Challenges and Opportunities for Whole Lifecycle Information Flow Underpinned by BIM: Technology, Process, Policy and People

I. INTRODUCTION

According to ISO12006-2, construction information is information used to support one or more construction processes\(^1\). A construction process is a process which transforms construction resources into construction results. In this paper it is hypothesized that Lifecycle processes include:

a) inception / design / production: including creation of a construction entity from initial concept up to occupation by its users. Project stages might include inception, design, production information, tender, construction, commissioning.

b) use / maintenance: including maintenance / servicing of a construction entity over a given period. Project stages might include specification, tender, maintenance.
c) refurbishment / alteration / re-commissioning. Project stages might include inception, design, production information, tender, construction, commissioning.

d) decommissioning / demolition. Project stages might include documentation, tender, demolition

We consider lifecycle information flow enabled by BIM as a set of rules, represented graphically through process maps, or in writing, to enable the steady and continuous evolution and use of BIM information and knowledge from the design stage, through the construction stage, to the facility management stage, while reflecting the policies and being enabled by an adequate IT infrastructure. Such definition mostly agrees with the literature, defining building lifecycle information management as “the integrated coordination, organization and control of all of the information about a building project in advance of its design, construction and the day to day operation of the building until and including its demolition” [2]. To further develop the subject area, this paper argues that a WLC flow is not only integration and coordination of information in design or construction processes but also most of the information/knowledge generated along the RIBA Plan of Work stages. One of the issues with construction project development stages is that information generated in previous stages, in some cases, has little value to the succeeding stage. This can cause information redundancy at every stage and ultimately leads to massive inefficiency. Figure 1 depicts this in a simplified way. As project development processes proceeds from one stage to another, information is lost in the transition. The ultimate goal in the WLC information flow concept is to minimize or eliminate information loss, achieve efficiency by re-using the information and adding value to it when it is transited from one stage to another (this is depicted by the red line in Figure 1).

For the purpose of this paper we will consider building lifecycle information management ending with the operational stage of building construction entities in accordance with the RIBA plan of work stage 7[3].

This is an important distinction to some other approaches, e.g. building Life Cycle Assessment (LCA) which considers ‘cradle-to-grave’ building lifespan, lasting often more than 50 years[4]. LCA would thus consider waste treatment as part of the building life consisting of the following phases: design, construction, operation, demolition and waste treatment. Other approaches are also found in literature. For example, whole life cycle building energy performance analysis would distinguish only 4 stages: preparation (manufacture and transport), construction, maintenance and demolition[5].

FIGURE 1. INFORMATION VALUE IS LOST IN THE TRANSITION BETWEEN BUILDING PROJECT WORK STAGES
In this context the aim of this paper is to introduce and discuss a framework that enables the whole lifecycle information flow underpinned by BIM.

II. FRAMEWORK FOR WHOLE LIFECYCLE INFORMATION FLOW

The framework for WLC information flow is composed of four pillars: processes, technology, policy and people. These are developed concurrently and are highly dependent on each other. Figure 2 shows the processes embedded in each of these pillars.

The technology pillar consists of a classification of BIM technologies, according to their functions such as: design, analysis, management and review technologies. The mapping of technologies onto project processes should assist in linking BIM deliverables to suitable BIM technologies and interoperability requirements. Technologies can include:

- Identify detailed functionalities needed: this to include design, programme, analysis, management and review.
- Map current available tools onto the functionalities identified and create technology diagram and where possible identify data exchange/interoperability.
- Create detailed protocol manual that will include detailed instructions about setting up a collaboration server, model sharing rules, modelling instruction for each functionalities.
- Provide training and continuous assessment.

