TAMPEREEN TEKNILLINEN YLIOPISTO
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MARKET ENTRY POTENTIAL FOR FOREIGN COMPETITORS VIS-À-VIS FINNISH WOOD CONSTRUCTION MARKETS WITH AN EMPHASIS ON STRUCTURAL CONNECTIONS

Master of Science Thesis

Examiners: University Teacher Pekka Huovinen and Professor Kalle Kähkönen

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ABSTRACT

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This Master's thesis has been commissioned by Rotho Blaas S.r.l. of Italy. The main aim of the study is to design a strategy for the segmentation of and entry into the Finnish wood construction markets from the point of view of interested foreign manufacturers of structural connections. The conduct of this strategy design task was based on the three literature reviews (a desk study) and the theme interviews (a field study). Sub-aim 1 is to select and review the theoretical frameworks and typologies for the formulation of entry strategies especially with contexts embedded in foreign construction markets. In Ch. 2, the phases, the modes, and the key frameworks, the international expansion process and the Spearhead Entry Strategy, are reported upon. Sub-aim 2 is to review and understand the structural connection systems used in combination with engineered wood products. In Ch. 3, these highly technical results include the connecting solutions in the CLT, LVL, and Glulam assemblies. Sub-aim 3 is to investigate the wood construction in Finland via a desk study. In Ch. 4, the results cover the market development between the years 2005 and 2015 as well as the technical assessments and the certification systems currently used in Finland. New residential building production is taking place as multi-storey buildings also in the coming years. Typically, wooden frame structures are being recognized as structures for small buildings only. Thus, the Finnish wood products industry should renew its offerings and operating mode in order to meet this new evolving demand. This implies the development of systems for high wood-framed buildings and the increasing use of engineered wood products. Sub-aim 4 is to identify and analyze the key factors in competitiveness and procurement within wood construction in Finland via the theme interviews. In Ch. 5, the conduct of this field study and the key results are reported upon, by the four interviewee groups. In the same vein, the most interviewees stressed the importance of connections in big structures, i.e., they play a focal role in the enhancement of competitiveness of wood construction in the near future. The attainment of these four sub-aims, i.e., the results enabled to design a segment entry strategy for foreign manufacturers of structural connections. In Ch. 6, the framework of the Spearhead Entry Strategy is applied to this focal context. The segment entry strategy is designed in terms of screening a market potential, segmenting a target market, adapting a marketing mix, developing a marketing plan, and selecting a mode of entry. Interested foreign structural connectors should identify "soft" key decision-makers among wooden frame manufacturers and focus early marketing efforts on them. Finally, the conclusions are put forth. In Ch. 7, the analysis and critique of the study, the scope of strategy applications, and future studies are dealt with.

TIIVISTELMÄ

JARNO NASKALI: Ulkomaisten kilpailijoiden mahdollisuudet astua Suomen puurakentamisen markkinoille erityisesti rakenteiden liitosten alueella
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Tämä diplomityö on tehty italialaisen Rotho Blaas S.r.l.:n toimeksiannosta. Tutkimuksen päätavoitteena on suunnitella strategia markkinasegmentointiin ja toiminnan aloitukseen Suomen puurakentamisen markkinoilla kiinnostuneiden ulkomaisten kiinnitysjärjestelmien valmistajien kannalta. Tämän strategian suunnittelutehtävää varten on suoritettu kolme kirjallisuustutkimusta (kirjoituspöytätutkimus) ja teemahaastattelut (kenttätutkimus). Alatavoitteena 1 on valita ja kuvata teoreettiset viitekehykset ja luokittelut markkina-avausstrategioiden laadintaan erityisesti ulkomaisten rakennusmarkkinoiden kontekstien tapauksessa. Luvussa 2 raportoidaan ko. strategian laadinnan vaiheet ja moodit sekä kansainvälisen laajentumisprosessin viitekehys ja Keihäänkärkiavausstrategian viitekehys. Alatavoitteena 2 on esitellä ja näin ymmärtää kiinnitysjärjestelmät insinööripuurakenteiden yhteydessä. Luku 3 sisältää nämä teknisesti syvälliset tulokset eli liitosratkaisut käytettäessä CLT-, viilu- ja liimapuurakenteita. Alatavoitteena 3 on analysoida puurakentamista Suomessa kirjoituspöytätutkimuksen avulla. Luvussa 4 esitettävät tulokset kattavat markkinakehityksen vuosina 2005-2015 sekä Suomessa käytettävät tekniset hyväksynnät ja sertifiointijärjestelmät. Uusien asuntojen tuotanto painottuu kerrostaloihin myös lähivuosina. Tyypillisesti puurunkoratkaisujen mielletään soveltuvan lähinnä pientaloihin. Siten Suomen puutuoteteollisuuden tulisi uudistaa tarjontaansa ja toimintamalliaan vastatakseen kehittyvään kysyntään. Tämä tarkoittaa järjestelmien kehittämistä korkeisiin puurunkoisiin rakennuksiin ja insinööripuutuotteiden lisääntyvää käyttöä. Alatavoitteena 4 on tunnistaa ja analysoida avaintekijät puurakentamisen kilpailukyvyssä ja hankinnoissa Suomessa teemahaastattelujen avulla. Luvussa 5 raportoidaan tämän kenttätutkimuksen toteutus ja avaintulokset neljän haastateltavien ryhmän mukaan. Useimmat haastateltavista korostivat liitosten tärkeyttä suurissa rakenteissa ja näkivät liitokset merkittävänä tekijänä puurakentamisen kilpailukyvyn parantamisessa lähitulevaisuudessa. Näiden neljän alatavoitteen saavuttaminen ja ko. tulokset mahdollistivat segmenttien avausstrategian suunnittelun ulkomaisten, rakenteiden liitoksia valmistavien yritysten kannalta. Luvussa 6 sovelletaan valittuja prosessikehystä ja keihäänkärkistrategiakehystä puurakenteiden liitosten kontekstiin Suomessa. Segmenttiavausstrategiaan sisältyvät markkinapotentiaalin arviointi, kohdemarkkinan segmentointi, markkinointi-mixin sopeutus, markkinointisuunnitelman kehittäminen ja avausmoodin valinta. Kiinnostuneille ulkomaisille kiinnitysjärjestelmien valmistajille suositellaan ”pehmeiden” avainpäätöksentekijöiden tunnistamista puurunkoratkaisujen valmistajien joukosta ja markkinoinnin keskittämistä alkuvaiheessa heihin. Lopuksi tuodaan esille johtopäätökset. Luku 7 sisältää tutkimuksen analyysin ja kritiikin, strategian sovelluskentän käsittelyn sekä ehdotukset jatkotutkimuksen suuntaamiseksi.

FOREWORD

I initiated this study by proposing the topic to Rotho Blaas S.r.l based in Italy, one of the leading manufacturers of technical solutions for wooden buildings. I am hereby whole-heartedly thanking my former Colleague, the co-initiator of this study, the world's most Finnish-Spanish person, and my friend, Mr. Patricio Gomez-Salas Ramirez at Rotho blaas S.r.l, especially for many good conversations and being a great team player. I miss our collaboration.

This Master's thesis has been conducted in the area of Construction Management and Economics in the Laboratory of Civil Engineering at Tampere University of Technology (TUT). University Teacher, Lic.Sc., Pekka Huovinen and Professor Kalle Kähkönen assumed the dual roles of acting as the instructors and examiners of the Master's thesis. I would sincerely like to thank Pekka for good conversations, his help and endless ideas and professionalism. When I ran out of ideas, he always had plenty of them.

Moreover, I would like to thank my closest friends for the years we spent together during our degree studies at TUT. All of you recognize yourselves. Nowadays, many of you are located in Helsinki, but let's develop Tampere so that you can make a comeback!

Most of all, I would like to thank my parents for their endless support all along my studies. Mother, You always listened, if I complained, and encouraged, when I had doubts. Father, from Your example, I originally got a sparkle for this wood construction thing and I am lucky for having found my interest a long time ago.

From now on I hope my new path as an entrepreneur will be a rewarding experience.
Now I will go and grab a beer. Cheers!

Tampere, 30th of November, 2017

Jarno Naskali

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LIST OF TERMS AND ABBREVIATIONS

Block of flats building / Multi-storey building — Residential buildings of at least three dwellings in which at least two dwellings are located on top of each other and which do not belong to the previous categories. (Official Statistics of Finland 2016c)

CLT — *Cross Laminated Timber.* CLT is an engineered wood product that uses multiple layers of wood panels assembled crosswise on top of each other with adhesives. (Stora Enso Oyj 2016)

CE — Through a CE mark, a manufacturer can ensure that the properties of a construction product are in line with the harmonised European product standard, or the European technical assessment (ETA). (Ministry of the Environment 2016a)

Detached house — Residential buildings containing 1 to 2 dwellings, including semi-detached houses and other comparable detached residential buildings. (Official Statistics of Finland 2016c)

DoP — *Declaration of Performance.* The Declaration of Performance is a requirement for obtaining a CE marking for a product. The manufacturer draws up the Declaration of Performance according to a harmonised product standard (hEN) or the European Technical Approval (ETA). The Declaration of Performance must list all values regarding product properties that are required to meet the official regulations. (Ministry of the Environment 2016a)

Dwelling — A dwelling refers to a room or a suite of rooms which is intended for year-round habitation; is furnished with a kitchen, kitchenette or cooking area; and has a floor area of at least 7 square metres. Every dwelling must have its own entrance. A single-family house may be entered through an enclosed porch or veranda. If a dwelling is entered through the premises of another dwelling, it is not regarded as a separate dwelling but instead those two constitute one dwelling. (Official Statistics of Finland 2016c)

ETA *European Technical Assessment.* The European Technical Assessment is a document providing information about the performance of a construction product, to be declared in relation to its essential characteristics. (European Organisation for Technical Assessment 2016)

GDP *Gross Domestic Product.* GDP, gross domestic product at market prices is the final result of the production activity of resident producer units. It can be defined in three ways: as the sum of gross value added of the various institutional sectors or the various industries plus taxes and less subsidies on products; as the sum of final uses of goods and services by resident institutional units (final consumption, gross capital formation, exports minus imports); as the sum of uses in the total economy generation of income account (compensation of employees, taxes on production and imports less subsidies, gross operating surplus and gross mixed income). (Official Statistics of Finland 2016)

GL *Glued Laminated Timber / Glulam.* Glulam is an engineered wood product that uses multiple layers of wood panels assembled in the same direction on top of each other with adhesives. (Finnish Glulam Association ry and Puuinfo Oy 2014)

hEN *Harmonized European Product Standard.* European harmonized product standard, which automatically leads to CE marking. (hEN Helpdesk 2016)

LVL *Laminated Veneer Lumber.* LVL is an engineered wood product that uses multiple layers of thin wood veneers assembled with adhesives to form a continuous plate. (Metsä Wood 2016)

VTT	*VTT Technical Research Centre of Finland Ltd* is a national research centre of Finland and one of the leading research and technology organisations in Europe (VTT 2017)

1 INTRODUCTION

1.1 Background of the study

A need for this study was acknowledged when an internationally operating manufacturer of wood construction products, Rotho Blaas S.r.l, made in the year 2014 a decision to enter wood construction markets in Finland. The company is based in the Northern Italy. The company was already operating in the two Scandinavian countries, i.e., Norway and Sweden. By that time, the management had learned that country-specific experiences are neither directly comparable, nor applicable to a new neighboring country like Finland. Thus, the management felt that a study of the Finnish wood construction markets be conducted in order to enable proper understanding of local construction practices, traditions, and building trends. In turn, such understanding was needed for making decisions on future operations

1.2 Aims of the study

The main aim of the study is to plan and suggest a strategy for the segmentation of and entry into the Finnish wood construction markets from the point of view of interested foreign manufacturers of structural connections. The technical emphasis is on big structures made of engineered wood products such as cross laminated timber (CLT), laminated veneer lumber (LVL), and glulam (GL). The main aim has been approached via the four sub-aims as follows:

1. To identify, select, and review the key theoretical frameworks and typologies for formulating a company's international expansion strategies.

2. To introduce and analyze the solutions used as the connections in the wooden frame structures in Finland - particularly in a combination with engineered wood products consisting of CLT, LVL, and GL.

3. (a) To investigate the development of wood construction markets in Finland during a period of the years 2005-2015 as part of the total building construction sector and by the major building types, and (b) to learn about the technical requirements and assessments as well as the certification systems governing wood construction in Finland as one of the EU member countries.

4. To explore the competitiveness of wood construction and related professional practices in design, contracting, manufacturing, and purchasing in Finland empirically from the point of view of the four stakeholder groups.

1.3 Limitations of the study

The international scope of the study is theoretically limited to a company's international business expansion and therein the focus is on a foreign entrant planning and executing its entry and penetration process in a new target country. This focus corresponds to the real entry problem that triggered this study, i.e., the Italian case company had started to plan their first operations in the Finnish markets in the year 2015.

The technical scope of the study is contextually limited to big wooden structures used in load-bearing framing in multi-storey buildings and hall buildings in Finland and similar country contexts. Among big wooden structures, the study deals only with the three kinds of engineered wood structures, i.e., CLT, LVL, and GL. The focus is on the main connection types used in these three structures.

The two-part market scope of the study is contextually limited to the building construction sector and therein the wood construction markets in Finland. The first part deals with the role, national associations as well as the building type-specific volumes and market shares of the wood construction. The second part deals with the regulation, the technical assessments, and the certification systems in the context of Finland.

The solution scope of the study is limited to the design of a strategy for entering the wood construction markets in Finland from the point of view of foreign manufacturers of structural connections. The design is based on the choice and application of one of the existing frameworks in the literature as well as the key results of the study to be produced by its international, technical, and market scopes.

1.4 Conduct and reporting of the study

The study process was divided into the three phases, i.e., a desk study, a field study, and a solution development. The desk study consisted of a 3-part literature review and the results have been reported in Chapters 2, 3, and 4. The field study involved the theme interviews and the conduct and the results have been reported in Chapter 5. The solution was developed based on these study results and suggested for foreign entrants in Chapter 6.

In Chapter 2, the international expansion frameworks and typologies selected from within the literature are reviewed. Cateora et al. (2011) divide their generic expansion process into the four phases wherein also the selection of a mode of entry is included. Chen and Messner (2009) emphasize the key aspects in choosing a particular mode for entering international construction markets. In turn, Huovinen and Kiiras (1998) define the entry problem, design the 6-element framework, Spearhead Entry Strategy, and determine alternative entry positions related to competitive arenas in international building markets. In this study, the spearhead framework has been applied to formulating a solution for the foreign market entry problem at hand.

In Chapter 3, the products and the technical solutions for the connections of the wooden frame structures known in the professional literature and used also in Finland are reviewed. The types of the wooden frame structures in single- and multi-storey buildings are introduced. The structural connections for wood are briefed. The detailed focus of the review is on the connections used as part of the three kinds of the engineered wood products: CLT, LVL, and GL.

In Sub-chapters 4.1-4-4, the developments in the building construction sector and particularly the wood construction markets in Finland are analyzed over a period of the years 2005-2015. The available national statistics have been relied upon. The national associations of the wood working industries are listed. Multi-storey buildings involve 4-storey and higher wooden blocks of flats and other spaces. The roles and shares of the wood framed buildings are analyzed in the four segments of detached houses, free-time houses, multi-storey buildings, and hall buildings. In Sub-chapter 4.5, the regulation, the technical assessments, and the certification systems related to the wood construction in Finland are briefed. A combination of the EU regulation and the national procedures is addressed.

In Sub-chapter 5.1, the conduct of the theme interviews is clarified in more detail. The competitiveness of the wood construction industry and the related professional practices are explored. In total, the 14 professionals in the wood construction markets were interviewed. In Sub-chapter 5.2, the results are presented and interpreted by the four groups of the interviewees: investors, designers, wood element manufacturers, and contractors.

In Chapter 6, a segment-based entry strategy is suggested for foreign manufacturers of structural connections for entering the wood construction markets in Finland. The strategy with the recommended actions have been designed by applying Cateora et al.'s (2011) expansion planning process and Huovinen and Kiiras' (1998) entry strategy framework and by taking into account the results in Chapters 3-5.

In Chapter 7, the conduct and results of the study are being criticized, the contribution of the study is stated, and some promising directions for future research are put forth.

In Chapter 8, the conduct, the key results, and the concluding remarks are summarized.

2 SELECTED THEORETICAL FRAMEWORKS AND TYPOLOGIES FOR FORMULATING ENTRY STRATEGIES WITH CONTEXTS IN FOREIGN CONSTRUCTION MARKETS

2.1 Process of international expansion planning

A new foreign entrant should make several decisions before trying to step on a new market area. For each new country, an entrant selects an entry product from among its current products and adapts this product with related resources to targeted local conditions. When a company is already committed, the key decisions involve the allocation of efforts and resources among countries and products, the choosing of new market segments as well as the launching of market developments or, alternatively, the abandoning of some potential markets at early phases. Guidelines and systematic procedures are necessary for the evaluation of international opportunities and risks and the development of strategic plans in order to take advantage of such opportunities. Thus, the following *Phases 1–4* offer a systematic guide to plan a company's international expansion across several countries.[1]

Phase 1: Preliminary Analysis and Screening – Matching Company and Country Needs.[2] The first task is to evaluate both the characteristics of potential markets in preselected countries and a company's internal capabilities to enter new markets over barriers (Figure 2.1, the 1st column). Critical choices for an entrant involve accepting potential countries for deeper reviews and at the same time rejecting other countries that are not potential enough. These choices are based on a match between a focal company and each country's market potential and constraining factors. Internally, management analyses and screens many factors, such as business objectives, capabilities, strengths and weaknesses, a range of products, and company philosophy.

Externally, environments can be scanned as a process of collecting, scrutinizing, and providing necessary information.[3] Criteria are established for screening potential new markets. Reasons for penetrating new markets are determined including an estimate of returns from such an investment. For future action, minimum requirements for criteria are set, such as minimum market potential, minimum profit (also related to return on investment), the acceptable levels of competitive and political situations together with

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[1] Cateora, P. et al. 2011 p. 340

[2] Cateora, P. et al. 2011 p. 340-341

[3] MSG Management study guide 2016a

national legal requirements and market trends. Environments consist of controllable and uncontrollable elements set by both a company's home country and host countries.[4] By managing and developing controllable elements, usually set by a company and a home country, it is possible to be prepared for surprises by uncontrollable elements in a host country. Phase 1 results in the specification of the operations needed for the understanding of acquirements for further actions within selected countries. The environmental scanning of selected countries can be repeated and improved on a continuous basis.[5]

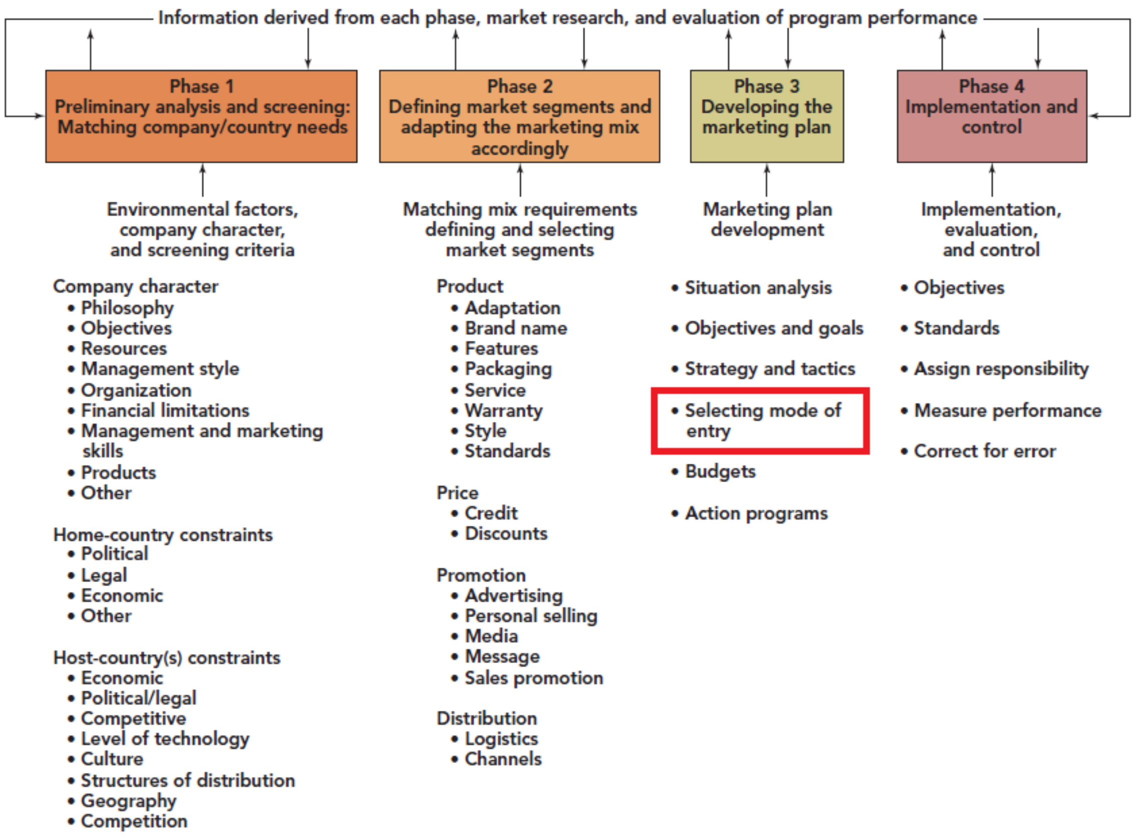

Figure 2.1 Process of the planning of a company's entry into a new country (Source: Cateora, P. et al. 2011, p. 341)

Phase 2: Defining Target Markets and Adapting the Marketing Mix Accordingly [6]. The main idea is to select and adapt a marketing mix properly according to a host country's behavior based on the information collected in the previous phase. It is critical that uncontrollable elements be recognized and understood when choosing a marketing mix towards a host country environment. Wrong or vague information may lead to wrong choices in pricing, advertising, or promotion, which can prove to be extremely costly and hard to fix. In Phase 2, the collected information is exploited in addressing the three major questions, i.e., "Are there identifiable market segments that allow for a common marketing mix tactics across countries?", "Which cultural/environmental adaptations

[4] Koch, A. J. 2001 p. 354-358
[5] MSG Management study guide 2016a
[6] Cateora, P. et al. 2011 p. 342-343

are necessary for the acceptance of a marketing mix?", and "Will adaptation costs allow a profitable market entry?" Phase 2 results in rejections and acceptance. By finding the answers to these questions, some countries logically become rejected because of a lack of potential, uncertainty, or too high costs. Instead, many countries with assessed high potentials are accepted.

Phase 3: Developing a Marketing Plan for a Target Market in a Selected Country [7]. Planning begins with a situation analysis based on the previous phases. Factors influencing objectives setting need to be analyzed. A company sets long-term objectives. A company must practically fix the quantitative target values for some objectives. New potential markets are compared with existing long-term customers, in order to evaluate contributions that might be made by product zones or operating departments.[8] Next, a strategy is formulated and a tactics is specified as the mediums for the attainment of the objectives. Thereafter, strategic entry decisions can be taken. A company may choose from among four different modes of foreign market entry: exporting, contractual agreements, strategic alliances, and direct foreign investment. Based on the selected mode of entry, a company creates an action program. An entry plan establishes what is to be done, by whom, how it is to be done, and when. A plan includes also budgets, sales, and profit expectations. In the end, an entrant has to make a final decision of market entry: to go or not to go. Phase 3 results in a marketing plan, including the selection of an entry mode, a budget, and an action plan.

Phase 4: Entry Implementation and Control [9]. A marketing plan requires coordination and control during the period of implementation. Continuous monitoring and control can increase success. Under control, an entrant is more awake about a situation and capable to make fast corrections if some meter obviously is moving towards problems. If a company is spreading its business to many new countries simultaneously, this weakens the control of the implementation of a marketing plan almost without an exception.

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[7] Cateora, P. et al. 2011 p. 343

[8] MSG Management study guide 2016b

[9] Cateora, P. et al. 2011 p. 344

2.2 Alternative modes for entering international construction markets

The choice of a mode of foreign market entry is critical and related to risk and control. The choice of a mode of entry defines an entrant's operations and affects future decisions concerning a target market in a selected country. Control enables an entrant to deal with risks and returns, relational friction between buyers and an entrant, and, ultimately, the performance of a foreign entry investment. The methods of foreign market entry mode may be divided in high control entry modes with greater risk (direct foreign investments, strategic alliances) and low control entry modes (exporting, licensing and franchising, and contractual agreements) with less risk (Fig. 2.2).[10]

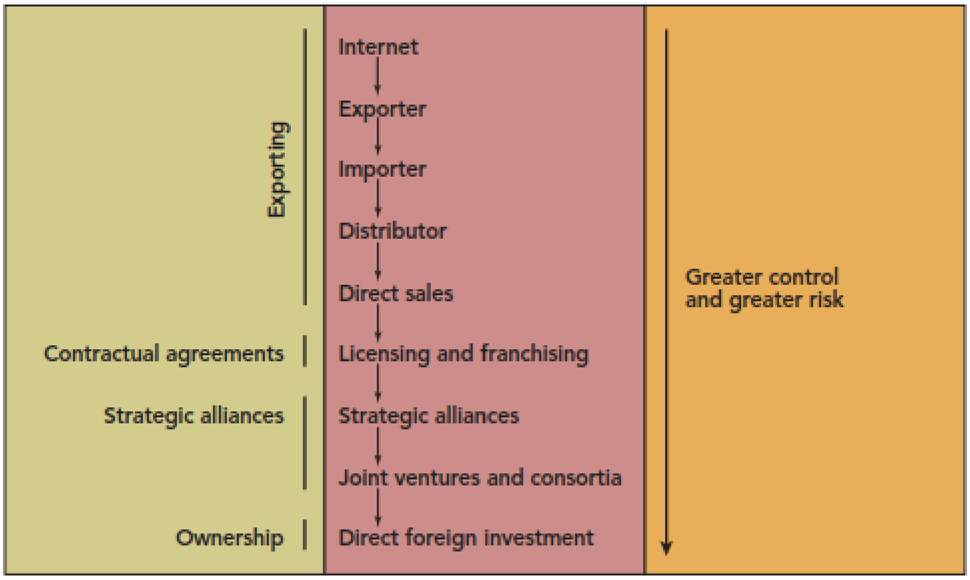

Figure 2.2 Alternative market entry modes (Source: Cateora, P. et al. 2011 p. 345)

EXPORTING

The Internet is becoming increasingly important as a foreign market entry method for large and small companies alike. Companies are crossing borders of countries and continents and, thus, receiving orders from customers located in other countries. International marketing and sales via the Internet involves the design of Internet catalogues and the targeting of specific countries with multilingual company Web sites and online shops. However, the laws of Internet marketing are varying between countries and might become hard to control. Indeed, the taxation of Internet sales causes a great concern. Many unexpected problems appear and companies need to tackle them accordingly.[11]

[10] Blomstermo, A. et al. 2006 p. 214
[11] Cateora, P. et al. 2011 p. 345-346

Exporting can be either direct or indirect. With indirect exporting, a company sells its product to a middleman, traditionally an exporter or a distributor in a home country, which in turn exports this product. Customers include large retailing chains, supply and trading companies, and other buying firms, which supply customers abroad. In contrast, with direct exporting, a company sells directly to customers in other countries. Most commonly, companies use direct exporting for taking their first international steps since it involves low risks of financial losses. In turn, direct sales may require the establishment of a representative office in a host country, particularly with high-technology products and project articles. It is a quick and relatively simple way to establish a formal presence and to employ local management and staff. In addition, companies may rely on local sales agents. All this is dependent on market size and expected sales revenues.[12]

In addition, companies support their construction businesses in various countries by engaging themselves with local agents. Typically, agents provide information about market conditions, important contacts, and assistance in administration and logistics. In some countries, it is mandatory to have a local agent before bidding for projects.[13]

LICENSING AND FRANCHISING

The contractual agreement mode of entry includes licensing, franchising, or technology transfer. Parties in different countries sign a contract on a licensee's use of limited rights or resources like patent rights, trademark rights, and rights to use technological processes. For example, the revenues from licensing are usually lower than the revenues from modes of direct foreign market presence. Advantages of licensing are most apparent when capital is scarce, import restrictions forbid other means of entry, a country is sensitive to foreign ownership, or patents and trademarks must be protected against cancellation or non-use. Risks involve the choice of a wrong licensee and bad quality resulting in damage to a licensor's trademark and reputation. Moreover, a foreign licensee may become a competitor of a licensor. [14]

STRATEGIC ALLIANCES

A strategic alliance is a long-term business relationship established by two or more companies to cooperate out of mutual need and to share risk in achieving a common objective. Within an alliance, companies agree to share resources, technology, and profits as well as to supplement each other's needs for a long period. Motives include opportunities for a rapid expansion into new markets, access to new technology, a more efficient production and innovation, reduced marketing costs, strategic competitive moves, and access to additional sources of products and capital. Strategic alliances often contribute nicely to profits.[15] A strategic alliance does not incorporate a subsidiary, an affil-

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[12] Chen, C. and Messner, J. I. 2009 p. 5-6

[13] Chen, C. and Messner, J. I. 2009 p. 5-6

[14] Chen, C. and Messner, J. I. 2009 p. 6

[15] Cateora, P. et al. 2011 p. 349

iate, or a partnership. It is formed for a long period or a group of projects. A local partner is acquainted with local construction codes and market conditions.[16]

JOINT VENTURES AND CONSORTIA

A joint venture is a partnership of two or more companies that have joined forces as a separate legal entity. A joint venture can be on a project basis or a company basis. A project-based joint venture, sometimes called a consortium or a contractual joint venture, is a mode in which profits and other responsibilities are assigned to each party according to a contract. Revenues and responsibilities do not necessarily accord with each partner's percentage of a total investment. Partners have an option to form a limited liability entity or a partnership with or without a legal person status, similar to a joint venture company, but even if a company is formed, this entity exists for the sole purpose of completing a specific project. A project-based joint venture can provide flexibility and mobility in foreign market conditions and save costs by using overseas partners' infrastructure and liability limitations. The head office of an internationally operating corporation can also form a project-based joint venture with its own subsidiary in a host market.[17] In turn, the legal form of a company-based joint venture may be a corporation or a partnership. A specific partner enters into a majority, equal, or minority joint venture, depending on an equity percentage. Each partner may contribute in terms of cash, facilities, equipment, materials, intellectual property rights, or labor in order to set up a company-based joint venture.[18]

DIRECT FOREIGN INVESTMENT

Direct foreign investments may take place as investments in local companies, the acquisitions of local companies, or the establishments of new operations facilities like local branch offices or manufacturing plants. Local firms can undertake business transactions in a host country and enjoy many benefits, such as a substantial technology transfer and a capability to export to a more diversified customer base. Several factors influence the structure and performance of direct foreign investments: (i) first movers with advantages and risks, (ii) contract complexity and contingencies, (iii) transaction cost structures, (iv) technology and knowledge transfer, (v) degrees in product differentiation, (vi) the previous experiences and cultural diversity of acquired firms, and (vii) advertising and reputation barriers.[19]

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[16] Chen, C. and Messner, J. I. 2009 p. 4
[17] Chen, C. and Messner, J. I. 2009 p. 5
[18] Chen, C. and Messner, J. I. 2009 p. 7
[19] Cateora, P. et al. 2011 p. 355

2.3 Framework for formulating spearhead entry strategies with foreign building product markets

2.3.1 Foreign entry problem and its 6-element solution

The problem of entering building product markets in a new, neighboring EU country is herein addressed through the framework of the Spearhead Entry Strategy. Initially, the foreign entry problem is divided into the three sub-problems, i.e. “What kind of offerings?”, “What kind of capabilities?”, and “How to enter a new market segment?” (Fig. 2.3). These sub-problems are a result of ‘’hard’’ walls that a foreign entrant faces when entering a new country. A hard wall consists of resisting local architects, contractors, engineers, investors, suppliers, officials, and other stakeholders with their negative attitudes towards a change of their environment. It also contains local building regulations, contracting rules, and traditional construction practices. Thus, it is likely that foreign entrants keep trying to sell their products to potential clients with extremely high internal, mental barriers in vain, i.e., without any real possibilities of future sales. However, it is herein assumed that it is possible for foreign entrants to identify and focus on those “soft” clients whose doors may readily be half-open to new entries.[20]

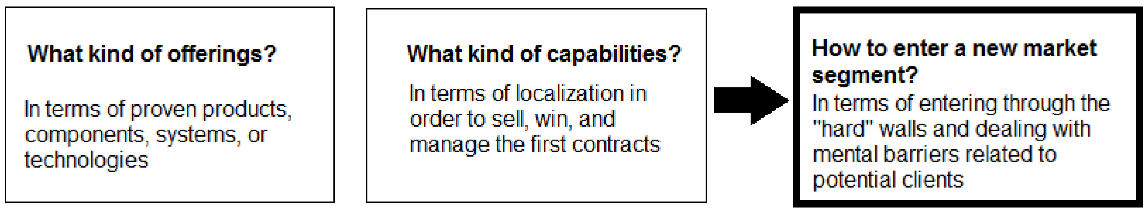


Figure 2.3 Three sub-problems of a foreign entry problem vis-à-vis building markets (Source: Huovinen, P. and Kiiras, J. 1998)

As a solution to the foreign entry problem, Huovinen and Kiiras (1998) have designed the Spearhead Entry Strategy with its six lean and product-based elements, i.e., (1) the choice of a proven entry product, (2) market segmentation and soft client identification, (3) product adaptation, (4) product differentiation, (5) capability localization, and (6) sales rationale and arguments (Fig. 2.4).[21]

[20] Huovinen, P. and Kiiras, J. 1998
[21] Huovinen, P. and Kiiras, J. 1998

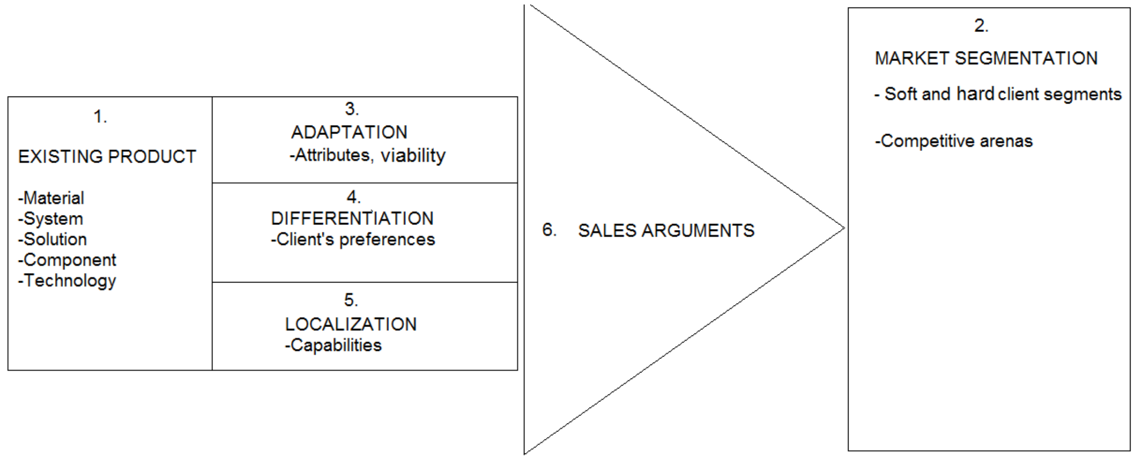


Figure 2.4 Six elements of the Spearhead Entry Strategy (Source: Huovinen and Kiiras 1998)

2.3.2 Choice of a proven entry product

An entry product, service, or technology is chosen from a range of proven, existing products with the pre-existence of exports production capacity. Accordingly, an investment in a new market includes only product adaptation and differentiation as well as local promotion and direct sales. Element 1 corresponds to the direct exporting mode (Phase 3; in Sub-chapter 2.1). In other words, an entrant neither invests in the development of a new entry product, service, or production technology, nor builds up a local production capacity in order to avoid foreign direct investments with high risks. [22]

2.3.3 Positioning of a foreign entrant into competitive arenas

Market segmentation is a critical phase, i.e., an entrant is choosing and focusing on the first potential client segments. A degree of entry success determines consecutive operations in a host country. The aim is to identify and focus on soft clients with positive signals and not to waste time and efforts on likely hard clients. The pre-screening of potential markets is carried out as a desk study, relying on available statistics, reports, etc. In the field, a lean client search covers and the interviewing is directed toward both hard and soft clients. [23]

[22] Huovinen, P. and Kiiras, J. 1998
[23] Huovinen, P. and Kiiras, J. 1998

A foreign entrant may target and divide building markets into the arena of supplies and the arena of buildings. Based on the results of the desk study, an entrant may choose from among the four alternative entry positions related to these two Porterian[24] competitive arenas (as shown in Fig. 2.5). (1) A direct entry to the arena of supplies means that a foreign entrant plans to join competing subcontractors, wholesalers, sales agencies, suppliers and engineers where potential buyers and decision-makers include architects, contractors, building owners, wholesalers, or other suppliers. This entry position offers a less risky possibility to enter a new market with a reduced range of products and, thus, an entrant can first learn local construction conditions and practices. (2) An indirect entry to the arena of supplies means that an entrant plans to export or sell its accumulated knowledge about product designs and life-cycles, production processes, or assembly techniques to current competing suppliers. An entrant may transfer and sell such knowledge through licensing and delivery contracts. In turn, (3) a direct entry to the arena of buildings means that an entrant plans to join current competition by playing the same role as design-and-build contractors but with its own building systems and products. (4) An indirect entry to the arena of buildings means that an entrant plans to open a market by providing its own building systems to current competitors through licensing or plant delivery contracts.[25]

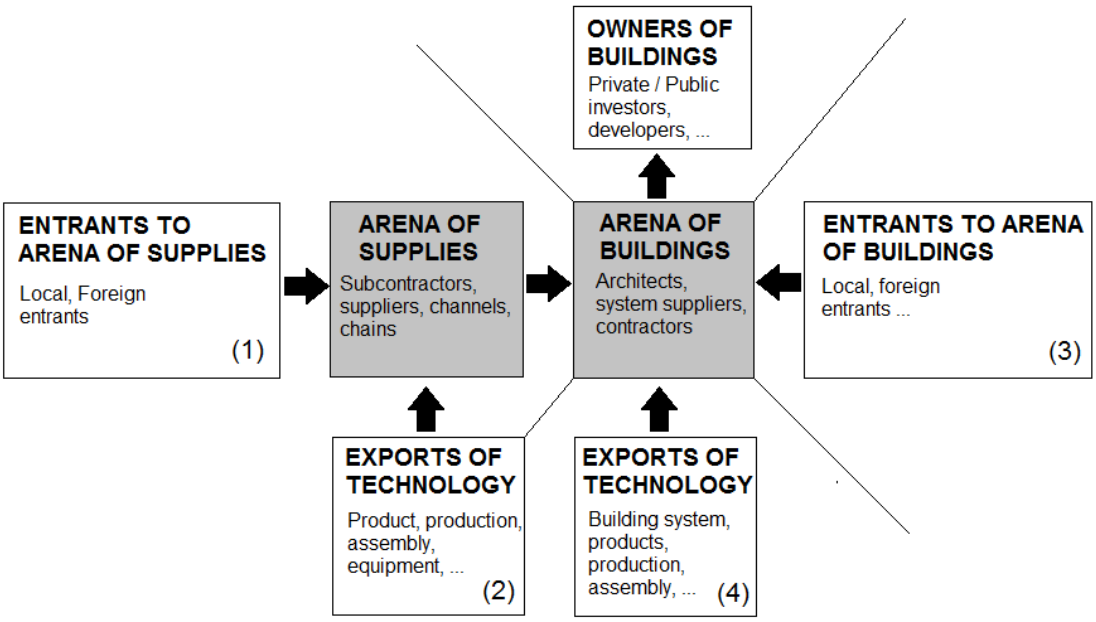


Figure 2.5 Two competitive arenas and four alternative entry positions in building markets, available to a foreign entrant (Source: Huovinen, P. and Kiiras, J. 1998 p. 8)

[24] Porter, M. E., 1980 etc. p. 396
[25] Huovinen, P. and Kiiras, J. 1998

2.3.4 Adaptation and differentiation of a foreign entrant's building product

The aim of the adaptation of a foreign building product is to minimize technical and other risks related to an entrant's product attributes and technical viability, and to find out margins for a product range and the tailoring of products. Common standards and regulations are simplifying the transfer of goods between the EU countries. Concerning building markets, national annexes differ from each other mainly due to climate conditions and local traditions. Local product requirements are often a combination of country, region, city, and client specific requirements (such as laws, directives, standards, regulations, buying criteria, and conditions of building contracts). A particular entrant may meet resistance among local officials and competitors who intend to slow down a product approval process and to restrict significantly its application area. An entrant can ensure that its existing building system, product, or component meets local requirements by collaborating with local designers, technical and contractual experts, having an entry product tested, getting certificates, entering into a local quality control system, and procuring crucial or locally/uniquely specified components and trade contracts from a local subcontracting market.[26]

The differentiation is geared towards potential clients and in relation to current competitors. Typically, an entrant can differentiate along its entry product scope and/or contractual form. The differentiation of a new building system or product, and related production technology can be based on the attribute(s) that potential clients find highly attractive, distinguished architectural design, or prefabrication with exceptionally high quality or modularization. Instead of lowest prices, an entrant can provide a unique product with better performance compared to products available in a market. An entrant's pricing and profit margin may be on a higher level versus client benefits. An entrant may also introduce a well-known product or material for a completely new area of application.[27] The differentiation along contractual forms may involve an entirely new or modified contractual form, from a potential client's point of view.

