BIM IN EUROPE: INNOVATION NETWORKS IN THE CONSTRUCTION SECTORS OF SWEDEN, FRANCE AND THE UK

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European countries are developing or implementing policies that promote or require the use of Building Information Modelling (BIM) and give BIM a central role in strategies for national sector-level transformation. It is necessary to understand BIM as a systemic innovation that is enacted and adopted by firms, projects and users but also by national actors. The Industrial Marketing and Purchasing (IMP) approach has shown how the evolution of innovations can be understood in terms of networks in which actors mobilise and combine technical and social resources in order to perform activities – the Actors-Activities-Resources (ARA) model. A comparative study of BIM adoption in France, Sweden and the UK was undertaken using data from independent country-specific research projects and a pooled desktop study. A grid was developed based on the ARA model that provided a framework to inform data collection and analysis salient for explaining the extent, processes and type of adoption of BIM in each country. Similarities between countries included: the importance of large and international firms in the innovation network; and project types (non-residential public buildings and either complex or repetitive building types). Differences were found in, for example, the activities and national institutions of architecture and the policy positions and mechanisms of government actors. The analysis highlights both the value and some limitations of a country-level focus and provides a basis for thoroughgoing network analysis.

Keywords: BIM, France, innovation, network, Sweden, UK.

INTRODUCTION

The construction sector is characterised by a high degree of fragmentation, the dependence on a broad variety of actors and relationships (Dainty *et al*., 2001), the temporary project-based nature of construction activities (Winch, 2003), and increasing complexity of projects (Chan *et al*., 2004). The sector depends on collaboration and interaction of many actors across many construction projects. This is thought to constrain efficiency, productivity and innovation in the industry. In the last two decades, ICT technologies have been adopted and in the last ten years Building Information Modeling (BIM) has been introduced to facilitate the construction process. Succar (2009: 357) defines BIM as *"a set of interacting policies, processes*

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and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle". BIM is both technology and a process for project or asset management (Bryde *et al*., 2013). Implementing BIM as an innovation is not only a matter of technology but also a matter of re-organising work and work flows. Hence the implementation of BIM requires technological and organisational changes. Scholars put forward the difficulties in implementation and use of any new innovation due to the non-linearity, uncertainty and complexity of any innovation (e.g. van de Ven *et al*., 1999).

Except for Bryde *et al*. (2013), there is little research on BIM on a general level beyond specific construction projects, also there is lack of cross-country comparisons. This paper presents preliminary data related to BIM in three European countries: the UK, France and Sweden. We investigate how the implementation of BIM as an innovation is played out in these different national contexts with the aim to discuss differences and similarities in facilitating and hindering new construction innovations.

IMPLEMENTING BIM

BIM use affects all stages and actors in a project: understanding needs, design, development, management, operation, and maintenance (e.g. Hartmann *et al*., 2012). Travaglini *et al*. (2014) classify and rank construction sector actors according to their level of interest in BIM, namely; client, project manager, architect, principal contractor and engineer. These actors can be directly involved, such as an architect, or indirectly involved, such as national authorities. Benefits of BIM (e.g. Succar, 2009) include; cost reduction, efficient time management, improved communication and coordination along with quality improvement. BIM is globally associated with *"improved efficiency"* by *"limitating rework"* (Arenda-Mena *et al*, 2009).

Barriers for BIM adoption include difficulties in changing working habits and adapting workflows (Sebastian, 2011) and legal issues (Olatunji, 2011). Sebastian (2011; 181-2) details the changes of activities that BIM implementation may entail: 1) BIM requires a new *"model manager"*, which *"provides and maintains technological solutions required for BIM functionalities, manages the information flow, and improves the ICT skills of the stakeholders"*, but will not *"take decisions on design and engineering solutions, nor the organisational processes"*, 2) BIM will impact on Intellectual Property Rights (IPR), 3) BIM will change the payment arrangements since *"a new proportion of the payment"* is required in the early design phase, 4) BIM will also change the use of open international standards.