The process pillar includes identifying and standardising different work streams for each RIBA stage and their interactions with different RIBA stages and supply chain roles and responsibilities. The processes include:
• Identify work streams and provide standards/manuals for each stream. For example, design authoring, cost estimation and control, planning and building regulation approvals, energy assessment and calculation, construction planning and monitoring control, etc. Work streams to be mapped onto RIBA stages of work.
• Establish level of details (LOD) and level of information (LOI) for each process and in each stage. AIA standards are to be adopted and used in a formalised way.
• Document processes using different presentation format and templates to facilitate adoption.
• The policy pillar shows a number of processes that needs to be developed at project, company, sector, regional and country levels. These processes include:
  • Establish modelling standard, this can include adoption of BS 1192:2007 or other related available standards.
  • Contractual arrangements and the use of standard forms of agreement related to model or ‘partial’ model ownership. Also, this will include identify roles and responsibilities of developing and re-using information. This is of particular importance as adding value to information produced in proceeding processes should assume that information is accurate and the new value to be added is the responsibility of the actor ‘or a person’ who contributes to this.

The final pillar is people issue which is one of the important elements of the policy. This
pillar includes training, competency assessment standards for both, people and organisations, leadership, teamwork and others. The people pillar cuts across all three other pillars, as technology, processes and policy will not operate properly unless well-trained and developed human resource are available.

III. THE UK CASE OF ADOPTING WLC UNDERPINNED BY BIM

The United Kingdom has been active in developing whole life cycle information flow strategies and BIM policies for improving the performance of its construction industry. In May 2011, the UK Government published its “Government Construction Strategy” which emphasized the need to develop standards for enabling all members of the supply chain to work collaboratively through BIM. The strategy also announced that the “Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016”.

UK BIM government strategy is based on 7 elements and some of these have been already delivered:

• PAS 1192-2:2013 Specification for information management for the capital/delivery stage of assets using building information modelling (see Figure 3)
• PAS 1192-3:2014 Specification for information management for the operational stage of assets using building information modelling.
• BS 1192-4 Collaborative production of information. Part 4: Fulfilling employers’ information exchange requirements using COBie – Code of practice.
• Building Information Model (BIM) Protocol
• GSL (Government Soft Landings). FM requirements embedded and incorporated in BIM.
• Digital Plan of Work: Defines information requirements aligned to specific project stages. It follows a reference library of definition templates describing the typical level of definition for different stages of a project consistent with the unified classification system Uniclass 2015.
• Classification (Uniclass 2015): Uniclass is a voluntary classification system for the construction industry that can be used to organise information throughout all aspects of the design and construction process. Adopting a standard classification facilitates interoperability between different systems

A “BIM Task Group” bringing together the expertise from industry, government, public sector, institutes and academia, was formed and tasked to deliver the Government strategy. The first version of the UK BIM guidelines was then developed and released in 2013 and identified three major milestones (called maturity levels) for industry to aim for: Level 1 (2D / 3D CAD file based collaboration), Level 2 (BIM file based collaboration), and Level 3 (fully
open and integrated web service environment). These milestones have been depicted in Figure 4. The three levels are shown with their related British standards and protocols. Task Group then went on to mandate deliverables to be at Level 2 by 2016. Compared to Singapore which mandated Level 3 UK-equivalent by 2015, the UK strategy seems much less ambitious. However, this phased approach to BIM implementation—recommended by a Strategy Paper to the Government Construction Client Group—actually reflects how most UK firms are still at Level 1.

The levels considered by the UK strategy are:

• Level 0: Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism.
• Level 1: Managed CAD in 2 or 3D format using BS 1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.
• Level 2: Managed 3D environment held in separate discipline “BIM” tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as “pBIM” (proprietary). The approach may utilise 4D Programme data and 5D cost elements.
• Level 3: Fully open process and data integration enabled by IFC / IFD. Managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

In addition to the publications sponsored/released by the UK government and BSI, industry associations are also playing a significant role in releasing NBPs. For example, the Royal Institute of British Architects (RIBA) has updated their popular RIBA ‘Outline Plan of Work’
to include a ‘BIM Overlay’ reflecting the changes BIM introduces to different project stages.