[26] Huovinen, P. and Kiiras, J. 1998a

[27] Huovinen, P. and Kiiras, J. 1998b

2.3.5 Localization of a foreign entrant's capabilities

The localization of an entrant's in-house capabilities may concern all the knowledge, skills, and systems that an entrant needs in order to market and sell its product to local clients, and if successful, to deliver its products, too. An entrant may try to change local procurement practices or distribution rules, provided it possesses a design ability to increase flexibility, installment services, etc. to guarantee performance. An entrant gets access to local competences by collaborating with a local operator, recruiting a local representative and staff as well as arranging consultancy and training for all key personnel in a host country.[28]

2.3.6 Client buying behavior and the sales arguments of a foreign entrant

Most selling problems in new markets relate to local buying behavior wherein the buying centers of potential clients are influenced by local building practices and competing sellers with their building products. Thus, the sales rationale and arguments of a foreign entrant should be based on the learning and understanding of procurement processes and therein especially elimination procedures among soft clients. It is assumed that, in their minds, decision-makers pick up one or two factors as the criteria for this elimination[29]. Typically, the decision-makers of clients eliminate foreign entrants and their new products because an entrant does not offer the lowest price, a client relies on the same, known suppliers, or a client perceives too high a degree of uncertainty. Thus, a foreign entrant may plan its sales rationale and present sales arguments in the order of (i) detecting and dealing openly with reasons for a client's possible negative attitude, (ii) discussing perceived and true weaknesses related to a product, (iii) addressing actively uncertainties and risks that a client perceives, (iv) exploring opportunities to support a client's buying and other business processes, and finally (v) convincing decision makers of benefits related to an entrant's product and performance.[30]

In addition, an entrant can become sensitive to the professional buying rationale inherent in the five primary supply channels for building products or systems. An entrant focuses on the channel-specific clients, identifies decision-makers, and matches its sales arguments with the buying criteria of such channel-specific clients (Fig. 2.6). [31]

[28] Huovinen, P. and Kiiras, J. 1998a
[29] Wichmann, M. et al. 1999
[30] Huovinen, P. and Kiiras, J. 1998b
[31] Huovinen, P. and Kiiras, J. 1998a

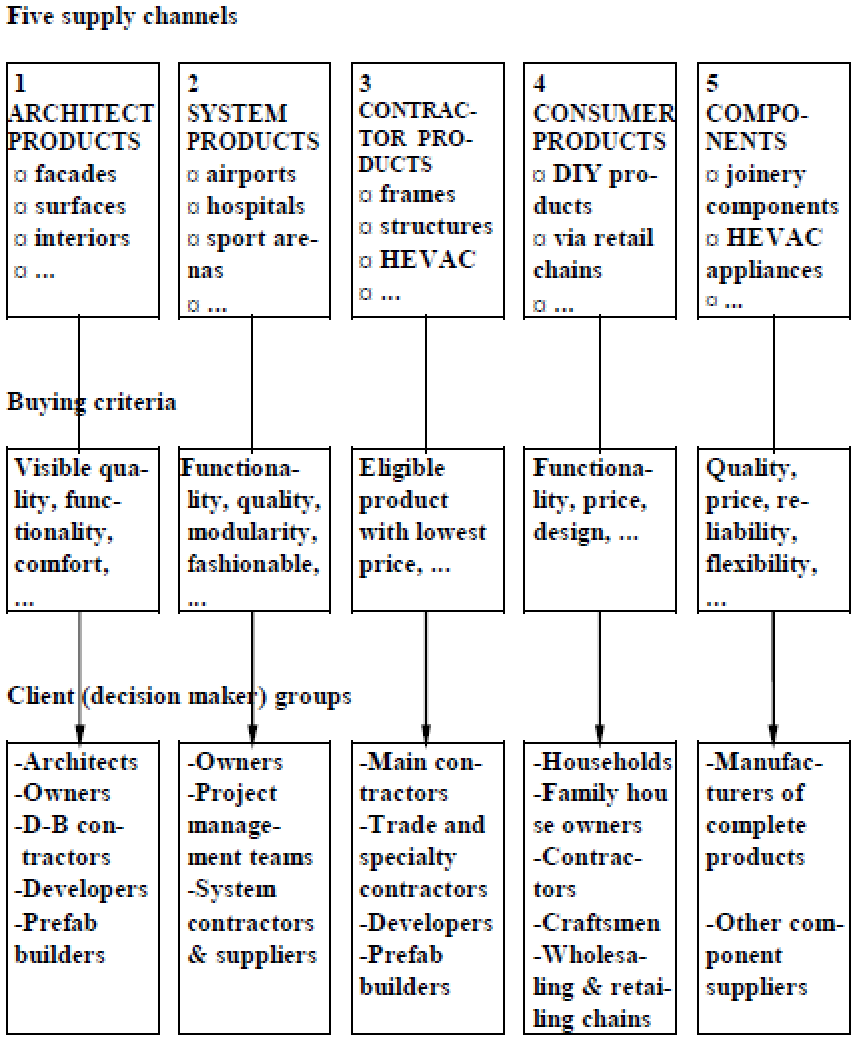
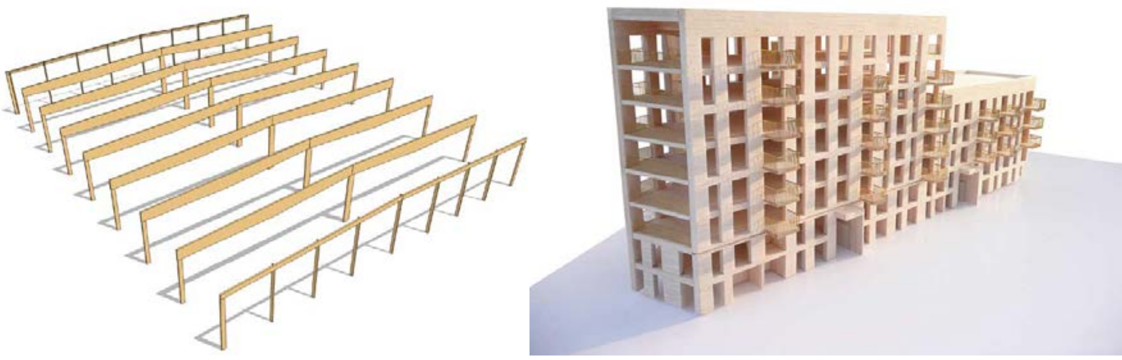


Figure 2.6 Five alternative supply channels for exporting building products. Key: HEVAC stands for heating, ventilation, and air-conditioning. Prefab stands for prefabrication. DIY stands for do-it-yourself. D-B stands for design-build. (Source: Huovinen, P. and Kiiras, J. 1998)

3 EXISTING PRODUCTS AND TECHNICAL SOLUTIONS FOR CONNECTIONS IN WOODEN FRAME STRUCTURES

3.1 Categories of wooden frame structures

Wooden frame structures are used in the two categories of single-storey and multi-storey buildings. In both of them, wooden load-bearing frame structures can be realized as beam-and-post frame systems or load-bearing wall systems. In Finland, beam-and-post frame systems are more common in single-storey hall buildings (Fig. 3.1a) and load-bearing walls are more common in multi-storey buildings (Fig. 3.1b). The focus of this study is on structural connections in load-bearing frames made of CLT and beam-and-post frames made of LVL and GL.



(a) Single-storey frame (b) Multi-storey frame

Figure 3.1 Wooden frame solutions for single-storey and multi-storey buildings (Source: Powney, S. 2011)

3.1.1 Single-storey buildings

Large single-storey buildings with wooden frame structures are mainly used as warehouses, industrial buildings, sports halls, ice-hockey halls, trade fair and expo halls, swimming halls, agricultural buildings like manages for horses, and commercial buildings. All of them involve multiple different framing solutions. Wooden structures enable the flexible execution of buildings by various sizes and shapes to address different needs among investors and users. From among numerous variations, it is possible to choose the most viable solution to meet the economic, technical, and architectural requirements of each client and its building. Requirements are varying from high-profile architecture in public buildings to fast erections on sites for industrial and commercial purposes.[32]

In single-storey buildings, wooden frame structures like columns, beams, and secondary beams are applicable. The most critical factors in determining frame structures are open space needs and horizontal spans. Other factors include accommodation for future expansions, purposes of buildings versus fire regulations, architectural requirements, and economic solutions for clients.[33]

In large sports halls, mainly long distance arch structures are used due to their high load-carrying capacity allowing for open spaces. In agricultural buildings, common solutions involve three-pinned portal frames that offer large, high, and open spaces. In industrial buildings, large floor areas and moderate heights are enabled by using mast columns and proper beam types (Fig. 3.2). The use of mast columns accommodates possible future expansions.

Figure 3.2 Mast frame for a single-storey hall building carried out with a boomerang beam and braced with large roofing elements (Source: Puuinfo Oy 2009 p. 74)

[32] Puuinfo ry 2009 p. 10

[33] Puuinfo ry 2009 p. 10

In single-storey halls, a very common frame solution is a portal frame (Fig. 3.3). Portal frames do not require massive foundations because all connections between haunches and pillar bases are schematized as hinges. In poor soil ground conditions, horizontal reactions at supports can be undertaken by installing tension bars between foundations placed inside or under a ground floor. Therein, a load on a substrate is principally vertical. In order to avoid creep on an apex, the angle of a slope should not be less than 14 degrees.[34]

Figure 3.3 Portal frame for a single-storey hall building carried out with bolted or screwed haunches and braced with large roofing elements (Source: Puuinfo Oy 2009 p. 82)

Theoretically, the spans of three-pinned portal frames could be up to 40 meters. However, logistics is in practice limiting measures down to a principle that frame structures shall not exceed a total length of 24 meters and a total width of 3,7 meters for avoiding problems in logistics chains.[35]

The three main alternatives to realise three-pinned portal frames consist of (a) curved haunches, (b) finger jointed haunches, and (c) built-up haunches (Fig. 3.4). Since haunches are vertical without any distracting columns, finger jointed haunches enhance more efficient use of floor areas close to walls. This can be an advantage in commercial buildings or warehouses wherein many racks are placed for hundreds of articles.[36]

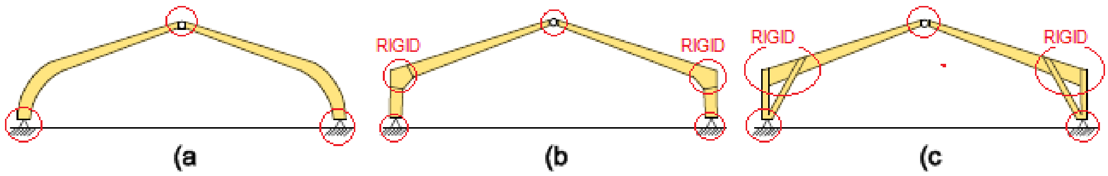


Figure 3.4 Three-pinned portal frames: (a) curved haunches, (b) finger jointed haunches, and (c) built-up haunches
(Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 162)

[34] Nordic glulam handbook 2001 p. 89-90
[35] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 162
[36] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 162

3.1.2 Multi-storey buildings

The wood building construction techniques have originated from the use of American platform systems to the construction of timber building frames on-site. Over time, these methods have been developed to currently used modular systems and load-bearing wall elements, enabled by the light self-weight of wood. A mass of a multi-storey building with a wooden frame is only one fifth of that of a building with a concrete frame. When wooden frames are used, there are much smaller vertical loads onto foundations. This causes more uplift to structures. In turn, uplift can be kept as small as possible by using high and bracing mast-walls. One of the observed challenges is related to structural connections as anchoring the tensile strength of joints and bearing stresses between the surfaces of two wooden elements. Another challenge involves the control of acoustic and vibrational functionality in buildings. Neither walls, nor intermediate floors are braced continuously since intermediate flooring needs to be divided into fields in accordance to sharing walls between apartments in order to reduce the transition of vibration and acoustic noise between structures.[37] Since wood is a hard and light material, it is prone to transfer low frequencies between structures. This leads to the use of different types of acoustic reduction materials between structures.

According to Kevarinmäki[38], the three focal features are required from a load-bearing frame system of a wooden multi-storey building, i.e., (i) the simplicity of routes for transferring loads, (ii) the simplicity of a bracing system, and (iii) the simplicity of the connections between bracing structural elements.

There are the three major building systems to produce wooden load-bearing frame structures for multi-storey buildings. (a) Load bearing walls also known as a mast-wall system is the most common wooden framing system in multi-storey buildings in Finland (Fig. 3.5a). Bracing walls are chosen from among the most stressed load bearing walls for reducing uplift, combined with the use of a horizontally bracing intermediate flooring.[39] Load-bearing walls can be realized by using one of many alternative systems, such as load-bearing timber frame wall elements or massive wood elements made of CLT or LVL. Principles for bracing are similar in the case of timber frame elements and massive wood elements. A diverging factor lies therein that massive wood elements have themselves a strong internal stiffness, while timber frame elements are braced by gypsum boards or wood panels.

[37] Lepikonmäki, L. 2014
[38] Kevarinmäki, A. 2016 p. 40
[39] Lepikonmäki, L. 2014

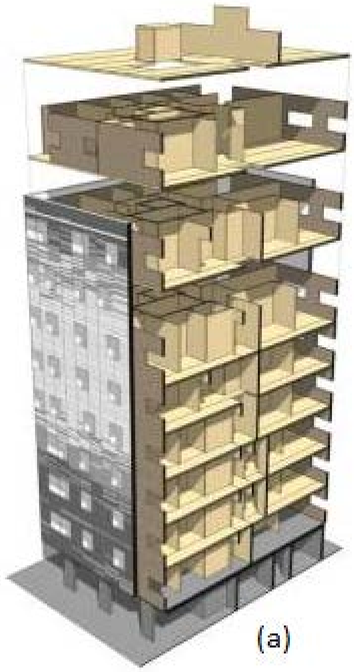


Figure 3.5 Wooden frame solutions for multi-storey buildings: (a) load-bearing walls system and (b) modular system (Source: Lahtela, T. 2014 and Weber Thompson 2013)

In prefabricated modules systems, ready-to-assemble modular space units are assembled in a factory including a façade, walls, windows, a floor, a roof, HEVAC, thermal insulation, interior materials, and fixtures (Fig. 3.5b). Typically, the maximum dimensions of a prefabricated space module are 12 x 4.2 x 3.2 that accommodate logistical limitations. The load-bearing structure of a box element can be realized by many different methods, for example, by using a column-beam system, a timber frame structure or CLT massive wood panels.[40] In Finland, the most common load-bearing frame structure for a modular multi-storey building is CLT. Therein, bracing is solved by using a mast-wall system and a so-called 'tower reinforcement' consisting of building modules installed on top of each other. Mast walls are located symmetrically, high enough, and continuously based on a foundation.[41]

In beam-and-post frame systems, also known as mast frames, a building's frame comprises of several storeys high GL or LVL columns that are working as mast-columns by bracing a building, in a combination with beams, whereon an intermediate floor and roof elements are placed (Fig. 3.6). The rigidity of a frame is usually achieved by diagonally installed stiffening reinforcements or due to mast columns that are rigidly installed onto foundations. The loads of roofing elements and intermediate floor elements are transmitted from beam to column and from column to foundations. The low number

[40] Puuinfo Oy 2016a

[41] Lepikonmäki, L. 2014

of load-bearing walls in a beam-and-post frame system enables high structural flexibility for openings and partition walls.[42] A beam-and-post frame system is an acceptable and cost-effective solution for shallow, at maximum 4 storeys high buildings.[43]

Figure 3.6 Beam-and-post frame multi-storey system in a combination with prefabricated building elements (Source: Metsä Wood 2013c)

3.2 Structural connectors for wood frames

In heavy timber construction, steel connectors play an essential role in big CLT, GL, and LVL structures providing strength, stiffness, stability, and ductility. The post-collapse surveys have revealed that structural failures often have taken place due to inadequately designed connections or improperly installed connections. Those may cause an interruption of continuity in a timber structure that may result in a decrease in the overall strength and stiffness (i.e., if a structure is not designed or constructed properly).[44] Viable connections in wooden structures can be realized by using a variety of available steel fasteners as follows.

SELF-TAPPING SCREWS

Nowadays, self-tapping wood screws are widely used in all types of wooden structures due to easy installation, fast penetration as well as high performance in withdrawal and shear capacity. A range of different features and measures of these screws is extremely wide. Different features involve fully and partly threaded screws as well as double threaded screws with countersank heads, cylindrical heads, or large (flat) heads (Fig. 3.7).[45]

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[42] Metsä Wood 2013b

[43] Lepikonmäki, L. 2014

[44] FP Innovations and Binational Softwood Lumber Council 2013 p. 187

[45] Rotho Blaas S.r.l 2015a

Fully and double threaded screws are having better performance in withdrawal capacity than partly threaded screws do. However, a gap between wooden surfaces may occur when joints are assembled with fully threaded screws. This known gap is being reduced by instead using partly threaded screws or by pre-stressing elements before the installation of fully threaded screws.[46]

Typically, the diameters of normal screws are ranging up to 12 mm. The lengths of normal screws are ranging up to 1000 mm. Commonly used lengths are up to 600 mm. Longer normal screws are mainly used in beam reinforcements and with hard to install on-site conditions.[47] Traditional wood screws and lag screws normally require pre-drilling at least for bigger diameters in order to avoid cracking in wood. In turn, self-tapping screws do not normally require pre-drilling in softwood ($\rho<500$ kg/m^2).[48] However, the use of pre-drilling is recommended when driving self-tapping screws with lengths more than 450 mm in order to avoid structural failures in screws due torsion moments inside screws and to help in the positioning of screws in correct directions.

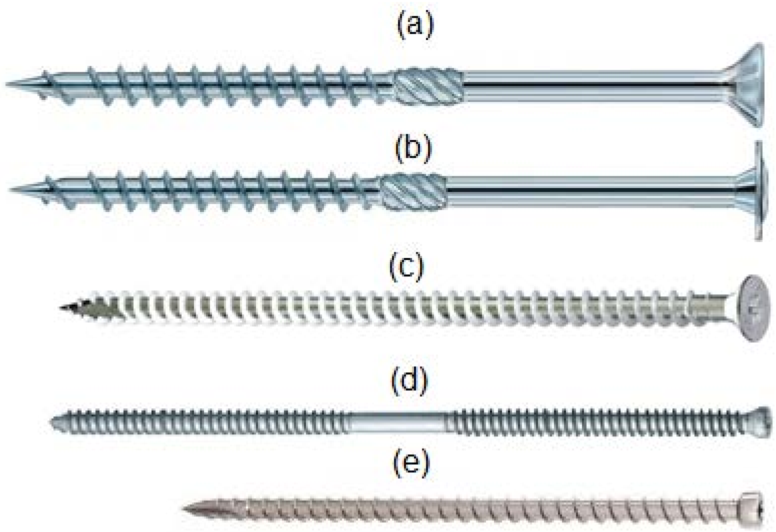

Figure 3.7 Self-tapping wood screws: (a) partly threaded screw with a countersank head, (b) partly threaded screw with a large head, (c) fully threaded screw with a countersank head, (d) double threaded screw with a cylindrical head, and (e) fully threaded screw with a cylindrical head (Source: Rotho Blaas S.r.l 2015a)

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46 Flatscher et al. 2014 p. 4

47 Mohammad, M. 2011 p. 9

48 Metsäwood 2013b p. 2

LAG SCREWS

Lag screws are partly threaded screws where the outer diameter of a threaded part is equal to the diameter of a smooth part (Fig. 3.8). Pre-drilling is required for lag screws when diameters are bigger than 6 mm and always if the characteristic density of wood is greater than 500 kg/m^3. The commonly used diameters of lag screws are ranging up to 20 mm. The commonly used lengths are ranging up to 600 mm.[49]

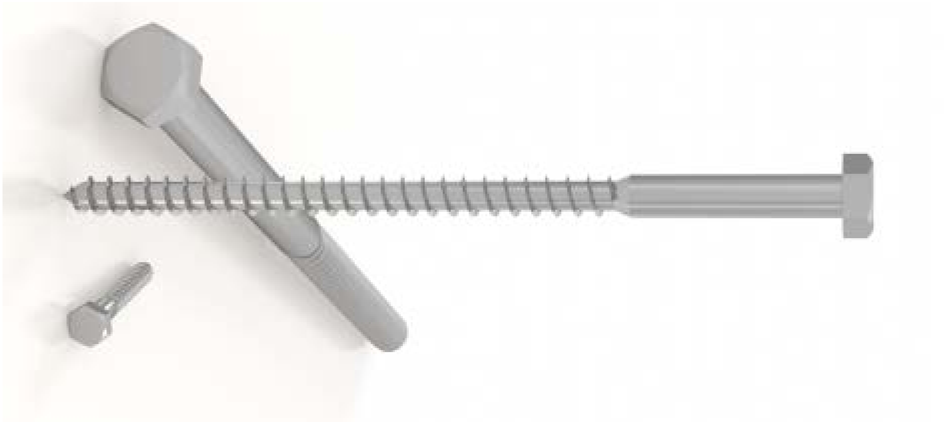


Figure 3.8 Lag screw (Source: Rotho Blaas S.r.l 2015a)

BOLTS AND DOWELS

Bolts and dowels are common fasteners in heavy timber construction and especially in GL and LVL structures (Fig. 3.9). High shearing capacity makes it possible to use bolts and dowels typically in combinations with metal plates, beam hangers, or concealed connectors. Traditional dowels cannot resist any withdrawing forces. Thus, self-perforating dowels have been developed as an alternative, acceptable solution for middle loaded structures. Such dowels are capable to perforate through three pieces of 5 mm thick steel plate. There are no requirements for pre-drilling into wood or metal, thus self-perforating dowels reduces time used in assemblies on-site. [50]

Figure 3.9 Bolts and dowels: (a) self-perforating dowel, (b) traditional dowel, and (c) bolt and nut (Source: SFS Intec 2016 and Rotho Blaas S.r.l 2015b)

[49] Metsäwood 2013b p. 2

[50] SFS Intec 2016

NAILS

Traditional smooth nails (Fig. 3.10a) are having low withdrawal capacity. This is why most standards do not allow the design of nailed connections in the direction of end grain. Instead, nails suit well to panel-to-timber connections and timber-to-timber shear connections that are used, for example, in pre-fabricated space elements or on-site assembled timber frames. However, smooth nails may be used in secondary structures in end grain in Finland, for example, for connecting fascia boards to rafters. In this latter case, the design values of load-carrying capacity are specified only as one third of the design values of nails installed in right angles to end grain.[51] Nails with specific surface features, such as fully threaded anchor nails are having better withdrawal performances and, therefore, they are commonly used in combinations with perforated metal plates and brackets on wooden surfaces (Fig. 3.10b).

Figure 3.10 Nail types: (a) smooth nails and (b) a fully threaded anchor nail (Source: Rotho Blaas S.r.l 2015b)

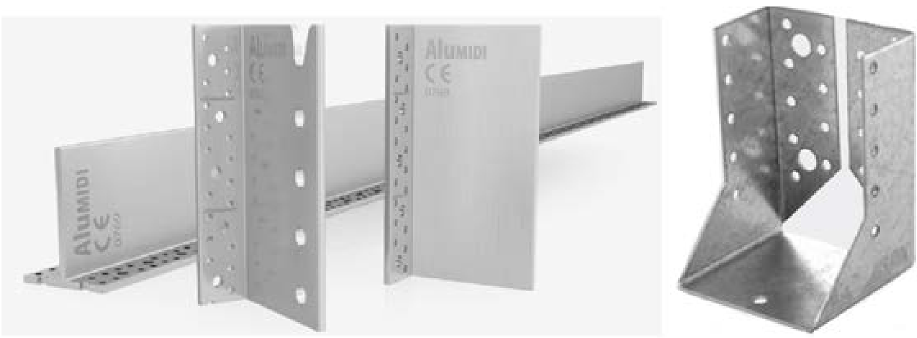
[51] Metsä Wood 2013c p. 2

CONCEALED AND EXPOSED BEAM HANGERS

Main-to-secondary joist connections in timber structures are schematized as hinges. This joist type restrains element translation, but not rotation. Hinge nodes transfer shear force from a secondary joist to a main joist. However, they cannot bear a strong bending moment or torsion.[52]

Concealed beam hangers are placed entirely inside timber elements in order to provide optimal aesthetic and fire protective performances since a joint is covered by surrounding timber (Fig. 3.11a). Under fire conditions, a reduction of a cross section takes place, but a portion of wood that is not affected by carbonization remains efficient. Hence, there is no reduction of strength in a fastener. It maintains its mechanical properties unaltered over a required period. A beam can be fixed to a hanger either by using self-perforating dowels or traditional dowels with pre-holes in a bracket.

Exposed metal beam hangers are placed on the outer surfaces of timber elements, being visible and directly exposed to fire (Fig. 3.11b). Such a placement results in the limited load-bearing capacity of connectors in the case of fire and, thus, it may be required that hangers be covered by fire protective paint.



(a) (b)

Figure 3.11 Metal beam hangers: (a) concealed beam hanger and (b) traditional exposed beam hanger (Source: Rotho Blaas S.r.l 2015b)

[52] Rotho Blaas S.r.l 2015a p. 22-23

METAL PLATES AND ANGLE BRACKETS

Both tensile and shear stresses can be transferred through metal plates and angle brackets. There are traditional small size angle brackets and bigger, more durable angle brackets. Typically, hold-downs are used for transferring vertical tensile stresses between storeys and finally down to foundations (Fig. 3.12a). External steel plates (b) are used for transferring both horizontal and vertical stresses, depending on size. Also wide angle brackets are normally used for transferring horizontal shear stresses (c and d). In addition, these brackets in combinations with reinforcing washer plates can be used for transferring vertical loads. All these connectors are available in versions for exterior and interior use. Normally, metal plates and brackets are used in combinations with anchor nails, screws, and bolts. To concrete, brackets can be fastened in combinations with glued-in threaded bars, concrete anchors, or chemical anchor resins.[53]

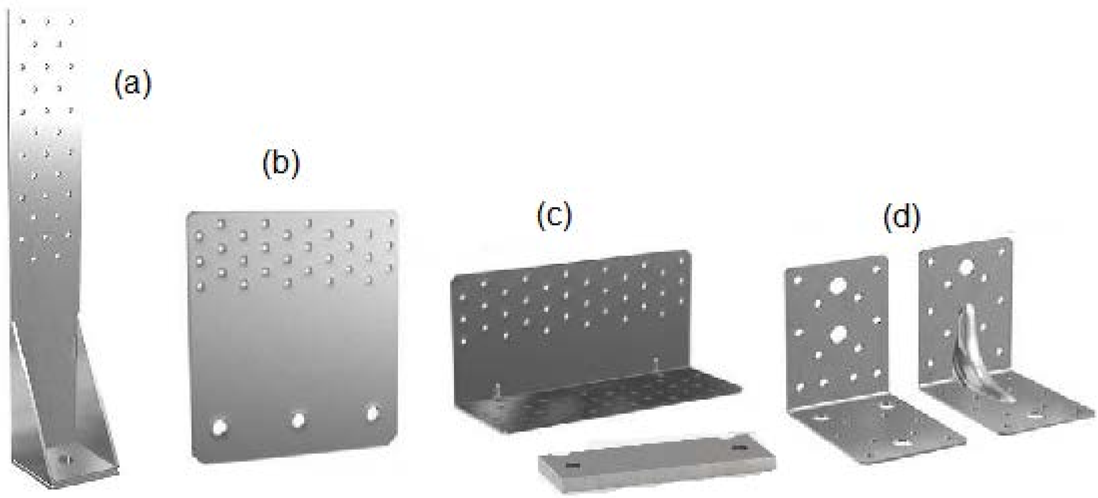


Figure 3.12 Examples of metal plates and angle brackets: connector (a) as a hold-down for vertical tensile stresses, connector (b) as an external steel plate for horizontal shear stresses – also a taller version for vertical tensile stresses, and connectors (c) and (d) as angle brackets mainly for horizontal shear stresses (Source: Rotho Blaas S.r.l 2015b)

[53] Rotho Blaas S.r.l 2015b p. 130-175

3.3 Cross laminated timber (CLT)

CLT is a relatively new engineered, solid wood construction product, developed initially in the Central Europe (Fig. 3.13). CLT consists of at least three single-layer boards placed at right angle, usually crosswise, on top of each other and glued to each other. A load is transferred along the two axes. Gluing is the dominant method to attach layers. In addition, nails or wooden dowels can be used. CLT solid wood panels are available in different thicknesses and measures for various structural requirements. Panels are statically stressed and they are used in walls, ceilings, and roofs in solid timber construction projects. CLT panels have crosswise structures, which is minimizing expansion and shrinking of wood and enhancing structural load-carrying capacity and dimensional stability.[54] On-site erection phases are fast due to high degrees of pre-fabrication and the ease of assembly with modern fasteners.

The dimensions of CLT panels are mainly depending on a manufacturer's production capacity and logistical limitations. Known standard thicknesses are ranging up to about 300 mm, maximum widths are ranging up to about 2,95 meters, and lengths are ranging up to about 16 meters. In structural calculations, the self-weight of CLT panels is 5.0 kN/m^3.[55]

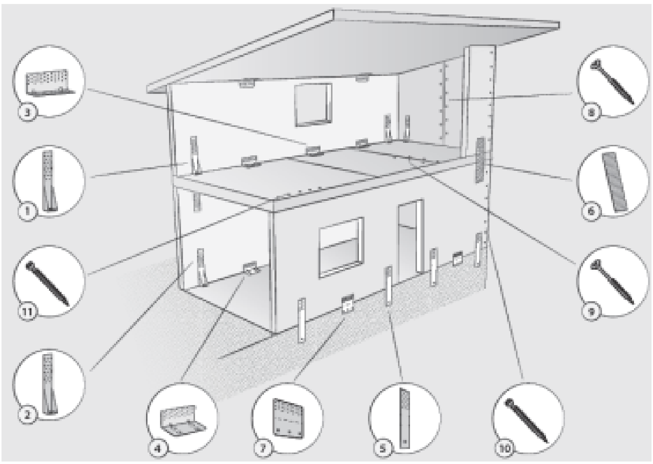
Figure 3.13 Cross Laminated Timber (CLT) construction (Source: Stora Enso Oyj 2016)

[54] Stora Enso Oyj 2016

[55] Stora Enso Oyj 2016

3.3.1 Connections in CLT assemblies

Laterally loaded CLT elements provide high stiffness and load-carrying capacity. However, the behavior of a wall system primarily depends on connections. Typically, CLT assemblies include panel-to-panel (in floors, walls, and roofs), wall-to-foundation, wall-to-wall intersection, and wall-to-floor/roof connections (Fig. 3.14). About 60% of all connections in CLT structures are realized with screws. The realization of connections in CLT panels involves the basic features as follows: edge distances, screwing is proposed at an angle of 45 degrees, screwing in a panel edge perpendicular to a wood grain (→ screwing parallel to a grain causes critical losses in a withdrawal capacity), and screwing between gaps of wooden boards should be avoided. [56]



Points where design of connections must be undertaken:

Tension angle brackets
1. Wall-Ceiling
2. Wall-Foundations

Shear angle brackets
3. Wall-Ceiling / Wall-Wall
4. Wall-Foundations

Perforated plates
5. Wall-Foundations (tension)
6. Wall-Wall (tension)
7. Wall-Foundation (shear)

Self-tapping screws
8. Wall-Wall 9. Ceiling-Ceiling
10. Wall-Corner wall
11. Ceiling-Wall / Roof-Wall

Figure 3.14 Illustration of connections in a two-storey CLT building (Source: Rotho Blaas S.r.l 2015b p. 99)

In CLT panels, different layers are strained at different angles due to 90 degrees of cross lamination. In GL structures, all laminated boards are strained and aligned in the same direction. CLT panels are thick orthotropic plates and GL structures are beam-like members. This comparison is illustrated in Figure 3.15.[57]

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[56] Flatscher et al. 2014 p. 1

[57] Mohammad, M. 2011 p. 11

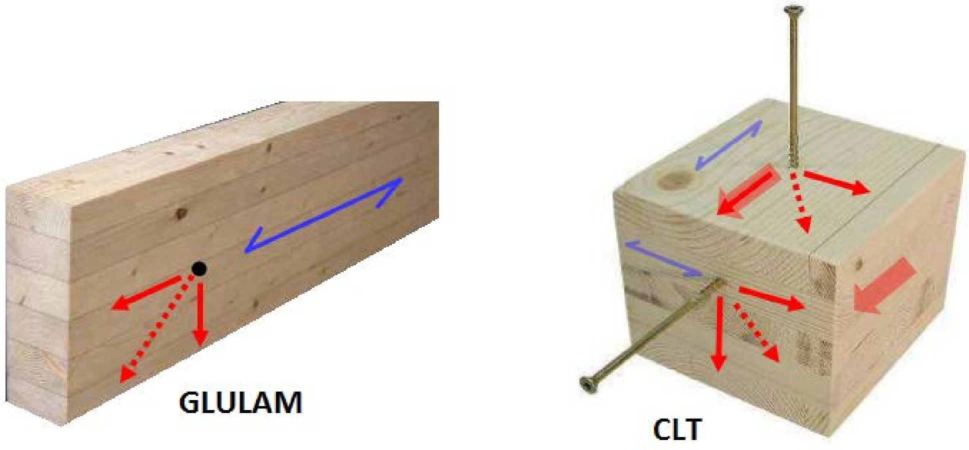

Figure 3.15 Different cross lamination effects between connections in CLT structures and connections in solid timber or glulam (GL) (Source: Mohammad, M. 2011 p. 12)

3.3.2 Wall-to-foundation connections in CLT

In multi-storey buildings with wooden frames, it is common to use concrete in the first floor and to make upper storeys of wood elements. Alternatively, the first storey can be made of wood if only a façade is fire protected. Direct contacts should be avoided between CLT panels and a concrete foundation in all cases. At least a moisture stop layer must be used, such as a bituminous sheet or an EPDM sheet. Options for connecting CLT wall panels to concrete slabs can be divided into exposed and concealed connections. The transfer of vertical and horizontal loads to foundations is designed by using connecting metal fasteners.

