics to Deliver Extraordinary Results, Wiley, 2016
7. Mitchell, D., The BIM Hub, Big Data Drives Wise Construction, 2015
8. Muzvimwe, M. (2011), 5D BIM Explained, http://www.fgould.com/uk/articles/5d-bim-explained/
9. Salman A,. Abid N., John Y.N.M., Brian H. Y. L.,(2008) Building Information Modelling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects (www document)
10. Shih-Ping Ho, Hui-Ping Tserng, and Shu-Hui Jan (2013) Enhancing Knowledge Sharing Management Using BIM Technology in Construction, Scientific World Journal Vol 2013 Aricle ID 170498
11. Walsh, K., and Sawhney, A., International Comparison of Cost for the Construction Sector *in* Civil Engineering and Environmental Systems 21(3):151-167 · September 2004
12. Yeung, Daisy K.L., Skitmore, R M, Data Pooling For Early-Stage Price Forecasts, 2005.

CONTACTS

Alan G MUSE
RICS
Parliament Square
London
SW1P 3AD
United Kingdom
Tel: +44 207 334 3803

Mercy T IYORTYER, Nigeria
Managing Partner
MTI Partnership
Website: http://www.mtipartnership.com/
Official email: Miyortyer@gmail.com
Personal Tel: +234 803 332 3243