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Efficiency in the delivery of multi-story timber buildings

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Abstract

The construction of wooden multi-story buildings was boosted by changes in building regulations in 2011, which allowed the use of wood in up to 8-story buildings. Thus far more than 50 wooden multi-story buildings have been built in Finland. The public sector has an important role in promoting wood-based multi-story building. Despite of intensive development, the experiences in wood-based multi-story building in Finland are still limited. Building processes may still suffer from some lacks in efficiency in terms of process management and use of resources. It may be possible to address different kinds of issues which would be able to make the process more effective and lean. The objectives of the research were 1) to find inefficiencies in multi-story timber building projects, 2) to address reason and causes for the lacks of efficiency, and 3) to make suggestions that might help to improve the lean nature of the process.
The premise of this research was that some of the following reasons may cause ineffectiveness in the delivery of wood based multi-story building projects: lacks in development and standardization of structural systems, lacks in the availability of BIM software for wood buildings, specific additional building requirements set for timber buildings, inexperience of different actors with regard to multi-story timber building and current project delivery and procurement methods.
The approach was to study recent literature, select two significant on-going cases which represent different structural systems, interview the representatives over the whole value chain and study the results against our hypothesis and make conclusions.

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Keywords: Multi-Story Timber buildings; Design and Construction; Lean Construction

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1. Introduction

The Strategic Program for the Forest Sector (MSO) was based on the former Finnish Prime Minister Katainen's Government Program and the main task of the MSO has been to promote the competitiveness and renewal of the forest sector. In accordance with its development targets the market share of wooden multi-story buildings should grow to 10% [1]. The construction of wooden multi-story buildings was boosted by changes in building regulations in 2011, which allowed the use of wood in up to 8-story buildings [1]. Roughly 43 per cent of all residences in Finland are in multi-story buildings and roughly 40 per cent of new dwellings (12,000–13,000 residences per year) are in multi-story buildings. Concrete has dominated the multi-story building market for the past 50 years but recently wood-based construction has undergone intense development in Finland. Development efforts have focused particularly on building of multi-story wooden buildings and on enhancing buildings' energy-efficiency [2].

The public sector has an important role in promoting wood-based multi-story building in Finland [3]. In addition to the government program, some cities also aim at promoting wood building. For example, the City of Espoo has a promotion program for wood building for years 2014 – 2020[4] and city of Helsinki has implemented several significant wood-based building projects [5].

Despite of active development, the experiences from wood-based multi-story building in Finland are limited and building processes may still suffer from inefficiencies in process management and use of resources. It can be reasonably assumed that processes could be made more effective and lean by identifying and solving such inefficiencies. Lean projects deliver the product while maximizing value and minimizing waste [6]. For building projects, for example, reduction of defects during different phases of building process can effectively contribute towards lean construction by eliminating waste [7].

2. Objectives, hypotheses, approach, methods

The following subsections introduce the objectives for this research, along with research hypothesis, utilized research approach and the research methods.

2.1. Research objective and research premise

The objectives of the research were 1) to find inefficiencies in multi-story timber building projects, 2) to address reason and causes for the lacks of efficiency, and 3) to make suggestions that might help to improve the lean nature of the process.

Our premise was that some of the following reasons may cause ineffectiveness in the delivery of wood based multi-story building projects: lacks in development and standardization of structural systems, lacks in the availability of BIM software for wood buildings, specific additional building requirements set for timber buildings, inexperience of different actors with regard to multi-story timber building and current project delivery and procurement methods.

2.2. Research approach and methods

The research approach was selected in order to fulfill the research objectives.

Our approach was to:

- collect and study recent literature results on the resource and process efficiency, with focus on lean construction of timber buildings in urban context
- select two significant on-going cases which represent different timber structural systems
- interview the stakeholders of the two cases over the whole value chain
- study results against our hypothesis and make conclusions.

The results of the recent literature and the results of interviews were assessed qualitatively against our research hypothesis.

2.3. Case-study method

The research was conducted with the help of two recent real multi-story timber building cases in Helsinki metropolitan area. The research team had a direct access to the project documentation of both of the cases. The documentation used in the case studies included: information models (BIM) and design documents, meeting memos from design and site meetings, project and site schedules. In addition to this, the projects submitted supplementary information, as deemed necessary by the research team.