Exposed connections

Metal angle brackets may be the most traditional way to connect CLT wall panels to concrete foundations, enabled by system simplicity and ease in installation works. A system consists of tall and thin hold-down metal brackets for transferring vertical tension loads (Fig. 3.16b). Shallow and wide angle brackets are relatively transferring horizontal shear forces (Fig. 3.16a). These connectors can be fixed to CLT panels by using anchor nails or screws. For concrete fastenings, preferably threaded bars are used, or bolts with chemical anchor resins can be used. Hold-downs are used in places where vertical loads are strongest. This means hold-downs for the both sides of panels and for the both sides of large openings, such as wide windows. Shear angle brackets are normally placed in the middle of panels, between hold-downs, in order to resist horizontal movements caused by lateral loads, like those by wind.[58]

[58] FP Innovations and Binational Softwood Lumber Council 2013 p. 21

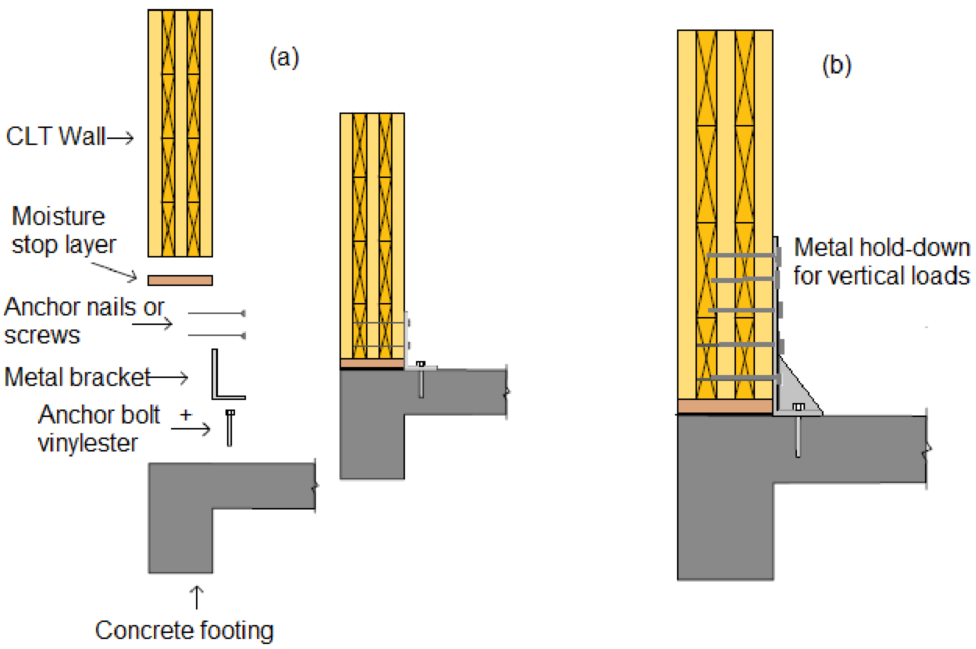

Figure 3.16 Wall-to-foundation connection with metal angle brackets for shear loads and hold-downs for tension loads (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 22)

Exterior metal plates are an alternative way to connect CLT wall panels to foundations in cases when visible connecting fixtures cannot be exposed inside a building, or a connection cannot be established from inside (Fig. 3.17). A range of available dimensions accommodates variations in tensile and shear stresses and the transfer of loads. Exterior metal plates are easy to install and they are normally fastened with anchor nails or screws to wood parts and with glued bolts or threaded bars to concrete. Exposed plates and fasteners must be protected against corrosion by galvanization, stainless steel, or special coating.[59]

[59] FP Innovations and Binational Softwood Lumber Council 2013 p. 21

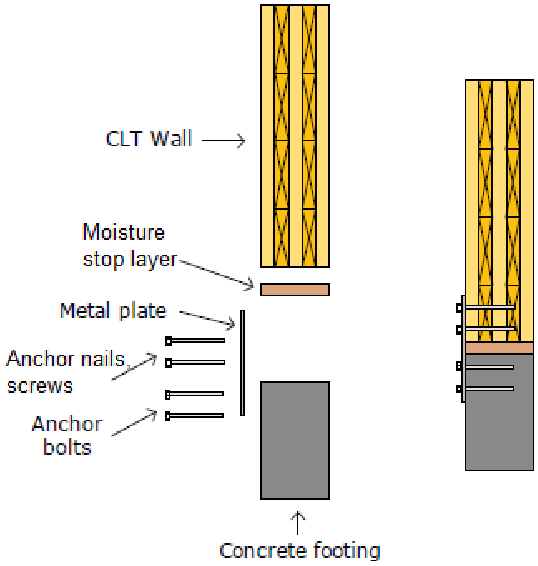

Figure 3.17 Exterior metal plate for a wall-to-foundation connection (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 21)

Concealed connections

Concealed connections for CLT walls are an alternative to exposed junctions. Concealed connections are providing better fire resistance and aesthetics properties. In Finland, concealed connections can be utilized mainly in detached houses. This is so because the normal fire regulation protocol does not allow showing CLT surfaces in multi-storey buildings. Concealed metal brackets, similar to concealed beam hangers, can be used as connecting fixtures (Fig. 3.18). When metal brackets are used, grooving in panel edges must be mortised already at CLT manufacturing plants. Plates are fastened to CLT panels with traditional dowels or self-perforating dowels and, if required, dowel holes can be covered by wooden caps to improve fire protection of fasteners.[60]

[60] FP Innovations and Binational Softwood Lumber Council 2013 p. 23

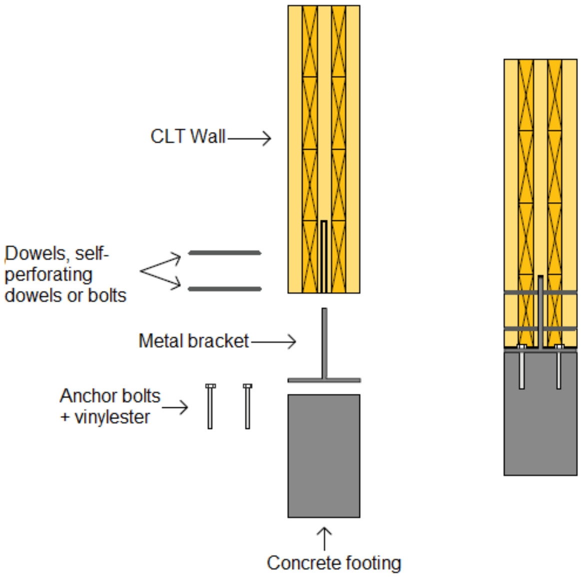

Figure 3.18 Concealed connection for a wall-to-foundation joist (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 23)

3.3.3 Wall-to-wall connections and slab-to-slab CLT panel connections

Wall-to-wall and slab-to-slab CLT panel connections can be used for vertical wall assemblies and horizontal slab assemblies. Panels are connected along longitudinal edges and joints are schematized as hinges, so they are not moment resisting connections. Connections facilitate the transfer of in- and out-of-plane forces through wall assemblies or slab assemblies. For example, wall-to-wall connections are being designed to resist in-plane shear and out-of-plane bending. When slab assemblies are acting as diaphragms, connections must be capable of transferring in-plane diaphragm forces and maintaining the integrity of diaphragms and an overall, lateral load-resisting system.[61]

Half-lapped joints

Half-lapped joints are a commonly used system to connect CLT panels without using third plates, enabled by simplicity and fast installation (Fig 3.19). Half-lapped notches in the edges of panels must be mortised. They are connected together by using fully or partially threaded self-tapping screws driven at the angles of 45 or 90 degrees perpendicular to a grain. A joint carries vertical and transverse loads, but it is not a moment resisting connection. The design of joints must take into account a risk of splitting in cross sections due to the concentration of tension perpendicular to grain stresses in notched areas, particularly in cases where uneven loading on floor areas occurs.[62]

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[61] FP Innovations and Binational Softwood Lumber Council 2013 p. 7
[62] FP Innovations and Binational Softwood Lumber Council 2013 p. 9

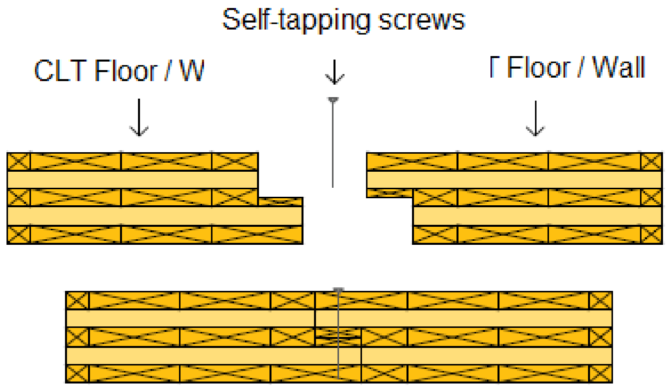

Figure 3.19 Half-lapped joint for a panel-to-panel connection (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 9)

Single surface butt joints with external splines

Single surface splines are an easy way to realize on-site panel-to-panel slab connections or on-site panel-to-panel wall connections (Fig. 3.20). Panel edges are mortised for placing the connecting splines made of timber or engineered wood, such as LVL, or plywood. Splines can be fixed to CLT panels by using self-tapping wood screws or nails. Typically, these single shear connections are inferior to internal spline connections.[63]

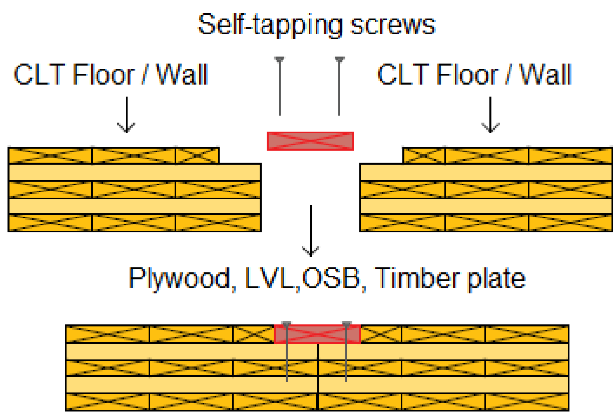

Figure 3.20 Single surface butt joint with an external spline (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 8)

[63] FP Innovations and Binational Softwood Lumber Council 2013 p. 8

Internal splines

Internal splines are carried out by using single or double wooden plates placed inside a milling in a panel edge (Fig 3.21). Connecting plates placed between CLT panels should have quite the same material properties as CLT panels themselves do. In this way, a structure is kept continuous without any gaps in strength or elongation values. Internal splines provide a double shear connection and this is an advantage compared to the use of single surface splines. Another advantage is a better capability to resist a normal or out-of-plane loading. Internal spline connections can be established on-site by using self-tapping wood screws or nails. Chemical adhesives between surfaces can be added in order to provide more rigidity and air-tightness to connections.[64]

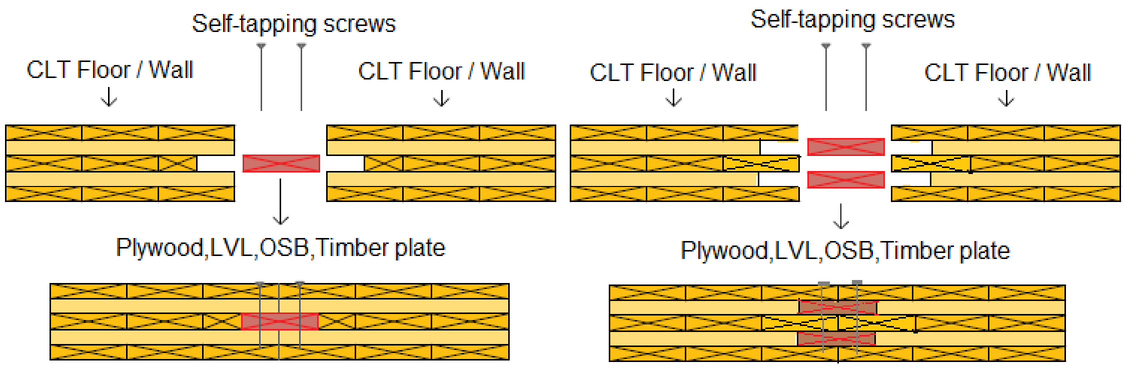

Figure 3.21 Single and double internal spline connections (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 7)

Double surface butt joint with external splines

Double surface butt joints consist of two external splines placed on the both sides of panels (Fig.3.22). The use of double surface butt joints increases connection strength and stiffness in comparison to the use of single surface butt joints. The use of a double amount of screws and splines results in the doubling of the number of shear planes for resisting normal and out-of-plane loads more efficiently. When the numbers of fasteners, splines, and millings are doubled, this connection requires a double amount of time for installation and milling. [65]

[64] FP Innovations and Binational Softwood Lumber Council 2013 p. 7
[65] FP Innovations and Binational Softwood Lumber Council 2013 p. 9

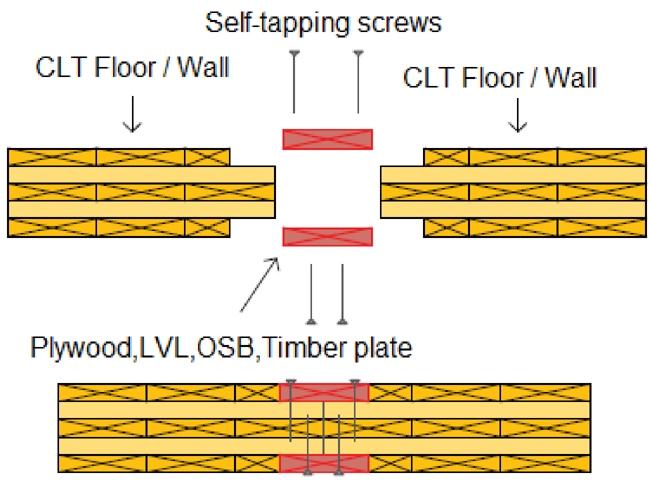

Figure 3.22 Double surface butt joint with external splines (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 9)

3.3.4 Corner joints for walls in CLT panel connections

Herein, schematized connection details are presented for realizing wall-to-wall junctions at right angles (90 degrees) with connections between simple external corner walls, partition walls, and both of them. Designers and carpenters alike have to place commonly used self-tapping screws at correct angles or perpendicular to wood grains. They have to recognize CLT layers so that screws are driven diagonally and, thus, losses in withdrawal capacity are avoided.[66]

Corner joint for walls established with self-tapping screws

Simplest wall connections rely on self-tapping wood screws. Designers and carpenters should use inclined screw connections ensuring that screws with full, partial, or double threatings are penetrating through several CLT layers and at least some of them perpendicular to a screwing direction. In the narrow edges of CLT panels, every second layers are crosswise, which means that the driving of screws in end grains parallel to wood fibers should be avoided (Fig. 3.23). In the case of small loads, this may not become a critical issue. When a wall is subjected to resist high lateral forces, like wind, this may become a problem.[67]

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[66] Flatscher et al. 2014 p. 1

[67] FP Innovations and Binational Softwood Lumber Council 2013 p. 10

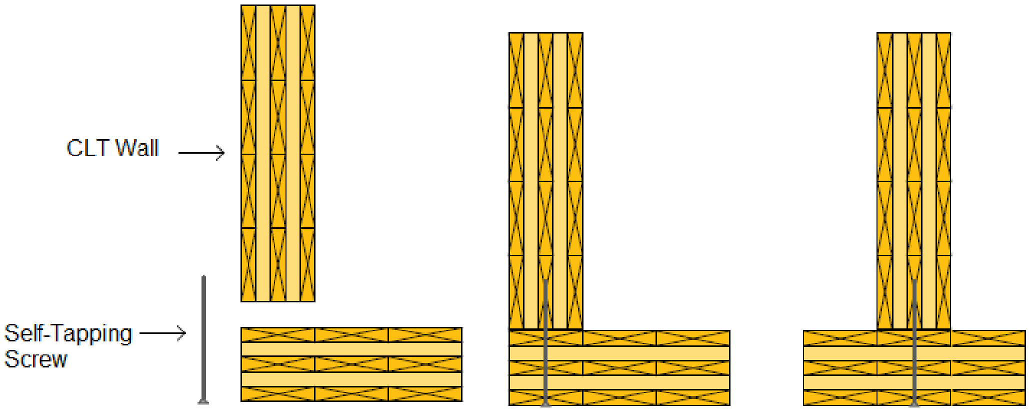

Figure 3.23 Corner joint by self-tapping screws installed from exterior, also screws driven diagonally (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 11)

Alternatively, connections can be realized from interior wherein screws are automatically driven diagonally (Fig. 3.24). On construction sites, this can be a solution when there are no opportunities to establish connections from exterior.[68]

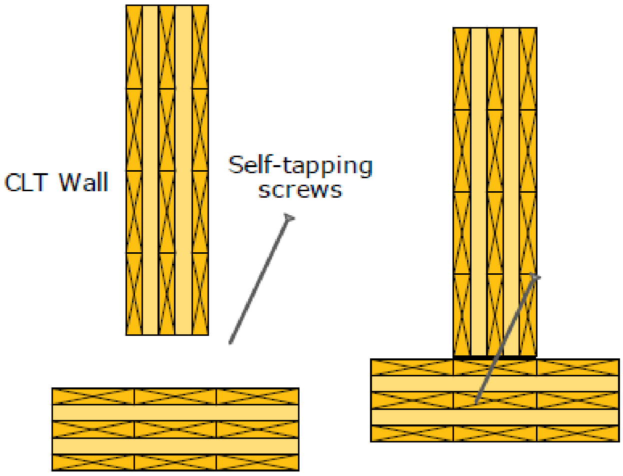

Figure 3.24 Corner joint by self-tapping screws driven at an angle from interior (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 12)

[68] FP Innovations and Binational Softwood Lumber Council 2013 p. 10

Corner joint for walls established with metal brackets

Another way to establish wall-to-wall corner joints is to use metal brackets in corners with anchor nails or screws (Fig 3.25). Metal bracket connections are one of the most efficient connections, enabled by fastening in a direction perpendicular to the plane of panels. It is easy to fasten metal brackets on sites. Due to numerous parts, fastening is significantly slower than when using self-tapping wood screws. When corner joints with metal brackets are not concealed inside wood, a fire protective coverage is required, such as gypsum boards.

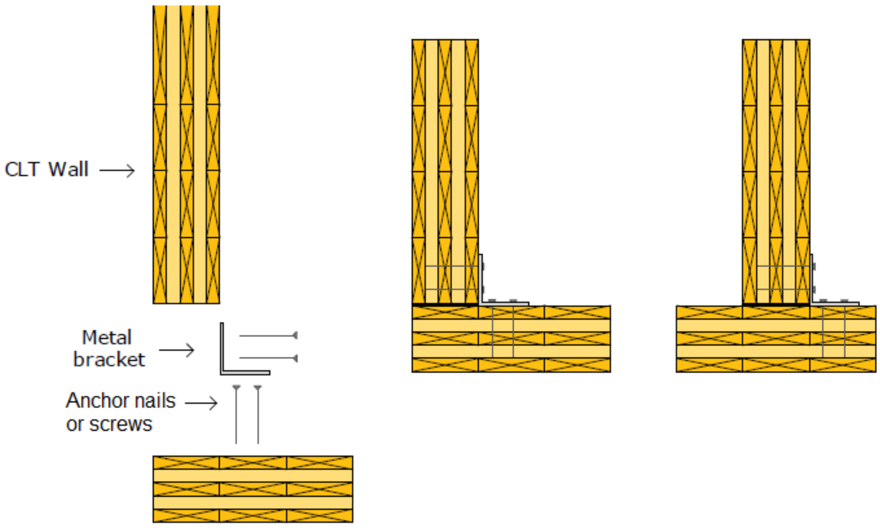

Figure 3.25 Corner joint by metal angle brackets from interior (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 13)

Corner joint for walls established with concealed metal brackets and dowels

Compared to exposed metal bracket connections, concealed metal brackets and dowels are providing better performance over fire resistance and aesthetics (Fig 3.26). The edges of CLT panels should be mortised with CNC machinery already at production plants. Anchor nails or screws are needed for fastening metal brackets to CLT walls from bases. Respectively, self-perforating dowels are a quick way to establish connections without pre-holing for fastening metal plates into mortising inside panel edges. Alternatively, traditional dowels are used when having pre-holes. Both fastenings can be closed inside wood by using wooden caps.[69]

[69] FP Innovations and Binational Softwood Lumber Council 2013 p. 14

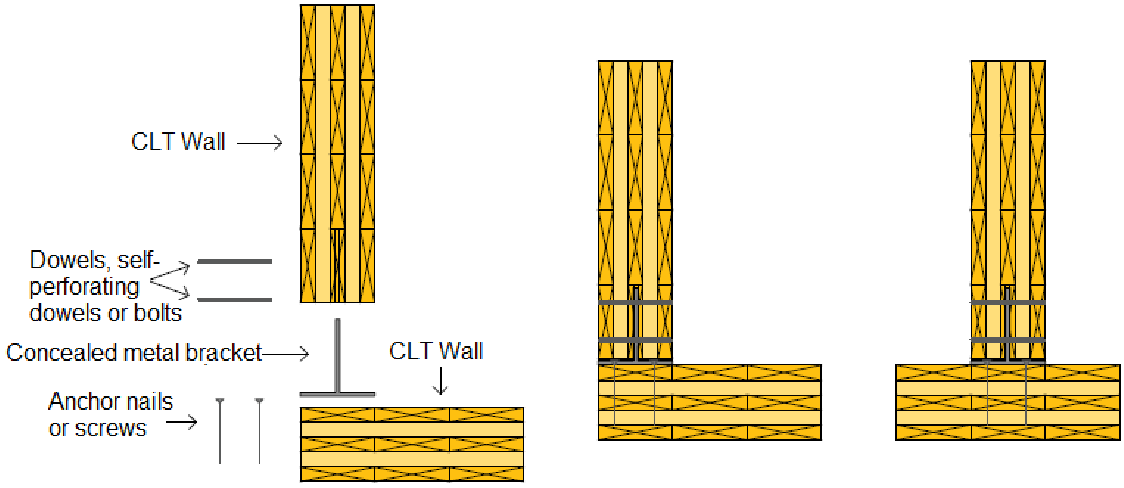

Figure 3.26 Corner joint by a concealed metal bracket and dowels (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 14)

3.3.5 Slab-to-wall joints in CLT panel connections

There are several slab-to-wall connection methods, coupled with respective structural systems, such as mast frame systems, platform frame systems, and modular systems. Herein, joints between upper walls, intermediate floors, and walls below are presented with four ways to establish related connections as follows.

Connection established with self-tapping screws

Connections established with long, partly, or fully threatened self-tapping screws can be used with platform frame systems wherein loads are transferred from walls above to walls below by the presses of intermediate floor slabs (Fig. 3.27). This is the simplest way to connect intermediate floor slabs to walls below. The capacity of joints in panel edges are maximized by driving screws at an angle. Similarly, inclined screws can be used for connecting walls above to intermediate floor slabs. Screws can be driven diagonally in walls or through floor slabs inside walls below, depending on the angles and lengths of screws. This reinforces connections between these three structural elements and provides more ductility.[70]

[70] FP Innovations and Binational Softwood Lumber Council 2013 p. 15

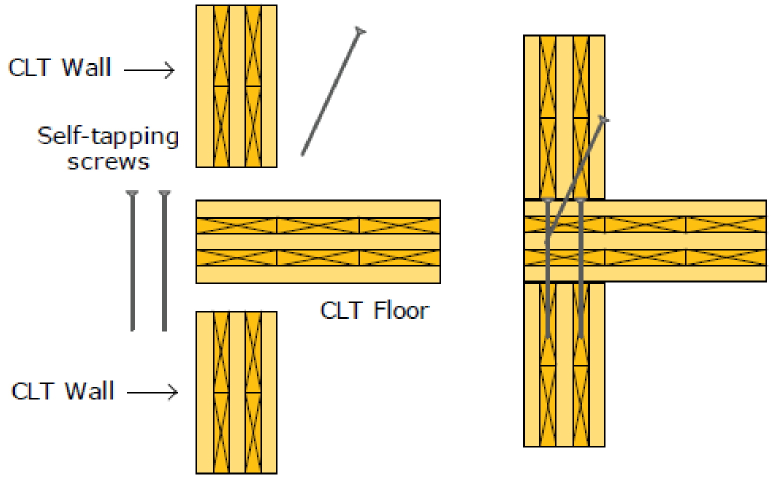

Figure 3.27 Walls-to-floor slab connection using self-tapping screws (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 15)

Connection established with self-tapping screws and metal brackets

Metal brackets can be used for connecting upper walls to intermediate floor slabs, providing better shear capacity against lateral loads than in the case of using only screws (Fig. 3.28).[71]

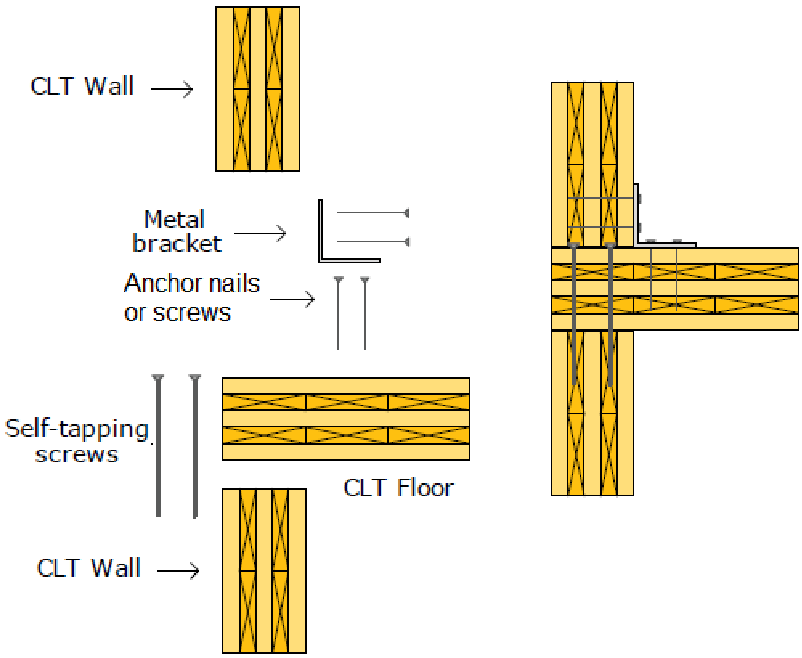

Figure 3.28 Walls-to-floor slab connection with angle brackets and self-tapping screws (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 16)

[71] FP Innovations and Binational Softwood Lumber Council 2013 p. 16

Connections for shear and tension established with metal brackets

Wall-to-floor slab connections with higher performance in shear capacity can be realized by using metal angle brackets on the both sides of structures (Fig. 3.29a). There are also wide angle brackets that reduce on-site work and the total number of fastening units compared to smaller angle brackets. Metal brackets are fastened by using anchor nails or wood screws. In addition, connections can be established with hold-down brackets in order to resist high tension loads, caused by the uplift of a building (Fig. 3.29b). Hold-downs are placed on the both sides of CLT wall panels and on the both sides of CLT floor slabs to permit the transmission of vertical stresses continuously down to foundations. There are tension connectors with different features for interior use and exterior use, such as hold-down brackets are used in interior tension connections and tall metal plates, like fishplates, are used in exterior tension connections.[72]

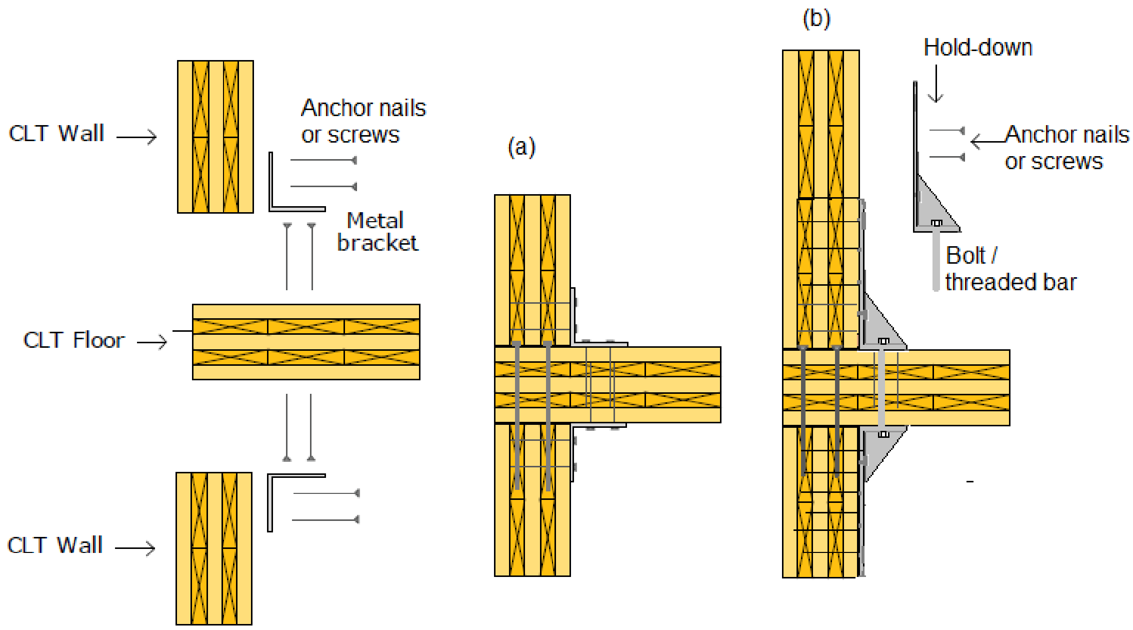

Figure 3.29 Walls-to-floor slab connection with metal angle brackets: (a) angle bracket for horizontal shear stresses and (b) hold-down for vertical tensile stresses (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 16 and Rotho Blaas S.r.l 2015b)

[72] Rotho Blaas S.r.l 2015a p. 102-121

Connections established with bearing supports

CLT wall panels are herein acting as mast walls when floor slabs are fixed to continuous wall panels (Fig. 3.30). This connection is commonly used in smaller residential buildings and 1-storey non-residential buildings, such as farm and industrial hall buildings. The simplest way to realize these joists is to use wooden ledgers as bearing supports for floor slabs and to fasten elements with self-tapping screws or nails. However, connections with bearing supports may remain exposed since in many cases the cross-sections of wooden ledgers become relatively big to accommodate load bearing.[73]

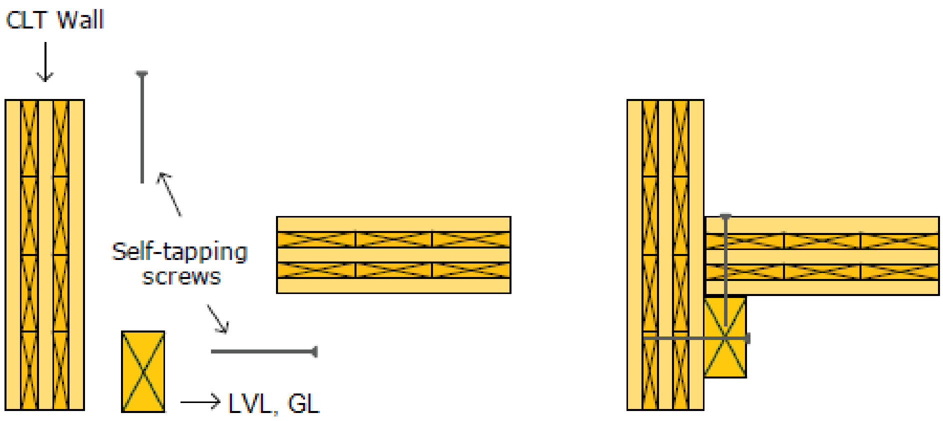

Figure 3.30 Floor slab-to-continuous wall panel connection established with a bearing support (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 18)

[73] FP Innovations and Binational Softwood Lumber Council 2013 p. 18

3.3.6 Roof-to-wall joints in CLT panel connections

In roof-to-wall connections, it is possible to use partly the same connecting methods as presented in the case of slab-to-wall joists (in Section 3.3.5). These same methods are suitable especially for connecting flat roofs. The three common connection types for sloping CLT roof panels to wall panels below are established with exterior screwing, interior screwing, and angle brackets (Fig. 3.31a-c). Self-tapping screws are most commonly used, together with metal angle brackets.[74]

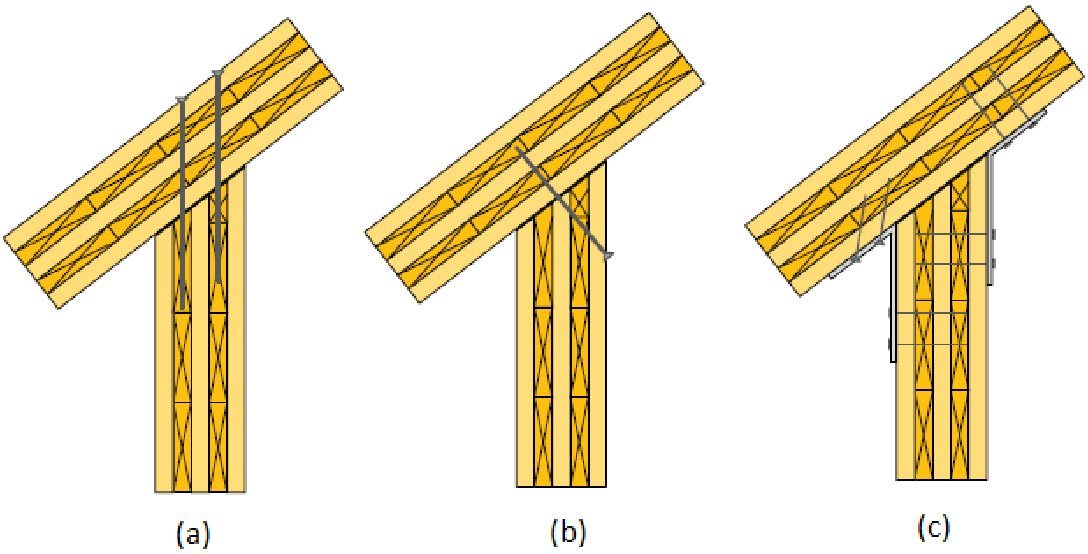

Figure 3.31 Sloping roof-to-wall connections established with: (a) exterior screwing, (b) interior screwing, and (c) angle brackets (Source: FP Innovations and Binational Softwood Lumber Council 2013 p. 19-20)

[74] FP Innovations and Binational Softwood Lumber Council 2013 p. 19

3.4 Laminated veneer lumber (LVL)

LVL is an engineered wood product consisting of multiple layers of 3 mm thick veneer sheets glued together in order to form a continuous wide billet. Veneers can be glued together all parallel grained, like LVL beams and columns, or some veneers can be cross-grained in order to achieve more two-dimensional mechanical strength by the cross-lamination effect for wider construction panels and boards. Billets can be cut to size as structural beams, columns, and boards with a range of average density between 410 - 480 kg/m^3. There are LVL products according to various dimensions. The normal cross-sections of LVL beams are between those of GL and solid timber. LVL products are having high-quality, weather-proof characteristics and they are significantly more homogenous than sawn timber. LVL structures are applied to many common uses, such as load-bearing structures in construction elements, light frames in detached houses, and reinforcing structures in renovation and repair work (Fig. 3.32).[75]

The standard dimensions of LVL panels are depending on each manufacturer's production capacity and logistical limitations. Thicknesses are ranging from 21 mm up to 90 mm, maximum widths are ranging up to 2 500 mm, and lengths are ranging up to 24 meters. The thickness of final products can be enlarged by gluing standard LVL panels on top of each other.[76]

Figure 3.32 Load-bearing structure made of LVL (Source: Metsä Wood 2013c)

[75] Kairi, M. 2011

[76] Metsä Wood 2016

3.4.1 Connections in LVL assemblies

According to the study of Kerto® connections, most common connections related to LVL structures are divided into connections in rod structures and connections in building elements.[77] The latter are not reviewed in this study. Structural connections in LVL assemblies consist mainly of screw, nail, bolt, dowel, and beam hanger joists. The particular issues in the design of LVL connections involve edge compression strength values, the edge distances of fasteners, and distances between fasteners. In comparison to GL, LVL billets are produced gluing several layers of thin veneer sheets parallel to grains or strained at different angles due to crosswise lamination. Pre-drilling is required when using lag screws with diameters of more than 6 mm and self-tapping screws with diameters of more than 8 mm.[78]

3.4.2 Column-to-base LVL connections

Column-to-base joists can be carried out as moment rigid connections that are transferring moments or they can be schematized as hinged shear connections that are transferring only shear stresses. The choices of connection types have effects also on the design of foundations. Rigidly fixed columns require heavier foundations since they are transmitting moments down to foundations.[79]

Most commonly used column-to-base LVL connections are hinged joists established with saddle brackets and dowels (Fig. 3.33 a). Such visible connecting parts often require extra protection from fire, like fire retardant paint. Standard base saddles are supplied by many fixture manufacturers. The transfer of forces between concrete and cast-in rod or hollow sections is either by adhesion between metal and concrete or by contact pressure with washers and nuts at the cast-in ends of rods. In designs, it cannot be assumed that adhesion and contact pressure co-act. Instead, total forces must be taken up either by adhesion or contact pressure. Nails or screws/bolts are used for the transfer of forces between U sections and GL columns.[80]

Angle bracket connections are mainly used in buildings with light wooden frames as shear connections between wall studs and sill plates (Fig. 3.33).

