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Context, drivers, and future potential for wood-frame multi-story construction in Europe

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ABSTRACT

Compared to many manufacturing industries, there have been few major improvements over the past few decades in the productivity, profitability, or the environmental impact of construction. However, driven by institutional changes, promotion campaigns, and technological development in the 1990s, novel industrial *wood-frame multi-story construction* (WMC) practices have been emerging in some European countries. The aim of the study is to explore the WMC market potential in Europe by combining two complementary approaches: Top-down scenario analysis and bottom-up innovation diffusion analysis. The results show that the WMC diffusion is heavily dependent on the regulatory framework and the structure of the construction industry. The risk-averse nature of the construction value chain resisting the uptake of new practices appears to be a more significant hindrance for the future market potential of WMC, compared to the possible competition from alternative construction practices. It would require both increasing competition within the WMC sector and increasing co-operation between wood product suppliers and the construction sector to attract investments, to reduce costs, and to make the WMC practices more credible throughout the construction value chain.

1. Introduction

1.1. Background and objectives

Compared to many manufacturing industries, there have been few major improvements over the past few decades in the productivity, profitability, or environmental impact of construction (ECTP, 2005; Höök, 2005; Kim et al., 2009; ECORYS, 2010). That is, despite the continuous attempts to adopt prefabrication and industrial mass production in construction already since the 19th century (Atkin, 2014), few of the expectations of industrialized building have been realized (Ågren and Wing, 2014).

Driven by institutional changes, promotion campaigns, and technological development in the 1990s, novel industrial *wood-frame multi-story construction* (WMC) practices have been emerging in some European countries. WMC has been attributed to contribute both to the productivity of construction (Brege et al., 2014; Malmgren, 2014) and to the environmental impact of construction (Sathre and Gustavsson, 2009; Sathre and O'Connor, 2010; Ritter et al., 2011; Oliver et al., 2014).

A large body of literature explores the technical and regulatory aspects of WMC (Lattke and Lehmann, 2007; Smith and Frangi, 2008; Nord et al., 2010; Tykkä et al., 2010; Östman and Källsner, 2011; Van De Kuilen et al., 2011; van Egmond, 2011). Previous research has also focused on life cycle analysis and other sustainability impact assessments (Gustavsson et al., 2006; Gustavsson and Sathre, 2011; Ruuska and Häkkinen, 2012, 2013, 2014; Pajchrowski et al., 2014), and the attitudes and awareness of the construction sector actors and the residents (Karjalainen, 2002; Roos et al., 2010; Heino, 2011; Riala and Ilola, 2014; Wang et al., 2014; Xia et al., 2014). Malmgren (2014) discussed WMC in the context of the production processes in industrialized construction in general. Added to the more specific studies, there are a few general descriptions of the WMC markets in more than one country or studies discussing general WMC market opportunities (Walford, 2006; Nord, 2008; Shmuelly-Kagami and Matsumura, 2008; Jonsson, 2009; Mahapatra and Gustavsson, 2009a; Mahapatra et al., 2012). Few studies focus on the role of WMC in the construction value chain or the business logic of WMC (Höök, 2005; Brege et al., 2014; Mahapatra and Gustavsson, 2008). In particular, to the best of our knowledge, there are no future-oriented studies of WMC market diffusion in Europe.

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The aim of this study is to identify the key drivers influencing the WMC market potential in Europe, using a combination of two future-oriented approaches: Firstly, we apply scenario analysis to assess possible changes in the operational environment of construction and the implications of the changes in the competitive position of WMC. Secondly, we apply innovation diffusion analysis to explore the attributes of WMC affecting the diffusion from the perspective of construction value chain. Consequently, the objective of the study is to fill the gap in future-oriented market analyses on the WMC sector in Europe, and secondly, to contribute to foresight methodology by exploring the linkage between the innovation diffusion and scenario analysis frameworks.

1.2. Context and recent developments

1.2.1. Characteristics of the construction sector

In order to analyze the diffusion potential of an innovation, it is necessary to define the structure of the system and the key actors in the system that the product or process is a part of (Wirth and Markard, 2011). The construction industry is generally considered more risk-averse, fragmented, and path dependent than many other sectors of economy (Arora et al., 2014). That is, accustomed building practices are favored over alternatives due to existing norms and institutions, investments in the existing infrastructure, know-how, capital intensive machinery, and the large number of loosely coupled small actors in the construction value chain (Mahapatra and Gustavsson, 2008). Further, as a result of the site-specific nature of construction projects, i.e., the lack of permanent networks, the actors are tied to short-term decision making and competitive tendering with its dominant strategy of pursuing lowest costs (Nord, 2008). The established, path dependent innovation systems based on cost competition encourage incremental innovation and easily make the actors unwilling to accept new practices which potentially cause extra work and associated costs in the short-term (Höök, 2005; Arora et al., 2014; ENBRI, 2005; Knowles et al., 2011). Also, the life cycle of buildings is longer (30 up to 1000 years) compared to consumer products. The rate of commercialization of new products, processes, or business models to the markets typically takes several decades.