The above discussion highlights that the implementation of BIM will require both technological and organisational changes and in particular new interaction patterns between actors of the supply chain (Succar, 2009). It also shows that the diffusion of BIM is dependent on a larger structure of interrelated actors, individuals, humans and other technologies in use. In the following we outline an approach to theorising and researching this structure that has influenced our data collection and analysis.

Innovation networks- a prerequisite of implementing innovation

Several authors (e.g. Miozzo and Dewick, 2004) highlight the importance of innovation networks to successfully implementing innovation in the construction industry. In line with earlier innovation studies (e.g. van de Ven *et al*, 1999), these findings underline that the implementation of any innovation requires changes of already established work practices and technologies in use and is therefore dependent on a network of actors. Researchers of the Industrial Marketing and Purchasing Group

(IMP) developed the Industrial Network Approach (INA) based on the idea that industrial development happens through interaction and business exchanges between actors. These exchanges result in networks of relationships constituting the *"market"* (Håkansson *et al*., 2009). For the INA, the development and implementation of innovation requires interaction between organisations (e.g. venture capitalists for funding; users for design and testing). As summarised by Håkansson (1987: 3): *"An innovation should not be seen as the product of only one actor but as the result of interplay between two or more actors; in other words a product of a 'network' of actors"*. To be successful, an innovation should thus be embedded into users' contexts. This process involves several actors who combine and adapt their resources to commonly develop the innovation. The ARA model develops this link between Actors and Resources in innovation networks (Håkansson *et al*, 2009). In this model, Actors are defined by the Activities they perform and the Resources they use and control. The ARA-model enables investigation of the network involved in the development and implementation of a particular innovation within a certain industry.

In this paper we present the different implementation patterns of BIM and discuss the different national construction contexts along with their specific conditions in promoting and hindering construction innovations. With a view to providing a basis for the analysis of the corresponding innovation network, we use the ARA-framework to structure our data collection and analysis on how BIM has been adopted by main actors and their role. The study is inspired by Miozzo and Dewick (2004) study on construction innovation across five European countries. However we focus on one focal innovation, BIM, to enable comparisons across three different national contexts.

METHOD

Primary data consists of expert interviews with construction companies, engineering companies, architects and project owners. Methodologically, these were expert interviews in which. Expert interviews are widely used in construction management research (e.g. Bassioni *et al*, 2005) as an informed but indirect source of data about specific cases and the wider network. The data assembly, and some of the primary data collection, was guided by an analytical grid based on the ARA-framework. The issues covered by the interviews varied between studies but included: factors explaining the adoption or reluctance to adopt BIM; the main characteristic of the processes of adoption; the type of usage made of BIM. The interviews were predominantly conducted in person, ranged from one to three hours and were recorded and transcribed for analysis. Sample: France: 6 interviews at five architectural firms, 5 interviews at one construction firm, 3 interviews at two engineering firms, 1 interview at a software provider. Sweden: 4 interviews at four architectural firms, 4 interviews at four construction firms, 5 interviews at four engineering firms, 4 interviews at four project owners, 2 interviews at two suppliers, 2 interviews at two NGOs. UK: 4 interviews at one architectural firm, 16 interviews at one construction firm, 4 interviews at three engineering firms.

Secondary data came from the numerous industry and policy reports that have been produced about BIM with a European or national scope plus general sector-level overviews and statistics. These reports are particularly useful as a continuously updated source of figures on BIM adoption. While reports such as these are necessarily limited and vary in the quality of their methodological implementation they add detail and breadth to the sector-level picture built up from the interviews.

PRESENTATION OF DATA

The Swedish study

Construction companies: The total number of companies is around 93,000 but 81,000 of these have only up to 4 employees (BI analysis, 2013). Hence the construction industry is mainly constituted of very small firms and few large ones. Sweden has four big construction companies; Peab, Skanska, NCC and JM. NCC and Skanska have international activities, while the others focus on the Nordic countries.

