

DIGITALISATION AND INDUSTRIALISATION: EXPLORATION OF THE CURRENT AND FUTURE CHALLENGES IN THE SWEDISH BUILT ENVIRONMENT SECTOR

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Digitalization and industrialization are central topics in the Swedish government agenda and digitalization and industrialization of the built environment sector, as the largest single sector in Sweden, are with reason seen as crucial goals. In the Swedish strategic innovation programme Smart Built Environment (SBE), digitalization and industrialization are addressed and explored as a means to reduce environmental impact, planning and construction time, total construction costs, and to enable for new business logic in the built environment sector. One of the projects within SBE aims to measure effects and consequences of digitalization and industrialization to support the long-term assessment of the progress towards the programme goals. In this paper is presented the main findings from the first measurement, addressing a sample of SBE partners and their focus on digitalization and industrialization and what they perceive as the main challenges to reach the expected effects of changes and investments made in these areas during the period January 2016 - December 2017. Data presented in this paper was collected through dialogues, interviews and a questionnaire addressing SBE partners from companies, public organizations and agencies. Findings propose that much focus has been on digitalizing the information flow within and between organizations, yet many respondents state they now struggle with getting the organization and working methods “in place” to also benefit from the (mainly technical) investments made. Many respondents also express having implemented or at least initiated the implementation of applications in digitalization that are new to the Swedish built environment sector. Yet, there seem to be significant differences between what levels of digitalization different actors currently find themselves at, as well as what they are aiming for, which has implications for the efficiency of the information flow. Moreover, what is understood to contribute to further digitalization and a more unbroken information flow is described differently within as well as between organizations.

Keywords: digitalization, industrialization, information flow, BIM, change

INTRODUCTION

In Sweden as in many other countries, industrialization in construction has been proposed as means towards addressing perceived construction-industry problems such

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as high building costs, productivity falling behind other industries, and the overall environmental impacts of the building and construction sector (Goh and Loosemore 2017; Larsson *et al.*, 2014; Zhang *et al.*, 2016). Lately, digitalization has been added to, or even integrated with, industrialization and put forth as a key transformation route for prosperity, growth, and long-term sustainability (Isaksson *et al.*, 2018). However, it is unclear what digitalization means in terms of e.g. the effective actions building industries need to undertake.

The strategic innovation programme Smart Built Environment (SBE) is one of the larger current initiatives in Sweden focusing on industrialization, digitalization and how, in particular, the building and construction sector can contribute to the realization of new opportunities that digitalization brings. SBE is funded by government research councils (Formas, Vinnova, the Swedish Energy Agency) and has a broad foundation in the sector with partner organizations representing authorities, public and private building-process stakeholder organizations as well as digital developers. In SBE, industrialization and digitalization in construction is addressed and explored as the means to reduce environmental impact, planning and construction time, total construction costs, and to enable for new business logic in the built environment sector.

Started in January 2016, SBE is set to run for up to 12 years. To support the long-term assessment of the progress towards SBE goals a project has been assigned to measure effects and consequences of digitalization and industrialization during the length of the programme. The aim of this paper is to present some of the main findings from the first measurement, addressing a sample of programme partners and their focus on digitalization and industrialization during the period January 2016 - December 2017. More specifically, in this paper is addressed the expected effects of changes and investments made in these areas and what the addressed programme partners perceive as the main challenges to reach these effects. From findings, the authors will argue that: despite most of the previous conducted researches focus on technical tools current challenges to develop digitalization may rather be found in accomplishing concrete changes in organizations, and; a reason for such a slow digitalization process in the building sector might be found in different views of digitalization held by interacting organizations.

