



RIGA TECHNICAL  
UNIVERSITY

**Antra Viļuma**

# **WOODEN STRUCTURES IN LATVIAN ARCHITECTURE**

Summary of the Doctoral Thesis



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**RIGA TECHNICAL UNIVERSITY**

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Department of Architectural Design

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IN LATVIAN ARCHITECTURE**

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# **DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF SCIENCE**

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Join Zoom meeting:

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## **DECLARATION OF ACADEMIC INTEGRITY**

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Science (Ph. D.) is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Antra Viļuma ..... (signature)

Date: .....

The Doctoral Thesis has been written in Latvian. It consists of Introduction; 3 Chapters; Conclusions; 40 figures; 3 tables; 7 appendices; the total number of pages is 174, including appendices. The Bibliography contains 414 titles.

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# INTRODUCTION

Public opinion and a considerable number of scientific researches affirm that wood is a sustainable and competitive building material in contemporary architecture and construction. Its use in construction promotes a rational use of resources and reduces the adverse effects of construction on the environment [152]. Growing trees and forests play a significant role in carbon removal and climate change mitigation [107], [249], [400]. Wood is a renewable local material and its wider use significantly affects the local economy as well [119], [151]. In some countries, an increasing number of buildings are constructed from wood using industrially manufactured structures [70], [94], while there is also a competition for the construction of the tallest wooden building [104], [171], [327], [381], [393]. Healthy microclimate in wooden buildings [173], [197], [210] and other advantages of using wood [43], [193], [301] are being increasingly valued. Wooden structures are improved by means of experimentation [40], [163], [208] and creation of new solutions.

Climate change and global warming are global challenges which require urgent action. According to the Paris Agreement on Climate Change [407], [414], each country considers how to mitigate climate change and the adverse effects of human activities on the environment [392]. The sphere of construction constitutes approximately 40 % of total CO<sub>2</sub> emissions [130], [339], [400]; therefore, municipal support has been found in many countries for sustainable architecture projects and for the use of renewable materials [279], [372]. For instance, Sweden intends the introduction of a CO<sub>2</sub> tax [107] in order that a sustainable construction, which has produced a reduced impact on the environment, would have lower tax payments.

Latvia has a developed timber industry and produces laminated timber structures and panels, wooden carcass panels and buildings, as well as trusses and modular buildings. Approximately 90 % of the produced wooden products are exported [333], [363]. Each year in Latvia, certain objects are built from wooden structures [149], [215], [258], [385], while architectural elements for some of these objects are procured in Lithuania or in other countries, which in turn amounts to additional CO<sub>2</sub> emissions. Local producers would like to sell more of their products in the domestic market [315]; however, small enterprises experience a shortage of experts and resources in order to be able to counsel, calculate prices and to promote in a targeted manner the use of wooden structures to customers, architects, and engineers.

In many European and world countries, educational activities [153], [275], [346], cooperation programmes [262], [265], and the rewarding [246], [330] of the best wooden architecture projects are organised in order to promote a wider use of wooden structures. State support programmes [119], as well as advertising campaigns and informative platforms [370], [395] are created so that information on wooden buildings would be available to the general public and professionals. In Latvia, forest territories and a sufficient amount of timber resources are managed sustainably, there is a developed production of wooden structures and buildings [317]; however, only a few timber construction projects are implemented each year. In order to reach climate neutrality objectives and reduce the negative impact of construction

on the environment, the strategy for selecting building materials has to be changed and motivating and limiting factors, which influence the choice of wood, have to be identified [387]. Despite many advantages of wood as a material, its use in Latvia's architecture does not take place fully.

In Latvia, similarly to other Baltic States, wooden architecture is discussed primarily with regard to architectural heritage. In Lithuanian *medis architektura*, and in Estonian *puit architekturi* are widely used denominations not only in architecture but also in historical notes and in tourist information. Likewise, Scandinavian countries do not have a concise definition for wooden architecture, while in Swedish *trä arkitektur*, in Norwegian *tre arkitektur*, in Danish *træ arkitektur*, and in Finnish *puu arkkhittuuri* are used in order to denote both historical and contemporary wooden buildings. There are two denominations in the Russian language: *деревянная архитектура* and *деревянное зодчество*. Only one source [394] specifies the concept of wooden architecture, which is “the art of construction from wood that is of specific character and which is determined by qualities of material and methods of construction”.

The English *wooden architecture* and German *Holzarchitektur* are not widely used terms nowadays. European countries use the term *wood construction* more frequently [151], [209]. For instance, in German it is *holzbau*, in English – *wood construction* or *timber construction*. Denominations *wooden architecture* and *wood architecture* are also used; however, these are more frequently used equivalents for the term from other languages. For instance, Finland's informative website for wooden architecture is *woodarchitecture.fi* [396].

