Knowledge Mining for Inferring BIM Skills and Roles to Promote Energy efficiency in the built environment

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Abstract

Global warming has drastically increased the pressure to reduce energy use in buildings. The European construction sector is facing unprecedented challenges to achieve ambitious energy efficiency objectives and generalize near-zero energy buildings during an economic crisis that is dominated by reduced investments, and a search for cost effectiveness and high productivity. Moreover, the industry is experiencing a digital revolution and the Building Information Modelling (BIM) approach has been gaining interest across Europe. The member states of the EU have implemented many different approaches through regulations and maturity targets, which have to constantly face the traditional low-tech and informal practices of construction businesses.

This paper will provide an in-depth analysis of BIM-related roles and skills for construction professionals to inform current and future training strategies, and with a view to deliver energy-efficient buildings. The methodology included a Europe-wide consultation with experts and practitioners, as well as an in-depth analysis of social media sources used across construction communities, informed by a comprehensive literature review. This has helped to infer the roles and skills that are necessary in delivering a BIM-based project, as well as informing future BIM training and education needs. One of the main findings is that these roles, skills and associated training needs are not static but evolve to reflect the maturity and evolution of technology and the construction workforce.

Keywords: Building Information Modelling, Energy Efficiency, Skills, Roles

1. INTRODUCTION

The construction industry faces significant skills gaps and training deficiencies, particularly with the advent of advanced digital technologies. Building Information Modelling (BIM) has emerged as a pivotal solution in promoting energy efficiency and sustainability within the built environment. However, effective BIM adoption is hindered by a lack of specialized skills and inadequate training frameworks. This study seeks to address these challenges by identifying the specific skills and roles necessary for successful BIM implementation and exploring potential training strategies that align with evolving industry demands. The construction industry is highly fragmented and it is often portrayed as involving a culture of adversarial relationships and risk avoidance, which is exacerbated by a linear workflow. This often leads to low efficiency, delays and construction waste (Rezgui 2011). The process of designing, re-purposing, constructing and operating a building or facility involves not only the traditional disciplines but also many new professions in areas such as energy and environment (Rezgui 2011). There is currently an increasing alignment of interest between those who design and construct a facility, and those who subsequently occupy and manage it. The latter demands dedicated skills and competencies to address multi-objective sustainability (including energy) requirements (Bryde et al. 2013). While low carbon construction and energy-efficient buildings represent substantial opportunities in the sector, particularly with the fast adoption of ICT, there are (a) substantial low training among self-employed and (b) skills shortages among trade and professional occupations that inhibit technology deployment and innovation (Government 2017). The current training system is perceived as confusing because it has multiple entry points, a plethora of qualifications, a wide variety in the quality of training provision, and complicated funding options can overwhelm and confuse businesses and individuals. Tough economic conditions have led to a substantial fall in apprenticeship completions in construction related industries (e.g., from about 22,000 in 2008/09 to about 16,000 in 2011/12 in the UK) (Global Construction Perspectives and Oxford Economics 2013). Moreover, uncertainty in the market has led employers to reduce the number of workers on the books and use a more flexible self-employed workforce. In fact, the industry is currently dominated by a high number of self-employed who often face an 'earn or learn' dilemma (Adamu 2016). In this context, the challenge facing the industry is to

identify and target new recruits for skilled trades and the professions, and address training and development needs on a more strategic basis (Debrah and Ofori 2006). The transient nature of the workforce and the changing nature of the industry make this issue particularly important. Finally, there is a need to address the issues associated with career planning, and to change training and development from a supplier led to a demand-led model. There is also a need to encourage a more strategic approach to continuing professional development (CPD) and Continuing Craft Development (CCD) across the industry (Debrah and Ofori 2006). This paper aims to analyse and infer BIM roles and skills for construction professionals as a means to inform BIM training programs and to promote informed energy-efficient practices. Also, this paper will use data science techniques to identify BIM trends and practices for education and training, aiming to address the increased demand for professionals who have BIM skills.