Expected effects and challenges highlighted in literature

The promising effects of digitalization has frequently been promoted by consultancy firms, for example McGrawhill Construction (Smart Market Reports, 2010, 2012, 2014) and by researchers, sometimes a bit uncritically (Dainty *et al.*, 2017), claiming that the introduction of digital technology or tools in the construction sector will help increasing efficiency, productivity and performance. In particular, digitalization of standardized information flows is proposed as means to provide new methods for information exchange and coordination between all actors in the building process (see Andersson and Lessing, 2017). However, the introduction and implementation of industrialization and digitalization in construction has till now been far from straight forward. Researchers have proposed and reported on challenges and problems needed to be overcome in order for sector transformation to progress, and for organizations in the sector to benefit from any transformation taking place.

Research has frequently addressed the potential of technical solutions of different kinds and thus, technical matters regarding software/hardware compatibility have typically been in focus. Researchers have also suggested that whereas organizations

recognize the capital investment needed in information technology (typically in software and hardware), the return of such investments are considered to be unclear as well as uncertain (Liu *et al.*, 2017). Besides investments in information technology competencies also need to be developed (*ibid.*) in order for the investments to be implemented and put into proper use. Redwood *et al.*, (2017), Ghaarianhoseini *et al.*, (2017) and Eadie *et al.*, (2013) argue for example that organizations reject investments in digital technology due to not only perceived cost of technology investments but also due to such things as a lack of skills and experience in using the new technology or software, and thus not being confident about their organizational ability to attain expected gains in efficiency.

BIM (building information models/modelling/management) as well as lean construction has during recent years been closely related to industrialization and digitalization in construction. Saieg *et al.*, (2018) argue that with BIM we can affect quality, productivity, efficiency and gain sustainable benefits. Yet they state BIM technology and lean management in organizations are in the beginning of the learning phase (*ibid.*). BIM based lean tools also need more experienced, trained and active stakeholders to realize its potential. Moreover, technical matters in need for better attention according to Saieg *et al.*, (2018) include integrated and interoperable information systems, and investments in equipment, technologies and user-friendly interfaces are called for. When it comes to building the model, Pinheiro *et al.*, (2018) found that when there is a collaborative environment where all project stakeholders are involved and included at the early stage of the project an effective exchange of information between the disciplines is facilitated and, thus, the necessary information can be included in the model. Eadie *et al.*, (2013), in their study in UK focusing on measuring the impacts of BIM use throughout the project lifecycle, also infer that BIM is primarily used at the early stage of the project for designing, visualization, procurement and for construction, manufacturing and coordination; whereas it is less used at the later stages of the project for commissioning as well as for facility management, retrofit and demolition stages.

According to Liu *et al.*, (2017), BIM is more of a process than a software. Still, Merschbrock and Munkvold (2015) showed in their study addressing BIM deployment in a major hospital construction project in Norway that most of the companies thought that BIM is for creating 3D models and visualization only. Very few companies, the researchers conclude, did consider it for creating semantic rich BIM models or used it for creating multidisciplinary models (*ibid.*). Researchers such as Arayici *et al.*, (2018) also infer that sustainable projects call for multi-disciplinary involvement and collaboration, but BIM-use from this view is not common practice. Acknowledging BIM as a common reference and example of digitalization, frequently related also to industrialization in construction, research seems to indicate that the understanding as well as the realization of potential is limited and potentially differing between different stakeholders (*ibid.*).

Diaz *et al.*, (2017) stated that the main barrier is changing the working method from 3D method to programming. Other researchers have proposed that people and organizations being used to their traditional working process may simply not be ready to change so that the digital transformation can take place, and that lack of knowledge together with lack of motivation among construction organization members regarding the use of new digital technology in the project is a major problem for progressing digitalization in construction (see e.g. Pauwels *et al.*, 2017; Corry *et al.*, 2014).