Globally, **wooden structures** have been studied from the perspective of historical development of timber construction, from the perspective of regional aesthetics [23], [31], [45], [85], [190], and of territorial spread [38], [98] by analysing the use of wood in the architecture of different countries. In recent decades, ever since many countries have changed their construction standards [195], factors influencing the selection of construction materials have also been studied [127], [218], [228], which promote or limit the selection of wood. The attitude towards the use of wood of those involved in the construction process is also being identified.

One of the oldest compiled materials on wooden structures is study “Wooden Architecture” (*Die Holzbaukunst*) by Professor Paul Lehfeldt from Berlin's Building Academy (*Berliner Bauakademie*), issued in 1880 [64] and published anew in 2013, in Berlin. It lays out the history of wooden buildings, construction technologies in different regions of the world and different typologies in buildings. A manual for the use of wood in the 19<sup>th</sup> century has been issued in France as well [13]. Historical and contemporary wooden architecture has also been studied in Scotland [12], Germany [43], [48], Austria [31], Estonia [18], [98], and in other countries [41], [239]. Studies on wooden architecture have also been published as chapters in architecture reviews of some countries [54]. Moreover, there are publications available [29], [37]–[39], [81], [88] containing a summary of wooden architecture projects from many countries.

There is abundant information **on historical wooden structures** in Latvia available in historical overviews and publications of German and Latvian researchers. “*Die Holzbauten*

*und Holzgeräte der Letten*” conducted by German ethnographer August Johann Gottfried Bielenstein was published in 1907 in German [2] and in 2007 it was translated into Latvian “*Latviešu koka celtnes un koka rīki*”, part one [3]. During his study years, architect Pauls Kundziņš conducted studies on the Latvian barn. Subsequently, there have also been studies on the methods of folk architecture [59], [175]–[177], which have been published in 1974 in book “*Latvju sēta*” [60]. The study on wooden churches conducted by architect Artūrs Krūmiņš has been published in book “*Latgales koka baznīcas*” [58]. These works contain information on wooden structures, construction technologies, as well as architecture styles and typology of wooden buildings. In previous centuries and decades, wooden architecture has been mainly studied within the context of historical buildings [49] and typical domicile [116], [124]–[126]. Such studies have also been conducted by Latvian architects Konstantīns Pēkšēns [205], Eižens Laube [183], Pēteris Bērzkalns [109], [110], and Jānis Jaunzems [34], [35]. Likewise, literary scholar and publicist Janīna Kursīte describes folk architecture and analyses the impact of historical construction on regional architecture in her book “*Latvieša māja*” [61].

**Studies on wooden buildings in urban environment** from different aspects and information on wooden structures and styles of wooden buildings have been discussed in publication “*Rīgas arhitektūras stili*” [53] by Professor Jānis Krastiņš and in the publication “*Koka Rīga*” [90] by art scholar Laima Slava, with articles by architects Pēteris Blūms, Ilmārs Dirveiks, Juris Zviedrāns, Vija Strupule, and Artūrs Lapiņš. Information on wooden buildings in Kurzeme has been summarized by architect Gunārs Jansons in book “*Kurzemes pilsētu senās koka ēkas*” [33]. There are also certain studies available on wooden buildings designed by a single architect. Information on wooden buildings designed by Jānis Alksnis has been published in the monograph by J. Krastiņš [50]. Art scholar Laura Plūmiņa has studied wooden architecture of Alberts Ašenkampfs [207]. Architect Zaiga Gaile has conducted an extensive study on a wooden building in Riga, 55 *Lāčplēša* Street, in relation to a restoration project of the building. The findings have been published in book “*Koka māja*” [22]. An architectural and artistic study has been conducted on many wooden buildings in Riga [115], [188], [237], Kuldīga [364] and in other populated areas; however, the majority of research materials are available only to the owners of the buildings and in the archives of the building authority.

**Studies on wooden architecture** have also been conducted in Kuldīga, Jūrmala, Sigulda, Aizpute, Jelgava, Liepāja and other cities in Latvia, and this information is available in publications on the history of cities [26], [51], [52], [63], [89], [103], [206]. A general overview of architecture in Aizpute, including its wooden architecture, is available in book “*Aizpute. Pagātne un tagadne*” by Ivars Silārs and Varis Sants [89]. The study of wooden architecture in Sigulda has been conducted within the research on thematic design that forms the identity of Sigulda [356]. On the order of Jūrmala municipality, photo chronicle “*Jūrmala. Koka dekorī*” has been created [79]. A study on construction components and decor of wooden buildings has been conducted by doctoral student Jānis Kalniņš [164] of the Institute of Design Technologies of Faculty of Materials Science and Applied Chemistry of Riga Technical University (RTU), architect Juris Zviedrāns [90] has conducted an extensive



research on wooden doors, while architect Ilmārs Dirveiks [15] has carried out a study on the 19<sup>th</sup> and 20<sup>th</sup> century wooden windows in Riga. Log buildings [65], [108], [204] and the development of their construction technologies in Latvia [165] and in other countries [102], [143], [170], [181], [223], [369] have been the most studied historical type of construction. In 2005, international conference “Log Home Builders and Wood Construction Specialists” organised by Professor Vilnis Kazāks was held in Riga [169]. At the University of Oulu, Jari Heikkilä studies the architecture and construction methods of Finnish log buildings [143].