IV. THE CASE OF QATAR

The construction industry in Qatar, similarly to the European and American construction industries, is not immune to delays and cost overruns. Al Jurf and Beheiry interviewed 15 grade ‘A’ contractors operating in Qatar and found that time and cost overruns are not unusual on both small and large projects. Qatar’s construction market will remain one of the fastest growing in the world throughout the next decade. Currently ongoing and planned construction projects exceed US$220 billion, including such projects as Lusail and Urjuan real estate developments, new Doha Port, new Hamad International Airport, Doha Metro Rail project, as well as construction of stadiums and related infrastructure ahead of the Qatar 2022 FIFA World Cup. Therefore, the possibility of savings on such a large volume of construction is enormous. In addition to the savings that can be achieved through the implementation of BIM, new scenarios comparing design alternatives for various aspects such as buildability, sustainability, structural, spatial configuration can be enabled with BIM. This matches fully with the current needs of Qatar. For example, with regards to sustainability, the need for sustainable and green building solutions in Qatar has never been greater than it is today according to the Qatar National Vision 2030; as such Qatar’s construction industry is looking for technologies and techniques that can enable more sustainable practices. A recent BIM survey conducted in Middle East (including Qatar) by buildingSMART showed that the BIM usage is around 25% and the level of competency is underdeveloped compared to regions such as Western Europe. The authors of this paper are embarking on a major research project funded by Qatar Foundation to develop whole life cycle information protocols for Qatar construction industry. The following sections briefly outline the current practices in the four pillars of whole life cycle information flow based on 28 semi structured interviews with industrial leaders (clients, consultants and contractors) in Doha. The interviews had a response rate of 67% and took place in Doha, between November 2014 and March 2015. They were part of our ongoing study to identify a lifecycle information flow framework and processes that can fit the needs for Qatari construction industry.

A. Interviewees Profile

Figure 5 presents boxplots of the number of years of interviewees’ experience on construction projects inside and outside Qatar. It can be noticed that the mean number of years of experience the interviewees had outside Qatar (16.3, inter quartile range (IQR): 10-19.5) is substantially higher than inside Qatar (4.7, IQR: 2-7). Such situation reflects the large
multinational presence in Qatar, nominating Qatari construction industry as a potential proxy for global construction trends add New reference [13]. The outliers presented in Figure 5 are selected as being more than 1.5 IQR higher than the upper quartile. However, outliers were not excluded from further analyses, as no statistical testing was performed due to the heavily skewed sample in terms of respondents’ experience. As basic underlying assumption for most statistical tests is normal distribution within the sample, validity of any statistical tests on a skewed sample would be questionable, while important information originating from the most experienced population representatives might be lost if the presented outliers were removed. Consequently, only descriptive statistics methods were used to obtain the results. Margin of error for the obtained results will be further discussed.

B, Margin of Error

Conducting the interviews raised a question of the required sample size. The required sample size for a certain margin of error and probability that the results of analyses might imply relations which do not really exist can be determined from Equation 1 [14], valid for categorical binary data.

\[ n = \frac{t^2 \cdot pq}{d^2} \]  \hspace{1cm} (1)

Here, \( t \) value is determined from t-distribution for a selected level of significance, as indication of risk that true margin of error may exceed the acceptable margin, \( d \). Values of \( p \) and \( q \) are used to estimate the population variance. Typically used \( t \)-value is 1.96 for populations larger than 120, with 5% level of significance, whereas \( p \) and \( q \) values of 0.5 are recommended for binary variables [14]. Assuming 20% as the acceptable margin of error, the required sample size can be estimated to 24.