Firms producing mostly single-family homes, they were first to adopt BIM (Myresjöhus, Fiskarhedenvillan). With the use of BIM they had already developed industrialised construction by the mid-2000s. The large construction companies became engaged in BIM from 2006-2008. NCC, Skanska and Veidekke Sweden are mentioned as having the highest BIM competence. NCC has the broadest experience with more than 700 projects related to BIM. Both NCC and Veidekke use the Virtual Design and Construction (VDC) concept to steer the technology, process and organisation. Veidekke have most VDC-certified personnel in Sweden with around 35 while NCC has 25 but another 25 on the way. Skanska have high BIM proficiency: the company is in charge of the largest hospital project in Europe, NKS, with one of the highest levels of BIM ambition in Sweden. The large construction companies started to implement BIM on internal housing projects and for Design and Build contracts, where they own the whole process. An internal BIM policy exists within all large companies. In general the large companies have invested in internal training of employees in BIM, also recruiting BIM-specialists; moreover VDC required investments in ICE-studios and new technology. Peab and JM are late-comers in relation to BIM, but Peab have during the last year implemented BIM-policies to increase BIM awareness at all levels. In general the status and power of construction companies have increased in Sweden and the companies aim at optimising the profit in the project delivery focusing on planning and production activities. There is a lack of attention to operations activities.

Engineering companies: Among engineering firms there are around 10 larger firms. Sweco being the largest followed by WSP Sweden, ÅF, Ramboll and Tyréns. These firms mainly have the Nordic counties as their market but WSP and Sweco have international operations. Engineering companies in Sweden have been leading the adoption of BIM. Engineering firms were open to new technology and realised the benefits of BIM and the possibilities to develop services in relation to BIM since 2007 onwards. All major firms have undertaken development projects to define the use of BIM and its possibilities. Engineering companies have a clear perspective of the clients; in the beginning these companies provided BIM competence to construction companies but due to increased BIM-competence within construction companies, engineering firms are now steering towards the client side of the construction industry. Engineering companies have made a profitable business of serving as BIM-coordinators along with providing BIM-training for companies. The BIM expertise among engineering firms seems to be lowest within mechanical services.

Architect companies: The Swedish Association of Architects has more than 12 000 members, and around 10 architects are larger firms (more than 50 employees), where White, Tengbom, Nyréns are the largest ones. In general architects have been slow in adopting BIM, according to the architects themselves they have been *"extremely uninterested"*. The large firms have been working actively with BIM from 2012, focusing on establishing its internal BIM-work and internal BIM-competence by employing more engineers and providing training of employees. One main reason for the late adoption by architects is the traditional division of labour in the design process; the architect provides the creative vision and delegates the drawing and modelling to an assistant. BIM on the other hand requires changing work flows and new ways of organising work (variation among architects exists - the younger firms find it easier to adapt to BIM work processes). Moreover the status of the architect profession in Sweden has been decreasing since the 1960s along with the increased price focus of the industry. Also architects do not have a project manager role in Swedish projects. Architects mention the adoption of BIM is required for more complex projects and that some clients require BIM. It is mentioned that BIM is *"an opportunity for architects to gain status and power"*, which is supported by the notion in the industry that architects are increasingly contracted to act as BIM-coordinators in projects.

Clients/project owners: Construction clients and project owners are a broader variety of companies including real estate companies managing housing, public or commercial and industry buildings along with companies within road and transportation. The clients have been the last group to support the adoption of BIM. In the industry the clients are typified as having not *"understood"* (as opposed to not accepted) the long-term benefits of BIM. Clients are still regarded as unaware of BIM benefits for facility management and operations. Hence some clients demand BIM but on a low level, and using BIM during the whole process including operation and facility management is far away. Implementing BIM in facility management and operations demands the development of new facility management systems which do not yet exist in the industry.

There are some initiatives going on especially among the public project owners, however there are no regulations in relation to BIM in Sweden. The biggest project owner in Sweden, Swedish Transportation Administration, issued a BIM-strategy in 2013 with the aim to include BIM for all new investment projects from June 2015. The company was inspired to a high degree by the government initiative in the UK. Another initiative is from five large public clients that have jointly formed a BIM-strategy (Specialfastigheter, Akademiska hus, Riksdagsförvaltningen, Statens Fastighetsverk och Fortifikationsverket) with the support of an engineering company. Locum AB is in the lead in implementing BIM- for instance the whole property stock is described in BIM models and the company demands BIM in every project. The largest real estate company Vasakronan have just started to work with identifying demands in relation to BIM- supported by the engineering company Sweco.