External steel plate shear connections are a common and cheap solution to realize hinged column-to-base connections when visible connecting parts do not cause problems with fire classification (Fig. 3.33c). These parts can be coated with fire retardant paint when protection becomes necessary. Hinged external steel plate connections are reviewed in more detail in Section 0.

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[77] Kovanen, H. 2014 p. 8
[78] Metsä Wood 2013a p. 2
[79] Lepikonmäki, L. 2014
[80] Nordic glulam handbook 2001 p. 257

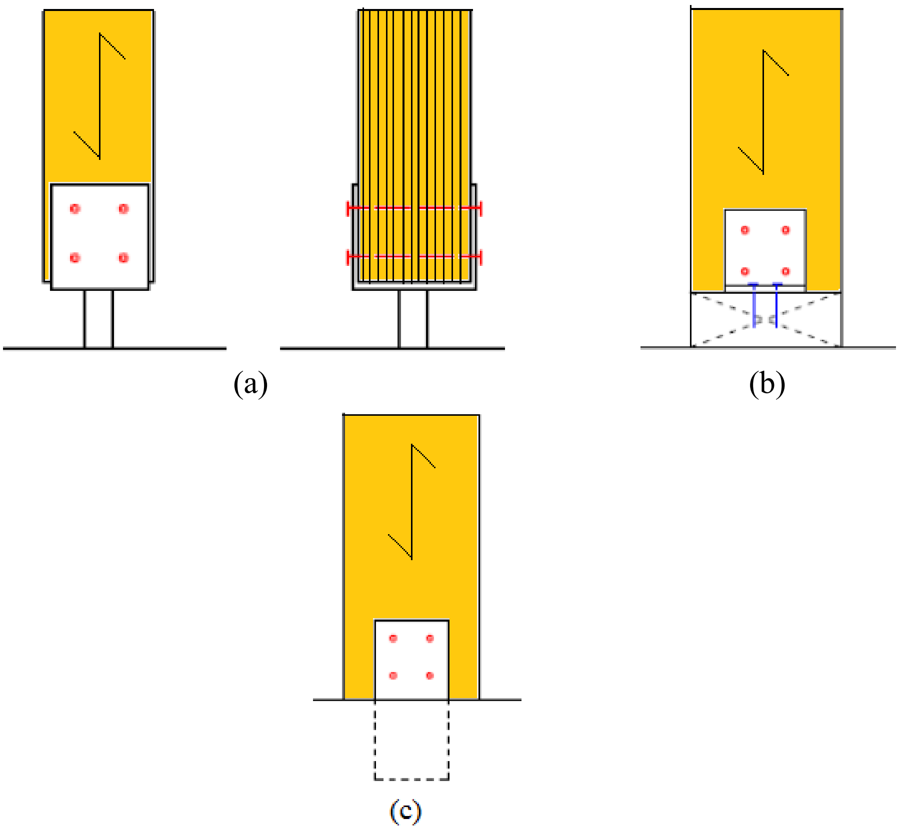


Figure 3.33 Column-to-base hinged shear connections with: (a) saddle bracket / column foot, (b) angle brackets, and (c) external metal plates (Source: Kovanen, H. 2014)

Glued-in screw connections are commonly used moment rigid joists to connect LVL columns to pillar bases (Fig. 3.34a). Glued-in screw connections transfer vertical and horizontal loads as well as fixing moments from columns to bases. Horizontal loads and uplifting forces, caused by moments, are transferred by glued-in screws. Vertical loads are transferred by the compression of surface areas. Glued-in screw connections are fire resistant.[81] They are reviewed in more detail in Section 0.

External steel plates is a common and cheap solution to realize rigid column-to-base connections when fixing moments are high and visible connecting parts do not cause problems with fire classification (Fig. 3.34b). Plates can be coated with fire retardant paint when protection becomes necessary.[82] External steel plate connections are reviewed in more detail in Section 0.

[81] Nordic glulam handbook 2001 p. 273
[82] Nordic glulam handbook 2001 p. 267

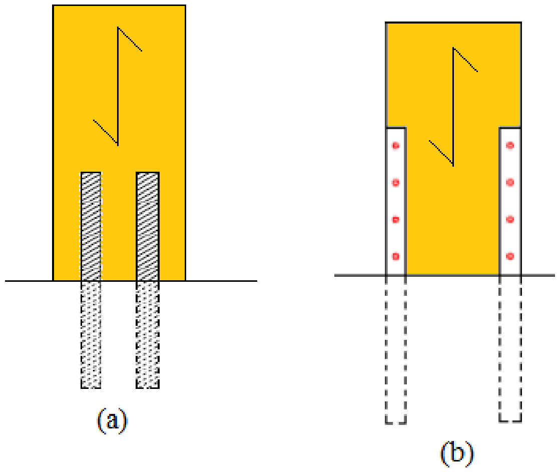


Figure 3.34 Moment rigid column-to-base connections with: (a) glued-in threaded bars and (b) external steel plates (Source: Kovanen, H. 2014)

3.4.3 Beam-to-column LVL connections

Beam-to-column connections can be divided into surface-contact joints and shear joints, based on the transmission of stresses by loads. In surface-contact joints, beams are placed directly on the top of columns, allowing the most of beam loads to transmit directly to columns by contact areas between surfaces (Fig. 3.35a-c). Beams are supported from sides so that beams do not fall. Metal connectors are mainly used for lateral shear forces and hold beams steady. Surface-contact joints for LVL can be assembled with plates or wooden block boards on the both sides of beams and columns (Fig. 35a). Supporting plates are metal plates or wooden boards that are fixed with screws. Concealed surface-contact joints can be connected with steel plates integrated inside structure members and fixed members by using dowels (Fig. 3.35b). Alternatively, concealed T-shape connectors are fixed to columns by using screws and top beams with dowels (Fig. 3.35c). These concealed surface-contact joints require mortising to structure members.[83]

[83] Kovanen, H. 2014 p. 12

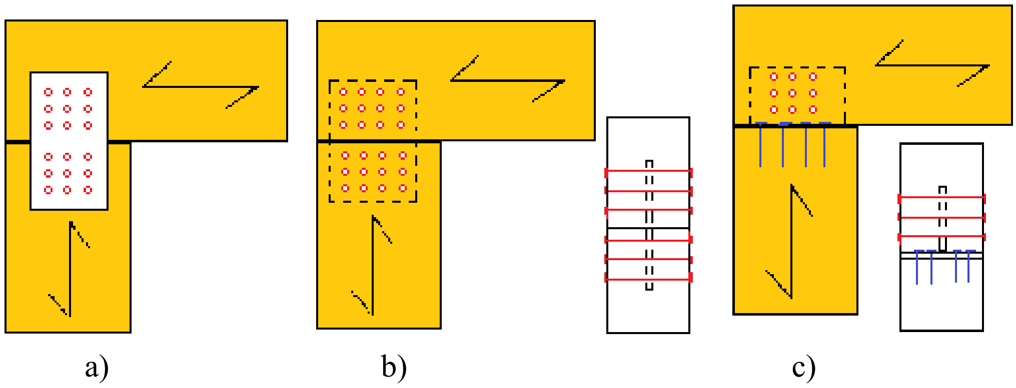


Figure 3.35 Variations of beam-to-column surface-contact joints for LVL: (a) connection with supporting wood plates or metal plates and (b-c) connections with concealed metal plates or brackets (Source: Kovanen, H. 2014)

In addition, columns and beams are more commonly connected with shear joints in the case of continuous columns. In shear joints, beams are supported towards the sides of columns (Fig. 3.36 a-c). The loads of beams are transmitted to columns through shear stresses by sections in connecting fixtures. Shear connections can be assembled with metal beam shoes (Fig. 3.36a). Beam shoes/hangers are a common solution in Finland for beams in general. Beam shoes with a manufacturer's certifications are mostly used connectors in column-to-beam and beam-to-beam connections in LVL structures. Beam shoes are suitable for shear forces because they are transmitting loads from beams to columns by sections in connectors. In concealed beam-to-column shear connections, beams are installed towards the sides of columns by using concealed beam shoes/hangers (Fig. 3.36b). Such shear connections provide better aesthetics and fire protection for joints. Simplest shear connections may be the ones assembled by using wooden bearing supports that are fastened with screws to the sides of columns (Fig. 3.36c). Simplest connections are suitable only for vertical loads and, thus, they are not a common solution in heavy structures. Simplest connections should be carried out in combinations with angle brackets in order to provide beams with better support against rotation.[84]

[84] Finnish Glulam Association ry and Puuinfo Oy 2015 p. 254-255

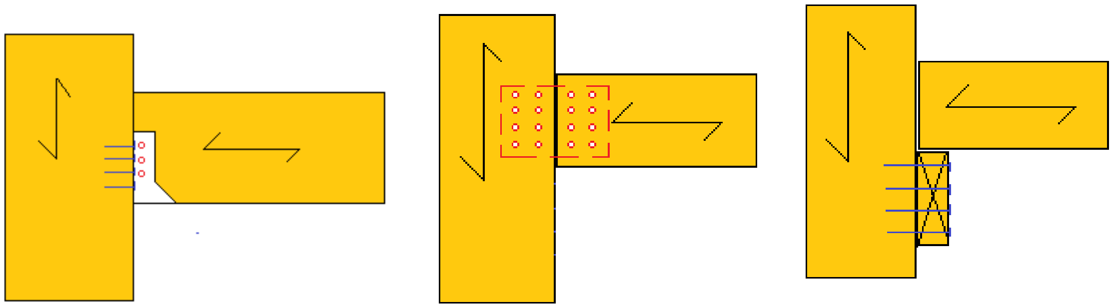


Figure 3.36 Variations of beam-to-column shear connections in LVL structures: (a) exposed beam hanger, (b) concealed metal plate/hanger, and (c) bearing support (Source: Kovanen, H. 2014)

One or two sectioned connections are used against shear forces. There are not-moment-resisting connections (Fig. 3.37a) and moment resisting connections enabled by the circular patterns of fasteners (Fig. 3.37b). The latter are used in three-pinned portal frames made of LVL or GL. Such moment resisting connections are usually carried out with bolts and dowels. In addition, they can be realized with modern self-tapping screws. Moment resisting connections are stable against horizontal forces in their own plane and statically determinate so that moment distributions are not affected by the uneven subsidence of foundations or by unforeseen deformations in joints and connections.[85]

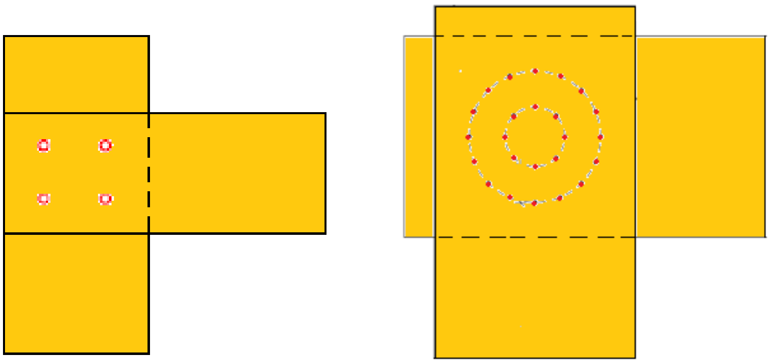


Figure 3.37 Multi-shear joints: (a) one sectioned, not-moment-resisting joints and (b) two sectioned, moment resisting joints enabled by the circular patterns of fasteners (Source: Kovanen, H. 2014 and Metsä Wood 2013b p. 23)

[85] Kovanen, H. 2014 p. 16-17

3.4.4 Beam-to-beam connections

Connections between primary and secondary beams can be engineered in two alternative ways. In on-top connections, secondary beams can be installed on the top of primary beams by using metal angle brackets. In this way, vertical loads are mainly transferred from secondary beams to primary beams (Fig. 3.38). These joints are resisting only low shear stresses. On-top connections and surface-contact joints are both applicable. On-top connections are mainly used in the gables of buildings and in situations where the heights of primary beams are so low that installations to sides are not possible. In roof elements, on-top connections are also enabling continuous ventilation spaces for roofing.[86]

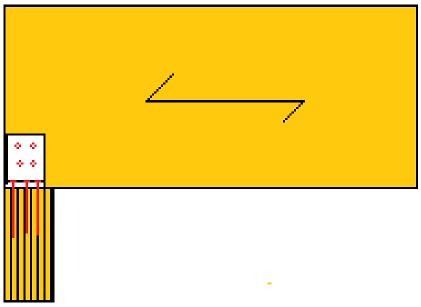
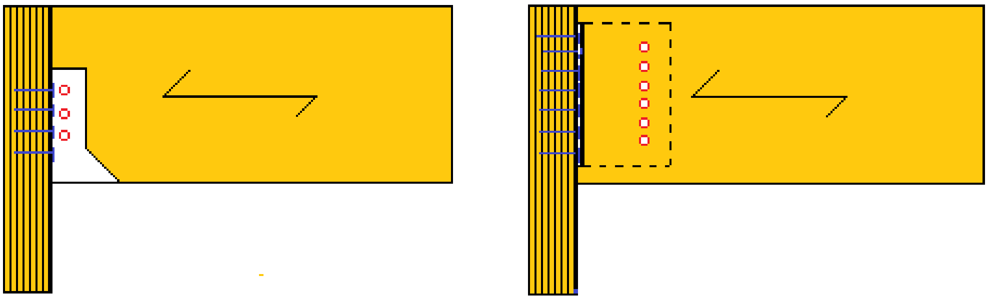


Figure 3.38 Beam-to-beam on-top connection with angle brackets (Source: Kovanen, H. 2014)

Alternatively, secondary beams can be connected to the sides of primary beams and, thus, joints are made to also resist stresses in the directions of secondary beams. From the viewpoint of space, on-side connections do not increase the total heights of structures as on-top connections do. Secondary beams can be installed towards primary beams by using metal hangers (Fig. 3.39). This is a commonly used method to connect LVL beams in Finland. Beam hangers are transferring heavy vertical loads from secondary beams to primary beams. They are also resisting shear stresses, but usually not torsion moments. Some of exposed beam hanger connections are also capable for transferring low torsion moments.[87]

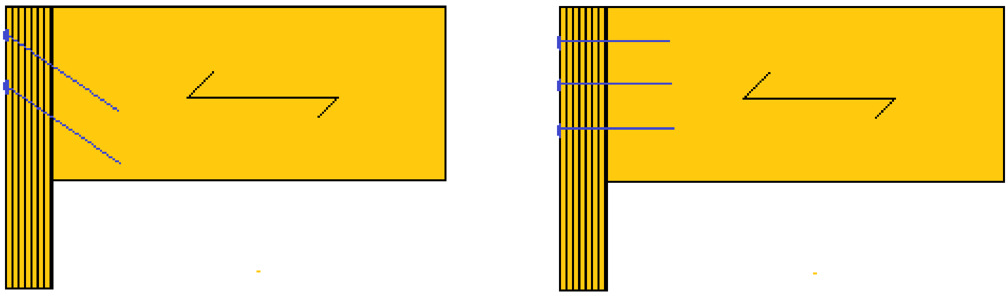
[86] Puuinfo Oy 2012d p. 1
[87] Puuinfo Oy 2012a p. 2



(a) (b)

Figure 3.39 Beam-to-beam on-side connections with a metal hanger: (a) connection with an exposed beam shoe/hanger and (b) connection with a concealed beam hanger (Source: Kovanen, H. 2014)

Diagonally screwed joints can be implemented as crossed screws connections that are collated of full or double threated screws wherein one is working for traction and another is working for compression. A more simple alternative is to drive screws diagonally only in one direction (Fig. 3.40a). Since there are no cross joints, connections are only working for traction forces. Screw inclination angles α should be 30°≤ α ≤ 60°, both in regard to connection forces and screwing surfaces. Another alternative for realizing on-side connections with screws or nails is a direct gable screwing/nailing (Fig. 3.40 b). These connections are acceptable only when loads are not high and the capacity of joints stay low.[88]



(a) (b)

Figure 3.40 Screwed beam-to-beam on-side connections: (a) inclined screws connection and (b) screws/nails driven perpendicular to a gable (Source: Kovanen, H. 2014)

[88] Metsä Wood 2013a p. 34

3.4.5 Suspended LVL connections

Axially suspended screw connections are mainly used for the installation of hanger systems as part of the pre-fabricated roofs of industrial and commercial buildings (Fig. 3.41). A cable rack or lights are usually installed to the lower surfaces of roofing elements or roof beams. Partly threaded self-tapping screws are usually driven to the edges of LVL beams parallel to laminated wood veneers. Pre-holing is needed if the diameters of the smooth parts of screws exceed 6 mm or the outer diameters of threaded parts exceed 8 mm. Minimum distances between screws parallel to grains are at least 10 times the diameters (*d*) of screws, minimum end distances are 12*d*, minimum edge distances are 5*d,* and minimum penetrations into wood 6*d*. Different or supplementary connection types and screw specifications may be used according to the European Technical Approval (ETA) or VTT's statement. When forces in connections act at angles to grains, the screws of laterally suspended joints should ideally be positioned at the compressed sides of members. In general, there is no need to check the tension capacities of beam members perpendicular to grains.[89]

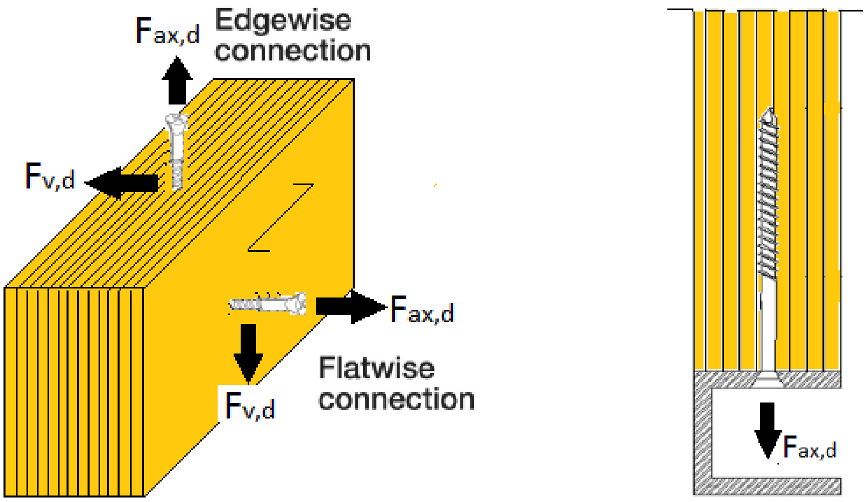


Figure 3.41 Suspended connections in LVL structures (Source: Metsä Wood 2013b p. 4, 27)

[89] Metsä Wood 2013a

3.5 Glulam (GL)

GL is more than 100 years old construction material originally invented in Germany. It has better structural characteristics compared to normal timber material thanks to its production process. Gluing processes guarantee that the weak parts of wood, such as branches, are divided into the different sections of final products, called as the lamellar effect. Related to its self-weight (5 kN/m^3), GL is one of the strongest construction materials and, thus, it is used in extremely wide, over 150-meter span structures (jointed arches). Typically, the maximum height of GL sections is about 2 meters. In combinations with post-installed GL components, the height can be raised up to 3 meters. The height of GL sections should not be more than ten times the width. The common maximum production length of GL members is about 30 meters, but GL sections can be manufactured even up to 40 meters. Logistics and manufacturing capabilities are the only limiting factors for the dimensions of GL beams. GL is a popular material when designing architectural buildings due to possibilities to choose the forms of GL sections (Fig 3.42). In Scandinavian countries, most commonly used GL quality is classified as GL30c or GL30h. [90]

Figure 3.42 Glulam (GL) structures in the airport terminal in the city of Jyväskylä (Source: Late-Rakenteet Oy)

[90] Finnish Glulam Association ry and Puuinfo Oy 2014 p. 20-22

3.5.1 Connections in GL assemblies

Typical connections in GL assemblies are carried out with steel plates or other connecting parts made of wood or steel. They are fastened with nails, screws, or dowels. Modern fastening methods such as self-tapping screws, glued-in screws, or bars are becoming a more common solution among structural joints and reinforcements. Wood has different strength capacities in different directions due to its grain structure. Traction stresses perpendicular to a wood grain need to be avoided since wood is weakest in this direction, about one hundredth of the traction capacity in direction parallel to a grain. Cracking is highly likely when metal fasteners inside wood are causing traction forces perpendicular to a grain. When wood is a hygroscopic material, the expansion and shrinking of wood is undertaken in the design of connections in order to avoid forced stresses. The metal fastening parts of joints are usually resisting corrosion and fire less than surrounding wood does.[91] GL chars about 0,6-1,0 mm per minute in fire situations.[92] As a rule, standard stock connectors are used in GL assemblies. However, many big structures become so heavy that the expensive customization of connectors is needed.

3.5.2 Column-to-base connections

Column-to-base joists can be carried out as moment rigid connections that are transferring moment. Alternatively, column-to-base joists can be schematized as hinge connections that are not transferring moment. A connection type has an effect on the measuring of columns and foundations. Rigidly fixed columns require heavier foundations since they are transmitting moment down to groundings.

Moment rigid connections

Moment rigid column-to-base connections are the most common way to connect GL columns to concrete bases, such as those in mast-braced hall buildings. Connections transfer also moment to horizontal shear force and vertical traction force. Connections can be used for stabilizing the frames of buildings against horizontal forces, such as wind loads and braking loads from hoist blocks and traversers.[93] Designers are taking into account the expansion and shrinking of wood caused by varying humidity and the low traction capacity of wood perpendicular to grains, in comparison with the relatively strong bending capacity of wood.[94]

In principle, external steel plates should be used in moment rigid columns with high fixing moments in the ends of columns. In turn, glued-in screw connections and dowel connections are more appropriate when fixing moments are relatively low and when there are high requirements for aesthetics or fire protection issues. Since the ends of

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[91] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 235

[92] Finnish Glulam Association ry and Puuinfo Oy 2014 p. 24

[93] Nordic glulam handbook 2001 p. 105

[94] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 248

columns are resting directly on a hygroscopic material, usually concrete, moisture rise is prevented by protecting the ends of columns with epoxy resin or by installing water-proofing membranes or oil tempered veneer boards between column ends and a hygroscopic material.[95]

Moment rigid connections with external steel plates

External steel plates are a common and cheap solution to realize rigidly fixed columns with high fixing moments in the ends of columns and when visible connecting parts do not cause problems with fire classification (Fig. 3.43a). In the case of fire protection, plates can be coated with fire retardant paint. For these connections, two external steel plates are placed on the narrow sides of columns. The thickness of a steel plate should not exceed the diameter of a hole in order to achieve high cost effectiveness. In base joists, external steel plates are usually placed in concrete cast. When separated base plates are used, such base plates are placed in concrete cast and external steel plates or fishplates can be post-welded to base plates. For fixing, each fishplate can have its own base plate. Same fixtures can be used for the columns of different cross-sectional sizes. External steel plates or fishplates can be fixed to columns with anchor nails, full threaded wood screws, or dowels. Wood screws are preferably used in large columns and screws should be fixed at the angle of 45 degrees in order to increase the capacities of joints. Nailed connections provide the most effective transfer of forces per unit area if only the designed spacing of anchor nails is followed. [96]

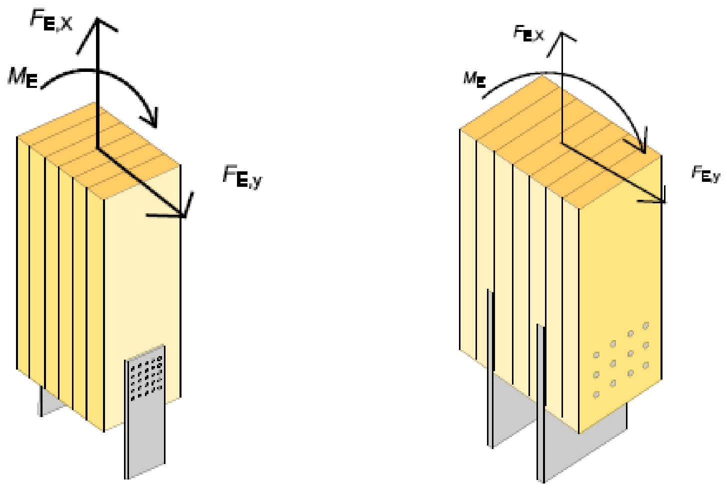

Figure 3.43 Moment rigid column-to-base steel plates connections: (a) connection with external steel plates or fishplates and (b) connection with dowels and internal steel plates (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 249, 251)

[95] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 248-251
[96] Nordic glulam handbook 2001 p. 267

Moment rigid dowel connections with internal steel plates

In moment rigid dowel connections, the ends of columns are mortised by placing at minimum two internal steel plates in the directions of the narrow sides of columns and parallel to panels (Fig. 3.43b). From below, steel plates are usually welded to a base plate. Internal steel plates are fixed to the ends of columns by using normal dowels with pre-holing or self-perforating dowels, depending on loads. Fixing moments are transferred from columns to internal steel plates by coupled forces constructed between steel plates. Therein, torsion bars are distances between plates. Vertical compression in beams is transmitted by compressed contact surface areas. Tension loads caused by traction are transferred by dowels to steel plates and down to foundations. The internal steel plates of columns, placed in millings, are transferring horizontal loads and compressed from one side. Moment rigid dowel connections are almost imperceptible and well protected from fire since dowels and plates are covered by surrounding wood and dowel holes can be plugged with wooden caps.[97]

Moment rigid glued-in screw connections

Glued-in screw connections are the most commonly used moment rigid joist type to connect GL columns to pillar base (Fig. 3.44). Vertical and horizontal loads and fixing moments are transferred from columns to foundations. Horizontal loads and uplifting forces caused by moments are transferred by glued-in screws. Normal vertical loads are transferred by the compression of contact areas.[98]

Typically, sand blasted lag screws with the length of 500 mm, the diameter of about 19 mm, and the threaded part of 100 mm are used in glued-in screwed connections. Such screws are made in factory conditions and through standardized production processes. The number of glued-in screws in connections depends on the loads and dimensions of beams. Inside columns, the outer surfaces of glued-in screws need to be raw or optionally sandblasted in order to make adhesion hold stronger. Empty spaces are left between the surfaces of pillar bases and underneath columns. After columns have been erected, empty spaces are post-filled with non-shrinkable concrete.[99]

Glued-in screw connections are a viable solution when fixing moment is relatively small. Normally, fire resistance issues are handled without extra protection, when all connecting fixtures are hidden inside wood or post-concrete. There are the three main solutions to realize glued-in screw connections, i.e., bolted column shoe connections, bolted steel plate connections, and welded steel plate connections. Bolted column shoe connections are the most commonly used solution in Finland. When steel plates are used, it may be required to cover visible connecting fixtures with fire retardant coating. However, the use of glued-in screw connections is not allowed under dynamic loads.

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[97] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 251-252

[98] Puuinfo Oy 2012b

[99] Puuinfo Oy 2012b

Instead, the use of steel plate connections is required in the cases of relatively high fixing moment.[100]

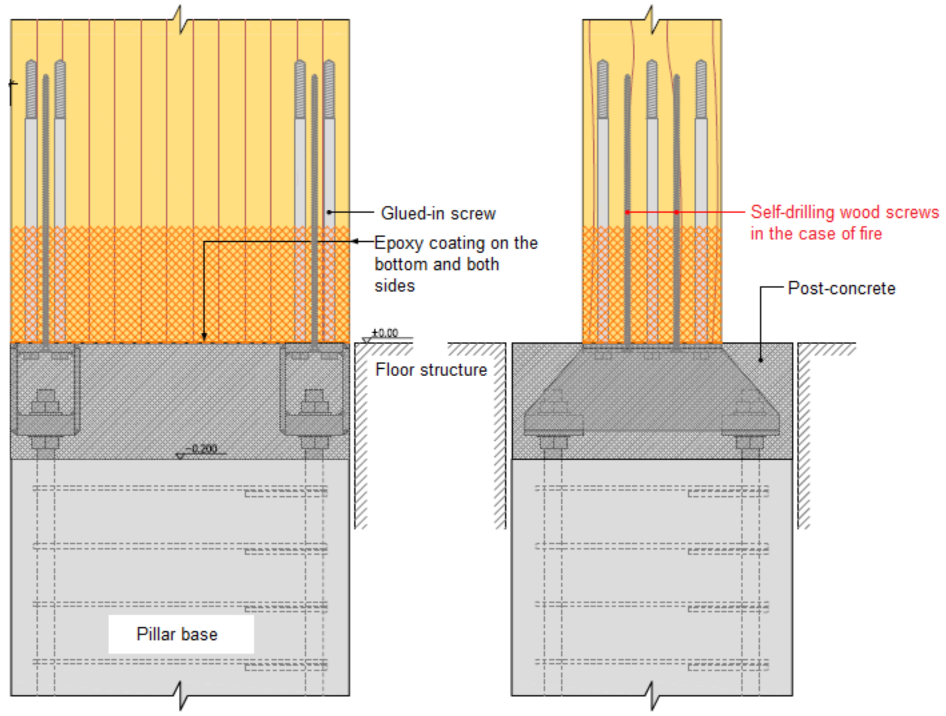


Figure 3.44 Moment rigid column-to-base connection with glued-in screws and a bolted column shoe filled with post-concrete (Source: Finnish Wood Research 2014 p. 2)

Hinged connections

Hinged column-to-base connections transfer horizontal and vertical loads from columns to foundations. In principle, hinged connections do not transfer a moment, but a small moment resistance is an advantage during the erection. The design of connections accommodates changes in the inclination of columns in order to avoid restraining forces that, in turn, could give rise to splitting.[101] There are many different solutions for the realization of these connections. The three main options used in Finland involve external steel plates connections, glued-in screw connections, and dowel connections with internal steel plates. External steel plates should be used when there is a higher fixing moment during the erection. Glued-in screw connections and dowel connections are solutions for high aesthetics and fire protection requirements without a high fixing moment in the erection. Since the ends of columns are resting directly on a hygroscopic material, usually concrete, moisture rise should be prevented by protecting the ends of columns with epoxy resin or by installing waterproofing membranes or oil tempered panel boards between the ends of columns and a hygroscopic material.