METHODOLOGY

The methodological approach selected for this study was designed to measure the Swedish building sector's level of digitalization and industrialization and to detect any hinder to pursue the scope of the programme. The research includes the collection of qualitative and quantitative data that are analysed through a theoretical framework based on scientific references selected from an international scenario. The theoretical frame of reference has been structure to investigate the following main topics: digitalization, industrialization, technical or organizational issues among the building sector. In order to trace the achievement of the SBE programme's goals, measurements with relevant partners are planned to be conducted every other year. In this paper the authors present findings of a first measurement conducted through twelve in-depth interviews and a questionnaire addressing a sample of partners (response rate 17/25) in the Smart Built Environment programme including: materials and components suppliers, consultants, architects and engineering companies, contractors, client, facility managers, property owners and public authorities. The questionnaire was developed through dialogues with a reference group of construction management researchers and with representatives from the sector. It included 66 questions structured in the following thematic areas:

- Digitalization and Industrialization
- Development and change work practice during the period 2016-2017
- Information Flow, including:
 - i) BIM and GIS integration
 - ii) Open data
 - iii) Object-based information
 - iv) Digitalization and data sharing
- Environmental and energy declarations

Dialogues to develop the questionnaires, in-depth interviews addressing expectations, current developments and understandings among SBE partners regarding digitalization, industrialization and SBE effects and goals, the questionnaire part of the measurement, and follow-up dialogues with responding organizations were conducted in several rounds from February 2017 to August 2018.

FINDINGS

Findings show that much focus among addressed organizations has been on digitalizing the information flow within and between organizations by introducing different technical tools and solutions. Most parties talk about digitalization in terms of information modelling and information management. However, the typical answer concerns the creation of digital data, information models and object-based information, mainly 3D objects and/or BIM.

[Current use of digitalization includes] 3D models with information, digital drawings.
(Contractor)

We demand for 3D object and model-based design. (Property owner)

Despite that, some organizations have limited perceptions of or make limited use of BIM opportunities, mainly because their clients are not willing to pay for something, they do not have any use of.

The digital transformation, as described by those who participated in the survey, primarily involves a transition from paper-based documentation and distribution to digital documents, but also from digital documents to digital data.

[...] we have reduced our handling and distribution of paper documents during the planning process, referring to a greater extent to our webpage and screens at the municipality service centre. (Local planning authority)

We convert conventional drawing material into BIM models, filling them with property-related data and present the results in our web archive for property management. [The focus of development efforts during the past two years include] accessing and providing environmental data which can better enable for LCA and LCC estimations. (Consultancy agency)

Some parties, mainly consultants, describe the use of digital data for different analyses in different systems aiming to a digitalized/automated information retrieval.

Concerning industrialization, the respondents' most common descriptions refer to standardization and prefabricated artefacts. They emphasize the lack of standardization (linked to methods, routines and working methods) as the cause or explanation for the reliability issues regarding digital data, and as an obstacle to/enabler for the digital information flow. Typical answers for application of industrialization relate to prefabrication and pre-planning. In some cases, the application is found within the organization or the business operations. In other cases, the application is mainly associated with construction production conducted by other actors (applies mainly to clients and authority side).

I connect our application of industrialization in construction with our use of prefabricated products and so-called type houses. (Property owner)

Different understandings of digitalization

An important prerequisite for being able to share data digitally between different actors is that data to be shared is in digitalized form. Most of the parties who answered the questionnaire state that they have allocated resources to digitize internal analogue data and/or that they have taken measures such as require the delivery of digital data from the partner companies. What the parties in the survey seem to have been digitizing to a large extent are errands, delivery descriptions, drawings and related documents. However, despite that all the organizations involved in the study claimed to have invested capital and time toward a more digitalized process and an improved digital information flow, their efforts pointed to different directions. Some organizations, mainly public authorities, seem to have invested significant resources on digitizing analogue documents by scanning and storing them as, for instance, PDF-files.

[...] for example, on the building permit department, we have digitized one archive. Two people were employed full time for about six months in order to scan (analogue) drawings and documents. (Local public authority)

At the same time and suggesting a different view of digital information and digitalization, other organizations claimed problematic the definition of "PDF-files as digital information" since data cannot be directly extracted and processed. One organization even claimed that pdf documents are not to be understood as digital information or data.