The French study

Construction companies: As in Sweden, the French construction industry's profile is two-sided. On the one hand, it is made up of a myriad of very small firms and on the other hand, it has some of the world's biggest construction firms. 4 major construction firms dominate with 3 of them ranking among the 10 largest construction firms in Europe and having an international activity (Vinci with 40b€, Bouygues with 26.6b€, and Eiffages with 14.3b€). Worth noting is the specific position of Bouygues (2nd construction group) who started using BIM at the end of the 2000s (for a Canadian hospital project) while the 3 other largest French construction firms are currently at the early adoption stage of BIM. BIM was then mostly used for complex (hospitals, airports...), large or repetitive projects (e.g. large office towers or residential housing). For Bouygues (and later major French construction firms), BIM is a way to promote more vertical integration (D&B; PPP/PFI, DBOM) and hence to be more active both upstream and downstream the supply chain (selling operations/maintenance services but also design services). This is consistent with their diversification strategy as most of them are able to offer all these services whereas smaller construction firms are not. This integration gives more power to construction firms. BIM is also seen as an opportunity to industrialize the production process and reduce construction costs through lean management. This early integration of BIM is intended to give them a cost advantage and to be more competitive in a period of economic crisis.

Engineering companies: France has a number of large, renowned engineering firms making more than 10M€ turnover (Altran, Setec, Egis, Ingerop, Systra, Technip). 20% of engineering firms have more than 1000 employees and 25% between 100 and 1000. Up until 2014, BIM had been mostly adopted by private architectural and engineering firms. In 2012, 51% of architects and 27% of engineering firms declared having adopted BIM 5 years ago or more while 29% of construction firms adopted BIM over the last 2 years. These early BIM adopters were mostly the biggest actors with international development plans. Engineering firms have been inclined to work with BIM due to the increased complexity of projects and to be able to work with the biggest construction companies such as Bouygues and later Vinci and Eiffages who use it as a criterion for choosing which engineering firms they appoint.

Architect companies: 80% of French architectural firms have less than 2 people and work on very small projects. 7 agencies have a turnover exceeding 20M€ and 9 between 10 and 20M€. Only the architectural firms with more than 30 employees develop an international activity (2.5% of the profession’s turnover). A number of France’s architectural agencies are world famous (Renzo Piano, Jean Nouvel, Portzamparc). Initially, members of unions and federations of architects were afraid of the required changes and investments linked to BIM implementation and to become, in the words of one respondent: *“the [unskilled workers] of large construction firms”*. Also there was also a lack of training available for architects on BIM use. For the architects, BIM was a means to increase their project success rate: *“When we use BIM, we win 3 projects out of 4”*; it acted as a lever towards internationalization and awareness: *“it is an excellent means of working internationally and transferring data”* or as a strategic bridging tool to access internationally renowned partners: *“it enabled us to work with Renzo Piano”* (comments from interviewees). At this time, the main motivations of these ‘early adopters’ in the AEC supply chain were to ensure differentiation on the French market, reduce costs and access to international projects and customers by acting as BIM model manager:

Client/project owners: Construction clients and project owners are for 72% of private origin (mostly individual customers and real-estate investors) and 28% public. Most public were not organized and did not have the resources to exploit BIM data. It was recognised that the French government did not support adoption up until recently: *“At the moment, the French legislation is not favourable to the use of BIM... A clear and predictable national framework at the highest levels are required conditions for the structuring of the sector”* (Sustainable Construction Plan, March 2014).