The study of **wood structures in contemporary architecture** is related to the features of innovative wood products and the way in which they are used [87]. Innovative wood products are examined [208], [234] during the tests of their exploitation potential and mechanical properties. In Latvia University of Life Sciences and Technologies the research on wood structures is conducted by Professor Lilita Ozola [82]. Over the last decades the studies of wood structures worldwide and Latvia are also connected with sustainability aspects [43], [156] and assessment of life cycle of buildings [128].

The research of **use of laminated timber** in architecture [179] is done by Manja Kitek Kuzman, researcher of University of Ljubljana. M. Kuzman in cooperation with researcher from Finland Katja Lahtine and researcher from Sweden Dick Sandberg has performed a comparison of situation in Slovenia, Finland and Sweden [178]. The studies of laminated wood in Latvia take place on both theoretical and practical level. One of the significant glued laminated timber research projects is the pedestrian wooden bridge in Tērvete. The length of its single glued laminated timber span is 32 meters, but the total length of the bridge together with ascents is 100 meters [300]. The bridge is equipped with monitoring devices to study its performance; for five years it has operated as a big laboratory.

The studies of **cross laminated timber** (CLT) are under way in several universities in the world [238], [243]. The doctoral thesis written in 1994 by Professor Gerhard Schickhofer, Graz University of Technology (Austria), is considered as a commencement of scientific research of CLT [244]. In 2003, the researchers joined with the leading partner Graz University of Technology in the research on solid timber solutions “COST Action FP1004” [262]. Professor Steffen Lehmann (Australia) has studied the potential of CLT offsite **constructions in urban environment** [184]. Handbooks on several wooden building elements: laminated timber [138], cross laminated timber [42] and the laminated veneer lumber [27] are published, extensive information and results of studies are provided there.

Several studies of wood structures: “COST Action FP1402 – Basis of Structural Timber Design” [263], “COST Action E55 – Modelling of the Performance of Timber Structures” [267] as well as an extensive research on the fire safety of wooden buildings “COST Action FP1404 – Fire Safe Use of Bio-Based Building Products” [264] are available on the European research platform COST. Brigit Östman, the expert of European requirements on fire safety, has examined the building regulations of several European countries [200], [201], [342]. In Latvia Professor Konstantīns Kreišmanis has carried out a research on the protection of timber structures during the 50s of the 20<sup>th</sup> century [55], [56]. Certain countries have established timber research centres, for example one of the oldest timber research centre is in

Great Britain, it is the Timber Research and Development Association (TRADA) [20], where the comprehensive research of timber properties and technical parameters are examined.

Several editions dedicated to the wood architecture in different parts of the world are available as well [28], [39], [74]. A collection of articles about the timber buildings of Slovenia summarises the information about 29 residential construction projects and 28 public buildings [62]. The wood construction promotion website Think Wood has published 100 projects constructed from cross laminated timber in Great Britain [101]. The examples of Austrian wooden architecture are outlined and published in the revised edition [31], they are classified according to the construction technology.

The **architects' and constructors' perception** of wood and forest sector overall is the subject of research of Kerstin Hemstrom' (Linnaeus University) doctoral thesis [241]. The use of timber in public buildings and the treatment of timber as construction material for public buildings are conducted in Australia [325]. It was done in 2005 in the framework of public contract. The aim of the research was to identify the possibilities of timber industry to expand in the construction. Canadian researcher Annie Gosselin together with colleagues from Quebec and Montreal [136] has studied the **incentive and limitations** of timber use for the design of multi-story and public buildings; during the research the analysis of the minutes of nine project meetings was carried out. Canadian researchers [135] have also examined the impact of media and marketing materials on the use of timber products and wood as the building material for the construction of public buildings.

The comparison of opinions of practising and upcoming architects was carried out by researcher Vladislav Kaputa of Zvolen Technical University, who completed a research of **architects' perception** and knowledge in Slovakia [167]. This paper deals also with the attitudes of consumers towards buildings of wood-based construction [166]. Norwegian researchers Kristian Bysheim and Anders Qvale Nyrud have evaluated the architects' and engineers' perception of wood in construction [197], [198]. Anders Roos, Lotta Woxblom and Denise McCluskey have studied the perception of timber of Swedish architects and engineers in the beginning of the 21<sup>st</sup> century [213] as well as the influence of architects and structural engineers [214] on the selection of building materials.