[100] Nordic glulam handbook 2001 p. 273
[101] Nordic glulam handbook 2001 p. 104

Hinged connections with external steel plates or fishplates

The most common and simplest solution for realizing hinged column-to-base connections is to use external steel plates or fishplates (Fig. 3.45a). In these connections, two external steel plates are placed on the wide sides of columns. Connections transmit vertical loads by the compression of contact areas between surfaces. Connections transfer both high and low horizontal shear stresses. Horizontal and vertical stresses are transmitted from columns to connecting steel plates through fasteners. Steel plates are fixed by using dowels, anchor nails, or full thread screws. The thicknesses of plates are chosen from inside the standard range and they must be at least 0,3 times the diameters of dowels, 0,4 times the diameters of screws, and also 0,4 times the diameters of nails. Pre-holes should be drilled 1 mm wider than the diameters of fasteners. Since steel plates receive small bending moments caused by the eccentricity of horizontal loads, steel plates are considered cantilevers and, thus, they are fixed rigidly into the concrete cast of bases. Alternatively, steel plates are fixed by welding them to a steel base plate that is pre-installed in the concrete cast on pillar bases. [102]

Hinged dowel connections with internal steel plates

In hinged dowel connections, the ends of columns are mortised wherein internal steel plates can be placed in the directions of the wide sides of columns and perpendicular to panels (Fig. 3.45b). Internal steel plates are fixed to the ends of columns by using normal dowels with pre-holing or self-perforating dowels, depending on loads. From below, steel plates are usually welded to base plates. Connections are almost imperceptible and they have high fire resistance performances since connecting fixtures are covered by wood and dowel holes are plugged with wooden caps. Connections resist low bending moments, which can be exploited during the erection.[103]

[102] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 244-246
[103] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 247-248

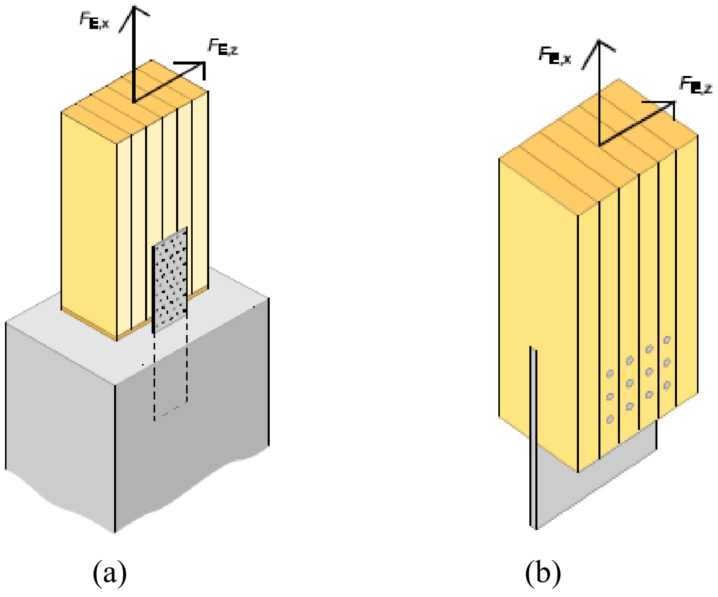


Figure 3.45 Hinged column-to-base steel plate connections: (a) external steel plates or fishplates and (b) an internal steel plate with dowels (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 245, 248)

Hinged glued-in screw connections

Alternatively, hinged column-to-base joints can be realized by using glued-in screw connections. Benefits include high fire resistance and concealed connecting fixtures. Connections are a solution for small and medium-sized horizontal and vertical loads. Connections can resist only very low bending moments and, therefore, columns are supported during the erection. Instead, the use of hinged glued-in screw connections is not allowed under dynamic loads or in Class of Use 3.[104]

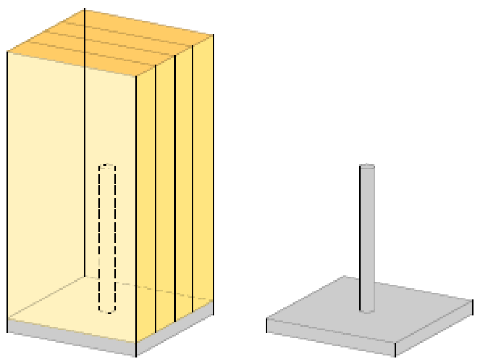


Figure 3.46 Hinged column-to-base connection with a glued-in screw (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 247)

[104] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 247

3.5.3 Beam-to-column GL connections

Beam-to-column connections are divided into surface-contact joints and shear joints. In surface-contact joints, beams are placed on the tops of columns, allowing most of the loads of beams to transmit to columns by contact areas between surfaces. Beams are supported from sides in order not to let them fall. Mainly metal connectors are used to handle lateral shear forces and to hold beams steady. In turn, shear joints are commonly used in the case of continuous columns. Beams are supported towards the sides of columns. The loads of beams are transmitted to columns through the shear stresses of connecting fixtures.[105]

Supporting block-board connections (hankolautaliitos)

Supporting block-board connections are the most commonly used connections between GL columns and main beams (Fig. 3.47). Wooden block boards made of GL, LVL, or lumber is a low cost and simple-to-assemble solution also for heavy loads. These boards are placed on the wide sides of columns by nailing or screwing. Nailing with adhesives is realized at GL production sites. The sizes of block board as well as the numbers and measures of connectors depend on the loads of joints. In the designs, the angular movements and changes of main beams are accommodated so that they work as hinged structures. The acceptable distances of block boards from the inner edges of columns are one third of the total widths of the longer sides, respectively, so that the rotation of beams is not restricted. Block board connections can easily provide 15 minutes of fire resistance. When the cross sections of block boards and the edge distances of screws are enlarged, fire resistance can be raised up to 30 minutes. When the heads of nails and screws are covered with plywood panel or wooden caps, more than 30 minutes of fire resistance can be achieved.[106]

[105] Puuinfo Oy 2012d p. 1

[106] Puuinfo Oy 2012c p. 1-3

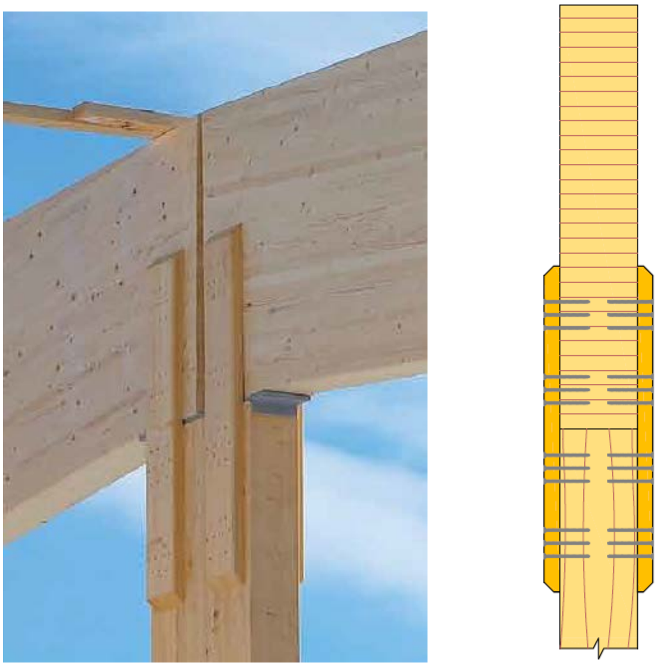


Figure 3.47 Hinged beam-to-column connection with supporting block-boards (Source: Metsä Wood, Puuinfo Oy 2012c)

Hinged steel plate or fish plate connections

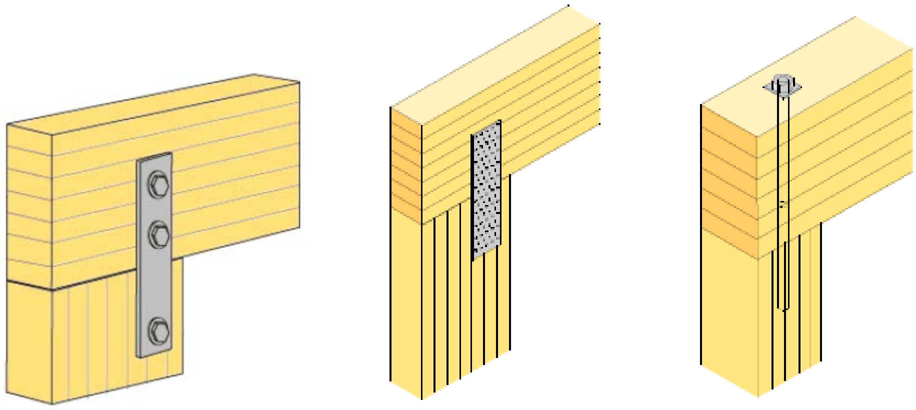
The principles in the design of steel plate connections are similar to those of supporting block board connections (Fig. 3.48a-b). In the designs, the transformations of beams caused by moisture living and angular movements are accommodated. Pre-drilled holes for dowels or bolts in steel plates are made to oval shapes in order to permit small movements without superfluous shear stresses. Steel plates should be placed as near as possible to the inner sides of columns so that the rotation of beams is not restricted. The thicknesses of steel plates should not exceed the diameters of holes so that high cost effectiveness can be achieved.[107] Pre-holed nail and screw plates made of galvanized steel are cheap alternative for moderate loads. Nail plates with various hole patterns and thicknesses can be ordered in standard sizes or customized from special manufacturers. The holes in a plate should be done about 1 mm larger than the diameter of a fastener. If screws are used (instead of nails), commonly used diameters are starting from 8 mm. Since a steel plate connection is an external connection made of steel, it is often required that such connections are covered with fire retardant coating.[108]

In Finland, the industry is currently using more supporting block board connections than steel plate connections. This is so because steel plates are a more expensive, less aesthetic, and less fire resisting solution. [109] However, the fire resistance of steel plates can be improved by fire retardant coating.

[107] Nordic glulam handbook 2001 p. 281-283

[108] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 258-259

[109] Puuinfo Oy 2012c p. 2



(a) (b) (c)

Figure 3.48 Beam-to-column hinged connections: (a and b) connections with external steel plates or fishplates and (c) connection with a glued-in threaded bar (Source: Nordic glulam handbook 2001 p. 281 and Finnish Glulam Association ry and Puuinfo Oy 2015 p. 258, 262)

Glued-in threaded bar connections

In pinned glued-in threaded bar joists, connecting fixtures between columns and beams are threaded steel bars that are glued inside GL columns (Fig. 3.48c). Steel bars go through main beams and bars are tied towards beams from above with nuts and washers. Gluing operations are carried out at GL production sites and, thus, columns are delivered with project-specific nuts, bolts, and washers. Connecting fixtures can be hidden inside mortised main beams and covered with wooden caps in order to realize completely hidden and fire resistant connections. Treaded bars are placed close to the inner edges of columns so that connections are working as hinged joints. Acceptable distances from edges are 4 times the diameters of threaded bars, respectively. When two or more bars are used, they are placed on a row next to each other.[110]

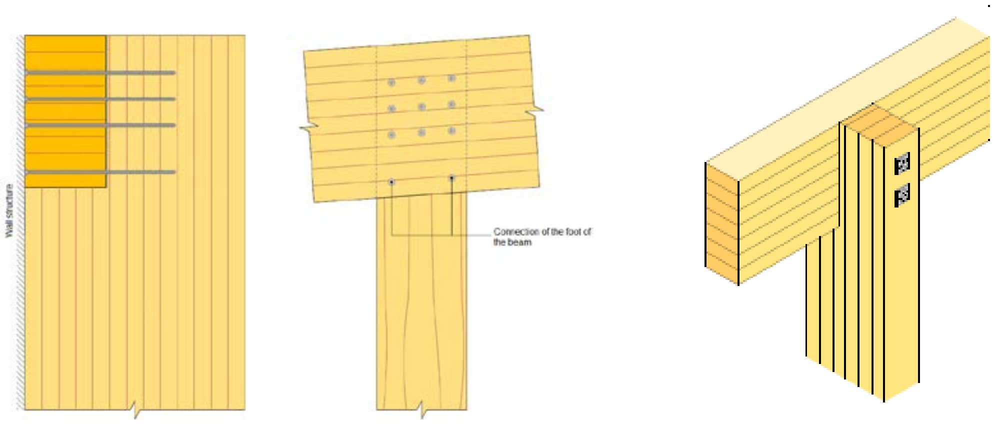
Glued-in threaded bar connections do not provide enough lateral support for beams. Thus, connections are separately braced from above by using, for example, secondary beams or bracing roof elements. These connections may not be an acceptable solution for Service Class 3 or structures subjected to dynamic or fatigue loads. Their use should be limited to beams less than 500 mm deep due to moisture movements.[111]

[110] Nordic glulam handbook 2001 p. 286
[111] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 262

Notched column head connections

Notched column head connections are a commonly used solution in the gables of buildings for the transfer of horizontal and vertical loads from beams to wind columns and corner columns. The tops of columns are notched for placing beam members in notches and fastening them with screws (Fig. 3.49a) or with threaded bars and nuts (Fig. 3.49b). Connections are designed to act as hinged joints. Connectors are placed accordingly. Connecting fixtures are transferring potential uplifting vertical loads and withdrawing horizontal loads. Screws can be used in relatively small loads and dimensions. Screws provide high fire protection and aesthetics. In the case of high loads and dimensions, threaded steel bars are used through beam members and columns, fastened with nuts and washers. Vertical loads from beams are transferred eccentrically to columns by contact areas between columns and beams. Notched column head joints are measured accordingly. In the case of high eccentricity, contact surfaces can be enlarged by using reinforcing steel plates under beams in order to avoid high shear stresses for connectors. The eccentricity of beams causes extra bending moments to columns that are undertaken in the design of connections.[112]

In general, screws should be used in cases when loads and dimensions are not too high. Screws enable the easy execution of connections versus fire technical and aesthetic issues.



(a) (b)

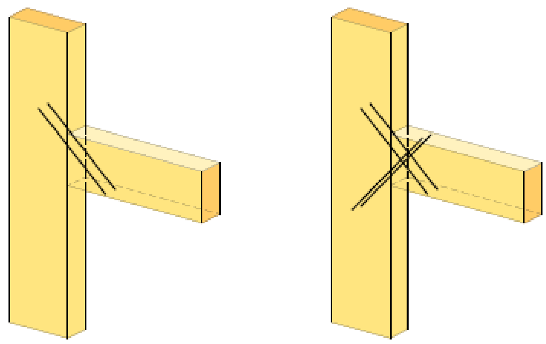
Figure 3.49 Notched column head connections: (a) with self-tapping screws and (b) with threaded bars and nuts with washers (Source: Finnish Wood Research 2014 and Finnish Glulam Association ry and Puuinfo Oy 2015 p. 262)

[112] Puuinfo Oy 2012d p. 1-4

Inclined screws connections

During the last ten years, inclined screws connections have become a more common solution (Fig. 3.50), enabled by the development of more durable, stronger, and larger size of wood screws with options for different threaded parts and heads (Fig. 3.7).[113] Shear forces and potential traction forces are transmitted through the shear and withdrawal capacities of screws. The compression of beams is transferred through contact areas between the surfaces of beam and columns. Diagonal screws connections and cross screws connections are built up by using the symmetrical pairs of screws driven at an angle of $30° \leq \alpha \leq 60°$. In a crossed screws connection, one pair of screws is working for compression and another pair is working for traction (Fig. 3.50b). In a diagonal screws connection, a pair of screws is working only for traction (Fig. 3.50a).[114]

For inclined screws connections, modern wood screws are with cylindrical heads (in order to penetrate well enough inside wood), self-tapping, and fully threaded or double threaded. Herein, five times higher rigidity is achieved for joints with a more than 50% higher mechanical capacity by using similar screws as in traditional, axially screwed connections.[115]



(a) (b)

Figure 3.50 Beam-to-column connections with inclined screws: (a) screws driven diagonally and (b) crossing screws (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 253)

[113] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 253

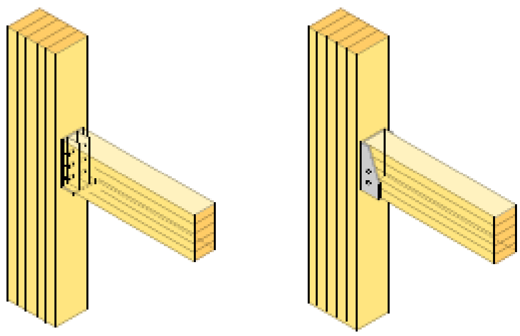
[114] Kevarinmäki, A. 2014

[115] Kevarinmäki, A. 2014

Connections with concealed beam hangers and exposed beam hangers

Metal beam hangers can be used for many different loading situations from light terrace structures to heavy main and secondary beams in hall buildings. Hangers are established as hinges or moment-resisting connections for limiting the rotation caused by the eccentricity of loads. There is a range of standard sized connectors. In the case of extremely high loadings and large cross sections, custom-made welded beam hangers are a viable solution based on the unique design and production.

There are connections with concealed beam hangers (Fig. 3.51a) and exposed beam hangers (Fig. 3.51b). In both connections, loads are transmitted from beams to connectors through the bearing seats or dowels of connectors and onwards from connectors to columns through the formed shear stresses of connecting fixtures. Hangers are fastened to the sides of columns with anchor nails or screws. There are lateral shear force and axial force as well as compression or tension in the direction of beam members. Small moments may appear due to the eccentricity of beam members. The two connections differ mainly in terms of visibility. Concealed beam hangers have better aesthetics and fire resistance since connecting fixtures are protected by wood layers.[116]



(a) (b)

Figure 3.51 Beam-to-column connection with beam hangers: (a) concealed beam hanger and (b) exposed beam hanger (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 254)

3.5.4 Beam-to-beam GL connections

Secondary beam connections can be carried out in two alternative ways. By placing a secondary beam on the top of a primary beam, a connection is mainly transmitting vertical loads from a secondary beam to a primary beam. This joint is capable to resist only low shear stresses. On-side connections instead are applicable also in moment-resisting joints. On-top connections are mainly used in the gables of buildings and in situations where the height of the primary beam is so low that installation to the side is not possi-

[116] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 254-255

ble. Thus, principally secondary beams are applied to connect on the side of the main beam for improving the use of space.

Wooden bearing supports with GL blocks (Liimapuuklossi)

Among GL beam member connections, a commonly used solution to connect secondary beams to primary beams are wooden bearing supports, such as wooden beam shoes that are made of two GL blocks and measured to accommodate the loadings and dimensions of secondary beams. Blocks are pre-fixed to the sides of primary beams with inclined wood screws in order to achieve high traction capacity. Secondary beams are placed into slots between GL blocks and fastened from both sides with inclined wood screws. In total, beams are supported from below and both sides. Alternatively, wooden bearing support connections can be carried out as one-side solutions wherein lateral supports are only on one of the sides of beams. Secondary beams are placed above primary beams and supported to the directions of roof slopes. Therein, secondary beams are more likely to buckle. GL blocks are a practical and economic solution for the placement of primary and secondary beams on same planes. When the heads of metal connectors are covered with wood, this solution provides 30 minutes of fire resistance.[117]

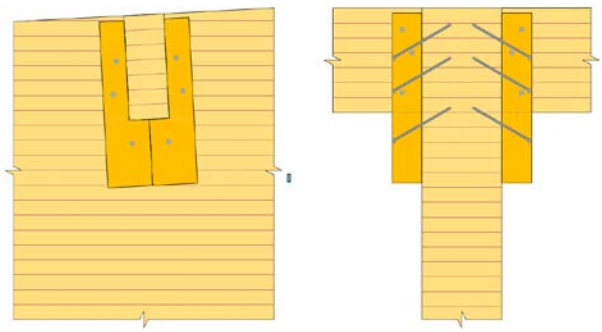
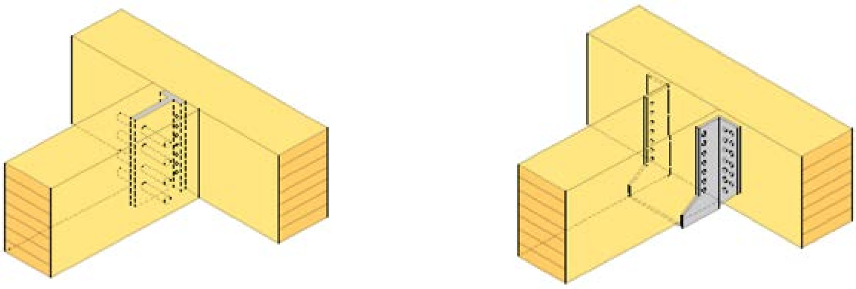


Figure 3.52 Wooden bearing support connection with GL blocks (Source: Finnish Wood Research 2014 p. 34)

[117] Puuinfo Oy 2012a p. 1-4

Connections with concealed beam hangers and exposed beam hangers

Beam-to-beam connections with concealed beam hangers (Fig. 3.53a) and exposed beam hangers (Fig. 3.53b) are working with the same principles as beam hangers for beam-to-column connections (see Section 3.5.3). The two connection types differ in terms of stresses that are transmitted to main beams. In beam-to-beam connections, stresses are transmitted perpendicular to the grain directions of main beams. Thus, a possibility that wood is cracking needs to be accommodated in designs. Beam hangers are placed and fastened as high as possible to the sides of main beams in order to avoid cracking.[118]

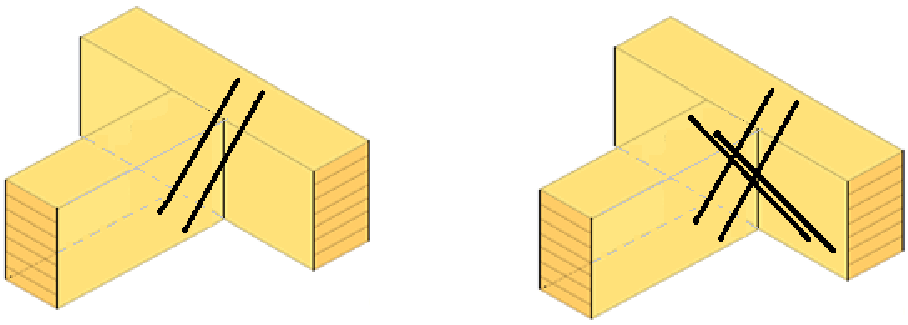


(a) (b)

Figure 3.53 Beam-to-beam connections with: (a) concealed beam hanger and (b) exposed beam hanger (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 257)

Inclined screws connections

Beam-to-beam joists carried out with inclined screws (Fig. 3.54) are working with same principles as inclined screws for beam-to-column connections (see Section 3.5.3).



(a) (b)

Figure 3.54 Beam-to-beam connections with inclined screws: (a) screws driven diagonally and (b) crossed screws (Source: Finnish Glulam Association ry and Puuinfo Oy 2015)

[118] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 257

Connections with overhanging beam shoes

Overhanging beam shoes provide the transfer of stresses more naturally through wider contact surfaces in combinations with other fastening systems (Fig. 3.55). In addition to normal force and shear force, connections can be designed to transfer moment. Normal and shear stresses from secondary beams are transmitted through contact surfaces, which enhances the transfer of high vertical loads.[119]

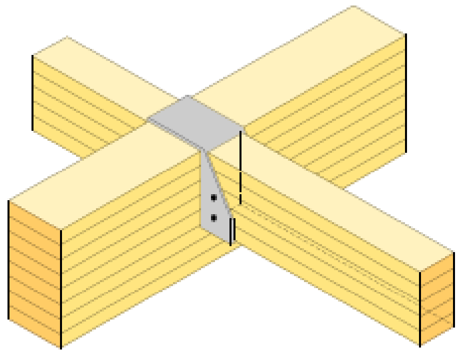


Figure 3.55 Beam-to-beam connection with an overhanging beam shoe (Source: Finnish Glulam Association ry and Puuinfo Oy 2015 p. 256)

[119] Finnish Glulam Association ry and Puuinfo Oy 2015a p. 256

4 ROLE OF THE WOOD CONSTRUCTION WITHIN THE BUILDING CONSTRUCTION SECTOR IN FINLAND

4.1 Outlook on the building construction sector in Finland

The total turnover of the building construction sector in Finland was 23.0 billion euros in the year 2015. The turnover of the repair and maintenance production was 12.2 billion euros and its share was 53%. The turnover of the new building production was 10.8 billion euros (Fig. 4.1). The long-term development of the construction production is strongly dependent on the evolution of the gross domestic product (GDP) of each country. After many years of the stagnation, it was forecasted that the GDP of Finland would start to grow again in the years 2016-2017. In the same vein, both the repair and maintenance sector and the new building sector would grow in the coming years. The new building sector will mainly grow through the residential buildings in the growing city centers. Nevertheless, the share of the repair and maintenance production will increase smoothly. [120]

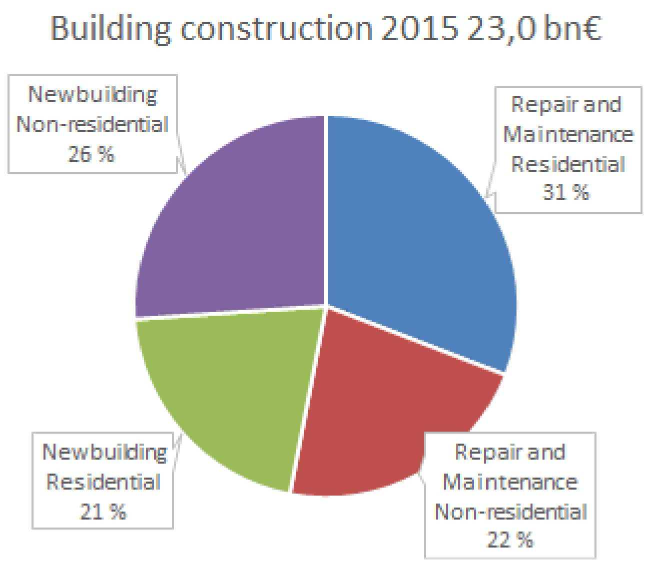


Figure 4.1 Building construction sector output in Finland in the year 2015 (Source: Confederation of Finnish Construction Industries RT 2016b)

[120] Confederation of Finnish Construction Industries RT 2016a

The volumes of the new started buildings by the six fields of use in Finland in the years 2005-2015 are illustrated, measured in cubic meters (m^3) in Figure 4.2. The volumes of the three fields increased and those of the three fields decreased in the year 2015. In the biggest field, the volume of the dwellings decreased to about 10.0 million m^3. It seems that this drop is due to a trend of investing in smaller dwelling units. The number of the started dwellings was 32 900 units, over 6 000 units more than the forecasted level in the year 2015. It was forecasted that 36 000 units were started in the year 2016, followed by a small drop down to 34 000 units in the year 2017.[121]

The volume of the started industrial buildings and warehouses grew up to 8.1 million m^3. It was forecasted that this volume increased 10% up to 8.9 million m^3 in the year 2016. The growth in the Finnish economy is mirrored also on the reactivated investment willingness in the new industrial construction after the low investment rates during the previous years. It is forecasted that this volume will increase slightly up to 9.3 milllion m^3 in the year 2017.[122]

The volume of the started commercial and office buildings grew up to 5.4 milllion m^3 in the year 2015. It was forecasted that this volume increased significantly up to 6.4 milllion m^3 in the year 2016, followed by a slight decrease down to 5.7 million m^3 in the year 2017.[123]

The volume of the started public service buildings was 3.5 million m^3 in the year 2015. It was forecasted that this volume increased up to 4.3 milllion m^3 in the year 2016, followed by a slight decrease to 3.8 milllion m^3 in the year 2017.[124]

The volume of the started agricultural buildings was unforeseen low, only 2.0 million m^3 in the year 2015, meaning a drop of 65% compared to the year 2014. However, it was forecasted that this volume increased again up to 3.4 million m^3 in the year 2016.[125]

[121] Confederation of Finnish Construction Industries RT 2016b p. 3
[122] Confederation of Finnish Construction Industries RT 2016b p. 5
[123] Confederation of Finnish Construction Industries RT 2016b p. 4
[124] Confederation of Finnish Construction Industries RT 2016b p. 4

[125] Confederation of Finnish Construction Industries RT 2016b p. 5

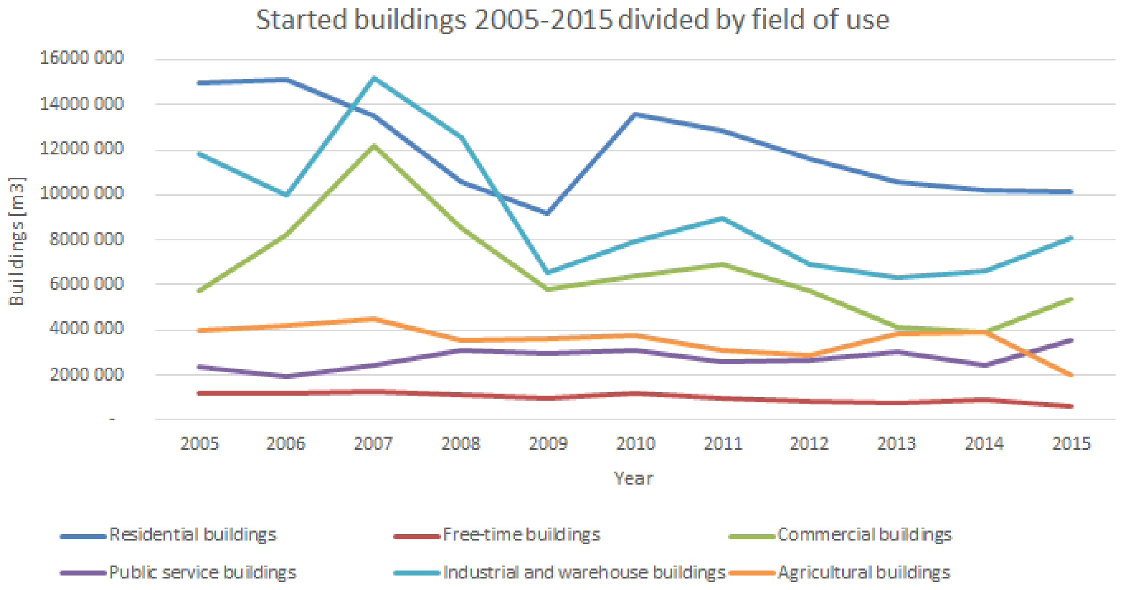


Figure 4.2 Volume (m^3) of the buildings started in Finland by the field of use in the years 2005-2015 (Source: Official Statistics of Finland 2016a)

Concerning the new residential building construction, the annual total number of the new dwellings started in Finland has experienced a rise, a dip, and again a rise in the years 2005-2015 (Fig. 4.3). It was forecasted that the total number increased 6.5% in the year 2016. The annual number of the started non-subsidized residential buildings is increasing as well, which is telling about the returned confidence among developers and home buyers. Households are willing to invest in new dwellings due to the positive economic development and the decreasing level of unemployment in Finland. [126]

Figure 4.3 Number of the dwellings started in Finland in the years 2005-2015 (Source: Official Statistics of Finland 2016b and Confederation of Finnish Construction Industries RT 2016a)

[126] Confederation of Finnish Construction Industries RT 2016a

The annual numbers of the started dwellings by the three types of the residential buildings, i.e., the blocks of the flats, the attached houses, and the detached houses are illustrated in Figure 4.4. The started detached houses were the most common residential building type during the years 2005-2008. This position was lost in the year 2009. The dwellings started in the blocks of the flats have been the most common residential building type during the years 2009-2015. It was forecasted that this trend would continue in the future. The main factor behind the increased numbers of the dwelling units built in the blocks of the flats is the migration into the urban areas in the cities of Helsinki, Tampere, Turku, Oulu, Kuopio, and Seinäjoki (listed in the order of the size of the migration). It has been estimated that the combined share of these six cities will be 89% of the net internal migration in Finland in the coming years.[127] The migration has been going on for decades. Thus, the demand has been exceeding the supply of the small dwellings and this has resulted in the increasing prices in the previously mentioned growing cities, especially in the Helsinki Metropolitan area.[128]

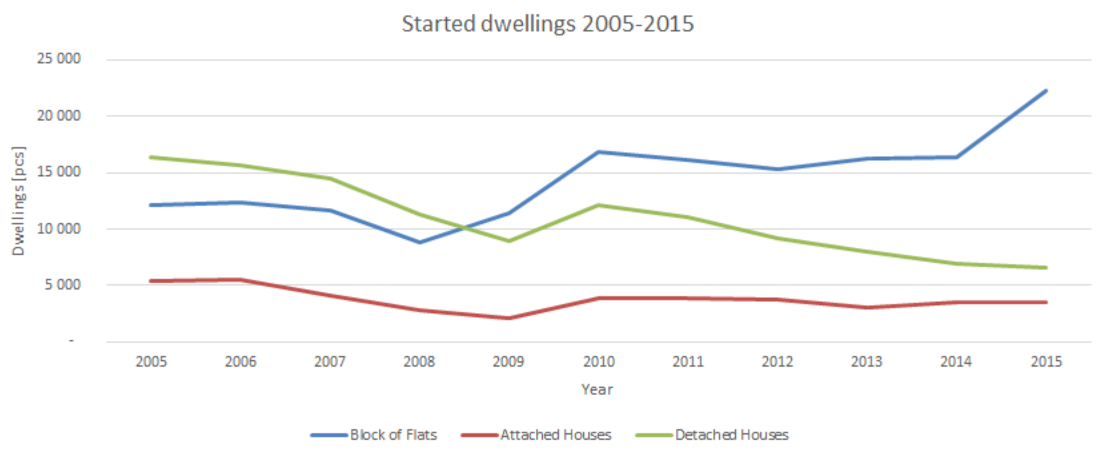


Figure 4.4 Number of the dwellings started in Finland by residential building type in the years 2005-2015 (Source: Statics Finland 2016)

4.2 Role of the wood construction in Finland

The Ministry of Economic Affairs and Employment in Finland launched the National Wood Construction Program, under the Strategic Programme for the Forest Sector, for the years 2011 - 2015. The main aim was to reduce the carbon footprint of construction by increasing the utilization of domestic wood significantly in buildings. Internationally, the Finnish wood construction brand has been built on the design of buildings by combining good architecture, environmental consciousness, and energy-efficiency. One of the aims was to double the value of the exports of refined wood products. The program aimed at increasing the market share of the wooden multi-storey buildings from approx-

[127] Official Statistics of Finland 2016b

[128] Aro, T. 2014

imately 1% to 10% of the total production of new multi-storey buildings in Finland. In the year 2011, the national building regulations were renewed to allow the construction of up to wooden 8-storey buildings. The completely new market segments for wood products were opened.[129] The Wood Construction Program has been carried out with the encouraging results, i.e., the market share of the wooden multi-storey buildings had increased to about 5-6% by the year 2015.[130]

The turnover of the total consumption of the building materials was about 15 billion euros in the year 2013. The total share of the wood based products was 29% or 4.5 billion euros. Therein, the share of the sawn timber was 29 % based on the exports-driven markets. The share of the wood elements was 19%. The share the wooden structures including LVL, GL, trusses, etc. was 10%. The other important client segments of the wood industry involved the window and door manufacturers, the furniture industry, and the wooden board producers.[131]

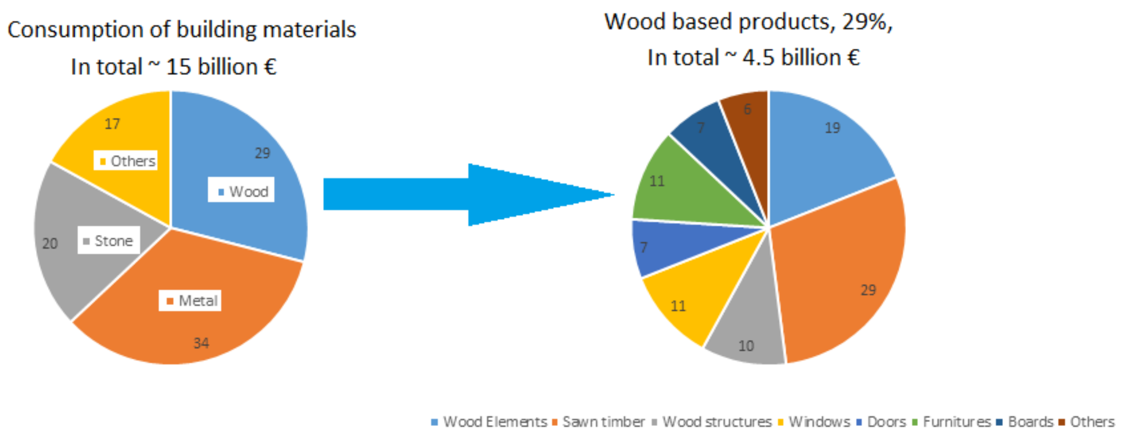


Figure 4.5 Consumption of the building materials in Finland as well as the total consumption of wood based products and its division by the eight product groups in Finland in the year 2013 (Source: Pajakkala, P. 2016)

[129] Ministry of Economic Affairs and Emplyment in Finland 2011
[130] Ministry of Economic Affairs and Emplyment in Finland 2015a
[131] Pajakkala, P. 2016

4.3 Four national associations related to the wood construction in Finland

There are several national organizations for the woodworking industry that gather all manufacturers together in order to share common interests and information over the wood working sector in Finland. The four key associations include The Federation of the Finnish Woodworking Industries, Puuinfo Oy, the Log House Industry Association, and the Finnish Glulam Association.