The relevant actors of each project's value chain, a total of 19 persons, were selected and interviewed with a standard set of questions. The whole set of questions was sent to the interviewees beforehand over e-mail, after which the interviews were conducted either in person, or over phone. The interviewees were allowed to focus on the most relevant topics of the question set, to allow finding the most crucial topics for different value chain actors. In addition to this, a representative of an Estonian module element manufacturer was interviewed with the same questionnaire to get a viewpoint of an established actor with standardized approaches and processes.

The following Table1 shows the number of interviews, and the value chain actors interviewed, from both of the cases.

The individual interview results were analyzed and synthesized into final results, based on project delivery stages. These stages were: 1) Project management (and collaboration), 2) Design, and 3) Construction. The aim of the interviews was to assess the issues that affect the effectiveness of the process and identify potential for improvements.

2.4. Case descriptions

Both studied cases were wood-based multi-story buildings, designed and built in 2013 – 2015. In Case A, the client was a public procurer, and in Case B the client was a foundation. Case A utilized prefabricated, large timber elements, and Case B prefabricated apartment modules.

Both case projects are located in the capital region of Finland. Case A is located in the city of Vantaa. It is a single building, with its first floor made of concrete and the other six floors made with timber elements. Case B is located in Helsinki. It comprises of four separate buildings, each of which have concrete first floor and other, four to six floors are made with timber modules. The following Table 2 shows the basic information of the two buildings.

Table 1. Number of interviews and the value chain actors interviewed, for both of the cases.

	Case A	Case B
Owner	1	2
Contractor	2	2
Timber element supplier	3	4
Architect	1	1
Designers	2	2
Total	9	10

Table 2. Basic information of the two cases

	Case A	Case B
Building type	Residential building	Residential building
Number of buildings	1	4
Number of apartments	186	93
Number of stories	7 stories, 1st story made of concrete, includes car park	5 to 7 stories, 1st story of each building made of concrete
Gross area	17 730 m²	9875 m²
Living area	10 120 m²	6287 m²
Timber system	Prefabricated timber elements	Prefabricated apartment modules

3. Study of literature

3.1. Delivery models

Project delivery systems refer to the overall processes, by which a project is designed, constructed and/or maintained [8]. They describe the relationships, roles, and responsibilities of parties and the sequence of activities required to provide a facility [9]. Traditionally, construction projects have favored the so called design-bid-build system, which separates design and construction services, but lately, interest towards integrated services has grown. For example, both of the case projects utilized a design build (DB) model, in which the owner provides requirements for the specified project and awards a contract to a company who will both design and build the project [10]. A contractor is responsible for the project's design and implementation as an entity. In DB, there is only one procurement step to award a project to a contractor, and only one contract between the owner and this contractor [10]. The DB-contractor performs design, construction engineering and construction according to design parameters, performance criteria, and other requirements established by the client [8].

In the Lean Project Delivery System, the project delivery team does not only aim at providing what the customer wants, but aims to first help the customer to decide what they want, effectively changing all the variables compared to traditional project delivery [11]. Integrated teams of owners, architects, facility users, builders, specialty contractors, subcontractors and suppliers are recommended for lean delivery [12]. Especially in demonstration and development projects, the client should form some sort of collaborative relation with the contractor and focus on very clear requirement setting as soon as early as possible [13].

3.2. Value chains

A value chain is the whole series of activities that create and build value [14]. Value chain thinking focuses on the end product and the chain is designed around the activities required to producing it [15]. Every company occupies a position in the chain, as upstream suppliers provide inputs for the next link downstream in the chain. The selected delivery model impacts the stakeholders' work in different stages of the building process and the degree of cooperation.

The trend is towards models where a bigger number of stakeholders work together to create value [16]. The value can be managed, for example, through team-based practices that address value in functional terms during project briefing and conceptual design [17]. The effectiveness with which the chain works towards delivering an end product fit for purpose, determines if value is added or reduced in the overall system [18].

The solid wood value chain is changing with regard to business logic and value-adding logic, moving from saw milling industry to wood-based products industry. The industry is moving downstream focusing more on customers and customer value, integrating downstream and taking over operations of further processing companies [19]. For example, for modular home manufacturers, strengthening the relations throughout the entire supply chain, from all suppliers to the customers is recommendable [20].

3.3. Lean construction and timber building

Tykkä et al. [21] say that companies that have become key actors in the timber framed construction industry have developed similar types of innovations including process, product and organizational innovations. The key innovations include: 1) lean production processes to produce timber-based housing elements, 2) design of new timber-based building elements or volumes, and 3) establishing off-site production and taking responsibility for design, and on-site assembly.