There are four key actor groups in the construction value chain having influence on the construction process, after a construction project has been commissioned by a person, organization, or an authority (Nord, 2008): *Developer* organizes and manages the process, and has the overall responsibility for design, specification, and economic conditions. Mandated by the developer, *consultants* such as architects, engineers, and project managers offer expert services for the design and management of the project. Main *contractor*, together with numerous sub-contractors, is responsible for the realization of the project. Finally, numerous *material suppliers* are responsible for supplying all the materials, components, and machinery for the building project. Generally, in North Europe the commissioner, developer, or main contractor has most influence over the choice of material, while in the Alpine region the architect is the most influential (Roos et al., 2010).

1.2.2. Recent developments in WMC markets in Europe

Until the late 1980s, wood-framed buildings with more than two stories were prohibited by building regulations in most European countries, due to the negative perceptions arising from historic city fires. However, driven by the Construction Products Directive adopted in the EU in 1988, the national building regulations are being revised towards functional criteria, as opposed to prescriptive criteria, thus allowing a larger number of stories with a wooden frame throughout Europe (Nord et al., 2010; Östman and Källsner, 2011). Simultaneously, new technical solutions have enabled the WMC practices to negotiate the issues related to for example unpleasant acoustic performance encountered during the first experimental projects.

Following the adoption of functional building regulations and the technological development, the WMC concepts have begun to challenge the conventional practices, most notably in the Nordic countries, the Alpine region, and the British Isles. The first modern WMC projects in Europe were carried out in 1994 in Sweden, which is commonly regarded as the WMC market leader. There are many conflicting estimates for the market share of WMC in Sweden in 2014, ranging from 3 to 15% (e.g., Brege et al., 2014). However, the upper end of the estimates includes also other multi-family buildings than multi-story buildings with three stories or more. The higher end estimates are therefore biased, in that row houses typically have a higher share of wood in the frames than multi-story buildings.

In Finland, there were many promotion campaigns and technology platforms in the 1990s, aiming to facilitate the diffusion of wood-based construction. However, unlike Sweden, and unlike the single-family building sector, the first wave of WMC failed to engage large firms in Finland, and the new technologies were not adopted according to expectations. According to Ilola (2014), the perceptions towards WMC were also negatively affected by the setbacks during the first projects in the 1990s.

After a long period of stagnation at less than 1% market share, the second wave of WMC in Finland began in the early 2010s (Tolppanen, 2014). By the first half of 2014, there were only 753 apartments and 39 buildings with a wooden frame in Finland. However, in 2014, 700 apartments were built, corresponding to a 4% market share, and there are 1500 apartments in the pipeline for 2015, corresponding to a 10% market share (see Fig. 1).

The rapid diffusion of WMC in Finland is the result of several factors. In 2011 the Finnish Government (2011) set a target of increasing the market share of WMC from 1% in 2011 to 10% by 2015, in pursuance of environmental and economic benefits through promoting the use of domestic wood resources. Subsequently, fire regulations were revised to allow WMC up to eight stories. These changes seemingly encouraged large forest industry firms to establish alliances with construction companies to develop novel WMC techniques. The investments of large players have increased the credibility of WMC. Finally, the investments, vertical co-operation (within the value chain), as well as increased competition have begun to lower the costs of WMC compared to rivaling practices, while also being able to solve the technical issues encountered in the experimental phase.

In the UK, the market share of wood-frame in residential construction has increased from 8% in 1998 to 25% in 2008 (Mahapatra and Gustavsson, 2009a), and the off-site construction sector including wood frame is expected to grow rapidly (Vokes and Brennan, 2013), yet no data on the WMC segment specifically could be found. Nevertheless, residential WMC has made a breakthrough in the UK, due to environmental policies, imposing architecture, and the rising interest towards WMC among the developers (Wang et al., 2014). The lightness of wood has also made it possible to utilize those building sites that could not carry the weight of corresponding buildings made of concrete. Also in Ireland, the building practice has been changing from on-site construction to wood-frame off-site construction (Mahapatra and Gustavsson, 2009a). However, while the overall market share of wood-fame in all construction has increased from 1% in 1990 to 30% in 2007, the market share in the WMC segment has yet remained small.

In Austria, wood-frame is common in the single-family housing sector, with a 40% market share, yet the regulations and attitudes towards wood use vary from one province to another, and on average the market share of WMC has remained low. Likewise, in Germany and Italy, there are regional differences in the attitudes towards WMC. In Southern Germany, the use of wood for construction has been increasing in the 2000s, and it has been suggested that the market share of WMC could increase from 2% to 10% towards 2030 (Jonsson, 2009).

In most parts of Europe, the WMC practices are completely unknown, with the exception of a few pilot projects. However, the pressure for changing the established construction practices keeps accumulating