In the case of a sample size exceeding 5% of the population, corrected sample size can be calculated from Equation 2 [13]:

\[ n_{cor} = \frac{n}{1+n/N} \]  \hspace{1cm} (2)
where \( N \) is the population size. The current study will attempt to estimate the population size of BIM users in Qatar by analysing the size of the online user group created on LinkedIn, Doha BIM Users Group\(^{[15]}\). The group was created on August 20, 2014. Its membership initially grew at a fast pace, exhibiting slowdown to standstill over the summer months of 2015. The group’s current membership stands at 560, of which 45% are located in Qatar. Assuming that such membership represents 65% response from the Qatari BIM users’ population, the population size of BIM users in Qatar can be estimated to 388, i.e. approximately 400 practitioners. For such a population, the corrected sample size given the aforementioned assumptions yields 23 participants. Consequently, the sample size of 28 interviewed in this study seems appropriate for the selected 20% margin of error. For a lower margin of error, a larger sample size would be necessary, as presented in Table 1.

The stated calculation applies only to dichotomous / binary questionnaire, whereas categorical multiple-choice questions where the respondents could choose a single answer among more than two response options, would require smaller sample sizes\(^{[14]}\). Therefore, the required sample sizes given in Table 1 represent conservative estimates. Although the conducted study in Qatar administered questionnaire with multiple-response questions, rather than binary questions, the respondents were typically able to select more than one answer to each question. For example, when asked about the BIM roles required for their organisations, the respondents could select any or all of the following: BIM manager, BIM coordinator, BIM lead, BIM modeller, and/or Other. In such a case, when no exclusivity was required between multiple response options for each question, each response option can be interpreted and subsequently coded as a binary yes/no response. Thus, the sample question about the required BIM roles can be interpreted as 5 binary choice questions: (1) Is BIM manager role required for your organisation; (2) Is BIM coordinator role required for your organisation; (3) Is BIM lead role required for your organisation; (4) Is BIM modeller role required for your organisation; and (5) Are other BIM roles required for your organisation.

Results within each of the 4 pillars (policy, people process, technology) are further presented and discussed.

### C. Policy

Project Delivery methods: The commonly used project delivery methods are traditional DBB (design bid build) (as stated by 75% of the respondents) and DB (design and build) (68%).

<table>
<thead>
<tr>
<th>Margin of error</th>
<th>20%</th>
<th>15%</th>
<th>10%</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required sample size</td>
<td>23</td>
<td>39</td>
<td>77</td>
<td>196</td>
</tr>
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TABLE 1. REQUIRED SAMPLE SIZE FOR ADMINISTRATION OF DICHOTOMOUS/BINARY QUESTIONS SUBJECT TO ACCEPTABLE MARGIN OF ERROR AND ASSUMED POPULATION SIZE OF 400
The use of Design and Build approach on projects varies from project to project. An adapted state of Design and Build project delivery method was being used on a complex project and this adapted state was named as Design-Development-Project. The project delivery in this method is done in such a way that partial design is completed by the designer and given to the contractor to develop it further and then execute it in construction.

Information standard: Based on the interviews, the BIM standards that are being used are mostly UK and US standards, as illustrated in Figure 6. BS 1192:2007, PAS1192-2, AEC (UK) BIM Protocol and BIM standards and guidelines from AIA are some common examples.

When asked about the need for BIM standards for Qatar, majority (89%) of interviewees agreed that there is a need to develop BIM standards for Qatar keeping in view the on-going and future construction projects that are planned for Qatar. The use of different standards on different projects may act as a barrier to adoption of BIM for Qatar Construction Industry.

BIM requirement for projects: While BIM is being increasingly required in the projects (68% of the respondents), the BIM requirements are deemed inconsistent by some interviewees. Part of the reason for this inconsistency could be lack of understanding of BIM from the clients/owners who define information requirements for the projects. Use of different BIM standards could also be a reason for this inconsistency of requirements.

The interviews have revealed that evaluation of BIM competency of designers and contractors is mainly done based on past experience with BIM enabled projects. Some weighting is given to the BIM competency either in prequalification or bid evaluation. This weighting coupled with other criteria (including both Technical and Financial) forms the basis for selection.