The studies on society perception of timber as a material are completed in Latvia [312]. In 2005 and 2016, professional discussions were organised in order to identify the issues of timber constructions [185], [280], [345]. Information on the timber structure use in architecture is provided in several professional media articles [123], [149] as well as in other publications [45], however the information on the use of various timber construction elements and constructive building solutions is scarce. Little research has been done on the practical aspects concerning the preference of timber constructions that have been used in the projects already realised as well as on the factors influencing the process of selection of building materials.

**The research object** is wooden structures in historical and contemporary architecture.

**The research aim** is to summarize and classify the social, economic and technical aspects influencing the selection of wooden constructions in Latvian architecture.

**The following research objectives have been outlined to achieve the research aim:**

- to summarize the data on use of **engineered timber** and the chronological development of **types of wooden construction**;
- to systemize the data on **engineered timber and types of constructions**, ways to use it, and manufacturers;
- to systemize the data on the **contemporary wooden architecture** (apartment buildings and public buildings) in Latvia and **classify** this data according to the way of use of wood;
- to identify **the possibilities of use** of wooden structures and gather the data on experimental wooden structures and evolution of innovative solutions;
- to identify the factors **restricting the preference of wooden structure** use in architectural projects;
- to summarize the methods **to promote** the wooden construction and the factors that affect it;
- to carry out a survey of architects and other actors in the construction process, in order to identify the factors impacting the selection of building materials in contemporary architecture.

**Research methods used**

The methodology of research is based on the research on history of architecture and studies of wooden architecture conducted in Latvia and other countries, the scientific literature, documents, publications, articles and Internet resources. An empirical survey was carried out based on theoretical analysis of sources of information using the following methods.

1. Comparative analysis has been used for:
  - analysis of aesthetics of historic and contemporary wooden architecture;
  - analysis of the wooden structure use in the architecture of Latvia and other countries;
  - evaluation of promotion of wooden structure in the Baltic states and Europe;
  - analysis of impact of regulatory framework in relation to the design and construction of wooden buildings;
  - content analysis of articles on wooden architecture and the texts of discussions with the actors in the construction process who are directly or indirectly involved in wooden construction projects and in the process of selection of construction materials.
2. Semi-structured interviews with architects and other actors in the construction process who have used wooden structures in their projects.
3. A survey of architects conducted online and Likert scale applied to assess the importance of factors mentioned in interviews with the wider audience of persons involved in the construction.
4. Collection and systemization of data in order to identify the development trends.

### **Scientific novelty of the Thesis**

The research contains arranged data on the use of wood in Latvian architecture. Information on the genesis of wooden construction materials, wooden structures, construction materials and construction systems, wooden construction projects in Latvia during the end of the 20<sup>th</sup> century and 21<sup>st</sup> century, as well as information on legislation, instruments of promoting and factors impacting the selection of wooden structures.

### **Practical value of the Thesis**

The research of the use of wood and wooden constructions in Latvian architecture and contemporary architecture in European context is an extensive scientific material and a source of information for practical use in the design of new architectural solutions. The information gathered in the research constitutes the basis for the formation of content of a new study course at Riga Technical university.

### **Approbation of results of the research**

The content and outcomes of research were presented at several international and national scientific conferences, as well as published in scientific journals, collections of scientific articles and industry publications.

### **Publications**

1. **Viļuma, A.** Rūpnīcā ražotas koka ēkas. *Latvijas Arhitektūra*, 2016, Nr. 110, 108.–111. lpp. ISSN 1407-4923.
2. **Viļuma, A.** Koks. Arhitektūra. Pieredze. *Būvinženieris*, 2016, Nr. 48, 102.–106. lpp.
3. **Viļuma, A.** Ilgtspējīgs būvmateriāls un koka arhitektūras konkursi. *Būvinženieris*, 2016, Nr. 55, 98.–103. lpp.
4. **Viļuma, A.** Koka konstrukcijas. *Latvijas Arhitektūra*, 2017, Nr. 128, 10.–16. lpp. ISSN 1407-4923.
5. **Viļuma, A.** Kalnciema kvartāls. *Latvijas Arhitektūra*, 2017, Nr. 128, 46.–51. lpp. ISSN 1407-4923.
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8. **Viļuma, A.** The Situation with Use of Wood Constructions in Contemporary Latvian Architecture. *Science – Future of Lithuania = Mokslas – Lietuvos Ateitis*, 2017, Vol. 9, No. 1, pp. 9–15. ISSN 2029-2341. e-ISSN 2029-2252. Available: doi:10.3846/mla.2017.1007
9. **Viļuma, A.** Lielākā guļbūves skola pasaulē. *Latvijas Arhitektūra*, 2017, Nr. 133, 68.–71. lpp. ISSN 1407-4923.