However, extensive focus on lean strategies and integration of different processes may risk agility of operations. Lu et al. [22] claim that certain choices of lean strategies in industrialized housing companies have led to decreased flexibility and responsiveness to market demands. According to authors, companies may fail to respond to fluctuating market demands and lose market opportunities if they do not remain agile.

Traditional construction planning and control focuses mainly on setting and meeting targets on the schedule and budget. However, as concept of lean construction makes the elimination of waste its main objective, some authors suggest moving from top-level targets to minimizing waste in the work of every individual of an organization [23]. It should be noted that the efficiency of individual tasks should be improved only by simultaneously considering the effectiveness of the overall project delivery to avoid creating waste elsewhere in process [24].

3.4. Modular building and efficiency

Offsite construction is thought to have the potential to increase efficiency, reduce costs and improve quality of construction. Johnsson and Meiling [7] claim that the use of modules may shift 90% of the work from the site into factories. According to [25] modular construction and factory production provides opportunities for applying lean principles and thus helps to better manager cost, schedule and project quality. Time and cost can be achieved through reduced work flow variation, and more predictable work flow [26], and waste savings can be repeated in several projects through technical and process solutions [27].

3.5. Knowledge and effectiveness

Sardén [13] analyzed the building process of multi-story timber housing process and recommended methods to handle complexity and uncertainty in solid timber frame housing projects. The author claims that adequate learning and communication has not taken place between timber building projects and recommends that a structured way of sharing and coordinating information between projects should be in place, for example through handbooks. Standardized structural solutions, such as runkoPES in Finland, are another way for knowledge-building [28].

3.6. BIM and lean construction

Sacks et al. [29] have studied the interactions between BIM functionalities and lean principles and Sacks and Koskela [30] found out that certain lean principles and certain BIM functionalities have strong positive interactions. The most positive interactions regarding lean principles were: 1) reducing product variability, 2) reduce production variability and 3) reduce production cycle duration. For the BIM functionalities, the most positive interactions were found for 1) design evaluation, 2) multiuser viewing of models, 3) visualization of construction schedule, and 4) online communication of information. The strong interactions highlight the potential of BIM in promoting lean outcomes but also underline that when BIM is utilized, the processes should contribute towards making processes leaner.

BIM also enables automating the design process. However, in order to support better the consideration of the needs of manufacture in design and lean thinking in construction, integration of BIM with lean principles is required [25]. Ultimately, the success of BIM depends on the ability to capture all relevant data in the BIM model, and to successfully exchange data between the various applications. For example, the configuration tools for modular building need to be integrated to the tools used by the architect [27]. At the present moment, BIM tools have largely matured for structural steel and concrete construction, but are not yet satisfactory for modelling wood structures [31]. Therefore, further development of design tools for timber construction is needed [28].

3.7. Lean design process

In building design, alternatives are evaluated throughout the process against design criteria and decisions are made at the last responsible moment [11]. In lean process, the design phases should overlap, and time before decisions should be used for developing and exploring alternatives to avoid rework [6]. The design of a building and its production should also overlap and take place simultaneously for optimal outcomes [12].

3.8. Lean and sustainable building

Traditionally price, timetable and quality are the success criteria used for projects [32], but for sustainable building projects, additional criteria, such as environmental impact, innovations and work environment should be used as additional criteria [33]. Current project delivery systems do no not fully support lean and sustainable building, and opportunities to reduce the environmental and economic footprint of the built environment and providing healthy and productive environments for occupants are commonly missed. Such projects tend to be more challenging to deliver due increased levels of building system integration, untraditional materials, and requirements such as recycling, total commissioning, and increased project documentation [34]. However, lean approach can assist in achieving sustainability goals, and reducing waste as shown by [35] for material wastes and production hours. Ray et al. [36] studied the leanness of wood product industry and found that energy consumption was the most significant single factor that affects the leanness of any wood products company. They recommended that companies with energy-intensive operations should first focus on ways to reduce energy consumption in any process re-design or improvement efforts, rather than focusing primarily on process flow improvements.

3.9. Project management

Lapinski et al. [37] claim that the key issue to make sustainable building projects lean is information management. The basic features of lean approach to project management include consideration of all life cycle phases throughout project, conceptualizing project phases and development through conversation, simultaneous decisions on process and product design, and using process design and control as primary management method [38].

Tam et al. [39] claim that waste management can be one of the major functions of construction project management and that waste can be reduced, or even completely eliminated with prefabrication. However, making informed decisions about pre-fabrication with inadequate cost and time data is difficult [40]. This calls for detailed information about fabrication, delivery and design impacts of solutions.