2. METHODOLOGY

This paper employs a qualitative methodology that integrates primary and secondary sources. Fifteen interviews were conducted with BIM professionals and industry experts, selected based on their expertise in energy-efficient construction practices and BIM implementation. Additionally, 40 industry best practice case studies were analysed, focusing on projects that exemplify successful BIM integration. Social media content, primarily from Twitter, was also examined to capture emerging trends in BIM skills and roles, utilizing a hashtag-based data mining approach. Primary sources of evidence are used to understand the dependencies and associations between BIM for energy-related concepts, primarily related to roles and skills.

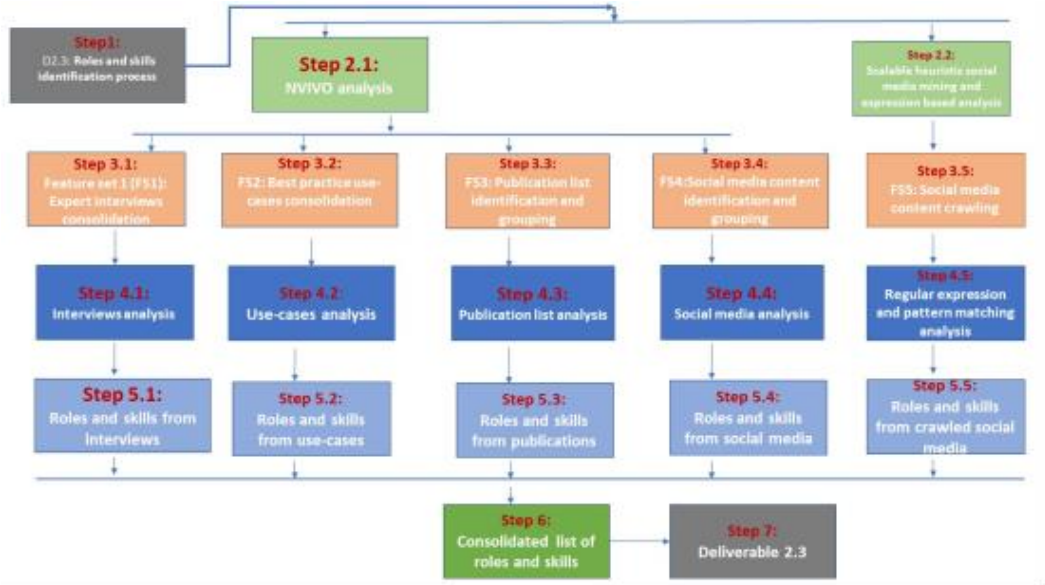

Figure 1. Roles and skills identification process

The author employs two primary methods for text crawling and mining:
1. NVivo: A qualitative analysis tool for examining text and multimedia data, useful for in-depth analysis of both small and large datasets.
2. Heuristic text mining algorithms**: Techniques for analyzing social media content.
To compile the list of roles and skills, the following steps were undertaken (see Figure 1):
1. Consolidation** of the energy-bim.com portal and monitoring web activity.
2. NVivo Configuration**: Setting up NVivo for analyzing interviews, use cases, publications, and social media (see Figure 2).
3. Content Preparation**: Organizing interviews, use cases, training descriptions, and publications for NVivo compatibility.
4. Twitter Data Crawling**: Implementing automated techniques, resulting in over 20 million tweets.
5. Analytics Application**: Using algorithms to identify skills and roles from the consolidated content.

6. Final Consolidation**: Compiling a complete list of relevant skills and roles for the BIM energy sector.
7. Living Paper Production**: Generating the final document.

In the following subsection, the author presents in detail how each type of analysis has been conducted identifying use-cases, interviews, scientific publications and social media analysis.