10. **Viļuma, A.** Energoefektīvs jūgendstila nams. *Latvijas Arhitektūra*, 2017, Nr. 133, 34.–37. lpp. ISSN 1407-4923.
11. **Viļuma, A.** Atjaunota ēka Čiekurkalnā. *Latvijas Arhitektūra*, 2017, Nr. 133, 24.–27. lpp. ISSN 1407-4923.
12. **Viļuma, A., Bratuškis, U.** Barriers for Use of Wood in Architecture: The Latvian Case. *Architecture and Urban Planning*, 2017, 13, pp. 43–47. ISSN 1691-4333. e-ISSN 2255-8764. Available: doi:10.1515/aup-2017-0006.
13. **Viļuma, A.** Ķīpsalas halle. *Latvijas Arhitektūra*, 2018, Nr. 139, 84.–86. lpp. ISSN 1407-4923.
14. **Viļuma, A.** Renovation of Wooden Buildings in Riga. *Architecture and Urban Planning/Arhitektūra un pilsētplānošana*, 2018, Vol. 14, No. 1, pp. 14–19. e-ISSN 2255-8764. Available: doi:10.2478/aup-2018-0002.
15. **Viļuma, A.** Skola koka konstrukcijās. *Būvinženieris*, 2018, Nr. 65, 142.–149. lpp.
16. **Viļuma, A.** Mjostārnet – koka augstceltne Norvēģijā. *Būvinženieris*, 2019, Nr. 66, 34.–41. lpp.
17. **Viļuma, A.** “Jāņa sēta” Elizabetes ielā. *Latvijas Arhitektūra*, 2019, Nr. 142, 78.–81. lpp. ISSN 1407-4923.
18. **Viļuma, A.** Atjaunojot saglabā daudzdzīvokļu koka ēku. *Būvinženieris*, 2019, Nr. 69, 78.–85. lpp.
19. **Viļuma, A., Gabrenas, A.** Glulam in Architecture of Latvia and Lithuania. *Architecture and Urban Planning / Arhitektūra un pilsētplānošana*, 2019, Vol. 15, pp. 59–66. ISSN 1691-4333. e-ISSN 2255-8764. Available: doi:10.2478/aup-2019-0008.
20. **Viļuma, A.** Koka kopņu ģeometrija. *Būvinženieris*, 2020, Nr. 74, 92.–96. lpp.
21. **Viļuma, A.** Helsinku jaunā Oda. *Latvijas Arhitektūra*, 2020, Nr. 147, 78.–81. lpp.

#### **Reports at conferences**

1. **Viļuma, A., Gabrenas, A.** Glulam in Architecture of Latvia and Lithuania. *Riga Technical University 60th International Scientific Conference*, Latvia, Riga, 17–18 October 2019.
2. **Viļuma, A.** Glued Timber Structures in Latvian Architecture, *Riga Technical University 55th International Scientific Conference*, Latvia, Riga, 17–18 October 2018.
3. **Viļuma, A.** Barriers for Use of Wood in Architecture: Latvian Case. *Riga Technical University 55th International Scientific Conference*, Latvia, Riga, 13–14 October 2017.
4. **Viļuma, A.** The Situation with Use of Wood Constructions in Contemporary Latvian Architecture. Science – Future of Lithuania = Mokslas – Lietuvos Ateitis. 12 May 2017.
5. **Viļuma, A.** Wooden building renovation in Riga. *Riga Technical University 55th International Scientific Conference*, Latvia, Riga, 17–18 October 2016.

6. **Viļuma, A.** Wooden structures in Latvian Architecture. *Riga Technical University 55th International Scientific Conference*, Latvia, Riga, 14–15 October 2015.
7. **Viļuma, A.** Sustainable local building material – wood (poster session) *Riga Technical University 55th International Scientific Conference*, Latvia, Riga, 14–15 October 2014.
8. **Viļuma, A.** Atjaunojamo materiālu izmantošana būvniecībā. Atjaunojamie energoresursi, *Elektrum* Energoefektivitātes centrs. 10 April 2019.

The dissertation consists of an introduction, three chapters and conclusions. The list of information sources used includes 414 titles in Latvian, German, English, Estonian, Finnish and French. Images from both the author's personal archive and other sources have been used to illustrate the textual part. Images that do not indicate the source have been created by the author of the study.

# 1. GENESIS OF USE OF WOODEN BUILDING MATERIALS

Wood is a natural building material with a long history of use. It is most widely used in areas of the world where forests grow naturally. The principles of using wood in construction and architecture have been determined by various economic, social and technical factors in different centuries. Wood as a building material was readily available in many regions of the world, so it was widely used for both construction [73], [97] and decoration [12], [21]. However, there have also been periods when the availability of wood construction materials has been difficult. In Latvia, it is related to the volume of timber exports. Also, the rational use of wood has been updated in different time periods [60], [93]. The use of wood has also been influenced by the development and industrialization of forestry and wood processing. Historically, most buildings in the Baltics and Europe were made of wood, but over the centuries, for various reasons, the volume of wooden buildings has decreased. Today, the wider use of wood is promoted by local and global issues related to ecology.