The contract documents usually mention the AIA Level of Development (LoD) for BIM model, with 64% of the interviewees stating that LOD 300 was required, 32% stating LOD 400, 18% stating LOD 200, 11% stating LOD 500 and...
7% stating that LOD 100 was required. Such requirements from designers and contractors at various stages of projects indicated issues related to practicability, as in most cases there was no clear plan set for facilities management about the ways the client/owner intended to use the developed BIM models, as illustrated in Figure 7.

D. People

Majority (79%) of the interviewees agreed on the ‘Lack of in-house expertise’ being one of the barriers to BIM adoption in Qatar. They (89%) further agreed on the need for training people on BIM specific positions e.g. BIM Manager, as well as providing BIM training to people who are not working on any BIM specific position in order to understand the benefits of collaboration using BIM (96%).

The contracts usually mention some BIM specific positions (BIM manager 89%, BIM coordinator 64%, BIM lead 50%, BIM modeller 50%) and put relevant experience as a requirement for people on such positions. However the interviewees indicated that it was not easy to find people complying with such requirements and 89% of the respondents believed that there was a need to upgrade the skills of people in BIM specific roles.

When asked whether they (interviewees) experienced any requirements of certifications with respect to BIM, the common answer was that there were no standard certifications for BIM so far, which gained acceptance in the construction industry in Qatar. Furthermore, 46% of the respondents reported issues their organisations faced when providing BIM training, e.g. getting people interested in completing the training and availability of the appropriate BIM training courses. The need for training is also evident from the frequency the interviewees reported they trained to upgrade their skills, illustrated in Figure 8.

E. Process
When asked about the use of project stages, no single standard project stages were identified, e.g., RIBA work stages. Rather, the clients tend to divide project requirements subject to their convenience, as indicated by the variety of obtained responses. Thus, 29% of respondents stated they used RIBA, 14% stated AIA, 7% of the interviewees stated PMI and CIC scope of services, and 46% of the interviewees stated ‘other’ responses such as: BSRIA, ‘a process developed into the contract’, and ‘traditional processes’.

Such a variety of used processes implied the need for standardisation, as indicated by 82% of the interviewees sharing the opinion that standardised project stages along with clear deliverables and process maps in each stage would be needed to allow better communication among the stakeholders. As an indication of the need for clearly defined BIM process maps, many interviewees were defining their own specific process maps, as indicated in Figure 9.

F. Technology

The survey investigated usage of BIM tools for a variety of BIM processes as indicated in Figure 10.

The respondents did not report major shortcomings in technology compared to other BIM...
fields. However, certain BIM tools had limitations when it came to complex architecture and
curves. In addition, most interviewees reported that the IFC exchange format caused data loss
and distortion of geometry when used to export the BIM models.

G. Challenges and Opportunities

As a summary, Figures 11 and 12 present general challenges and opportunities for BIM
adoption in Qatar. Apart from the aforementioned lack of in-house BIM expertise, availability
of skilled staff, training and standards, other challenges include concerns about additional
cost associated with BIM, and change to the existing work processes. Majority (75%) of the
responses stated that better collaboration, better quality and better prefabrication were all
opportunities, 68% of the responses also stated potential for time saving and reduced project
cost, 64% stated better communication, and 61% stated higher productivity. The 32% of
the responses categorised as ‘other’ talked about mitigating safety problems, 3D printing,
managing expectations and increasing motivation of the project team.

V. CONCLUSIONS

The aim of this paper was to define a whole life cycle information flow in the context of
construction processes. Four pillars that need to be developed concurrently to facilitate a
proper and efficient flow of information from one stage to another of construction processes
are explored. The case for both UK and Qatar has been identified and discussed. The current
project results showed that major developments are needed within processes, policies and
people pillars and pointed out additional limitations within the technology pillar.

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[9] Mentioned in the text should be superscripted to be consistent with the other references.

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