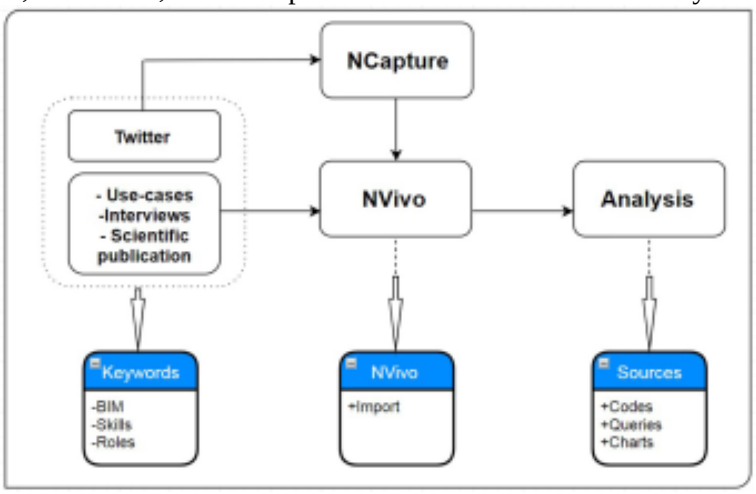

Figure 2. Progress of capture data from different sources by using NVivo software

3. RESULTS ANALYSIS

In this section, the authors present the findings of the NVivo analysis and the resulting roles and skills. The process that led into the identification of the skills and roles is summarized below:

3.1 Use-cases

A series of analyses were conducted on the portfolio of use cases to identify skills and roles for BIM in energy efficiency. The NVivo tf-idf (term frequency-inverse document frequency) technique was employed to pinpoint key "keywords" in the data. Using a word cloud method, the analysis highlighted important concepts, revealing new roles and skills along with their dependencies. This method effectively illustrates the significance of relationships between concepts. Additionally, the NVivo word tree technique was utilized to enhance formalism in the use cases and to visualize connections among different concepts as illustrated in Table 1.

Table 1. Consolidated list of skills and roles from use-cases

NO.	Roles	Skills
1	Architect designer	Optimal decision making
2	Construction engineer	Collaborative design open ICT platform
3	Facility manager	Operation energy running costs
4	Mechanical engineer	Operational energy demand
5	Structure engineer	The interaction between the project managers

3.2 Interviews

In the next round, the analysis has been applied to 15 interviews as gathered from the requirements elicitation phase. The input preparation phase has been necessary for importing the interviews into NVivo, where they have been modelled as word files and configured for successive evaluations. For the interviews, the researcher has applied word frequency queries leveraging NVivo advantages to enable words frequency determination with an associated percentage. This method has facilitated a better understanding of the key concepts and their correlation in the interview's portfolio. For instance, the most frequent words as derived from the interviews are BIM, energy, efficiency, construction, skills, but other relevant word dependencies have been determined and are presented in Table 2.

Table 2. Consolidated list of skills and roles from interviews

NO.	Roles	Skills
1	Architect	Educating on BIM
2	Project manager	BIM training
3	BIM instructor	Practice Energy Modelling
4	Training	A link between different software
5	Consultant of constructor	Understanding of graphical information

3.3 Scientific publications

In this section, more than 66 scientific publications have been found and imported into NVivo to identify the roles and skills as required for the study of BIM for energy efficiency. In addition, international standards for BIM and energy efficiency have been provided to get more skills and roles. To identify new skills and roles, the researcher utilised similar techniques as in previous cases using central concepts such as "role, skills and training" because these concepts have proven to provide the best results in the initial tests. New skills were retrieved and added to the overall list presented in Table 3.