## 1.1. Factors of Use of Wood in Architecture

There is a long tradition and widespread use of wood in world and Latvian architecture. The reasons why wood was used in construction have changed in each era, as well as the ways in which wood was used [10], [36], [99], [169], [222], [350]. Also, the advantages and properties of wood as a material have been evaluated differently in each era [271], [355]. The four main factors in the use of wood (Fig. 1.1) are availability in nature and on the market, the potential of size and geometry, the appearance and aesthetics of the material, as well as the structure and properties of wood.

The use of wood as a building material in architecture has developed and today is improving both in traditional types of construction and in the development of new wooden building materials and their uses. The impact of digitization on the development of contemporary wooden architecture is also significant, changing the design style and quality, transforming the construction process and significantly influencing the choice of material.

Availability nature/market	Size, geometry	Appearance, aesthetics	Structure, properties
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Fig. 1.1. The factors of use of wood in architecture.

## 1.2. Traditional Types of Wooden Construction

Historically, wood has been used in construction for centuries before our era. The most well-known and most widespread historical type of wooden construction in Latvia is a log building [169]. The second well-known type of construction, which is less common in Latvia, is a frame building or *fahwerk* (*feuchthwerk* – in German). Wooden buildings in the countryside were most often built by oneself, but carpenters of different nationalities also worked in the cities. Today, light wooden frame or lattice structures are still being built, which emerged in the 19<sup>th</sup> century to make more rational use of timber and to speed up the construction process. In the 1930s, Latvia criticized the inefficient use of wood and called for the use of new thermal insulation materials instead of building construction. An air barrier between the layers of materials was also used in the constructions. Traditional types of wooden construction continue to be used in the 21<sup>st</sup> century, and the determining factors are both the continuation of traditions and the desire to create an environment from ecological building materials. Both log and log houses and wooden frame buildings continue to be built in the world and in Latvia, using these traditional types of construction also in contemporary architectural projects.

## 1.3. Industrial production of Wooden Buildings

Nowadays, the construction of wooden buildings is gradually moving from the construction site to factories, and the traditional construction of wooden buildings (on-site) is gradually being replaced by the off-site assembly of prefabricated wooden structures [91]. In recent decades, this has been linked both to the targeted demonstration of the potential of new wood construction products and to other socio-economic factors [335], including the desire to build faster and reduce the environmental impact of construction [24]. In various periods of history, the principle has been used that mobile and prefabricated wooden buildings were made in a workshop and then transported by water or rail to construction sites, sometimes even to another continent [86]. In the 20<sup>th</sup> century, especially in the post-war period, the production of industrial wooden buildings was used to provide housing for the population as soon as possible. In order to provide the rural population in the 1970s, the production of industrial wooden buildings or the so-called “*Līvāni houses*” was started in Latvia. The increase in industrial production of wooden buildings has been influenced by the development of new design software that is compatible with the machine tools of the factory. This makes it possible to create individual architectural solutions from previously manufactured parts, rather than restricting construction by using standardized building components. The advantages of industrial production of wooden buildings – speed, quality and safety – are highly valued in Europe. Dozens of Latvian wooden building manufacturers work for export, selling wooden frame panel and modular buildings of various scales in the world. In the domestic market, this type of construction is still more expensive than the construction of traditional wooden frame buildings on site.



## 2. WOODEN STRUCTURES IN ARCHITECTURE

The use of wood in building construction has historically been an obvious and traditional choice because it was an easily accessible and workable material. However, in the earliest times, untreated or minimally treated wood was used, whereas nowadays wood becomes a wooden structure used in architecture only after several processing stages. In search of a rational and more efficient use of wood, experimental wooden structures were made in factories, new wooden construction systems were developed by civil engineers, and architects used them in both simple buildings and experimental contemporary architectural projects. In the 21<sup>st</sup> century, lumber and glued wood are still used in architecture, which was used in the construction of buildings throughout the 20<sup>th</sup> century. The new CLT and LVL panels are also increasingly used in projects, the initial production technology of which was very complex and expensive, so these panels became widely used industrially manufactured building elements only several decades after their first samples were created. The production and development of wooden structures is closely related to the availability of tools and machines, as well as the improvement of wood processing and related technologies. Parametric design and interoperable design and production software also play an important role. Several wooden building materials have been developed and are increasingly used [32], [114], while others have remained as scientific discoveries [97] or architectural experiments carried out once [11] or used for a short period of time [314], [344], [388]. Nowadays, new experimental wooden building materials are being developed and new uses are also being sought for existing ones in standardized building systems and unique architectural projects. Dozens of companies in Latvia produce wooden building materials and structures, and they are increasingly being used in Latvian contemporary architecture projects.