The Federation of the Finnish Woodworking Industries ry was founded under the top organization of the Finnish Forest Industries Federation ry in the year 2015. The Federation of the Finnish Woodworking Industries ry is coordinating the research and expertise in order to enhance the growing utilization of wood products inside Finland and internationally. The promotion of the use and acceptance of tightly-regulated construction products calls for shared industry endeavors as well as product based and material based lobbying in relation to legislation and standardization.[132]

Puuinfo Oy is an independent, non-profit association for wood products manufacturers with the aim on promoting wood based products and solutions for building professionals and private builders. Puuinfo Oy is providing a wide range of information related to wood construction through the internet and seminars. There are numerous documents available for free on the website dealing with wood based products and solutions, standards, and regulations, readily packaged for different wood builders.[133]

The Log House Industry Association ry is the joint organisation of the leading log house factories based in Finland. The member companies strictly adhere to the building regulations in design and production as well as to the approved terms and conditions in deliveries. When clients buy buildings from member companies, they know that they get high quality and reliable service. Together, the member companies produce more than 80% of all the log buildings in Finland. In turn, the share of the exports is over 30% of the total turnover of the member companies. They export log based products to over 40 countries. Their association is a member of the Federation of the Finnish Woodworking Industries.[134]

The Finnish Glulam Association ry is an organization of GL manufacturers in Finland. It is a joint body for national and international cooperation. The association provides statistics, participates in standardization, and promotes the consumption, research, and development of glued laminated timber.[135]

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[132] Federation of the Finnish Woodworking Industries 2015
[133] Puuinfo Oy 2016b
[134] Log House Industry Association ry (2016)
[135] Finnish Glulam Association ry 2016

4.4 Volume and market share of the wood construction in Finland

4.4.1 Detached houses

About 16 400 detached houses were started in Finland in the year 2005 (Fig. 4.6).[136] The number has been decreasing annually. Only 6 500 detached houses were started in the year 2015.[137] Pre-fabricated housing element packages delivered and installed on sites have been the most common solution among private house builders. The share of the pre-fabricated house packages was 74% of the total production of the new detached houses in the year 2015.[138]

More recently, it was estimated that about 6 400 detached houses were completed in the year 2016. Thereof, the share of the detached houses with the wooden frames was 88 % and the combined share of the detached houses with the brick and concrete frames was 12%. Further, it was estimated that the share of the (log) timber frames was 74% (14%) of the detached house completions in the year 2016. In other words, the 5 600 detached family houses with the wooden frames were completed with the average size of 105 square meters in the year 2016.[139]

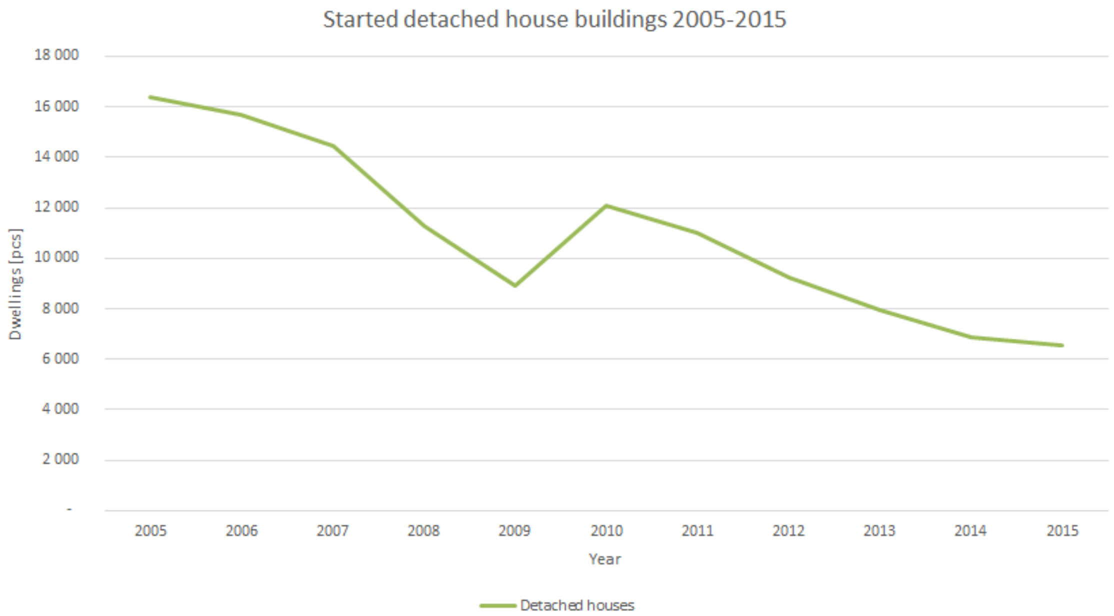

Figure 4.6 Number of the dwellings started in the detached houses in Finland in the years 2005-2015 (Source: Official Statistics of Finland 2016b and Confederation of Finnish Construction Industries RT 2016b)

[136] Official Statistics of Finland 2016b
[137] Confederation of Finnish Construction Industries RT 2016b
[138] Pientaloteollisuus PTT Ry 2016a
[139] Pientaloteollisuus PTT Ry 2016b

4.4.2 Free-time buildings

It is estimated that there are about 0.5 million free-time buildings in Finland, one building or cottage per each tenth Finnish citizen. The annual production was on the top level of about the 10 000 free-time buildings before the 1990s. The annual production decreased to the stable level of about 4 000 new free-time buildings in the 2000s. Recently, the 2 200 new free-time dwellings were completed in the year 2015. Thereof, most of the dwellings were completed in Southwest Finland and Lapland.[140] The average size of all the summer cottages is 48 square meters in Finland. The traditional small cabins may still be without comforts. In turn, the average size has increased up to 72 square meters in the free-time buildings completed during the years 2010-2015.[141] The increased floor area is supporting the trend of second homes with modern facilities. The overwhelming share of the wood as the construction material is 99% of all the free-time buildings[142]. The share of the log frames is about 80% of the free-time buildings with the wooden frames. The share of the prefabricated house packages is about 60% of the annually completed free-time buildings.[143]

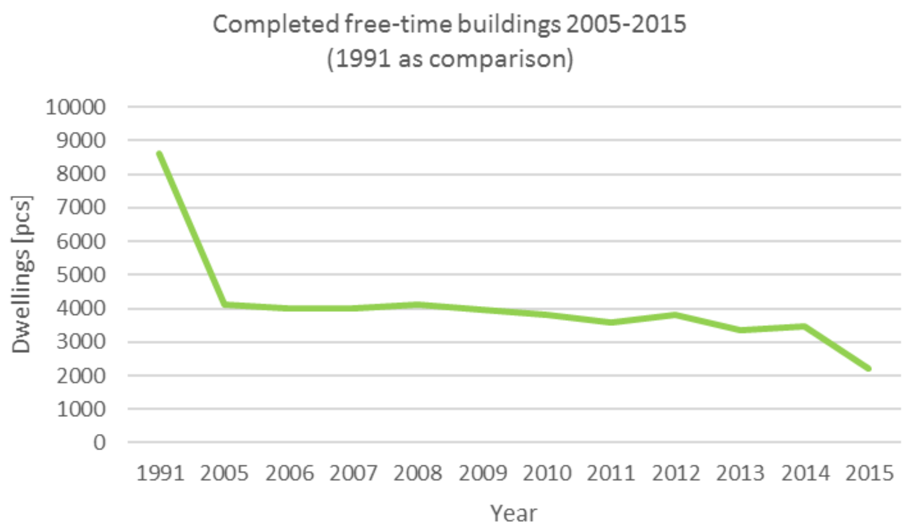

Figure 4.7 Number of the dwellings completed in the free-time buildings in Finland in the years 2005-2015 (Source: Official Statistics of Finland 2016d)

[140] Official Statistics of Finland 2016c

[141] Official Statistics of Finland 2016c

[142] Karjalainen, M. 2016

[143] Pientaloteollisuus PTT Ry 2016b

4.4.3 Multi-storey buildings

The share of the building permits granted for the multi-storey buildings with the wooden frames increased strongly from 1% of the total number of the permits for all the multi-storey buildings in the year 2010 up to about 4-5% of the same in Finland in the year 2015. It is estimated that the target share of 10% of the Ministry could be attained during the coming years. This estimate is supported by the increase of the number of the building permits for the dwellings to be built in the multi-storey buildings with the wooden frames, i.e., the 1 125 building permits were granted in the year 2015 (Fig. 4.8). [144]

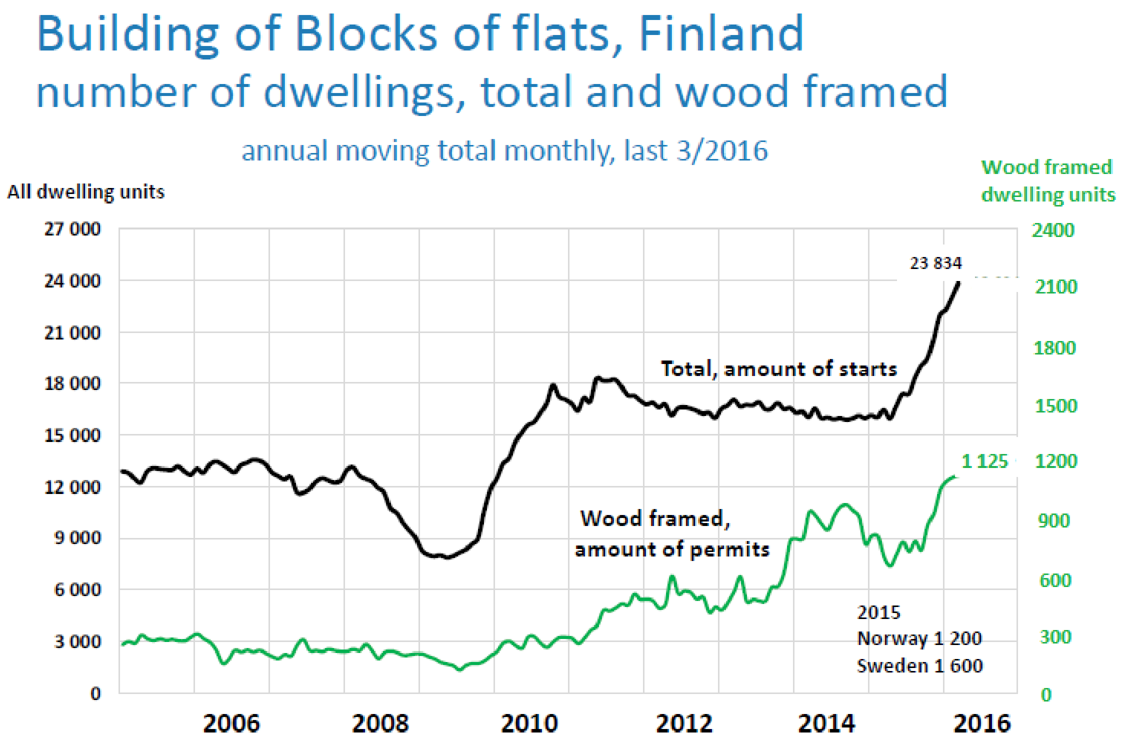

Figure 4.8 Annual moving total number of the blocks of the flats and the annual moving number of the dwellings in the blocks of flats with the wooden frames started in Finland in the years 2005-2015 (Source: Pajakkala, P. 2016)

The numbers of the annually completed, new, 4-storey and higher multi-storey blocks of the flats with the wooden frames are compiled over the years 1996-2015 in Figure 4.9. The average annual number has been about 40 dwellings during the years 1996-2014. In turn, the significant increase in the real terms took place, when the eight new blocks of the flats with the 376 dwellings were completed in Finland in the year 2015 (Annex 1). However, this only corresponds to a share of less than 2% of the total number of the new dwellings completed in the all multi-storey buildings.[145]

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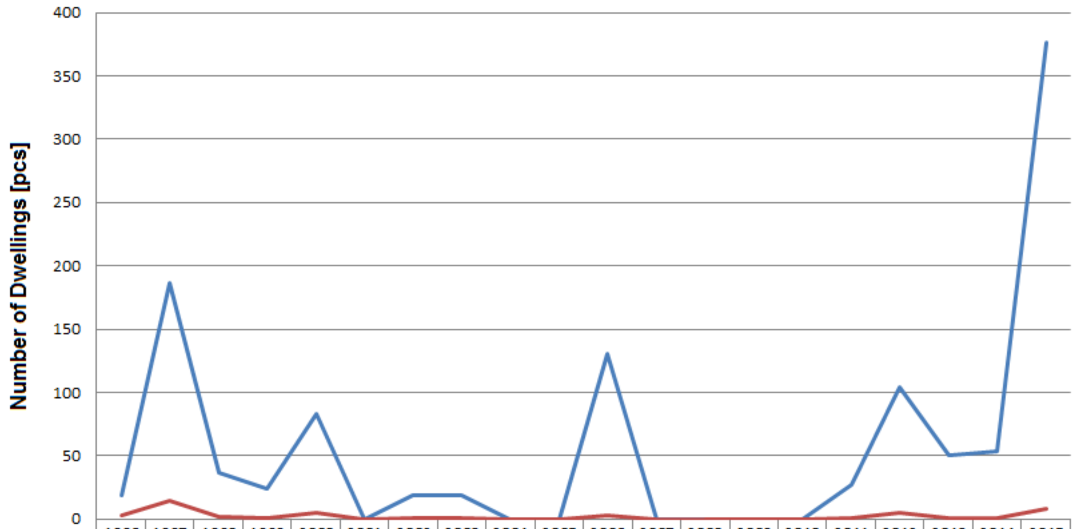
[144] Pajakkala, P. 2016 p. 19

[145] Puuinfo Oy (2017)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Residences	19	186	37	24	83	0	19	19	0	0	131	0	0	0	0	27	104	50	54	376
Buildings	3	15	2	1	5	0	1	1	0	0	3	0	0	0	0	1	5	1	1	8

Figure 4.9 Number of the dwellings completed in the wooden, at least 4-storey blocks of flats in Finland in the years 1996-2015 (Annex 1) (Source: Ijäs 2013 p. 58., Ministry of Economic Affairs and Employment in Finland, and Puuinfo Oy 2015, 2017)

Only the two wood building construction techniques were exploited for the completion of the eight, 4-storey and higher blocks of the flats with the wooden frames and therein the 376 dwellings in Finland in the year 2015 (Fig. 4.10). The modular element system assembled of the CLT panels were used to complete the six blocks of the flats and the 175 dwellings. There were only a few CLT panel manufacturers in Finland. In turn, the load-bearing wall frames were used to complete the two blocks of the flats and the 201 dwellings. Load-bearing wall elements can be made of GL, LVL, and sawn timber, which means that there are more manufacturers on the market.

Overall, the annual production volume of the wooden multi-storey buildings has been extremely low in Finland. However, the advantages of wood's self-weight could be demonstrated by the use of the two building construction techniques, i.e., modular systems and load-bearing wall elements during the top year 2015.

4.4.4 Hall buildings

The only available information about the construction materials used in the hall buildings in Finland was dating back to a period of the years 2008-2011. The overview of the production concerns the annual numbers in terms of the total areas in square meters of all the hall buildings, the areas and relative shares of the hall buildings with the wooden frames, and the shares of the wood, concrete, and steel by the three area categories as follows.

The annually produced total area of all the hall buildings varied between 44.2 and 62.0 million square meters in Finland in the years 2008-2011 (Table 4.1). Concrete was the primarily used construction material in the frames of the hall buildings. The produced area (share) of the hall buildings with the concrete frames varied between 23.2 (53%) and 34.8 (56%) million square meters per annum. The produced area (share) of the hall buildings with the steel frames varied between 12.5 (25%) and 16.7 (34%) million square meters per annum. In turn, the produced area (share) of the hall buildings with the wooden frames varied only between 7.0 (14%) and 9.5 (15%) million square meters per annmum. However, the wooden frames had annually gained the bigger shares in the small and middle-sized hall buildings, respectively, as follows.

Table 4.1 Annual total production (m2) of the hall buildings and the production (m2) of the hall buildings with the wooden frames in Finland in the years 2008-2011 (Source: Puuinfo Oy / Puuhalliklusteri)

	Wooden hall Buildings				Halls in total	Share of wood
	m2	m2	m2	m2	m2	%
	400-800	800-2000	2000-	Total		
2011	2 645 088,0	2 737 455,0	1 751 769,0	7 134 312,0	48 884 929,0	14,6 %
2010	2 743 551,0	2 476 157,0	1 826 889,0	7 046 597,0	44 183 592,0	15,9 %
2009	2 539 423,0	2 562 813,0	1 856 407,0	6 958 643,0	49 835 544,0	14,0 %
2008	3 542 203,0	3 460 940,0	2 467 304,0	9 470 447,0	62 022 541,0	15,3 %

The annually produced area (share of all the hall buildings) of the large (over 2000 m^2) hall buildings varied between 28.5 (64%) and 40.9 (66%) million square meters in Finland in the years 2008-2011 (Table 4.2). Concrete was the dominant construction material with the annual share of 60-70%. In the early 2010s, wood was the secondary material with the annual share of 5–6%.

Table 4.2 Annual production (m^2) of the larger than 2000 m^2 hall buildings with the wooden, concrete, and steel frames in Finland in the years 2008-2011 (Source: Puuinfo Oy / Puuhalliklusteri)

	Halls > 2000 m2			
	m2			
	Wood	Concrete	Steel	Total
2011	1 751 769,0	19 538 275,0	10 532 786,0	**31 822 830,0**
2010	1 826 889,0	18 038 562,0	8 606 519,0	**28 471 970,0**
2009	1 856 407,0	25 204 200,0	7 737 478,0	**34 798 085,0**
2008	2 467 304,0	28 764 015,0	9 643 515,0	**40 874 834,0**

The annually produced area (share of all the hall buildings) of the medium-sized (801-2000 m^2) hall buildings varied between 9.1 (18%) and 12.7 (21%) million square meters in Finland in the years 2008-2011 (Table 4.3). The average annual uses of concrete (37%) and steel (36%) were closely followed by the use of wood (27%) in the years 2008-2011.

Table 4.3 Annual production (m^2) of the 800-2000 m^2 hall buildings with the wooden, concrete, and steel frames in Finland in the years 2008-2011 (Source: Puuinfo Oy / Puuhalliklusteri)

	Halls 800-2000 m2			
	m2			
	Wood	Concrete	Steel	Total
2011	2 737 455,0	3 652 518,0	4 094 827,0	**10 484 800,0**
2010	2 476 157,0	4 153 548,0	3 084 424,0	**9 714 129,0**
2009	2 562 813,0	3 401 542,0	3 142 704,0	**9 107 059,0**
2008	3 460 940,0	4 478 431,0	4 778 947,0	**12 718 318,0**

The annually produced area (share) of the small (400-800 m^2) hall buildings varied between 5.5 (11%) and 7.4 (12%) million square meters in Finland in the years 2008-2011 (Table 4.4). Wood was the mostly used, light, economic frame material with the average share of 47% in the years 2008-2011. This dominance in the case of short spans and not so heavy loaded structures was already based on the use of GL and LVL structures as well as load-bearing walls, light timber frames, and timber made roof trusses.

Table 4.4 Annual production (m^2) of the 400-800 m^2 hall buildings with the wooden, concrete, and steel frames in Finland in the years 2008-2011 (Source: Puuinfo Oy / Puuhalliklusteri)

	Halls 400-800 m2			
	m2			
	Wood	**Concrete**	**Steel**	**Total**
2011	2 645 088,0	1 262 326,0	2 117 620,0	**6 025 034,0**
2010	2 743 551,0	1 054 926,0	1 841 363,0	**5 639 840,0**
2009	2 539 423,0	1 409 576,0	1 575 283,0	**5 524 282,0**
2008	3 542 203,0	1 531 861,0	2 297 992,0	**7 372 056,0**

4.5 Technical assessments and the certification systems related to wooden structures in the Finnish context

4.5.1 Framework for the design of timber structures

The Law of Land Use and the Building Act as well as the building codes, the regulations, and the guidelines are governing construction in Finland (Fig. 4.10). The law is controlling land use and construction activities. The law has the strong effects on urban planning and building production. The aim is to ensure a healthy, safety and comfortable living environment for each citizen.[146]

The Finnish Association of Civil Engineers (RIL) publishes the national guidelines for construction professionals in civil engineering, including the guidelines for timber structures. Guideline for Design of Timber Structures (RIL 205-2009) is in a harmony with Eurocode 5 (EN 1995) and its national annexes (NA). Therefore, this guideline provides an overview over the current timber construction traditions and methods in Finland. In turn, the Finnish Standard for Execution of Timber Structures (SFS 5978) is guiding the safe execution of timber structures and the avoidance of the past critical failures. The aim is to act as a link between designers and builders, i.e., to ensure that contractors take into account the structural solutions and requirements without deviations. The standard covers the essential documents wherein the technical requirements are specified to contractors for the proper execution of buildings.[147]

[146] Ministry of the Environment 2017
[147] Toratti, T. 2016

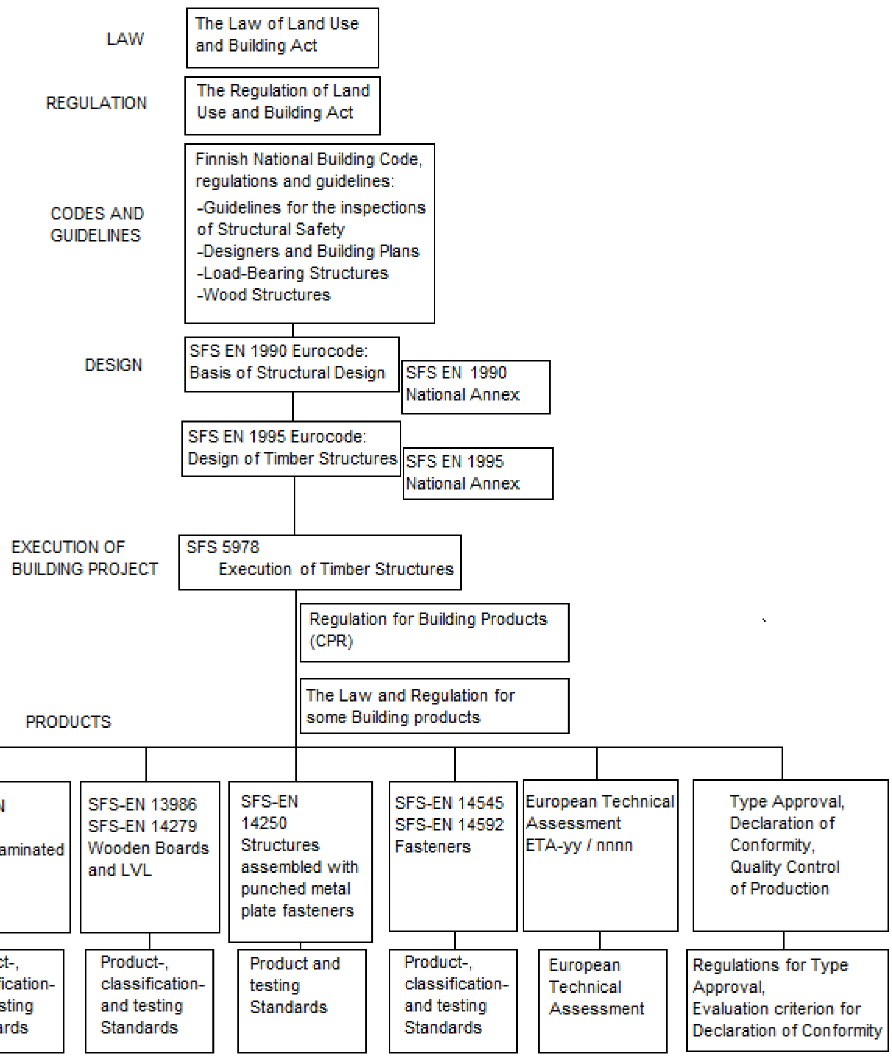


Figure 4.10 Hierarchy of the regulations for the engineering and execution of the timber structures in Finland in the year 2015 (Source: Toratti, T. 2016)

4.5.2 CE marking

The new regulation for building products came effective in the EU member countries in the year 2013. It is mandatory to have a CE mark for building products, if the Harmonized European Standard (hEN) exists for the product group in question. CE marks indicate that manufacturers' products are in accordance with the requirements of the hEN or the European Technical Assessment (ETA). The Declaration of Performance (DoP) is the key document of each CE mark, including the essential technical information of a product, in accordance with the hEN or the ETA procedure. DoPs allow comparisons between similar products with CE marks manufactured by different companies. A CE mark itself is not a guarantee of quality. The eligibility of a product for its purpose has to be defined separately in accordance with local circumstances and regulations. The aim is to ease comparisons between similar products of different producers, to open new markets for building product manufacturers, and to increase a range of available offerings within building product markets in each EU member country.[148]

Other technical assessments and certifications are voluntary procedures, but under supervision by third notified parties. The Ministry of Environment has accepted the following organizations to act as such a third party in Finland:[149]

- Inspecta Sertifiointi Oy
- VTT Expert Services Oy
- Contesta Oy
- DNV Certification Oy
- Finotrol Oy
- Ramboll Finland Oy
- SYKE Suomen ympäristökeskus (Finnish Environment Institute)
- XAMK Kaakkois-Suomen ammattikorkeakoulu Oy, entinen Kymenlaakson ammattikorkeakoulu Oy (South-Eastern Finland University of Applied Sciences).

4.5.3 European Technical Assessment (ETA)

When there is no hEN for a product, the ETA is a voluntary option to a manufacturer who wants to apply a CE mark to its product. The ETA is a common procedure to gain a CE mark for innovative and new products outside the current hENs. The ETA is granted in accordance with the European Assessment Document (EAD) and it is valid for five years. VTT Expert Services Oy is a notified, responsible body for conducting ETAs in Finland. The ETA application procedure is heavy and long in comparison with the hEN procedure. In the ETA procedure, the first step is to define a common frame of reference for a product evaluation. This frame must be agreed upon by all the European notified bodies appointed for conducting ETA approvals. In turn, this agreement ensures that once approved tests and results are not later questioned by other notified bodies or European countries. Tests are carried out by a certified laboratory in order to investigate the characteristics of a product.[150]

4.5.4 National procedures for product approvals in the case of Finland

The reliance of national procedures for product approvals is acceptable for building products without the ETA or the hEN or a product is not corresponding to the product range of the published hEN in terms of the field of use. Products with National Product Approvals are accepted to be used only in the country whose national Annexes have been exploited in the approval process. In this way, manufacturers can prove that prod-

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[148] Ministry of Economic Affairs and Employment 2011
[149] Ministry of Economic Affairs and Employment 2015
[150] European Organisation for Technical Assessment 2016

ucts are meeting the requirements of the national Law of Land Use and the Building Act.[151]

Type Approval

Type Approval is a voluntary procedure in Finland for building products that are notified in the Type Approval regulation of the Ministry of Environment. Type Approval can be applied to building products that are having strong impacts on the technical requirements of building projects. The Ministry of Environment can grant a Type Approval for building products only in special cases and if there are significant reasons. The period of validity for a Type Approval is five years in maximum. If a product meanwhile moves inside the sphere of influence of the hEN, the validity of the Type Approval expires.[152]

Verification Certificate

Verification Certificate is another voluntary procedure for manufacturers for proving that their products are fulfilling requirements and that they are applicable to uses in construction. In turn, contractors can prove the eligibility of products for building control authorities, or when contractors are applying for building permits, respectively. A process of the application for a Verification Certificate is administratively lighter than the one for a Type Approval. A notified body can grant a Verification Certificate either based on the continuous quality control of a manufacturing process or the control by suppliers, i.e., the own quality control by a manufacturer and the assurance and verification of the production control by a third notified body. In comparison, Verification Certificates are related to building products with less requirements and Type Approvals are related to those with more requirements.[153]

Certification of production quality control

The eligibility of building products can be stated by the quality control of production if they cannot be proved by Type Approvals or Verification Certificates. Manufacturers can prove that their products meet the main requirements and the eligibility concerning the reported field of use, if only the internal quality control of manufacturers can be proved. External third notified bodies ensure and verify that manufacturers use sufficient measures. Such bodies publish final reports that also include information about the use of evaluation methods.[154]

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[151] Ministry of the Environment 2016b
[152] Ministry of the Environment 2016b
[153] Ministry of the Environment 2016b
[154] Ministry of the Environment 2016b

Verification on a construction site

Verification on construction sites can be used in those cases when other verification procedures have not been carried out. An on-site verification by a building control authority offers a last chance to ensure the eligibility of building products. Normally, it is a one-time verification related to load-bearing structures, fire safety, or thermal action. However, the same on-site verification can be re-exploited in the case of large projects with similar conditions and buildings. A building control authority may require a verification on a construction site if a manufacturer has not given any other declaration about products or if there is a reason to suspect that a product is not meeting essential technical requirements. The owner of a project is responsible for the implementation and costs of an on-site verification procedure.[155]

[155] Ministry of the Environment 2016b

5 THEME INTERVIEWS ON THE COMPETITIVENESS OF THE WOOD CONSTRUCTION IN THE BUILDING CONSTRUCTION SECTOR IN FINLAND

5.1 Planning and conduct of the theme interviews in Finland

The aim of the field interviews is to collect the relevant information about the role of the wood construction as part of the building construction sector in Finland and especially about the practices related to the use of wooden frame structures in buildings in Finland. The potential interviewees should represent each of the four key professional groups, i.e., investors, structural designers, element manufacturers, and contractors. They should also have gained experience in the wood construction as well as its characteristics and practices in Finland.

The three themes and questions for the field interviews were planned so that they correspond to the study problem and the aims of the field study, based on this interviewer's pre-understanding and the results of the literature review. The semi-structured theme interviews consisted of both the open questions and the questions structured with many alternatives.[156] The interview forms with the group-specific questions are compiled and reported upon as Annex 2. The common theme A covered the background of each interviewee in terms of education, career (jobs), and working experience with wood construction. The common theme B focused on the status of the wood building construction in Finland in the light of an interviewee's own involvement with various past projects and those experiences and insights that an interviewee had gained through these projects.

In turn, the theme C was planned to accommodate the four project stakeholder groups, i.e., (1) investors as investing municipalities, (2) structural designers, (3) manufacturers of prefabricated wood elements, and (4) contractors. At the outset, a theme interview form and a set of the questions was formulated to cover the key aspects of the professional role of an interviewee. In practice, the first set of the key questions was specified

[156] Hirsjärvi, S. & Hurme, H. 2011 p. 42-44

for contractors and checked with Instructor. Thereafter, the same questions were modified to match the key aspects of the three other groups and roles, respectively.

For the identification and screening of potential candidates, the high likelihoods to sustain the current leading, innovative position or to become a major player in the wood building construction were used as the key common criteria.

Many potential candidates could be identified from within each of the four project stakeholder groups. The candidates from among municipal investors in Finland were pre-selected by using the recent experience, i.e., at least one major reference of the investing in and contracting of a public multi-storey building with a wooden frame as the key criterion. The candidates from among structural design firms in Finland were pre-selected by using the personal references of principal engineers, i.e., at minimum 10 years of experience in the design of wooden load-bearing structures as the key criterion. Initially, the candidates were identified from among those major design firms which were recently involved in the design of large building projects with wooden frame structures. The candidates from among wood element manufacturers were pre-selected from the list of the companies that was given on the web-source of Puuinfo Oy [157] by using completed reference projects and expertise in the prefabrication of large wooden elements for frame structures as the key criteria. The candidates from among contractors were pre-selected by using the recent experience, i.e., at least one major reference of an innovative building with a wooden frame as the key criterion.

The formal requests were sent to the 18 candidates during Summer 2016. Thereof, the 14 candidates were willing to assume the roles of the interviewees. Each of them had dealt with one or more wood construction projects at least during the past three years. The four candidates could not be included in the study due to a lack of time, mutually. The formal interview request is attached upon as part of Annex 2.

The 13 face-to-face interviews and the 1 on-phone discussion were carried in September and October 2016. The interviewer sent the interview form and questions (Annex 2) to each interviewee via e-mail beforehand so that he or she had a possibility to prepare for an interview and an actual interview would be mutually handled within a reserved time slot, respectively. The most interviews lasted the two hours, with a variance between one hour and four hours. The three themes and the questions were addressed in the planned order. The theme C with the modified questions allowed each interviewee to answer the questions and to express the interests according her or his professional role and the stakeholder group. The interviews resembled the open discussions of a relaxed nature. Thus, the most questions were answered with some variance in the scope and depth.

The interviewer wrote down and compiled an initial memorandum during and after each interview. The interviewer sent this memorandum to each interviewee and asked to

[157] Puuinfo Oy 2016c

check, change (when necessary), and approve the final memorandum. Each interviewee approved her or his final memorandum.

The answers of the 14 interviewees have been compiled in a set of tables, interviewee by interviewee, so that the similarities and differences in the scope of the answers within and between the four project stakeholder groups (professional roles) could be directly reported and complemented with the key notions in the text. Each interviewee has been coded and abbreviated by the project stakeholder groups. For example, the three interviewees with the roles as the investors are abbreviated as INV 1, INV 2, and INV 3. Nevertheless, the anonymity has been protected. Readers cannot couple any of the published answers with one specific interviewee. The results of the 14 interviews are reported in Sub-chapter 5.2.

5.2 Results of the theme interviews

5.2.1 Basic characteristics of the interviewees

Only the four manufacturers (MAN 1-4) had gained the continuous experience in the wood building construction. On the one hand, the 10 other interviewees (INV 1-3, DES 1-4, and CON 1-3) have carried out many buildings with wooden load-bearing frames or similar structures made of wood, but such project by project experiences have not been continuous (Table 5.1). On the other hand, these 10 interviewees had also at least some experience in the realization of concrete buildings, which turned out to be highly relevant when the interviewer asked each of them to compare wood and concrete solutions. MAN 3 had gained the deepest, 19-year expertise on the wood construction (since the year 1997). He had managed the deliveries of the large wooden roof and wall elements for the hall buildings, over 100 projects, and the company had the references on the large wood based elements over a period of the 25 years. The average experience of the investing municipalities (INV 1-3) and the contractors (CON 1-3) was significantly thinner than that of the two other groups. INV 2, INV 3, CON 1, and CON 2 had carried out many 4-storey and higher buildings with the wooden frames. INV 1 and CON 3 had gained the first experiences in the realization of the 3-storey buildings with the wooden frames, at maximum.

Table 5.1 Basic characteristics of the 14 interviewees

Participants in the interview	Interviewees role/title	Experience in wood construction (years)	How many projects carried out with wood (estimate)	Interviews identification	Abbreviation
Investor 1	Country Manager	2	3	Investor 1	INV 1
Investor 2	Construction Director		10	Investor 2	INV 2
Investor 3 *	Contractor	3	5	Investor 3	INV 3
Designer 1	Designer	16	> 100	Designer 1	DES 1
Designer 2	Chief Inspector	11	> 100	Designer 2	DES 2
Designer 3	Head od Department	10	30	Designer 3	DES 3
Designer 4	Designer	15	> 100	Designer 4	DES 4
Manufacturer 1	R & D Manager	11	100	Manufacturer 1	MAN 1
Manufacturer 2	R & D Manager	13	50	Manufacturer 2	MAN 2
Manufacturer 3	Project Manager	19	> 100	Manufacturer 3	MAN 3
Manufacturer 4	Head of Department	15	> 100	Manufacturer 4	MAN 4
Contractor 1	Project Manager	3	2	Contractor 1	CON 1
Contractor 2	Managing Director	6	4	Contractor 2	CON 2
Contractor 3	Entrepreneur	15	30	Contractor 3	CON 3
* Phone interview					

5.2.2 Wood related professional experiences of the interviewees

Involvement in wooden buildings

The 12 (out of 14) interviewees had been involved in the realization of the multi-storey buildings with the wooden frames. Most commonly, the 10 interviewees had used the timber as the frame members, which was not expected. Obviously, the timber had been used in the load-bearing walls systems and as the frame member complementing the load-bearing CLT, LVL, and GL structures. In addition, the 7 interviewees had carried out the multi-storey projects with the CLT structures in the combinations with the modular building systems.

The 11 interviewees had been involved in the realization of the wooden detached houses. Most commonly, the 7 interviewees had used the timber as the load-bearing frame members, which was also expected, followed by the LVL structures (4 interviewees), the CLT structures (3 interviewees), and the GL structures (2 interviewees). Typically, GL had been used as the roof rafters as well as the main beams and columns.

The 10 interviewees had been involved in the realization of the wooden hall buildings. The 7 interviewees had used GL mainly as the separate load-bearing frame structures. The 7 interviewees had used LVL as the load-bearing frame members to complement the frame elements, such as the roof and wall elements, followed by the timber structures (4 interviewees) and the CLT structures (3 interviewees). Typically, timber had been used in the smaller, light framed hall buildings.

Table 5.2 Involvement in wood building projects among the 14 interviewees

In which type of wood building projects have you been involving? (The main referances)	INV 1	INV 2	INV 3	DES 1	DES 2	DES 3	DES 4	MAN 1	MAN 2	MAN 3	MAN 4	CON 1	CON 2	CON 3	Σ
A. Detached houses		X	X	X	X	X	X	X	X	X	X			X	11
i) CLT						X			X		X				3
ii) LVL			X				X			X	X				4
iii) Timber		X	X	X	X		X	X		X				X	7
iv) Glulam			X				X								2
B. Hall buildings			X	X	X	X	X	X	X	X	X			X	10
i) CLT									X		X			X	3
ii) LVL			X	X	X	X	X			X	X				7
iii) Timber			X				X	X		X	X				5
iv) Glulam			X	X	X	X	X			X	X				7
C. Multi-Storey Buildings	X	X	X	X	X	X		X	X		X	X	X	X	12
i) CLT		X	X	X		X			X		X	X			7
1. Modular system		X	X	X		X			X		X	X			7
2. Panel system				X		X			X		X				4
ii) LVL		(X)	X	X	X	X			(X)		X	(X)			5(8)
1. Modular system									(X)						(1)
2. Beam and post frame					X	X			(X)		X				3(4)
3. Load-bearing walls (Panel system)		(X)		X	X	X			(X)			(X)			3(6)
iii) Timber	X	X	X	X		X		X	X		X		X	X	10
1. Modular system	X								X						2
2. Beam and post frame															
3. Load-bearing walls		X		X		X		X	X		X		X	X	8
iv) Glulam		X	X	X		X		X	X				X		7
1. Modular system															
2. Beam and post frame									X						1
3. Load-bearing walls		X		X		X		X					X		5
	(X) = Under construction														

Key advantages for choosing wood as the primary construction material in buildings

The 14 interviewees named 26 key advantages for choosing wood as the primary construction material. The frequencies varied between 13 interviewees (fast on-site building phases) and 1 interviewee (9 different advantages). Roughly, this illustrated the states of minds among stakeholder groups in Finland in the year 2016 (Table 5.3).

The 10 most commonly experienced advantages include fast on-site building phases (13 interviewees), high level of prefabrication (12 interviewees), positive previous experiences (8 interviewees), wood's ecological aspect (8 interviewees), wood's light self-weight (7 interviewees), aesthetics (7 interviewees), competitive price (7 interviewees), continuous dry-chain (6 interviewees), wood's easiness to work with on-site (5 interviewees), demand for wooden buildings (5 interviewees), and current trend/publicity (5 interviewees). The most beneficial advantages were clearly the shorter time that was needed for the works on the sites together with the high degree of the pre-fabrication. Obviously, the shorter times were achieved by the high level of the pre-fabrication, e.g., the modular buildings. In turn, the high degree of the pre-fabrication was enabled by the wood's light self-weight. This pre-fabrication would not be possible with the use of other construction materials, such as concrete or steel.