Table 3. Consolidated list of skills and roles from Scientific publications

NO.	Roles	Skills
1	Facilitator of sustainable	Simulation programs
2	BIM manager	BIM education
3	BIM modeller	Assess respondents' perception of BIM competence and requisite skills
4	Facility manager	Knowledge of BIM standards

3.4 Twitter

To enhance the list of skills and roles, the researcher expanded the analysis to social media content, starting with tag and ID searches to identify new BIM skills. This approach highlights the dynamic nature of skills identification, as new concepts often emerge on platforms like Twitter. Data was collected using NCapture, resulting in nearly 50,000 tweets, mentions, and retweets that formed a knowledge base for the analysis. By focusing on "skills, roles, and training," the researcher aimed to discover innovative skills relevant to BIM and energy efficiency, successfully identifying new competencies reported by active organizations and users in the field (as illustrated in Table 4).

Table 4. Consolidated list of skills and roles from twitter data

NO.	Roles	Skills
1	Architect	BIM education program
2	Energy manager	Certification scheme
3	Construction information manager	Good communication
4	BIM manager	awareness about BIM for energy efficiency
5	Digital technology designer	Training for energy efficiency skill

3.5 Scalable heuristic social media mining

To increase the data repository, the researcher has extended the social media analysis by implementing a social media crawler that has retrieved friends' and followers' activity based on the list of accounts those have relevant. The researcher has applied similar analysis but on a database of 40 million tweets, which was filtered by the expressions/queries. Table 5 presents sample of the roles and skills that have been recorded during the scalable heuristic social media mining process.

Table 5. Consolidated list of skills and roles from scalable social media

NO.	Roles	Skills
1	Architect	IoT, ICT
2	Energy Analyst	AEC organisations need to understand the power of Analytics
3	Advisory Roles	Negotiation and Building the bridge between the world of education and work
4	Construction Managers	Timber frame construction, Educational game construction, Solar panels

4. DISCUSSION

A list of skills and roles has been obtained from the analyses applied to the portfolio of use cases, interviews, publications and social media, and are presented in
Table ***6*** and Table 7.

Table 6. A consolidated list of BIM roles for energy efficiency from different sources (A: Use-cases, B: Interviews, C: Scientific publication, D: Twitter, E: social media mining)

Roles	A	B	C	D	E
(Construction, Architect, Mechanical, Structure, HVAC, Electrical, Civil, Automotive, Environment, Aerospace, Energy, Chemical, and Nanotechnology) Engineers	✓	✓	✓	✓	✓
(Facility, Team, Supply chain, O&M, Contracts, Site, Technical, Finance, Quality assurance, sale, Production, Purchasing, Store, Health & Safty, HR, Water, Market acquisition, Innovation, Program, Energy, BIM, Government affairs, Construction, and Project) managers	✓	✓	✓	✓	✓
Blue-Collar such as (technicians, ceramic worker, steel, builder, supervisors, and carpenter)	✓				✓
(Modeller, Instructor, Coordinator, Consultant, and Training and informing consultation professionals) about BIM	✓	✓	✓	✓	✓
(simulation expert, expert, Planner and consultant of energy efficient buildings, Energy efficiency expert, Digital energy economist, procurement, nuclear energy, solar energy specialist, and alternative) Energy	✓	✓	✓	✓	✓
Real estate maintenance data management consultant		✓			
Researcher and teacher in University		✓		✓	✓
Facilitator of sustainable			✓		
Decision makers "Advisory roles, Regulators, Senior organisational roles, and Policy designer"			✓		✓
Facility administration			✓		

The analysis of interview data revealed critical BIM-related skills that vary according to professional roles. For instance, architects and designers emphasized the importance of collaborative design and digital visualization skills, while project managers highlighted the need for comprehensive BIM training that aligns with energy-efficient practices. Several participants also mentioned the significance of advanced data management skills, as BIM increasingly relies on accurate data integration across project stages.

The case study analysis further supported these findings by showcasing how BIM has been successfully implemented to achieve energy savings. For example, one case study involving a large commercial project demonstrated that optimal BIM use required skills in both energy modeling and data-driven decision-making to streamline operations and reduce energy consumption. This suggests a strong link between BIM proficiency and energy efficiency outcomes.