### 2.1. Contemporary Wooden Building Materials

In recent decades, new wood construction materials have been developed and new value has been given to the existing types of wood, creating a wide range of construction materials. Construction uses sawn timber of various dimensions (beams, boards, etc.), wooden panels and composite beams fastened with pins, as well as glued wood materials and wood materials with metal fastenings. Glued building elements have the widest range of types: several types of glued wood panels – LVL (laminated veneer lumber), CLT (cross laminated timber), as well as glued solid wood panels, beams and columns (GLT). Both NLT (nailed laminated timber) panels and wooden trusses are fastened with metal parts. Part of the wooden building materials is used for finishing and enclosing structures, but part – for load-bearing structures to ensure larger spans (Fig. 2.1). **Lumber, glued timber, cross laminated timber, laminated veneer lumber, wooden trusses with metal plate joints and I-beams** are most widely used in load-bearing structures.

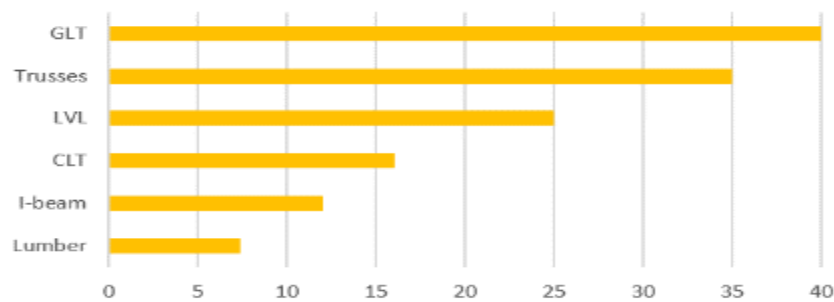


Fig. 2.1. Maximal length of engineered wooden materials.

## 2.2. Wooden Building Systems

In contemporary architecture, designers choose both new and traditional wooden building systems to use the aesthetic and technical advantages of wooden structures [32], [217], [236]. Over the centuries, traditional ways of using wooden structures to build in the most rational way have developed. The new wooden building elements – GLT, CLT and LVL – are also developing their own building systems, which are tested, improved and implemented in projects [67], [74], [220]. Research and practical experiments [279] are developing new wooden building systems by using improved fastening methods or combining wooden building elements with other materials. Constructive solutions or systems that have not been used for a long time are also relevant today. For example, the fastening of wooden elements with dowels was used in the Derevyagin’s beam developed by Russian engineer V. Derevyagin (*В. С. Деревягин*) in the 1930s [97], but today Austrian manufacturer “Thoma” uses such fasteners as an alternative gluing option [273]. In recent decades, almost all types of wooden construction systems have been used in the projects implemented in Latvia. The exception is LVL panels, which are not produced in the local market, therefore no projects with this building material have been implemented. Due to the relatively small number of wooden construction projects, none of the construction systems has gained a dominant position.

## 2.3. Experimental Wooden Structures

The most notable examples of contemporary wooden architecture are both the constructively complex buildings of well-known architects and the experiments of young architects with wooden structures, which are becoming iconic objects at the national or even international level. Projects with wooden structures are also classified as pilot projects [104] to test new technologies. The experience of designing and building wooden structures has been developed in recent decades, therefore their planning is a slow and relatively long process in which the designers and material manufacturers involved work intensively from the very beginning to create suitable, sometimes non-standard solutions and new construction systems. Experiments with the use of wooden structures have also been carried out in several architectural projects in Latvia, and the result of the projects has been praised both at the national [319] and European [249] level. Every project has architectural, economic or

functional reasons that have influenced the choice of wooden constructions, although often the aesthetics of wood has been the determining factor in architects' choice of using wood in the interior or exterior. The results of the survey of architects confirm that the knowledge of the material and the knowledge of the norms play an important role for the designers to be able to use all the advantages of wooden constructions.

### 3. FACTORS AFFECTING THE CHOICE OF WOODEN STRUCTURES

The choice of construction materials and constructive solutions in each project is determined by a set of many factors (Fig. 3.1). Each project participant has his own ideas, knowledge about building materials and experience in using it. In the process of material selection [105], wood is often left out of the list of possible building materials or is rejected as unsuitable during design because the parties involved do not have sufficient experience in working with wood. When competing with other materials [75], wood has to overcome prejudices and perceptions in society, although wood as a building material has not only disadvantages but also a number of advantages.