Table 5.3 Frequencies of the advantages for choosing wood as the primary construction material in buildings in Finland among the 14 interviewees

Experienced advantages of wood construction in general	INV 1	INV 2	INV 3	DES 1	DES 2	DES 3	DES 4	MAN 1	MAN 2	MAN 3	MAN 4	CON 1	CON 2	CON 3	Σ
Fast on-site building phase	X	X	X	X	X		X	X	X	X	X	X	X	X	13
High level of pre-fabrication	X	X	X	X	X		X	X	X	X	X	X	X		12
Positive previous experiences		X		X	X	X	X			X	X			X	8
Ecology	X	X	X			X			X		X	X	X		8
Light self-weight					X	X	X	X				X	X	X	7
Aesthetics	X	X		X		X			X	X				X	7
Competitive price			X		X	X	X	X		X	X				7
Dry-chain from the factory to the site			X					X	X	X	X		X		6
Wood's ease to work with on-site conditions (cf. concrete)					X		X			X			X	X	5
Demand for wooden buildings		X	X			X			X			X			5
Current trend / Publicity		X	X		X	X		X							5
Wood components' easy adaptability (from design to building site)					X		X		X	X					4
Well-established solutions	X						X						X		3
Wood's physical building performances						X		X							2
Economic logistics costs (incl. transportation and lifts on-site)							X	X							2
Wood's health impacts									X		X				2
Potential of modular buildings										X		X			2
Dimensional stability									X						1
Fast cycle of capital	X														1
Customer satisfaction		X													1
Good acoustics / Silent home		X													1
Finally an alternative to concrete in multi-storey buildings		X													1
Production of multi-storey buildings relieves the over capacity in traditional wood element production								X							1
Strong case for design of basic wood structures									X						1
Improved working safety on-site conditions resulting from pre-fabrication										X					1
Building plots for wooden buildings			X												1

The interviewees rationalized that, obviously, wooden solutions have turned out to be highly competitive in comparison with other building systems and materials. The interviewees perceived ecology and aesthetics to be the two relevant factors, but these factors were not seen as the main reasons for the utilization of wood. Many interviewees elaborated the advantages of wood building construction as follows:

’’People want ecology and they are interested in it – but not ready to pay extra for it’’. (INV 3)

’’Wood structures are easily adaptable and modifiable during different phases in construction projects from a design table to a building site’’. (DES 2)

’’Strong, already existed knowhow for designing basic wooden structures’’. (MAN 2)

’’A faster construction phase enables the faster circulation of capital’’ (INV 1)

’’The different sizes of openings and their sealing is easy. Likewise, many other details, e.g. eaves, are easy to implement due the flexibility of wood’’. (MAN 3)

’’When correctly built, the house is healthier since the structures are more breathable’’. (MAN 4)

’’Fast erection phases, no drying periods and wood is ease to work with on-site conditions’’. (CON 3)

’’Inhabitants living in wooden multi-storey buildings seem to be satisfied, according to the field inquiries that we have executed. Especially, they are satisfied with the acoustic and soundproofing levels, these buildings are being experienced as silent’’. (INV 2)

’’The continuous dry-chain of wood construction from a factory to construction sites’’. (MAN 4)

’’The level of pre-fabrication is notably higher in the wood element industry than in the concrete industry’’. (CON 2)

’’Improved on-site work safety due to the pre-fabrication, since most of the work is conducted under controllable factory conditions - not on-site. (MAN 3)

’’No drying periods and less losses in the use of material (the LEAN principle), thanks to pre-fabrication’’. (INV 3)

’’High potential of modular buildings’’. (CON 1)

Key challenges in wood building construction

On the other hand, the 14 interviewees named also 35 challenges related to the wood building construction in Finland (Table 5.4). The frequencies varied between 12 interviewees (lack of experiences and knowledge in design) and 1 interviewee (11 different challenges). The interviewees were addressing more challenges than advantages related to the new construction techniques. The most commonly experienced challenges include the lack of experiences in and knowledge about structural design and design management (12 interviewees), the lack of offerings on the market (10 interviewees), the Finnish regulations for wood construction, especially fire regulations (10 interviewees), the lack of knowledge in structural design of large wooden buildings (9 interviewees), the absence of well-established structural system (7 interviewees), the lack of knowledge in construction phase (6 interviewees), and challenges in soundproofing and acoustics (6 interviewees). Many interviewees elaborated the challenges as follows:

’’Lack of knowledge and experience in a construction phase – It is not a builder’s problem. Instead, it is the problem of the wood working industry. How to report the costs of a wood building system at a reliable level in comparison with competitors? The systems are inadequate’’. (DES 2)

’’Lack of experiences in the sector, especially conserning multi-storey buildings with wooden frames. Operations and processes are not yet refined’’. (DES 3)

’’Multi-layer structures in panel systems (CLT/LVL) are causing multiplied internal works on-sites, if they are not pre-fabricated’’. (CON 1)

’’The refinement of all processes and operations is overwhelmingly the biggest challenge, e.g. inquiries for offers are not working well. The big picture is not clear. The wood working industry does not know it’s products as well as the concrete industry does’’. (DES 1)

’’Lack of knowledge in architectural and structural design. There is no understanding of on-site conditions. Designers and other parties should be fully aware of the characteristics of wood, especially its limitations and possibilities as construction material.’’ (INV 3)

’’There is the lack of offerings for multi-storey buildings with wooden frames. However, there is no demand either.’’ (MAN 1)

’’Investors are concerned with the 50 years of lifetime used in design. What happens after these 50 years, up to 100 years?’’ (CON 1)

’’Lack of knowledge and experience in design and design management – especially when coordinating HVAC design versus structural design.’’ (DES 3)

’’In general, awareness of possibilities of wood based solutions is still scarce. There is not enough information about versatile uses and strengths.” (MAN 3)

’’Schedules in construction business are nowadays too tight. After project development phases, no time is reserved for structural design.’’ (MAN 1)

’’The Finnish regulations for the wood construction are very strict, for example, in a comparison with other Nordic countries. The cheapest and simplest multi-storey building with the wooden frame is automatically technically and architecturally established better than an equivalent building with a concrete frame.’’ (DES 3)

’’It is hard to find contractors for large projects.’’ (MAN 2)

Table 5.4 Frequencies of the challenges vis-à-vis the wood construction becoming more common in the building construction sector in Finland among the 14 interviewees

Experienced challenges of wood construction in general	INV 1	INV 2	INV 3	DES 1	DES 2	DES 3	DES 4	MAN 1	MAN 2	MAN 3	MAN 4	CON 1	CON 2	CON 3	Σ
Lack of experiences and knowledge in design and design management (Design phase)	X	X	X	X	X	X		X		X	X	X	X	X	12
Lack of offerings	X	X	X	X		X		X	X	X	X			X	10
Regulations for wood construction	X	X	X	X			X	X	X	X			X	X	10
Lack of knowledge in structural design of large wooden buildings	X	X	X			X		X	X	X	X		X		9
Lack of demand			X		X	X	X	X		X	X		X		8
Lack of offerings for large wooden buildings	X	X	X	X				X	X				X		7
No well-established structural system on the market		X		X	X			X	X	X		X			7
Lack of knowledge in construction phases of large wood buildings		X			X	X		X	X		X				6
Lack of experiences and knowledge in construction phases		X			X	X		X	X		X				6
Soundproofing, acoustics & vibrations			X				X		X			X	X	X	6
Humidity control during the construction phases		X		X	X		X					X			5
Lack of knowledge in design management of large wood buildings	X	X				X		X	X						5
Fire safety									X		X	X	X	X	5
Structural connections		X	X				X			X					4
Lack of knowledge in HVAC design of large wooden buildings				X		X						X			3
The trial nature of wood construction, "uniqueness"		X								X		X			3
Discovering cost effective solutions	X				X								X		3
Pessimism towards wood construction					X				X		X				3
Lack of contractors		X						X	X						3
Wood's "living"					X									X	2
Cost awareness of wood construction			X					X							2
Multi-layer structures resulting from light self-weight						X						X			2
Too compressed schedules (after project development, no time reserved for structural design)							X	X							2
Lack of knowledge in architectural design of large wooden buildings			X												1
Quality control on-site	X														1
Lack of design tools and softwares					X										1
Difficult to design (cf. concrete)						X									1
Over-capacity in the production of traditional wood elements (Hard competition)								X							1
Lack of knowledge in possibilities of wood based solutions										X					1
Lack of collaboration with wood working industry												X			1
Low utilization of hybrid-construction (Wood-Concrete solutions)												X			1
More expensive and more difficult												X			1
Sealings & tightenings (Air tightness)							X								1
Long-term durability												X			1

Potential growth sectors in the future

All the 14 interviewees prioritized the seven given growth sectors. The scales varied between from 1 to 2 and from 1 to 7. The average scores varied between 1.9 and 5.6. On average, they ranked multi-storey buildings with wooden frames as the most potential growth sector (with a score of 1.9), followed by the construction of additional storeys on the tops of existing buildings (2.7), public buildings, e.g., kindergartens and educational buildings (3.3), hall buildings (3.4), repair and maintenance (4.1), bridge construction (5.5), and detached houses (5.6) (Table 5.5). Each of the 12 interviewees ranked one of these five following sectors with the highest growth potential. INV 1-3 underlined multi-storey construction with one voice as the most potential sector for growth. Instead, MAN 2 ranked repair and maintenance, MAN 1 ranked additional-storey construction, and MAN 4 ranked areal construction as the highest growth potential, respectively. In addition, DES 1 and CON 2 ranked public buildings as the most potential sector.

Table 5.5 Ranking of the potential growth and attractiveness of the wood construction by sector in Finland in the order from 1 (most attractive) to 8 (least attractive) among the 14 interviewees

How would you estimate the potential growth on the sector of wood construction, divided in construction objects? (Number in order 1-8, the most attractive first)	INV 1	INV 2	INV 3	DES 1	DES 2	DES 3	DES 4	MAN 1	MAN 2	MAN 3	MAN 4	CON 1	CON 2	CON 3	av Σ
Multi-storey buildings	1	1	1	2	1	3	1	3	3	1	4	1	3	2	1,9
Hall buildings	2	5	3	2	3	4	2	5	4	3	2	5	5	3	3,4
Public buildings	2	3	2	1	2	5	4	4	5	6	3	3	1	5	3,3
Detached houses	2	4	7	2	7	7	7	6	7	8	6	5	7	4	5,6
Repair and maintenance	2	6	5	2	4	2	5	2	1	5	7	5	6	6	4,1
Additional-storey (+1) construction	2	2	6	2	5	1	3	1	2	4	5	2	2	1	2,7
Bridge construction	2	7	4	2	6	6	6	7	6	7	8	5	4	7	5,5
Else, what?															
Modular buildings										2					
Area construction											1				

5.2.3 Three investors (Group 1)

INV 1-3 had mainly realized residential buildings. INV 1 had acted as the developer and the builder in various construction projects, including wooden buildings with 1-3 storeys. INV 2 and INV 3 were more experienced in 4-storey and higher buildings with wooden frames. INV 3 had also been involved in the construction of wooden hall buildings. Each of INV 1-3 specified the five key advantages of wood building construction. The same three advantages were ecology, fast erection on sites, and the high level of pre-fabrication. The shared emphasis of INV 1-3 as the financiers of wood framed projects may implicate that ecology becomes a very strong advantage in the future. It is notable that the other three groups did not stress ecology. Concerning time saving, INV 3 estimated that the throughput times of entire modular wooden multi-storey projects were only one third of those of equivalent concrete building projects:

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''We spent only 12 months from the starting date of the design to the transfer date of the ownership''. (Investor 3)

INV 1-3 had used the shared contracting and the design & build (D&B, turnkey) contracting, respectively, for the procurement of the multi-storey buildings with wooden frames. In the *shared contracting,* they had divided the construction works into the packages and the competition on these packages enabled to achieve the cost savings. In the *design & build* contracting, they had handed the responsibilities for the design and construction including the choice of the building system over to the contractors. In a comparison, INV 1-3 needed to have the in-house expertise and to exercise the control more with the shared contracts and less with the D&B contracts.

INV 1-3 stressed the same three challenges of wood building construction, i.e., the regulations as one of the main barriers, the lack of experience in both the design and the design management as well as the lack of offerings for large wooden buildings. INV 1-3 elaborated the challenges and suggested the improvements of the operations of the wood building sector in the near future as follows:

''There are no well-established wood building systems on the market. This leads to D&B competitions and contractors choosing building systems to be used.'' (INV 2)

''There is no open cost information about wood construction systems and wood building components. This is a big shortcoming.'' (INV 3)

''More competition and development. The tradition to build with concrete elements is so strong that it cannot be challenged as long as the wood construction is only architectural specialties. Builders are favoring materials, solutions, and cost structures that they readily know. Wood is still full of surprises and the authoritative regulations are causing many of them. Why to build in this more difficult and more expensive way? The industrialization of wood construction is a focal part of the improving competitiveness. Multi-storey buildings with wooden frames have to become a competitive solution on the market.'' (INV 1)

''Urban planning should be refined and complemented with a recommendation to create preconditions for arranging open, neutral competitions between different construction materials among all future building projects.'' (INV 2)

All the INV 1-3 ranked multi-storey buildings (with an average score of 1.0) as the most potential growth sector for wood construction, followed by public buildings (2.3), hall buildings (3.3), and additional-storey construction (3.3).

5.2.4 Four designers (Group 2)

The answers of DES 1-4 varied significantly. The consensus was evident only in the case of some questions. However, it seems that the previous positive experiences of DES 1-4 have been one of the main factors for choosing wood as the material for frames in multi-storey buildings. DES 1-4 underlined that the design of multi-storey buildings with wooden frames was more expensive and burdensome in a comparison with the design of concrete buildings. DES 1-4 estimated that such cost differences varied between + 20% and even + 100%. This huge range may be in part due to the current trial nature of the wooden multi-storey building construction in Finland. In the same vein, DES 1-4 mentioned that the huge lack of knowledge and the similar excessive costs concerned also the HEVAC design for multi-storey buildings with wooden frames. Instead, DES 1-4 found neither time differences, nor cost differences between construction materials significant in the case of 1-storey hall buildings.

In total, at least one of DES 1-4 had used or recommended the 17 technical solutions for connections and connecting fixtures under the five categories (Table 5.6). Most of them have been introduced in the prior review of the technical literature (in Sub-chapters 3.2 – 3.5). DES 1-4 named screwing as the most commonly used connection type between wooden structures. Nailing was used only in the assemblies of wood elements and the fastening of frame members. Hangers were mainly used in concealed and exposed beam-to-beam connections. Custom made connectors were especially used in combinations with element anchoring for high shear and tension stresses. DES 1 and DES 3 had been involved in the design of multi-storey buildings with wooden frames and therein they had used anchoring products more than DES 2 and DES 4 had done.

Table 5.6 Frequencies of the five connection techniques for wooden structures in Finland, used or recommended by the four interviewed designers (DES 1-4)

Connection	Techniques	DES 1	DES 2	DES 3	DES 4	Σ
Beam-to-Column	Screwing	X	X	X	X	4
	Hanger	X		X		2
	Concealed hanger					
	Threaded bars and bolts			X		1
	Fishplates					
	Supporting block-board		X			1
Beam-to-beam	Screwing	X	X	X		3
	Hanger		X	X	X	3
	Concealed hanger	X		X		2
Element frame structure	Nailing	X	X	X	X	4
	Screwing				X	1
Element-to-Element	Screwing	X	X	X	X	4
	Nailing				X	1
Element anchorage	Screwing		X		X	2
	Angle brckets	X		X	X	3
	Steel plates	X		X		2
	Tension bars	X				1
	Custom-made	X		X	X	3

Concerning the product selection and recommendation behavior, each of DES 1-4 assigned the scores to the seven given priority factors. In addition, DES 2 prioritized also capacity/durability and DES 3 prioritized certifications. The average scores varied between 2.0 and 5.5. On average, DES 1-4 ranked the availability of product information clearly as the most decisive factor (with a score of 2.0), followed by previous positive experiences (3.5), quality (3.5), price (3.8), delivery time and easy reachability (4.0), fast installation / ease in use (4.8), and product/brand awareness (5.5) (Table 5.7).

Table 5.7 Ranking of the criteria for the making of product-based decisions on building designs in Finland, by the four interviewed designers (DES 1-4)

Which of the following factors has a higher priority on your product based design decisions? (from 1 to 6. 1=highest priority, 6=lowest priority)	DES 1	DES 2	DES 3	DES 4	av Σ
Delivery time & easy reachability	5	2	3	6	4,0
Price	6	3	3	3	3,8
Quality	4	2	6	2	3,5
Product / Brand awareness	6	6	5	5	5,5
Positive previous experiences	3	6	4	1	3,5
Information available about the product	2	1	1	4	2,0
Fast installation / Ease in use	1	6	6	6	4,8
Else, what?					
Capacity / Durability		1			
Certifications			2		

Especially, DES 2 and DES 4 elaborated the challenges and suggested the improvements of the operations of the wood building sector in the near future as follows:

’’Element systems and structural jointing technology are currently developing fast. There should be a common public portal, based on market needs, for sharing knowledge and information about wood construction systems. Regular updates on components should be provided. Design tools and cost information of building systems should become more public.’’ (DES 2)

’’The wood working industry in Finland should abandon the current closed atmosphere and start to interact openly and collaboratively with all stakeholders.’’ (DES 2)

’’Typically, clients (investors, contractors, and manufacturers) have readily decided upon, which framing material will be used in design. So it is more effective to influence the choices of frame materials via clients.’’ (DES 4)

DES 1-4 ranked multi-storey buildings (with an average score of 1.8) as the most potential growth sector, followed by hall buildings (2.8), additional-storey construction (2.8), and public buildings (3.0).

5.2.5 Four wood element manufacturers (Group 3)

Within this group, MAN 1 and MAN 2 were more specialized to supply wooden elements to multi-storey residential buildings. MAN 3 and MAN 4 were more specialized to deliver wooden elements to hall buildings. Each of MAN 1-4 specified key advantages of wood building construction. The same three advantages were fast erection on sites, the high level of pre-fabrication, and the continuous dry-chain from an element factory to a construction site. The shared emphasis of MAN 1-4 as the manufacturers of wood framed elements implies that a continuous dry-chain is a strong advantage. It is notable that the other three groups did not stress a dry-chain even though problems in the control of moisture in buildings have been addressed in media on a weekly basis.

Concerning main frame structures, MAN 1-4 were using the similar ways for the design and the assembly. MAN 1-4 had the internal design departments, respectively. In addition, they were using external design firms. The three of them were fully responsible for complete assemblies at factories, e.g., including fastening systems and sealants, as well as installation works on construction sites. Instead, the fourth manufacturer assumed the limited role and only delivered wood elements to sites.

In total, at least one of MAN 1-4 had used or recommended the 17 technical solutions for connections and connecting fixtures under the five categories (Table 5.8). Most of them have been introduced in the prior review of the technical literature (in Subchapters 3.2 – 3.5). Screwing was named as the most commonly used connection type between wooden structures. Nailing was used only for the fastening of frame members as part of the assemblies of wood elements. Hangers were mainly used in combinations with higher loads in concealed and exposed beam-to-column connections. Only one manufacturer used also custom-made connecting fixtures.

Table 5.8 Frequencies of the five connection techniques for wooden structures in Finland, used or recommended by the four interviewed manufacturers (MAN 1-4)

Connection	Techniques	MAN 1	MAN 2	MAN 3	MAN 4	Σ
Beam-to-Column	Screwing	X		X	X	3
	Hanger	X	X			2
	Concealed hanger	X	X			2
	Threaded bars and bolts					
	Fishplates	X				1
	Supporting block-board			X	X	1
Beam-to-beam	Screwing		X	X	X	3
	Hanger	X				1
	Concealed hanger	X				1
Element frame structure	Nailing	X	X	X	X	4
	Screwing		X			1
Element-to-Element	Screwing	X	X	X	X	4
	Steel plates					
Element anchorage	Screwing	X		X	X	3
	Angle brckets		X			1
	Steel plates		X			1
	Tension bars		X			1
	Custom-made		X			1

Concerning the product purchasing behavior, each of MAN 1-4 assigned the scores to the seven given priority factors. The average scores varied between 2.3 and 6.0. On average, MAN 1-4 ranked positive previous experiences as the most decisive factor (with a score of 2.3), followed by price (3.3), quality (3.3), delivery time and easy reachability (3.5), fast installation / ease in use (4.0), the availability of product information (5.5), and product/brand awareness (6.0) (Table 5.9).

Table 5.9 Ranking of the criteria for the making of decisions on the purchasing of building products in Finland, by the four interviewed manufacturers (MAN 1-4)

Which of the following factors has a higher priority on your purchasing decisions? (from 1 to 6. 1=highest priority, 6=lowest priority)	MAN 1	MAN 2	MAN 3	MAN 4	av Σ
Delivery time & easy reachability	4	5	4	1	3,5
Price	5	3	3	2	3,3
Quality	3	2	5	3	3,3
Product / Brand awareness	6	6	6	6	6,0
Positive previous experiences	1	1	1	6	2,3
Information available about the product	6	4	6	6	5,5
Fast installation / Ease in use	2	6	2	6	4,0
Else, what?					

MAN 1-4 stressed the same two challenges of wood building construction, i.e., the lack of offerings as one of the main barriers and the lack of experience and knowledge in both the design and the design management. In addition, MAN 1-3 stressed the strict regulations for wood construction as a challenge. MAN 1 and MAN 2 elaborated the challenges and suggested the improvements of the operations of the wood building sector in the near future as follows:

''The sector is at the low level of development in Finland, e.g., product approval procedures are unestablished, which makes construction with wooden structures more expensive." (MAN 2)

''Cost awareness of wood construction is at the low level among construction companies, for example in a comparison with the cost estimation software for concrete buildings in Finland (by Haahtela Oy).'' (MAN 2)

''The output information (data) in project development phases should be determined more carefully and collaboration with other stakeholders should be continuous from the beginning so that multiple designs and challenges in scheduling could be avoided.'' (MAN 1)

MAN 1-4 ranked multi-storey buildings (with an average score of 2.8) as the most potential growth sector for wood construction, followed by additional-storey construction (3.0), and hall buildings (3.5).

5.2.6 Three contractors (Group 4)

CON 1-3 had mainly been involved in residential building projects to the same degrees that the three investors had been. CON 1 and CON 2 were more experienced in 4-storey and higher buildings with wooden frames. CON 3 had also been involved in the construction of wooden hall buildings and detached house buildings, which partly explains the higher number of projects (over 30) with wooden frames. Each of CON 1-3 specified the key advantages of wood building construction. The same two advantages were fast erection on sites and the light self-weight of wood material. It is notable that the contractors' group named the lowest number of advantages in comparison with the three other professional groups. CON 2. CON 2 and CON 1 elaborated a high potential for time saving via modular construction as follows:

''The on-site construction phase of the multi-storey building with the large, prefabricated wood elements was 30% shorter in a comparison with an equivalent concrete building.'' (CON 2)

''We can reach shorter erection phases on sites with large frame elements. This is coupled with longer internal works phases due to multi-layer structures. There is a potential of time saving with a modular system. Currently, this is not significant because we need to start the design of buildings in very early phases.'' (CON 1)

Among the disadvantages, it was noteworthy that none of CON 1-3 agreed upon a claim about competitive prices with wood construction. In the same vein, they underlined that the construction of multi-storey buildings with wooden frames is currently more expensive in a comparison with equivalent concrete buildings. Their cost estimates of the entire projects including the design and construction of the multi-storey buildings with wooden frames were higher than those of the equivalent concrete-based projects, between +1% and +30%, respectively. According to one sub-estimate, the costs of the HVAC designs of the multi-storey buildings with the modular wooden systems were up to +50% higher than those of traditional concrete solutions. Such higher budget and cost frames were in part caused by the severe lack of knowledge about design and design management related to wooden building systems and structures.

In total, at least one of CON 1-3 had used or recommended the 13 technical solutions for connections and connecting fixtures under the five categories (Table 5.10). Most of them have been introduced in the prior review of the technical literature (in Subchapters 3.2 – 3.5). Screwing was named as the most common connection type between wood structures. Nailing was used only in the fastening of frame members as part of the assemblies of wood elements and it was carried out by manufacturers. Only CON 1 used custom-made connectors. None of CON 1-3 had used concealed beam hangers. In part, this may be explained by the purchasing behavior (see Table 5.11) in a combination with a fact that solutions with concealed beam hangers are more complex than those with traditional hangers.

Table 5.10 Frequencies of the five connection techniques for wooden structures in Finland, used or recommended by the three interviewed contractors (CON 1-3)

Connection	Techniques	CON 1	CON 2	CON 3	Σ
Beam-to-Column	Screwing		X		1
	Hanger			X	1
	Concealed hanger				
	Threaded bars and bolts				
	Fishplates				
	Supporting block-board				
	Angle brckets			X	1
Beam-to-beam	Screwing		X		1
	Hanger			X	1
	Concealed hanger				
Element frame structure	Nailing		X	X	2
	Screwing				
Element-to-Element	Screwing	X	X	X	3
	Steel plates	X			1
Element anchorage	Screwing		X	X	2
	Angle brckets		X		1
	Steel plates		X		1
	Tension bars	X	X		2
	Custom-made	X			1

Concerning the product purchasing behavior, each of CON 1-3 assigned the scores to the seven given priority factors. In addition, CON 1-3 named certifications as a relevant factor. The average scores varied between 1.3 and 6.0. On average, CON 1-3 ranked price clearly as the most decisive factor (with a score of 1.3), followed by quality (2.7), delivery time and easy reachability (3.3), fast installation / easy in use (4.0), the availability of product information (4.0), positive previous experiences (5.7), and product/brand awareness (6.0) (Table 5.11).

Table 5.11 Ranking of the criteria for the making of decisions on the purchasing of building products in Finland, by the three interviewed contractors (CON 1-3)

Which of the following factors has a higher priority on your purchasing decisions? (from 1 to 6. 1=highest priority, 6=lowest priority)	CON 1	CON 2	CON 3	av Σ
Delivery time & easy reachability	4	3	3	3,3
Price	1	2	1	1,3
Quality	2	4	2	2,7
Product / Brand awareness	6	6	6	6,0
Positive previous experiences	5	6	6	5,7
Information available about the product	6	1	5	4,0
Fast installation / Ease in use	3	5	4	4,0
Else, what?				
Certifications	X	X	X	

CON 1 and CON 2 elaborated the challenges and suggested the improvements of the operations of the wood building sector in the near future as follows:

''Lack of collaboration and interaction with the wood working industry is a problem. The element industry should invest more in the development of solutions and activities. In turn, this would enable the selection of wood building systems based on overall economic viability.'' (CON 1)

''Public and private stakeholders should continue the boosting of multi-storey buildings with wooden frames by allocating more building areas for this purpose. Yet, none of the previous and current buildings have been realized on a voluntary or commercial basis.'' (CON 2)

CON 1-3 ranked additional-storey construction (with an average score of 1.7) as the most potential growth sector for wood construction, followed by multi-storey construction (2.0), and public buildings (3.0). This ranking differed a lot from those of the three other professional groups.

6 SUGGESTED SEGMENT-BASED STRATEGY FOR ENTERING THE WOOD CONSTRUCTION MARKETS WITHIN THE BUILDING CONSTRUCTION SECTOR IN FINLAND

6.1 Preliminary analysis and the screening (phase 1)

In Phase 1, foreign entrants preliminarily analyze and screen the key constraints of a host country, i.e., Finland, in terms of economy, politics, legal issues, competition, technology, culture, client chains, and geography (Fig. 6.1). Herein, Cateora et al.'s (2011) framework could be applied (see Chapter 2).

Finland is a stable republic and currently the biggest political party of the government is the Finnish Centre Party. 73% of the Finnish citizens belong to the Evangelical Lutheran Church.[158] Finnish and Swedish are the two official spoken languages in Finland. According to Cribis D & B [159], the Finnish payment system was in the healthy state in the year 2015. Continuously, the share of the companies with the on-time payments (29,2% in the year 2015) in Finland has been lower than the European average level. On average, the majority or 68,2% tended to pay commercial transactions between 1 and 30 days late. It seems that the micro and small sized companies have been the most active payers by due date. From among the 19 product sectors, the construction sector has been as the 11th most active payer and, in turn, the manufacturing sector as a whole has been as the 16th most active payer by due date.

Finland is a highly technologized country known by its know-how in the design and production of high-tech solutions, systems, and components. In many product segments, the manufacturing costs have become so high that the production has been re-allocated to countries with lower costs. The most critical competition is being faced from the East-European countries.[160] However, according to the most recent reports, half-automatized production would be returning back to Finland in slightly growing numbers.

Located by the Baltic Sea, the most commonly used transportation form has been shipping as part of logistics chains. Trucks have been used for moving products mainly from Russia and through Estonia and Sweden. Incoterms® 2010, developed by the Interna-

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[158] Suomen evankelis-luterilainen kirkko 2016
[159] Cribis D&B 2016 p. 137-141
[160] The Research Institute of the Finnish Econmy 2006 p. 5-6

tional Chamber of Commerce (ICC), have been widely recognized also in Finland for clarifying logistics responsibilities. When Finland is at the same time one the largest countries (338 434 km^2) and one of the smallest countries (5 439 000 inhabitants) in Europe, this implies a very low density of 16,16 inhabitants per square kilometer (versus 191,60 inhabitants per square kilometer in Italy).[161] Accordingly, potential Finnish clients may be located far away from each other, which foreign entrants should take into account as part of their market entry strategies, respectively.

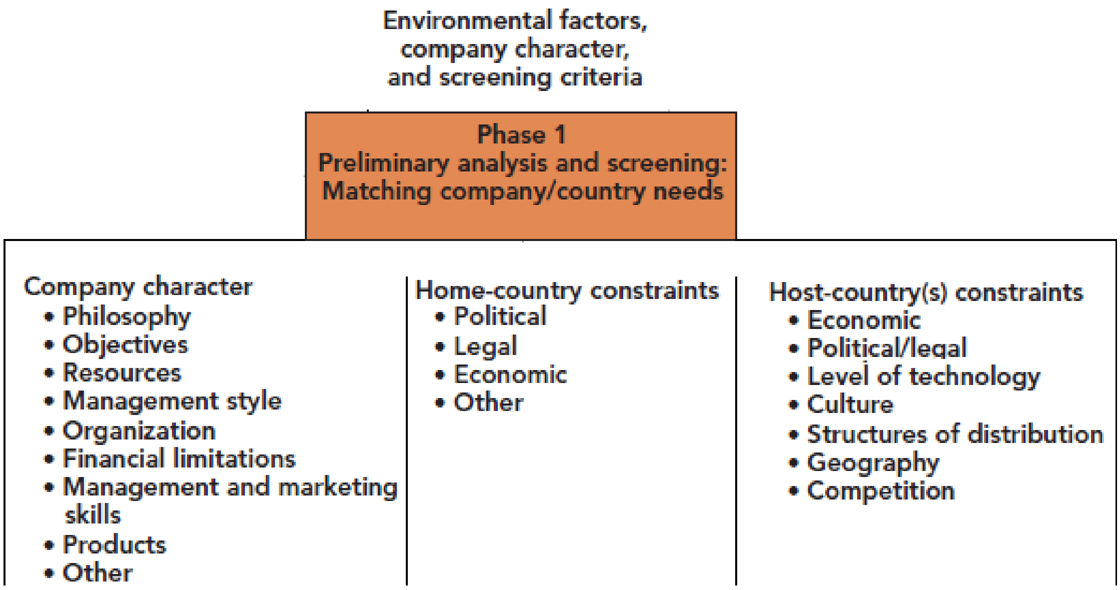

Figure 6.1 Preliminary analysis and screening: matching the needs of an entrant and a country (phase 1) (Source: Cateora, P. et al. 2011, p. 341)

6.2 Choice of targeted market segments and the adaptation of a marketing mix (phase 2)

In Phase 2, foreign entrants identify potential markets, choose and define targeted market segments and plan the adaptation of marketing mixes. Herein, entrants should learn and know the technical systems, the certifications (see Sub-chapter 4.5), the building traditions and practices, the construction techniques, and especially the connection systems (see Chapter 3) in the wood building construction sector in Finland. Based on such information, entrants choose their products for the adaptation and the exporting to Finland. As part of the certification systems, foreign entrants should assure that the labelling meets the rules and the norms applied in Finland and the EU. The CE marking is required for a construction product, if there is a valid hEN or ETA. The latter is more common in the case of steel connectors for wooden structures. Foreign entrants need to screen the price levels of targeted construction products in Finland in order to set competitive prices, respectively. In part, this needs to be based on the analysis of incum-

[161] The World Bank 2016

bents readily competing in potential market segments. (Competitor mapping was not a part of this study.)

Foreign entrants prepare plans for promoting, marketing, and selling exportable products to identified potential client groups and chains in the wood building construction sector in Finland. This is followed by the adaptation of each entrant's marketing mix in terms of products, prices, promotion, and distribution (Fig. 6.2). Herein, Cateora et al.'s (2011) framework could be applied (see Chapter 2). The useful channels and stakeholders for sales promotion include also the Finnish associations (see Sub-chapter 4.3). Entrants should also consider the reliance on one or more existing distribution networks that may readily connect entrants and individual potential clients, scattered widely across Finland. In addition, the use of warehouses would enable to offer fast delivery times and easy reachability of entry products and, thus, to meet priorities among potential clients, such as contractors (see CON 1-3 in Section 5.2.6).

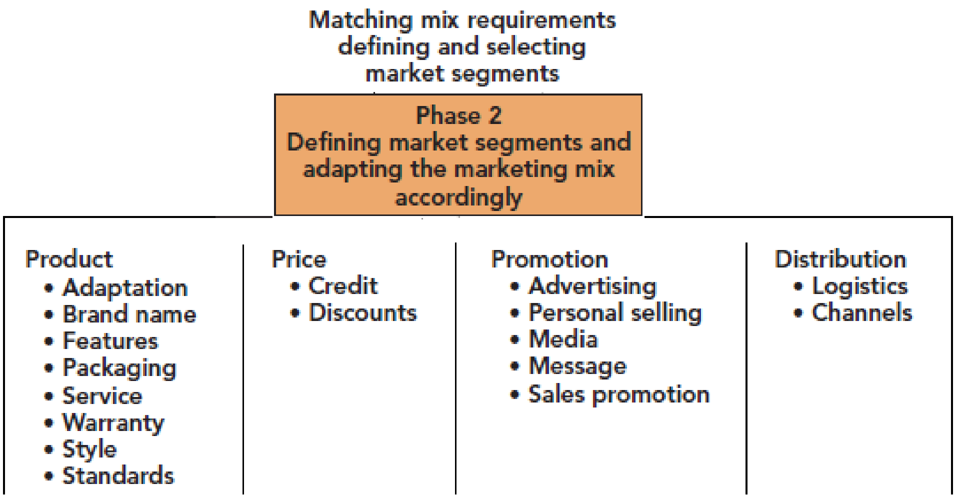

Figure 6.2 Definition of market segments and the adaptation of a marketing mix accordingly (phase 2) (Source: Cateora, P. et al. 2011, p. 341)

For example, an analysis for defining and adapting a competitive marketing mix for exporting products to the wooden building construction sector in Finland may be planned as follows. Entry management should furnish answers to numerous questions during the screening, such as "How do Finns rank wooden houses as part of living and free-time behavior in terms of detached (single) houses and multi-storey buildings?", "How common are wooden houses?", "What are the market positions and shares of wooden buildings versus competing materials by building types?", "What are the most common building construction methods?", and "What kinds of fastening systems are being used?"

Many of these questions have been answered in Chapter 4. Most importantly, the current feature of (a) the demand is that nearly 70% of the dwellings are built in multi-storey buildings and this share will be growing. The share of the multi-storey buildings with the wooden frames was only nearly 4% and this segment is expected to grow. In turn, the number of new detached houses has been decreasing for many years.

There are some alternative building systems with wood materials for realizing frame structures in wooden multi-storey buildings. Wood-driven investors choose a particular system from among these wood-based alternatives. Available frame solutions for realizing wooden multi-storey buildings include Platform Frame System, Modular Building System, Beam-and-Post Frame System, and Load-Bearing Walls System. Therein, engineered wood products may be CLT, LVL, GL, or even traditional sawn timber. The latter is classified according to its strength but usually in combination with engineered wood products.

Modular Element System with CLT modules has been the most common building system in terms of the six more than 3-storeys high wooden buildings with the 175 dwellings completed in Finland in the year 2015 (Fig. 6.3). It would be desirable to have more alternatives on the market in terms of more offerings, competition, and awareness.

Load-Bearing Walls System is the alternative solution for realizing wooden multi-storey buildings. Readily, the two such buildings with the 201 dwellings were completed in the year 2015 (Fig. 6.3). Load-bearing wall elements may be assembled with GL, LVL, and sawn timber. The number of manufacturers with load-bearing walls is higher than that of the modular CLT providers in Finland. This fact gives some advantage to clients because they can send inquiries to several wall element manufacturers.

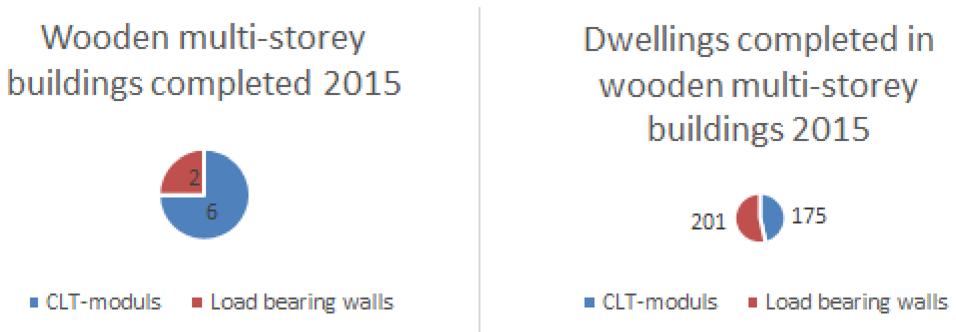

Figure 6.3 Number of the 4-storey and higher blocks of the flats with the wooden frames and the number of the dwellings completed in Finland by the building technique in the year 2015 (Annex 1) (Source: Ijäs 2013 p. 58., Ministry of Economic Affairs and Employment in Finland, and Puuinfo Oy 2015, 2017)

Concerning (b) the supply, the production volumes of the prefabricated wooden elements and elements for the large buildings (hall buildings, multi-storey buildings) have still been relatively small in Finland. Instead, the manufacturing capacity and the number of the manufacturers of traditional small pre-fabricated wooden elements have been huge, but these capacities are currently suffering from the lack of demand in the private sector. Thus, foreign entrants need to update and verify this and other related information in order to avoid costly mistakes in entry actions, respectively.