Digitalization is far from fully developed. [...] We receive instead fully non-digital documents such as [...] pdf documents without any data that can be transferred digitally and in a standardized manner to for example calculation models. (Component supplier)

Some of the consultants' state that working with digital data enables an improved information flow, better coordination of information and the performing of analyses and calculations. From their perspective scanned documents and practices similar to what is described in the quote above do not further digitalization.

(Digital) Information flow

As already indicated above, the respondents' answers to questions about what primarily contributes to a more unbroken (digital) information flow show a variety of views and different focus. Recurring, however, is the development and increased use of "models" (digital, 3D/BIM, object-based information solutions) described as important contributors in this development.

We have digital case management with standard workflows; [we] work with standard layouts in projects including LOD (Level of Development). (Consultancy agency)

Testing in ongoing construction projects appears to affect various aspects of the information flow among the parties. However, from the questionnaire and interview responses, public authorities do not appear to be involved to any great extent in tests on ongoing construction projects, or the involvement of authorities is not well communicated or known. At an overall level, tests in ongoing construction projects in several cases deal with trying something perceived "as new" e.g. moving from (paper) drawing usage to, instead, using digital information models (only).

Answers in the questionnaire indicate that most parties believe to have approached a more unbroken digital information flow during the period January 2016 - December 2017, which was also confirmed during dialogues and interviews. Two of the organizations addressed in the study did not believe their organization approached a more unbroken (digital) information flow, stating that the introduced digital applications have contributed to an increased (technical) ability to exchange information with external parties, but that the information flow thus cannot be considered "more unbroken" as, for example, routines and working methods are not yet fully developed.

Need for focus change: from technology to organization

Organizational changes are described as prerequisites for being able to benefit from investments made in the field of digitalization. So far, according to the questionnaire respondents, such changes have mainly concerned changed working methods, structures and roles. Respondents from different branches of the civil engineering sector also express a continuous need to get the organization and working method "in place" to achieve the expected and measurable effects of digitalization. Challenges related to managing the transition as identified by respondents include creating the incentives for behavioural changes and coming to a common understanding of how to do things in a new yet coordinated way within as well as between organizations.

Changing working methods rises uncertainties about [employees] behaviour. It does not have to do with the lack of [technical] competences, but rather with the lack of incentives that stimulate the changes for the individuals. (Client/Facility manager)

For some reasons, everyone always wants to invent their own instructions, own copies of data, etc. This is very much based on the lack of competence and insight I believe. (Consultant)

I find that in many cases we work with quite sophisticated tools, but that we hardly know where the steering wheel is. It is for example still a challenge to get designers delivering an IFC with the correct classification. [...] Not more than 50-70% of the files

follow the instructions. If we do not deal with these basic conditions, it is difficult to integrate and automate. (Consultancy agency)

Findings from one of the addressed organizations also indicate that the opportunity of introducing solutions to support the flow of information may call for mapping and assessing how information currently flows in the organization. From this organization it is further highlighted that organizations need to understand what the new organization and working methods should be to enable for a more digital flow of information, as well as that there is the potential need to develop an organization (in this case a team organization was created) to plan and prepare for the transition itself:

'Digitization and teamwork' has been a topic for the urban planning office in recent years, especially from 2016 [...]. The building permits department has worked extensively to establish a changed working method and to move towards a completely digital building permit process and working in teams. [...] During the second half of 2017, we have also increased focus on the digitization of the planning process and worked with reduced paper-based mailings during consultation and review. Great focus [has been put] on teams with effective flows between departmental boundaries (Public organization).