In 2013, *“BIM France”* (association of architects and engineers) followed later by the French government, public customers and professional organizations (FFB, CSTB...) decided to actively support the development of BIM in France. In 2014, the Ministry of Housing and Construction declared that the use of BIM will be mandatory in public markets from 2017 onwards. This public announcement was supported by several initiatives: the promotion of a Golden BIM award by a famous trade magazine, the development of BIM investment packages to ease up the equipment by architects (software + hardware + financing) as well as the organization of several training sessions by their professional unions. Today, several trade associations support BIM in France including actors from the entire industry: product manufacturers, engineering and consulting firms; construction contractors, norming and standard bodies; research and technical institutes; economists; architects and urban developers. As a result, BIM adoption is now considered by most of the industry actors as inevitable. France is thus entering the institutionalization phase with BIM. As noted by one architect: *"we are now at year 0 of BIM in France. Over the last few months and especially since September 2014, everything is accelerating."*

The UK study

Construction companies: The UK industry shares the same major structural feature as Sweden and France with a high number of very small firms and 60 that employ over 1,200. Large firms with turnover above £2b are; Balfour Beatty (£10b), Carillion (£4b), Kier Group, Interserve, and Morgan Sindall. There is a further split between general and specialist contractors with the latter tending to be smaller: larger firms are general builders, house builders, or civil engineers who operate similarly within their respective market sectors. Medium-sized firms are characterized by regional operations and/or specialization in one form of work. There has been both stability in the large firms and significant restructuring, with substantive changes and name-changing acquisitions. In general, BIM adoption has been led by larger firms, particularly major contractors that operate on a design-and-build basis and manage design work. Some reasons for adoption include: pressure from government clients; differentiation in bids; operational efficiency; and the desire to be seen as an employer of choice. Among smaller firms usage is less common, less developed and they are less confident. Smaller firms are less likely to be bidding for public-sector or complex work where BIM is technically indicated or required by an expert client. Smaller firms lack slack resources required to innovate. Smaller firms operating as tier-2 or -3 subcontractors still receive information in 'paper' form.

Architect companies: Architecture is similarly structured to contracting companies with 90% of architects having less than 10 employees and only 1% over 50 . In general, far smaller firms than building firms. Larger firms include Foster + Partners, BDP, and Atkins and these are significant, international organisations with considerable influence. In the UK, architects generally had a traditional role as the leader of (building) construction projects but this is increasingly not the case following deregulation of the profession and the increase in design-and-build contracting. The leadership role was reflected in the historical split between design and construction realised via professional institutions, firms' structures, contracts, education and practice. Construction firms rarely have design resources and architects have only been legally allowed to own construction business comparatively recently. On modern construction projects much of the design is actually undertaken by specialist trade contractors (M&E contractors, curtain walling firms) who can integrate management, design, manufacture, delivery and assembly.

The motivation for the adoption of BIM for the purposes of architectural design (rather than as a project information management solution) can be roughly divided into: the use of advanced CAD tools for sculptural, sometimes algorithmic, design; and the use of standard libraries of objects and parametric modelling in the design of more conventional buildings. Adoption is led by larger practices but in small architecture practices, once startup costs have been overcome, potentially offers significant discrete benefits in terms of efficiency of workflow and information production that offers them a competitive advantage. Consequently, there is an emerging 'BIM for small practices' movement.

Engineering companies: While similar to architecture firms, engineering organisations tend to be larger with 70% of firms having less than 10 employees and only 5% over 50. Large firms include Atkins, URS, Arup, Jacobs, AECOM and WSP UK. There's an increasing trend for larger multi-disciplinary practices (construction professional service firms: Atkins; Mott MacDonald; AECOM; URS Scott Wilson; EC Harris; etc.). The number of qualified staff in such organizations has more than doubled in the last 20 years. Patterns of BIM adoption is similar to that for architects: large and advanced design consultancies. 3D design and analysis is a natural progression for structural designers although M&E consultants still seem to be something of a brake as they typically only produce a concept design, delegating the detailed design of installations to M&E contractors.