In the case of large (over 2000 m^2) hall buildings, the share of wood could be increased by investing in new, larger manufacturing capacity.

In the case of medium-sized (801-2000 m^2) hall buildings, load-bearing wooden frames were usually separated from walls and made of GL. This solution enables long spans and the transfer of heavy loads. The share of wood could be higher, but the manufacturing capacity of heavy wooden structures is very limited in comparison to the manufacturing capacities of steel and concrete.

6.3 Development of a marketing plan (phase 3)

In Phase 3, foreign entrants develop their marketing plans in terms of analyzing situations, setting objectives and goals, defining strategies and tactics, choosing the modes of entries, calculating entry budgets, and planning action programs (Fig. 6.4). Herein, Cateora et al.'s [162] framework could be applied. Typically, foreign entrants with exportable structural connections should choose and adapt their entry strategies to the key characteristics of the wood building construction sector in Finland. In addition, Huovinen and Kiiras' [163] framework could be applied as follows.

6.3.1 Identification of decision-makers in client segments

The results of the field interviews on the purchasing behavior revealed that the decision-making concerning the connections of wooden frame members significantly differed between the four stakeholder groups, i.e., the three investors (INV 1-3), the four designers (DES 1-4), the four manufacturers (MAN 1-4), and the three contractors (CON 1-3), see Sections 5.2.3-5.2.6. Consequently, foreign entrants need to identify client chains, contracting forms, stakeholders (roles), and decision-makers especially related to the use of structural connections in Finland.

(i) It seems that very rarely investors are themselves interested in small single construction parts of buildings, such as the purchasing of connecting fixtures or other structural members of elements. Investors prefer to focus on the management of building projects as a whole in terms of cost frames, construction schedules, and the selections of contractors. From the viewpoint of investors, it would be desirable to have more alternatives on the supply market, which would create more offerings, competition and awareness.

In principle, (ii) designers choose products to be used in connections. In many cases, it is likely that experienced manufacturers and contractors hand over their lists to designers and such lists include products to be used already in early design phases, respective-

[162] Cateora, P. et al. 2011
[163] Huovinen, P. and Kiiras, J. 1998

ly, so that manufacturers and contractors can control costs and limit a wide range of connectors. Nevertheless, nearly all the interviewees, including the three designers (DES 1-3) themselves, underlined that experienced and skilled designers for heavy wooden structures were still very rare in Finland.

In the Finnish building practices, the design of frames, elements, and connections is mainly assigned to (iii) manufacturers. When manufacturers are using both internal and external design offices, decision-makers are in-house structural engineers, engineers in design firms, or the purchasing managers of manufacturers or those of contractors, respectively. The screws were overwhelmingly the most commonly used connection type in the building production of the four manufacturers (MAN 1-4). In addition, a high number of nails was used in the wood element production (timber frame elements) as the connecting fixtures between the element frame members.

The two roles of (iv) contractors involve (a) the purchasing of elements, connectors, and installation services as single sub-contracts or (b) the purchasing of elements and the execution of installation works by themselves, usually also the purchasing of connecting fixtures for element anchorages and between elements if not provided by element manufacturers.

Figure 6.4 Development of a marketing plan and the selection of the mode of entry (phase 3) (Source: Cateora, P. et al. 2011, p. 341)

6.3.2 Short-term entry strategy

Herein, foreign entrants could design their short-term entry strategies, respectively, by applying the six elements of Huovinen and Kiiras'[164] framework to targeted wood construction markets in Finland with an emphasis on focal structural connections (Fig 6.5). When a foreign entrant has readily the CE marking through the ETA or hEN procedures for its products, the certification should not become a barrier to an entry in the targeted market of wooden structures in Finland.

In principle, designers are not purchasing products. Instead, they give recommendations and alternatives to their clients, i.e., investors, manufacturers, and contractors. Thus, foreign entrants should approach designers with comprehensive information about technical details over a range of proven products.

It is herein suggested to foreign entrants that they would position the manufacturers of wood elements as their primary soft client segments. This is so because manufacturers are the only stakeholder group continuously conducting their businesses with wooden structures and wood elements. When manufacturers are purchasing big volumes of products and components for the assembly of wooden structures and wood elements, foreign entrants need to overcome barriers of changing repeat domestic buys from old, local suppliers to new imported buys from foreign entrants. One realistic option is to earn the trust of manufacturers by offering a trial order related to one project and by carrying the delivery out with excellent performance. When foreign component exporters could win such manufacturers as their first clients, this could enable the sustainment of continuous and stable component sales, exports volumes, and profits over many years. Moreover, stable entry incomes from such soft clients are a basis for market penetration and/or expansion into new client segments in the future.

None of the three interviewed contractors (CON 1-3) had a continuous production of wooden buildings. Despite of this fact, contractors are herein considered to be a highly attractive client segment for foreign connector suppliers due to their various building processes and the extensive use of construction products. The interviewed contractors (CON 1-3) were prioritizing delivery times and easy reachability. Accordingly, foreign entrants could fulfil such priorities by considering foreign direct investments in local distribution networks and/or warehouses, respectively.

Foreign entrants should thus aim at reaching participations in trial projects with the two client segments of manufacturers and contractors. For this purpose, foreign entrants need to identify actual decision-makers from within the technical and purchasing departments of manufacturers and from within the project and purchasing organizations of contractors. Moreover, foreign entrants could contact architectural and structural engineering firms for finding projects. In basic positive cases, designers would give to entrants such contact lists of manufacturers and contractors. In more rewarding cases, de-

[164] Huovinen, P. and Kiiras, J. 1998

signers would include and specify the products of foreign entrants in their future structural design assignments.

Correspondingly, foreign entrants should adapt their sales arguments to meet the ranked criteria of the designers (DES 1-4), manufacturers (MAN 1-4), and contractors (CON 1-3), respectively. Entrants should tailor the group-specific sets of sales arguments. In the case of the designers, the primary criterion for choosing wood-related products was the easy, comprehensive availability of technical product information. Entrants need to arrange technical support services and documentation to accommodate such needs among designers. In turn, both the element manufacturers and the contractors ranked the price and the quality as the main criteria for their purchasing decisions. Entrants should reorder their sales arguments accordingly. Typically, when an entrant introduces its products with low prices, it is likely that potential clients couple them with very modest product qualities. Alternatively, when an entrant can introduce its products in terms of saving clients' time and/or costs as part of the use of labor or materials, potential clients may confirm this by own estimates and even perceive that such entry products are advantageously different from competing, existing products.

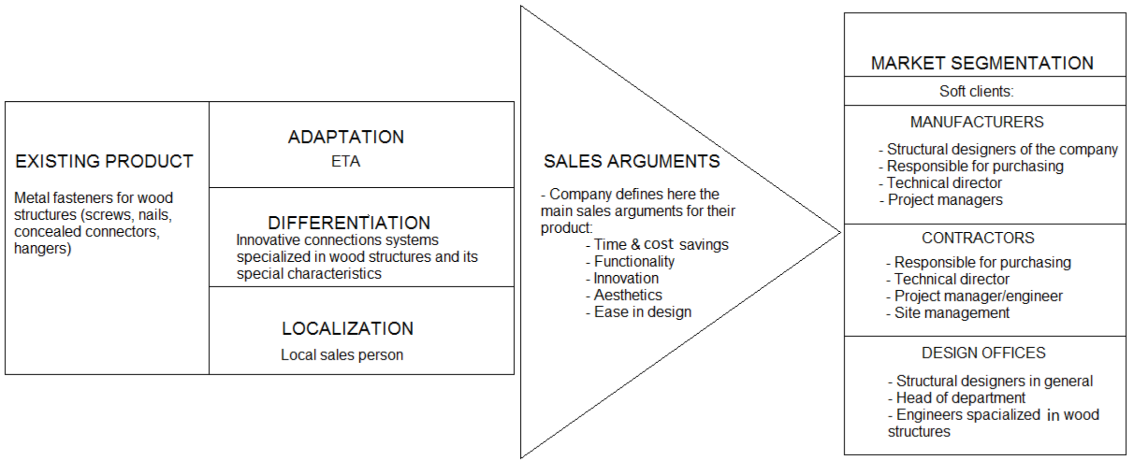

Figure 6.5 Six adapted elements of a spearhead strategy for entering the Finnish wood construction markets in the case of foreign manufacturers of structural connections (Source: applying Huovinen and Kiiras 1998)

The suggested entry strategy is coupled with a medium level of risk and the corresponding need of control in relation to the alternative entry strategies (reported in Ch. 2., see Fig. 2.2.) as follows. Foreign entrants should rely on local sales agents or units inside Finland for performing direct sales or exploiting the advanced form of exporting. It is herein posited that these risks are on the acceptable levels in relation to the suggested entry investments. In addition, foreign entrants may reduce risks by identifying "soft" decision-makers within potential client organizations.

6.4 Implementation and control of an entry process (phase 4)

It is herein assumed that a foreign entrant has started to implement its entry plans vis-à-vis the wood construction market in Finland. An entrant should carefully manage and control the execution of planned entry actions. The suggested entry strategy involves medium-level risks and corresponding needs to control actions. The international business management of a foreign entrant and its local sales unit in Finland could together monitor and forecast the degrees of the attainment of the planned action-specific or stepwise entry objectives. Actual positive entry performance encourages a foreign entrant to continue with its current plan. In turn, negative entry performance should alert an entrant to renew its entry strategy and plan.

7 CONCLUSIONS

7.1 Critique of the study

The nature of this study is that of the formulation of an entry strategy, based on the combined desk and field study, with a focus on the wood construction markets in Finland. The main aim has been approached via the four sub-aims. These sub-aims and the sub-results have been reported in a chronological order via the corresponding Chapters 2-5 of this report.

The main aim of the study is to plan and suggest a strategy for the segmentation of and the entry into the Finnish wood construction markets from the point of view of interested foreign manufacturers of structural connections. An initial strategy was formulated by applying Cateora et al.'s[165] expansion framework and Huovinen and Kiiras'[166] spearhead entry strategy framework as well as by adapting this initial strategy to the Finnish context based on the context-specific results. The outcome strategy is suggested and presented in Chapter 6. It is herein evaluated that the main aim has been attained to a large extent by suggesting such an entry strategy that focal foreign entrants, i.e., manufacturers of connectors, can adopt and apply to the planning of their entries into the selected segments within the wood construction markets in Finland, with a fairly high likelihood of success. This evaluation is supported with the high degrees of the attainment of the four sub-aims. Both the applicable theoretical results and the relevant, reliable empirical results enabled the design of the suggested segment-based entry strategy.

Sub-aim 1 was approached via the identification, selection, and review of the key theoretical frameworks and typologies for formulating a company's international expansion strategies. For this study, Cateora et al's[167] framework for international expansion planning was selected because they perceive the entry problem as a process and divide it into the four phases that were considered to be applicable. In turn, Huovinen and Kiiras'[168] Spearhead Entry Strategy was selected because this framework provides the key 6-element content for the solution of a focal entry problem. Sub-aim 1 was, thus, attained in terms of the gaining of pre-understanding and the adoption of the two applicable frameworks. The combined frameworks enabled the formulation of the suggested entry strategy as both an applicable 4-phase entry process and a satisfactory, relevant scope including the criteria for choosing a realistic entry mode.

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[165] Cateora, P. et al. 2011
[166] Huovinen, P. and Kiiras, J. 1998
[167] Cateora, P. et al. 2011
[168] Huovinen, P. and Kiiras, J. 1998

Sub-aim 2 was approached via the review of the technical, professional literature on the most common connections (systems) used in wooden structures made of CLT, LVL, and GL. In comparison, the more relevant information was available about the GL structures and the less relevant information was available about the CLT and LVL structures. Concerning GL, the Finnish Glulam Association and Puuinfo ry recently published the guidelines[169]. Concerning LVL, Kovanen[170] investigated the common connections in the LVL assemblies, assigned by Metsä Group, the leading manufacturer of LVL. He relied on the 10 professional respondents who had gained deep experience with the LVL structures used both in Finland and abroad. Concerning CLT, there is not yet a lot of experience on CLT assemblies in Finland. Thus, this part was based on the reviewing of the selected foreign study reports. Nevertheless, Sub-aim 2 was attained to a high degree by comprehensively reviewing the technical connection systems that were actually or potentially used in wooden frame structures in Finland. The results enable foreign entrants to overview the commonly used connection systems reliably, compare such connections with their own connecting products, and choose their entry products, respectively.

Sub-aim 3 was approached via (a) the investigation of the development of the wood construction markets in Finland during a period of the years 2005-2015 as part of the total building construction sector and by the major building types, and (b) the learning about the technical requirements and assessments as well as the certification systems governing wood construction in Finland as one of the EU member countries. Sub-aim 3 was attained only to a supportive extent from the viewpoint of key decision-makers within foreign entrants by compiling the statistical data published by the Official Statistics of Finland (OSF), by analyzing the volumes and shares of the wooden buildings as part of the total output of the construction sector (Sub-chapter 4.1) and the production by building types in Finland between the years 2005-2015. Overall, this data allows foreign entrants to gain broad understanding of the Finnish building construction sector and to learn about the changing shares of the uses of concrete, steel, and wood as the key construction materials by the different building types. In turn, the statistical data of the hall buildings constructed during the years 2008-2011 has been outdated. Nevertheless, foreign entrants may use this periodical data as a starting point for the conduct of their own focused analyses of the demand and supply of hall buildings, respectively.

Sub-aim 4 was approached empirically via the 14 explorative interviews on the theme, i.e., the competitiveness of wood construction and related professional practices in investing and contracting, design, element manufacturing, construction, and purchasing in Finland. The selection of the 14 interviewees was based on their respective experiences in the wood construction projects in Finland (and in part abroad), ranging between the 2 years and the 19 years, and being more than 10 years on average. The sub-themes could be satisfactorily addressed from the viewpoints of the four stakeholder groups: investors (3 interviewees), designers (4 interviewees), manufacturers (4 interviewees), and con-

[169] Finnish Glulam Association ry and Puuinfo Oy 2015
[170] Kovanen, H. 2014

tractors (3 interviewees). The interviews consisted of the common parts and questions with all the interviewees and the customized, stakeholder group-specific parts and questions. The semi-structured questions enabled the interviewer to pose and discuss the same issues in the repeated interview situations in the way that allowed for the production of the reliable, comparative results. In part, the multi-year, wood-focused experience of the interviewer ensured that he could produce the relevant results. When the same interviewer conducted all the 14 interviews, a bias related to the use of multiple interviewers could be avoided. If the interviews had been limited to one stakeholder group, such reviews would not have revealed any of the important diverging aspects between the four groups that are reported in Chapter 5. Moreover, this would have weakened the bases vis-à-vis suggesting a viable entry strategy.[171] If all the originally planned 18 interviews could have been realized, this would have added one interviewee to each stakeholder group and it is likely that some additional relevant aspects could have come up. Naturally, the results of the 14 explorative theme interviews were not covering the current state of the wood construction through the Finnish construction sector as a whole in the cross-section of the year 2016. Overall, the results of the theme interviews enabled this interviewer/researcher to formulate and suggest the elements of a viable segment-based entry strategy over the four phases.

It is herein reminded upon that foreign entrants need to acquire more detailed information about on-site functionality as well as time and cost savings through comparisons between various case buildings with wood, concrete, and steel solutions. This kind of comparative information enables them to formulate entry strategies and to tailor entry products with sales arguments. Such comparisons were not carried out as part of this study due to a tight schedule versus relatively long periods of projects and a difficulty to identify one or more pairs of comparable buildings and projects.

7.2 Entrants and incumbents in wood construction sectors in EU countries

The scope and results of this study may benefit all stakeholders in the Finnish wood construction sector. Especially, Chapter 3 may be considered as an introduction to a range of alternative connections used in engineered wood solutions in multi-storey buildings. In turn, Chapter 4 stands for a review of the production of the wooden buildings in Finland. In reality, it is likely that foreign entrants with their new brand solutions should not expect to achieve high sales volumes in entry years.

Moreover, the structure of this study may be adopted as a guideline or a reference when wood-based companies, based in the respective EU countries, are formulating entry and penetration strategies vis-à-vis wood construction sectors targeted in neighboring countries. Existing market reports serve readily as a workable means for screening potential markets. Obviously, serious foreign entrants are themselves committed and assign local

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[171] Hirsjärvi et al. 2007 p. 59

experts, inclusive local universities and students, to conduct focused, detailed entry studies by using both a local language and English, respectively. When a company intends to simultaneously expand its wood-focused business to many new countries, all this requires more capacity and competences as part of its international entry, penetration, and market management.

7.3 Suggestions for future research

The wood construction sector is developing strongly in Finland and other EU member countries. Many governments have been supporting national wood construction programs. New large and/or multi-storey buildings with wooden frames and other structures have been piloted. However, it seems that knowledge about wood construction solutions is still at a fairly low level. Therefore, it is herein suggested that key national stakeholders initiate comprehensive, comparative studies on solutions and costs in wood construction, steel construction, and concrete construction even across several EU countries. In this way, cost awareness of wooden buildings would be heightened significantly among key investors, designers, manufacturers, and contractors. At the same time, new applications of BIM and other software programs should be developed for structural design, project management, and cost estimation in wood construction.

8 SUMMARY

This Master's thesis has been commissioned by Rotho Blaas S.r.l. of Italy. The main aim of the study is to design a strategy for the segmentation of and entry into the Finnish wood construction market from the point of view of interested foreign manufacturers of structural steel connections. The conduct of this strategy design task was based on the three literature reviews (a desk study) and the theme interviews (a field study).

Sub-aim 1 is to select from the literature and to review the theoretical frameworks and typologies for the formulation of entry strategies especially with contexts embedded in foreign construction markets. In Chapter 2, the phases, the modes, and the key frameworks are reported upon. Cateora et al.[172] divide a company's international expansion process into the four phases, i.e. (1) preliminary analysis and screening, (2) market segmentation and marketing mix adaptation, (3) marketing plan development, and (4) entry implementation and control. In turn, Huovinen and Kiiras[173] have designed the Spearhead Entry Strategy as a solution to cross-country entry problems that suppliers of building products, complete building systems, or technologies are facing. This spearhead framework consists of the six elements, i.e., (i) existing products, (ii) market segmentation, (iii) product adaptation, (iv) entry differentiation, (v) entrant localization, and (vi) sales arguments based on a selection of "soft" and "hard" clients. Therein, local, soft clients find an entrant highly attractive, or at least a new interesting option. In this study, the framework has been applied to the case of manufacturers of steel connection systems that are used in wood structures. Readily, these manufacturers may have established local sales units in new target countries.

Sub-aim 2 is to review and understand the structural connection systems used in combination with engineered wood products. In Chapter 3, the highly technical results include the connecting solutions in the CLT, LVL, and GL assemblies. In this study, it is assumed that the same technical, principal solutions for connecting the wood structures are accepted within the EU member countries. Herein, the description covers the connections that are used in the frame structures composed of the wooden columns and beams as well as the panels in the single-storey or multi-storey buildings. Frame structures for smaller, light framed wooden single-storey buildings are usually made of timber. Frame structures for larger buildings, e.g., industrial buildings, are typically composed of prefabricated GL or LVL beams and columns completed with pre-fabricated wall and roof elements. Wooden multi-storey buildings are typically composed prefabricated modules, made of CLT panels, or alternatively frames are composed of load-

[172] Cateora, P. et al. 2011
[173] Huovinen, P. and Kiiras, J. 1998

bearing wall elements made of GL and timber. In the case of LVL and GL structures, the reviewed connections are very similar since the both structures are used as beams and columns. In the case of CLT structures, the reviewed connections differ from the previous ones significantly due to panel structures.

Sub-aim 3 is to investigate the wood construction in Finland via a desk study. In Chapter 4, the results cover the market development between the years 2005 and 2015 as well as the technical assessments and the certifications systems currently used in Finland. The references mainly include the documents published by the Confederation of Finnish Construction Industries, Puuinfo Oy, Pientaloteollisuus ry, and the Official Statistics of Finland. Mostly, small buildings like detached houses and leisure-time buildings are made with timber frames or log frames. Due to the migration to the big city centers, the bulk of the dwellings production in Finland has shifted from the detached houses to the dwellings built in the apartment blocks. The number of the completed detached houses has decreased from 16 000 units down to about 6 000 units annually. Thus, there is a huge overcapacity among the prefabricated houses manufacturers. In the case of large halls and multi-storey buildings, concrete is used as the primary material, overwhelmingly. The current market share of the wooden multi-storey buildings is only about 4%. When new residential building production is taking place as multi-storey buildings also in the coming years, it is herein considered that the market share of the wooden multi-storey buildings could be increased to 10%. Thus, the Finnish wood products industry should renew its offerings and operating mode in order to meet this new evolving demand. This implies the development of systems for high wood-framed buildings and the increasing use of engineered wood products.

In Finland, the compulsory system of the technical assessments and the certifications involves the Harmonized European Product Standard (hEN), the European Technical Assessment (ETA), and the CE marking. In addition, manufacturers may voluntarily rely on the four national procedures for product approvals: Type approval, Verification certificate, Certification of production quality control, and Certification on a construction site. The certification system is based on the reliance of the national research center.

Sub-aim 4 is to identify and analyze the key factors in competitiveness and procurement within wood construction in Finland via the theme interviews. In Chapter 5, the conduct of this field study and the key results are reported upon by the four interviewee groups, i.e., the 14 interviewees include Investors 1-3, Designers 1-4, Wood Element Manufacturers 1-4, and Contractors 1-3. The interviews were carried out in September and October 2016. The two manufacturers were focused on the production of elements for hall buildings. The other two manufacturers were specialized in residential buildings, including the multi-storey ones. Manufacturers acted as the suppliers of prefabricated elements under contracts with general contractors and investors. Investors 1-3 used the two procurement methods, the Shared Contract mode and the Design & Build Contract mode. Under building design management, the providers of connection systems and other technical products were selected before a design phase and, thus, the cost frames of the selected products were submitted to designers. Each of Manufacturers 1-4 had an internal design department, but each of them was also buying services from external design companies. Manufacturers 1-4 subcontracted assemblies on site to be executed by local contractors. As part of the connection systems, the screws were the most common solution for the fastening of wooden structures. The interviewees named a range of the challenges related to the wood construction, especially the lack of knowledge in design and design management as well as the lack of offerings for large wooden buildings. Among many advantages, the interviewees brought up the fast on-site erection phases and the high-quality prefabrications. In the same vein, the most interviewees stressed the importance of connections in big structures, i.e., they play a focal role in the enhancement of competitiveness of wood construction in the near future.

The attainment of these four sub-aims, the results, enabled to formulate a segment-based entry strategy for foreign manufacturers of structural connections. In Chapter 6, the international expansion framework of Cateora et al.[174] and the spearhead entry strategy (framework) of Huovinen and Kiiras[175] were applied to this focal context. The client segment-specific entry strategy was designed in terms of screening a market potential, segmenting a target market, adapting a marketing mix, developing a marketing plan, and selecting a mode of entry. Interested foreign structural connector manufacturers should identify “soft” key decision-makers among the manufacturers of wooden structures and frames and focus early marketing efforts on them. Instead of creating new exportable products, an entrant should choose its sales objects among the initial range of proven products and make only the necessary adaptations in order to meet a targeted country’s needs. An entrant could organize its sales activities through a local sales unit or a sales agent and, thus, avoid risks involved in a foreign direct investment in a production line and alike. A local unit is specialized on a targeted country’s market conditions and practices and it submits relevant marketing information to a company’s management for processing and re-utilization.

The conclusions have been put forth. In Chapter 7, the analysis and critique of the study, the scope of strategy applications, and future studies have been dealt with.

[174] Cateora, P. et al. 2011
[175] Huovinen, P. and Kiiras, J. 1998

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ANNEX 1. LIST OF WOODEN 4-N –STOREY BUILDINGS IN FINLAND, COMPLETED BETWEEN THE YEARS 1996 AND 2015

This list has been compiled in part from Ijäs 2013 p. 58., Ministry of Economic Affairs and Emplyment in Finland and Puuinfo Oy (2015) and Puuinfo Oy (2017).

	Completed wooden block of flats projects	City	Year	Buildings	Dwellings	Frame material	Buildings p.a.	Dwellings p.a.
1	Koy Ylöjärven vuokratalot	Ylöjärvi	1996	3	19		3	19
2	Koy Viikinmansio	Helsinki	1997	7	65		15	186
3	Koy Puukotka	Oulu	1997	3	33			
4	Tuusulan Hyrylän puukerrostalot	Tuusula	1997	2	46			
5	Raision asuntomessujen puukerrostalot	Raisio	1997	3	42			
6	Lahden Puu-Paavola 1	Lahti	1998	1	18	LVL	2	37
7	As Oy Porvoon Fradrika	Porvoo	1998	1	19			
8	As Oy Porvoon Aleksanterinkatu	Porvoo	1999	1	24		1	24
9	Naantalin puukerrostalot	Naantali	2000	3	51		5	83
10	Oulun Puu-Linnanmaa	Oulu	2000	1	14			
11	Lahden Puu-Paavola 2	Lahti	2000	1	18	LVL		
12	Lahden Puu-Paavola 3	Lahti	2002	1	19	LVL	1	19
13	Lahden Puu-Paavola 4	Lahti	2003	1	19	LVL	1	19
14	Vuosaaren kiinteistöt Oy Omenamäki	Helsinki	2006	3	131	LVL	3	131
15	As Oy Heinolan PuuEra	Heinola	2011	1	27	GL/T	1	27
16	Viikin Latokartanon puukerrostalokortteli	Helsinki	2012	5	104	LVL	5	104
17	Seinäjoen Lintuviita 2	Seinäjoki	2013	1	50	CLT	1	50
18	Koy Turun Palvelukoti	Turku	2014	1	54	CLT	1	54
19	As Oy PuuMera	Vantaa	2015	1	186	GL/T	8	376
20	Koy Puukuokka 1	Jyväskylä	2015	1	58	CLT		
21	Pukinmäen puukerrostalot	Helsinki	2015	4	93	CLT		
23	Omatoimi	Saarijärvi	2015	1	24	CLT		
24	Iin Kirjala	Ii	2015	1	15	GL/T		
25	Seinäjoen Mäihä (Asuntomessut)	Seinäjoki	**2016**	1	28	CLT	1	28
26	Honkasuo	Helsinki	**2016**			GL/T		
27			**2016**					
28			**2016**					
29			**2016**					
30			**2016**					

Key:
CLT=Cross Laminated Timber (Modular)
GL/T=Glulam / Timber load bearing walls
LVL=Laminated Vaneer Lumber (mast frame)

ANNEX 2. FORMAL REQUEST LETTER (IN FINNISH LANGUAGE) TO THE CANDIDATES OF THE THEME INTERVIEWS AND THE QUESTIONS FOR THE THEME INTERVIEWS

Formal request letter to the candidates of the theme interviews (in Finnish language). Sent by email to each of the 14 interviewees.

Asia koskien TTY:n Rakennustuotannon ja –talouden diplomityötä puurakentamisesta Suomessa – Pyyntö osallistua haastattelututkimukseen (lähetetty xx xx.2016)

HAASTATTELUPYYNTÖ
Pyydän teitä rakentamisen ammattilaisena osallistumaan haastattelututkimukseen, jolla selvitän Suomen puurakentamisen yleistä tilannetta, sen vahvuuksia ja ongelmakohtia, yleisimmin käytettäviä puurakenteiden välisiä liitosmenetelmiä sekä hankintamenetelmiä. Olen erityisen kiinnostunut kuulemaan teidän näkemyksenne ja kokemuksenne alan tilanteesta.
Noin 15-18 haastateltavaa edustavat investoivia rakennuttajia, suunnittelijoita, urakoitsijoita ja rakennustuotevalmistajia Suomessa. Lähetän jo ennalta oheisena teidän ryhmänne haastattelurungon. Haastatteluun kannattaa varata vähintään yksi tunti. Laadin jokaisesta haastattelusta muistion, jonka lähetän haastateltavalle tarkistettavaksi.
Haastattelujen tulosten raportointi tapahtuu anonyymisti em. neljässä ryhmässä. Yksittäinen haastateltava ja hänen vastauksensa raportoidaan ko. ryhmän lyhenteellä (esim. Suunnittelija Matti Meikäläinen = DES 1). Lähetän sitten myös diplomityöni tiedoksi jokaiselle haastateltavalle.
Toivon teidän suhtautuvan myönteisesti tähän haastattelupyyntööni ja haluaisin saada vastauksenne sekä myönteisessä tapauksessa jo ehdotuksenne haastattelun ajankohdaksi ja paikaksi xx.9. mennessä.

Rakentavin terveisin,
Jarno Naskali, tekniikan kandidaatti, diplomityön tekijä
Puh. +358.. ……., sähköposti …
Tampereen Teknillinen Yliopisto
Rakennustuotanto ja -talous

A. Background: Basic information about the interviewee
1. What is your educational background? And career?
2. How you ended up on the sector of wood construction?
3. How long you have experience about wood construction?
4. In how many projects you have been taking part?
5. Which professional role are you playing in a construction project?
6. What is your current profession and position?

B. Wood construction's competitiveness (Common part)
7. Which type of wooden buildings have you carried out (the main references)?
a. Detached houses
i. CLT
ii. LVL
iii. Timber
iv. Glulam
v. Else, what?
b. Hall buildings
i. CLT
ii. LVL
iii. Timber
iv. Glulam
v. Else, what?
c. Multi-storey buildings
i. CLT
1. Modular system
2. Panel system (load-bearing walls)
ii. LVL
1. Modular system
2. Beam and post frame + external wall elements
3. Load-bearing walls
iii. Timber
1. Modular system

2. Beam and post frame + external wall elements
3. Load-bearing walls
iv. Glulam
1. Modular system
2. Beam and post frame + external wall elements
3. Load-bearing walls
v. Else, what?
8. What critical problems have you found in wood construction projects? Mention 5 main problems.
9. What prominent advantages have you found in wood construction projects? Mention 5 main advantages.
10. Which factors are having affect the most, when choosing wood as a construction material? 5 main factors of the followings.
a. Competitive price
b. Ecology
c. Aesthetics
d. Wood's light self-weight
e. Good previous experiences
f. Fast erection phase on-site
g. Economic logistics costs (incl. transportation and lifts on-site)
h. Demand for wooden buildings
i. High level of pre-fabrication
j. Else, what?
11. How would you estimate the potential growth on the sector of wood construction divided in construction objects? Number in order 1 -8, the most attractive first.
a. Multi-storey buildings
b. Hall buildings
c. Public buildings
d. Detached houses
e. Repair and maintenance

f. Additional-storey (+1) construction
g. Bridge construction
h. Else, what?
12. Which factors of the followings would you relate as the biggest challenges for wood construction's becoming more common in the near future? Mention 5 most remarkable.
a. Soundproofing & Acoustics
b. Structural connections
c. Fire safety
d. Regulations for wood construction
e. Humidity control during construction phase
f. Humidity control during the use phase
g. Long-term durability
h. Lack of experiences and knowledge in design and in design management (Design phase)
i. Lack of experiences and knowledge in construction phase
j. Lack of demand
k. Lack of offerings
l. Else, what?
13. How would you evaluate the development of demand of wood construction during the period 2017 – 2019?
14. Do you wish to have more information for carrying out wood construction projects?
a. If yes, in which parts?
-
-
Free word about the theme of Finnish wood construction and suggestions for future development?

C. Customized part of the interview: Investors (INV)
15. In how many wood construction projects your company has been evolving?
16. How many wood construction projects you currently have in project planning?
17. How would you estimate the time used on wood a construction project, in relation to similar concrete and steel projects? (Detached houses, Halls, Multi-storey buildings)
18. How would you estimate the realized total costs of wood construction projects, in relation to similar concrete and steel projects? (Detached houses, Halls, Multi-storey buildings)
19. From investor's point of view, which are the advantages of wood construction compared to alternative building systems and materials?
20. From investor's point of view, which are the weaknesses of wood construction compared to alternative building systems and materials?
21. Based on your experiences, could you increase the share of wooden buildings in your production and what it takes?
PURCHASING
22. Which purchasing methods are currently used from your side, regarding a wood construction project?

C. Customized part of the interview: Designers (DES)

15. In how many wood construction projects your company has been evolving?
16. Which components are included in the scale of your know-how about wood construction? (e.g., frame designing, element designing [incl. manufacturing pictures] aso.)
17. How would you estimate the time used for designing phase of a wood construction project, in relation to similar concrete and steel projects? (Detached houses, Halls, Multi-storey buildings)
18. From designer’s point of view, which are the advantages of wood construction compared to alternative building systems and materials?
19. From designer’s point of view, which are the weaknesses of wood construction compared to alternative building systems and materials?
20. Based on your experiences, could you increase the share of wooden buildings in your business and what it takes?
TECHNICAL SOLUTIONS FOR STRUCTURAL CONNECTIONS
21. Do the current solutions for fastenings in wood structures correspond to your needs?
22. Have you designed custom-made connecting fixtures in your projects? If yes, which type of and in which structural joints?
23. Is there enough information available about connecting fixtures on the market? If no, about what subject would you like to have more information?
24. Which connection type you normally use in the following situations?
a. Post-Beam
b. Beam-Beam
c. Element frame member connections
d. Connection between elements
e. Anchoring elements
25. Which of the following factors has the most effect on your product based designing decisions? (5 the most valuable, in order 1-5)
a. Delivery time and easy reachability
b. Price
c. Quality
d. Product / Brand awareness
e. Good previous experiences
f. Information available about the product
g. Fast installation / Easy to use
h. Else, what?
26. How you see the development of connectors as part of development of wood construction? Do you have ideas for improvement? Where?

C. Customized part of the interview: Element manufacturers (MAN)
15. In how many construction projects your company has been evolving regarding wood components?
16. Does your company have an internal designing department or do you use an external designing office? Or both?
17. Which of the pre-fabricated wood components are included into your production?
18. From manufacturer's point of view, which are the advantages of wood construction compared to alternative building systems and materials?
19. From manufacturer's point of view, which are the weaknesses of wood construction compared to alternative building systems and materials?
TECHNICAL SOLUTIONS FOR STRUCTURAL CONNECTIONS
20. Do the current solutions for fastenings in wood structures correspond to your needs?
21. Have you used custom-made connecting fixtures in your projects? If yes, which type of and in which structural joints?
22. Is there enough information available about connecting fixtures on the market? If no, about what subject would you like to have more information?
23. Which connection type you normally use in the following situations?
a. Post-Beam
b. Beam-Beam
c. Element frame member connections
d. Connection between elements
e. Anchoring elements
24. How you see the development of connectors as part of development of wood construction? Do you have ideas for improvement? Where?
PURCHASING
25. Who are your typical customers and how are they purchasing from you?
26. How do you purchase the products for carrying out projects and what is the average delivery time?
27. Which of the following factors has the most effect on your purchasing decisions? (5 the most valuable, in order 1-5)
a. Delivery time and easy reachability
b. Price
c. Quality
d. Product / Brand awareness
e. Good previous experiences
f. Information available about the product

g. Fast installation / Easy to use
h. Else, what?

C. Customized part of the interview: Contractors (CON)
15. In how many wood construction projects your company has been evolving?
16. How would you estimate the time used for erection phase on wood construction sites, in relation to similar concrete and steel projects? (Detached houses, Halls, Multi-storey buildings)
17. How would you estimate the realized costs in wood construction projects, in relation to similar concrete and steel projects? (Detached houses, Halls, Multi-storey buildings)
18. From contractors point of view, which are the advantages of wood construction compared to alternative building systems and materials?
19. From contractors point of view, which are the weaknesses of wood construction compared to alternative building systems and materials?
20. Based on your experiences, could you increase the share of wooden buildings in your production and what it takes?
TECHNICAL SOLUTIONS FOR STRUCTURAL CONNECTIONS
21. Do the current solutions for fastenings in wood structures correspond to your needs?
22. Have you used custom-made connecting fixtures in your projects? If yes, which type of and in which structural joints?
23. Is there enough information available about connecting fixtures on the market? If no, about what subject would you like to have more information?
24. Which connection type you normally use in the following situations?
a. Post-Beam
b. Beam-Beam
c. Element frame member connections
d. Connection between elements
e. Anchoring elements
25. How you see the development of connectors as part of development of wood construction? Do you have ideas for improvement? Where?
PURCHASING
26. How do you purchase the products for on-site use and what is the average delivery time?
27. Which of the following factors has the most effect on your purchasing decisions? (5 the most valuable, in order 1-5)

a. Delivery time and easy reachability
b. Price
c. Quality
d. Product / Brand awareness
e. Good previous experiences
f. Information available about the product
g. Fast installation / Easy to use
h. Else, what?