DISCUSSION

Findings propose that much focus among addressed organizations has been on digitalizing the information flow within and between organizations by introducing different technical tools and solutions. Thus, the focus of organizations seems to reflect well the focus of research on digitalization in construction which to a great extent has focused on technical tools, technical systems and technical structures, including the development of features and possibilities as well as addressing technical problems hampering a more widespread adoption and use (Andersson and Lessing, 2017; Liu *et al.*, 2017).

Though compatibility still is a concern to some of the addressed organizations, many seem to be at a point where their primary struggle is not with hardware and software but rather with getting the organization and working methods "in place" (Redwood *et al.*, 2017; Ghaarianhoseini *et al.*, 2017; and Eadie *et al.*, 2013). To some extent the latter refers to what can be understood as a generic competence-related need i.e. being able to use the technical tools in day-to-day work. But as highlighted by some respondents getting the organization and methods "in place" has also to do with gaining leverage from the technical competences and digital capabilities the organization has already invested in, acknowledging for example the need for common understandings and agreements on how to do things in a new way as well as presenting proper incentives for humans to change.

Hence, moving from the technical to the organizational seems to involve doing things differently rather than simply using available tools in response to direct/explicit demands from clients and other stakeholders. To benefit from the (mainly technical) investments made such transformation seems to be on top of the digital challenge among several of the addressed organizations, where the challenge is generally described in terms of being greater or more problematic to address and solve than are those challenges which concern technical matters, or could be solved by further investments by the organization in technical tools and technical infrastructure.

Moreover, organizations seem to agree that in order to progress towards a more unbroken digital flow of information the actions of many stakeholders are of importance. Yet, how digitalization is actively progressed as well as what is

understood to contribute to further digitalization and a more unbroken information flow seems to be described differently within as well as between organizations. First, besides the differences between what levels of digitalization different actors currently find themselves at there seem to be differences regarding what they are aiming for; i.e. whereas some of the organizations intend to move towards digitalizing data others are currently focussing significant resources on digitizing analogue documents by scanning and storing them as e.g. PDF-files. The potential implications for the efficiency of the information flow include methods for information exchange and coordination between all actors in the building process (see Andersson and Lessing, 2017). Second, the most common description of digitalization in terms of current practice in the addressed organizations relates to 3D-models and BIM. The use of BIM and the development and use of object-based models is referred in the Smart Built Environment programme, as well as by respondents, as one important progression towards better managing building information using digital opportunities. However, similar to Gemalto (2018) findings suggest that some organizations have limited perceptions of or make limited use of BIM opportunities. When these organizations are found on the demand side of construction the potential of BIM use for maintenance and lifecycle use is not realized at the beginning of the project, since clients are not willing to pay for value they do not foresee or expect, and thus, the limited perception and use becomes a self-fulfilling prophecy.

The findings from the first measurement seem to indicate different views on further developments of digitalization and digital flow of information. There is the difference between finding ways of digitalizing the current flow of information and to make use of digitalization to rethink and improve the flow. On the other hand, there is the difference between understanding the flow of information as a necessity to realize and maintain the physical (constructed or built) asset or envisioning the information as an asset itself.

CONCLUSIONS

Based on the findings and as argued in the preceding discussion, the authors propose that though much research have focus on technical tools to develop digitalization, organizations currently seem to struggle more with organizational and human matters. The authors also propose that a significant reason for such a slow digitalization process in the building sector might potentially be found in different views of digitalization held by different interdependent organizations, as demonstrated by the partners participating in this research.

The organizations' perceived main challenges to reach the expected effects of changes and investments made toward a digitalized building process seem to include such matters as:

- the development of working methods and organizational structures to benefit from previous, ongoing and planned investments in technical solutions
- the management of change, including the development of technical know-how capabilities as well as that of human mind-sets and behaviours
- the views of information as value and asset
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These challenges do seem to indicate a shift from technical concerns to social and economic which, in turn, might be understood as a challenge not only for the organizations in this study but as the collective challenge for the research community.

This latter is called to further investigate organizational and social matters toward a digitalized building process, taking into account all the interested parties.

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