Social media analysis, particularly on Twitter, offered additional insights into emerging BIM trends. For instance, frequent mentions of 'BIM for sustainability' and 'energy-efficient BIM skills' indicate a growing industry focus on green BIM competencies. The data suggest that while core BIM skills remain essential, there is an increasing demand for specialized training that includes sustainability principles. Table 6 below summarizes the key roles and associated skills identified across data sources, highlighting the need for adaptable, cross-functional skills that evolve alongside technological advancements in BIM.

Table 7. A consolidated list of BIM skills for energy efficiency from different sources (A: Use-cases, B: Interviews, C: Scientific publication, D: Twitter, E: social media mining)

Skills	A	B	C	D	E
Data management	✓	✓		✓	✓
Integrated information management framework	✓	✓			
ICT skills	✓			✓	✓
Teamwork skills	✓		✓	✓	✓
Understand BIM standards	✓		✓		
Understand energy efficiency principle	✓	✓		✓	
BIM tools updates skills	✓	✓	✓		
BIM Educating		✓	✓	✓	
BIM training		✓	✓		
Link between different software		✓			
Enhance the stakeholders' skills of BIM for energy efficiency		✓	✓		✓
Capability to use CAD programs and other EE software		✓		✓	
Formulating the model with EE simulation programs		✓	✓		
Good communication between designers, client, supplier		✓		✓	
Increase the awareness of energy consumption			✓	✓	
Increase the awareness of building regulations and how they will continue to evolve over time			✓	✓	
BIM competence certification. Others suggest EU level certification.			✓	✓	
Focus on soft skills like collaboration and communication, negotiation, teamwork, leadership and conflict management.		✓	✓	✓	✓
Programme management			✓	✓	
Conflict management			✓		✓

Reflecting the diversity of roles and skills in this area, the table contains roles such as architect, project manager and BIM coordinator, and skills such as training of BIM and understanding of how graphical information can help to inform appropriate training programme, which are all related to addressing the process of BIM for energy efficiency. The "training" concept has returned results that facilitated the identification of new skills and roles, creating new correlations between terms that exist in the same semantical space.

It should be noted here that data from best practice use-case studies and interviews has delivered several state-of-the-art roles and skills for energy efficiency, whereas scientific publications reported more traditional and fewer new BIM roles and skills as disseminated in the field of research; as illustrated in Table 6 and Table 7. The novelty in terms of new skills and roles was identified when conducting analysis on social media data based on the list of Twitter accounts (as presented previously). By combining such diverse data sources, the researcher has managed to address the two main objectives for this study: (i) determine skills and roles required for the implementation of BIM for energy efficiency and (ii) capture the dynamic nature of BIM to keep up with new industry requirements and trends. Given that BIM relies on data and the AEC industry represents a sector where new technical solutions are now implemented, especially with the emergence of IoT discoveries, approaching BIM training for energy efficiency holistically can give the industry sector a significant advantage to absorb innovations and shift towards sustainability in the overall landscape of climate change.

5. CONCLUSION

This paper conducts knowledge mining to identify new skills and roles for BIM training in energy efficiency. The researcher implemented four analysis scenarios: use cases, interviews, scientific publications, and Twitter. Findings indicate that BIM is dynamic, necessitating new training programs to address existing gaps. Social media analysis revealed a novel list of roles and skills, offering insights for BIM training and education. The study emphasizes the need for organizations to adapt to support new BIM processes and highlights that traditional methods fall short in capturing BIM's complexity. A holistic methodology for assessing BIM competencies is essential, along with a focus on organizational and human skills. The analysis also points to the often-overlooked importance of training to maximize

BIM's potential. Resistance to change poses risks, underscoring the need for greater involvement of end-users in decision-making and implementation processes.

6. ACKNOWLEDGMENTS

The author is thankful to the civil engineering department at Najran University at Saudi Arabia and Cardiff University at UK for their supporting in this paper.

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