Lean construction management is very different from traditional top-down management methods, commonly used in construction. The basic setting calls for management based upon cooperation, conversation, commitment and learning, where plans are seen as agreements not as orders [41]. Subcontracting most of the work by subcontractors – as commonly done by general contractors in the housing construction process – may cause inefficiency and low productivity in subcontractors' work [22].

4. Interview results

The following subsections present the interview findings. Each subsection is dedicated for a different project delivery stages and show synthesis of findings for that specific project stage. The following Table 3 summarizes how the interview results for each of the project stages supported the premise of this research.

Table 3. Summary of interview results: - Did the interview results support the premise of this research?

Project Stage/Area	Potential reasons causing inefficiency in the delivery of wood based multi-story building projects				
	Lacks in development and standardization of structural systems	Lack of available BIM software for timber buildings	Specific additional requirements set for timber building	Inexperience of different actors in the process	Current delivery and procurement methods
Project Management	Yes	No	Yes	Yes	Yes/No
Design	Yes	Yes	Yes	Yes	No
Construction	Yes	No	Yes	Yes	No

4.1. Project management and collaboration

The interview results showed that it is critical that technical possibilities and limitations of the selected timber system are known to the architect and structural designer. Timber product manufacturer has a central role in this and should actively participate in design and suggest, promote and push for design solutions that match the factory production capabilities. This would ensure optimal outcome and lean processes. However, the interviews underlined that if the systems and processes are not fully developed the timber product manufacturer is not be able to guide the design effectively. This causes inefficiency in the process through re-work and suboptimal design solutions.

According to the interviews, the ideal situation is if the project team has both, experience on the specific structural system and from working together as a team. At the present moment, there are only a limited number of designers experienced on timber construction, and a limited number of completed projects. When considering that the structural systems are still developing, and that multiple different systems co-exist, it is evident that the ideal situation rarely realizes. In short, multiple timber construction systems have slowed adoption of lean processes.

At the present moment, the role of principal designer (architect) is highlighted, as the communication with the authorities is more frequent than in typical projects. This is especially true concerning fire-technical issues, which are open for local interpretations and require negotiations with the local authorities. At present moment, this leads to an increased in need for design resources.

The quality control requirements vary between timber element systems. For example, CE-marked building products, combined with building-site supervision are sufficient for quality control of prefabricated timber elements. There is an additional requirement for the prefabricated apartment modules, as the whole factory production process, including all system installations, needs to be verified for authority approvals.

Timing and required level of detail for design documents changes as production moves to factory. The factory production schedule becomes the dominant factor, which shifts the timing weeks or months earlier than in traditional construction. The key is that the process should be further streamlined so that every step of the process would focus on the end-product. Timber product manufacturer should be engaged early on in the design process to allow optimization of elements and components, so that the number of identical components and elements could be maximized. This would enable longer production series and cost savings at the component and element manufacturer's production lines. The production line machinery for the components of timber elements requires exact measurements. Due to this, timber element design needs to be complete before the orders for components of the elements are placed. Design solutions are directly linked to procurement, as products are specified in the design. This means that changes in procurement stage (use of comparable products) require changes in design. In order to avoid re-work and waste of resources, products to be used should be agreed between the procurement and design early on in design. The following Figure 1 illustrates the shift in design timing for timber construction, compared to traditional construction.

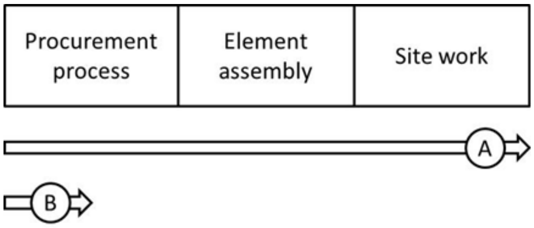

Fig. 1. Traditionally, technical design is finalized only after start of site work (marked with 'A'), as partly finished design is sufficient to start production. With timber elements, technical design needs to be completed for the whole building before the start of procurement process (marked with 'B'). Effectively, this means that higher level of detail is required in design earlier in the process.

The interviews underlined that in design-build-contract model, all the technical solutions should be agreed on between the contractor and the owner before signing the contract. At its best, the delivery form enables the contractor to utilize its full expertise and to conduct and benefit from research, development and innovation. It was apparent that if the structural system is still under development, the owner may limit the degree of freedom for the contractors to minimize their risks and impose extensive quality control requirements and measures.
All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately.