Client/project owners: UK government plays, and has played, a significant role in the industry (although national and regional government are no longer a major employer of construction labour). Activity and influence includes: monitoring and comment; acting as a major client; economic policy; legislation and regulation; subsidy; research/technical/facilitation. They have been influential in championing, facilitating and mandating BIM adoption by 2016 for some projects via procurement routes and have established the BIM Task Group. There is a push to adopt BIM from government and other public-sector clients increasingly in infrastructure. Government-backed facilitation has developed a network and set of communities to encourage BIM adoption including; professional institutions (RIBA, RICS, CIOB, ICE, I.Strcut.E, CIBSE), research and facilitation organisations and networks. (CIC, BRE, CIRIA, Regional BIM Hubs, NBS, CPIC).

DISCUSSION AND CONCLUSIONS

We have started to investigate the innovation networks of BIM in Sweden, France and the UK by focusing on large actor groups in construction. A significant similarity between the countries is the importance of large firms in driving BIM development. Some actor groups drive the implementation while other actor groups are late comers.

Early adoption

Even though France is deemed to occupy a leading position regarding BIM adoption in Europe in recent surveys, this seems to correspond to a rather recent move and the adoption of this innovation can still be considered at an introduction or early development stage depending on the actors. In the 2014 Mc GrawHill Report, UK is considered, in Europe still as a beginner in BIM adoption. The beginner status qualifies the first development stage of specific BIM skills (to be followed by a moderate, advanced and expert status). This status, according to the Mc GrawHill report is to be linked with the recently announced government mandate. Sweden can also be considered as an early adopter and the actors have during the last 5 years developed and established BIM skills.

Construction companies as early adopters

For all countries the clients have been late adopters and BIM development has been supplier-led. Even in the UK where the government in its client role has been influential the mandate has largely reflected rather than driven capabilities and building owners are under-represented in the *"national conversation"*. Construction companies have been influential adopters in all countries. The value of the 3D CAD component of BIM for detailed design might help explain the relative rates of adoption between design firms in the different countries. Swedish architects role is largely limited to concept design and seem to lag behind in adopting the new technology compared to the UK where architects often produce detailed design information (a similar comparison can be drawn between the apparent readiness of structural and M&E consultants within the UK).

The role of government policies

The role played by the UK government plays is significant. By 2016, BIM use will be mandatory in all public sector projects. France is aiming for regulations and in 2017 BIM used will be require for all public buildings. No such BIM-regulation exists in Sweden however the large public actors have been inspired by the UK development when adopting BIM strategies, which is in line with the 2014 Mc GrawHill report that indicates many public properties and public clients require BIM for their projects. These differences are important to take into account, so far as the role of major private but also government owners were considered by the 2014 Mc GrawHill report important drivers for BIM usage acceleration.

Not yet an integrative tool…

Another aspect to note is that in all three countries observed, actors have adopted BIM from their perspective to achieve firm, rather than necessarily project or client advantage, hence focus is mainly on planning and design activities, maintenance and operation activities. This means that we are far from a situation of full integration of the different actors involved in a construction project. BIM, at the current stage of adoption, has not become yet the integrated collaborative tool supporting both data interoperability and life cycle management.

Questioning the traditional *"way of doing things"*

More broadly, we can see that BIM challenges the traditional practices of coordination and couplings in the construction supply chain. As shown by Dubois and Gadde (2002), the construction industry is traditionally characterised by loose coupling between actors outside of any project (strategic level) and very tight couplings within a given project (project level) to adapt resources to the specificities of each project and construction site. This adaptation model contrasted with the manufacturing industry that evolved towards increased collaboration and standardisation at the strategic level to gain economies of scale and reduce costs. The introduction of BIM challenges traditional practices of on-site adaptations and lack of standardisation. BIM encourages pre-fabrication and introduction of standardised *"objects"* (e.g. bathroom modules in hospital or student housing projects). The power is shifted upstream in the design stage and the construction site becomes more and more standardised with little room for change. The construction manager and his team will focus more and more on *"quality, security"* and optimisation aspects rather than on purchasing, redesign and adaptations on site of the project: changing the role of construction manager with less rooms for manoeuvring and adapting the project leading to a focus more on perfect execution and cost and time optimisation.

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