4.2. Design process

According to the interviews, timber multi-story buildings need to be modelled with BIM, because cross-checking of structural and HVAC-models is a necessity for timber building design and this can be only done effectively with BIM. However, the design process of timber buildings is still developing, causing inefficiency in many ways. Currently, the piloting nature of a structural system increases the design workload, as lack of reference projects leads to both planned and unplanned additional work. The interviews on the both cases showed that the project parties felt that they were participating in a product development project, more than in a standard design project. Different timber building systems are in different stages of development, but it seems that for all systems, standard solutions and models are still partly missing or under development.

The production of timber-elements requires highly detailed BIM-models, as the production line control codes are based on the models. The BIM-software and production line control software should be interoperable. However, it seems that this is currently not the case and design needs to be re-drawn for production. At the present moment, models are not utilized in factory assembly lines, and 2D-printouts are a standard.

It became clear in the interviews that the design work load is increased with timber structures, due to broader work scope and requirement of higher level of detail. The statics, fire technical design, acoustic design and moisture technical design of timber-framed buildings require additional work and new experts in the design team, compared to traditional buildings. The amount of work is also increased, as the number of detailed drawings increases in timber construction. This is especially true for building components, whose detailing has been traditionally left to site. For example, the number of detailed drawings for balconies may be multi-fold compared to traditional buildings. The required level of detail also increases in timber construction. As timber element design needs to be done at millimeter precision, all the other design disciplines need to have the same level of detail. In addition to this, each component of a single element, together with their factory and site installation, needs to be pre-planned in detail to the last screw specification. Increased level of detail does not mean that each timber component should have its own dimensions. The accuracy needs to be high, but not so that every timber component is custom-made. There is a need to have a set of standard sized timber components to bring down the procurement costs of individual components.

4.3. Construction stage

It was commonly brought up in the interviews that at the present moment, the full potential of industrial manufacturing is not utilized in timber construction. It was seen that indoor manufacturing improves the quality, but schedule and cost benefits are not fully utilized. Currently, the biggest savings potential seems to be in the timber element factory, procurement process and in developing general flow of work. Timber elements allow fast installation of large building masses, but degree of pre-fabrication can still be increased. In optimal situation, the work on site is only minimal and limited to connections between elements and external finishes. On-site installation possesses improvement potential in fastening methods, and standard, repeatable methods will make work faster. There is also improvement potential in temporary supports and stiffening of structures, which now utilize large safety coefficients and cause extra work in installation.

Effective site processes require that joints, seams and such are pre-planned so that installation flow is smooth. In addition to this, the roles and responsibilities of the timber element manufacturer and other contractor's factory and site work need to be clearly defined and agreed on. The prerequisites for timber element installation and boundaries between the scopes of contractor need to be made clear. This is not the case at the moment in all projects.

According to the interviews, weather covering is the most important additional requirement in construction stage, when comparing to traditional building projects. It seems that the weather covering needs to be developed in the future projects, as it brings delays and extra costs on site, if not planned and executed properly. Weather covering brings unavoidable costs in terms of rental and installation of the covering. However, improper covering causes unnecessary delays in schedule through extra work due to correctional work on coverings, and to the actual building through for example moisture problems. Also, insufficient weather cover causes weather delays more often than proper covering. Weather covering should be such that it could be installed once, would allow work on site in most weather conditions, and would offer sufficient cover to avoid corrective work from drying of structures. The interviews revealed that moisture damages do currently occur and that their correction needs, and is given a high priority. However, there were also indications that most of these damages could be avoided through developing the in-transit-protection of the elements, weather covering on site and making the timber elements more weather prone and resistant to light moisture exposure.

It became very clear in the interviews, that unplanned shift of factory work to site causes significant waste of resources. In optimal process, site work is only minimal and limited to installing the elements and other system components and making external finishes. The production process in the factory should be scheduled and managed with high accuracy and each step of the production line should be error-free for the next step. The production schedules are tight, and as problems start to accumulate in the production line, they are very difficult to correct before shipping. The element manufacturer should have full control over all the actions impacting factory's critical production path in order to take corrective actions. Shipping unfinished elements to site leads to multi-fold costs in many cases. A good way for corrective actions seems to be to finish the elements outside factory production line, but inside factory premises to avoid delays in production line and expensive extra work on site. Effective corrective actions require that timber element manufacturer is in control of all the subcontractors work in the production line and relevant on-site installation work. The following figure 2 illustrates how resource needs increase as work stages (marked from 1 to 4) increase and/or move from factory to site.

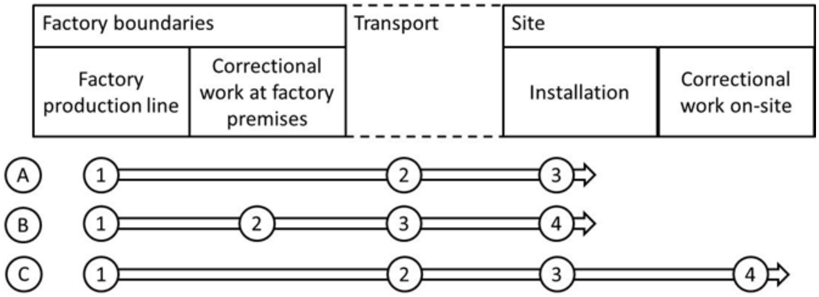

Fig. 2. Resource needs (manpower, time, cost) go up from A to C as work shifts away from factory production line due to complications / correction needs. Some resource needs can be avoided with approach B, compared to C. Each process A to C can be improved but move towards A should be preferred.

5. Summary and conclusions

Based on the conducted research, the timber construction processes still suffer from lacks in efficiency in terms of process management and use of resources. Our premise was that certain specific reasons may cause ineffectiveness in the delivery of wood based multi-story building projects. The paper discussed the effectiveness of timber building with regard to issues that may cause problems for overall project management and design and construction processes and thus consequentially have an impact on consumption of time and resources. The results of the study were relatively well in line with the stated premise. However, communication, collaboration and overlapping of process phases / timing of phases were emphasized more than we expected. On the other hand, demanding regulations were not highlighted in the literature from the view point of efficiency and saving waste. The summarized results are shown in the following sections.

5.1. Standardization of structural systems

The interviews on cases A and B gave similar results as those of the literature review. The design process of timber buildings is still developing, causing inefficiency in many ways. Currently, the piloting nature of a structural systems increase the design workload, and lack of reference projects leads to both planned and unplanned additional work. The interviews on the both cases showed that the project parties felt that they were participating in a product development project, more than in a standard design project. Different timber building systems are in different stages of development, but for all systems, standard solutions and models are still partly missing or under development.

5.2. Availability of BIM software

Utilization of BIM supports the lean thinking through minimization of re-work and waste, and through automation of design. The interviews suggested that BIM-based design is a necessity for multi-story timber construction, thus enabling lean processes. According to the interviews, timber multi-story buildings need to be modelled with BIM, because cross-checking of structural and HVAC-models is a necessity for timber building design and this can be only done effectively with BIM. The lack of software was not deemed as the critical issue, but lack of standard solutions and models and interoperability of software were seen critical.

5.3. Demanding regulation

Demanding regulations were not highlighted in the literature from the view point of efficiency and saving waste. However, it became evident through the interviews that current status of legislation causes waste in the process. At the present moment, the communication with the authorities is more frequent than in typical projects. This is especially true concerning fire-technical issues, which are open for local interpretations and require negotiations with the local authorities. At present moment, weather covering is the most important additional requirement in construction stage, when comparing to traditional building projects. It seems that the weather covering needs to be developed in the future projects, as it brings delays and extra costs on site, if not planned and executed properly.

5.4. Experience in multi-story timer building

The literature review suggested out that adequate learning and communication has not taken place between timber building projects in the past. Similar results were found from the interviews. At the present moment, there are only a limited number of designers experienced on timber construction, and a limited number of completed projects. When considering that the structural systems are still developing, and that multiple different systems co-exist, it is evident that the ideal situation rarely realizes.

5.5. Procurement methods

The literature review pointed out that the design-bid-build system is a traditional way of procurement, involving the separation of design and construction services. The assessed cases both utilized design-build approach, in which the design and build are under control of the contractor. The results indicated that traditional design-bid-build is not the best option for timber construction, as cooperation between project parties, designer, architect, contractor, timber product manufacturer, is needed early on in the projects. The interviews underlined that in design-build-contract model, all the technical solutions should be agreed on between the contractor and the owner before signing the contract. At its best, the delivery form enables the contractor to utilize its full expertise and to conduct and benefit from research, development and innovation. It was apparent that if the structural system is still under development, the owner may limit the degree of freedom for the contractors to minimize their risks and impose extensive quality control requirements and measures.

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