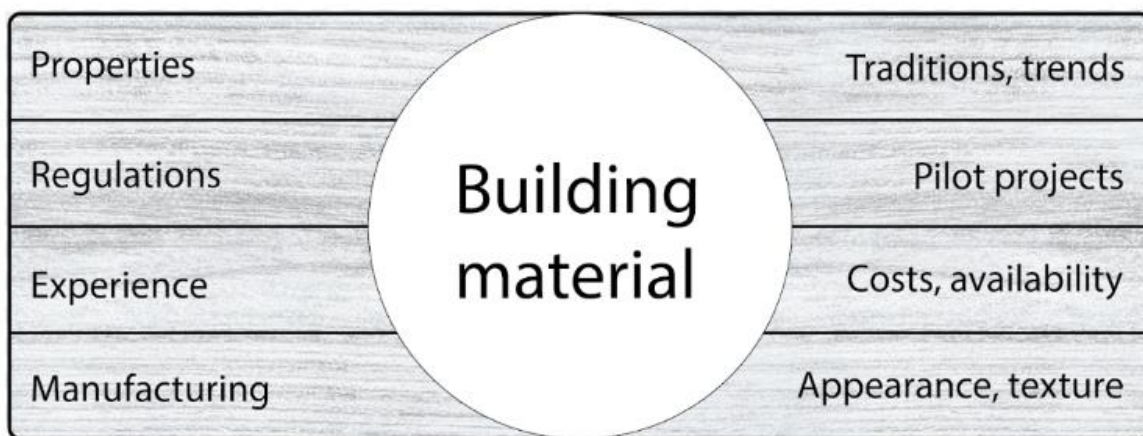


Fig. 3.1. Factors influencing the choice of construction material.

In the 21<sup>st</sup> century, the return of wood to the range of building materials is associated not only with the availability of new and more load-bearing wood materials, but also with the planned cooperation of the state with the forest and wood processing industry. In Latvia, wood is widely used in the industrial production of wooden buildings, which is currently more export-oriented. The industry has no direct interest in creating demand in the local market and rarely participates in measures to promote wood constructions. Whereas in Scandinavia and some European countries the companies of the industry purposefully plan activities to promote wooden construction, educate the public and professionals by organizing seminars, consultations and awarding the best wooden buildings, and engage in introducing changes in building standards.

#### 3.1. Normative Acts in the Design of Wooden Structures

When talking about wood constructions in Latvia, building codes are mentioned as the main barrier for building using wood. Stereotypes, lack of demand and other factors are also mentioned in the research and discussions of the construction process, however, regulations are one of the most frequently highlighted limitations in all surveys. The situation in Latvia has not improved even after the entry into force of the amended version of the Fire Safety

Code in Building [403]. Wooden constructions in the world are mainly implemented as analytical (performance based design) projects in which the safety of users has been proved by calculations. In Latvia, deviations from the norm can be proved by calculations, but the methodology is not specified, so any calculations can be questioned. The compliance of wooden building projects and structural solutions with the minimum requirements is assessed in many countries by fire safety experts who are familiar with both building structures and fire safety. In Latvia, these areas have not yet been combined, and projects are being implemented in accordance with all regulations.

### **3.2. Promotion of the Wooden Construction Process**

The volume of wooden construction decreased in Europe and Latvia in the second half of the 20<sup>th</sup> century, as several other building materials were recognized as more advanced and suitable. Wood became a less sought-after material, the number of carpenters decreased, and the process of transferring wood construction skills and experience was stopped. Today, the paradigm of wooden architecture has changed and interdisciplinary sectoral cooperation at the national and global level is needed to restore the reputation of wood as a building material [280]. Many countries are creating a system to promote timber construction [229], while others prefer the impact of a free market economy on changes in the volume of timber construction. Typically, strategies to promote timber construction are targeted activities at national level initiated or organized by forest and timber companies and organizations [231]. Sustainability, reducing CO<sub>2</sub> emissions and reducing the environmental impact of construction are key goals that are relevant in a global and national context. The most common forms and tools of promotion are information platforms, conferences, research and innovation projects, pilot projects and the award for the best wooden buildings. There are other types of initiatives [212], [287] that are most often the direct result of a high-level strategy or, on the contrary, the lack of such a strategy.

### **3.3. The role of Knowledge and Experience in the Choice of Building Materials**

Today, the range of building materials is growing every year. Wood in this range of building materials, on the one hand, is a little used traditional building material, but on the other hand, it is a new material in the form of various wooden building products. The choice of materials in each new architectural project is influenced by both subjective and objective considerations, as well as the knowledge and experience of the participants in the construction process, which in turn is influenced by each individual's perceptions and public opinion about building materials. The most commonly used is the read-across method [1], which is based on existing experience. The knowledge and experience of designers play an important role in the process of choosing wood as a building material. The impetus to go into the use of wood as a building material can also be created by a new order, interest in innovative construction methods, read information or research of implemented projects, as well as the desire to

support local manufacturers of wooden structures. The long-standing notion that wood is not a suitable material for multi-storey buildings is gradually being replaced by the belief that wooden structures are a suitable solution for architectural projects of various scales.

## CONCLUSIONS

The diverse **advantages of wood as a building material** have been promoted according to the requirements of each era. Material availability and technical properties for a long time were the factors of note for the existence and development of wooden construction, but the appearance and aesthetics of wood have raised the interest of architects and public in wood today. In the 21<sup>st</sup> century, the main advantages of wood are sustainability and the impact of use of wooden building elements on reducing climate change.

**Traditional wooden building systems** continue to exist today and are being improved using new technologies. For centuries, carpenters passed on the tradition of wood construction from one generation to the next, and even without the buildings surviving, wood construction skills were maintained. Today, the tradition of transferring practical experience in traditional wooden construction has transformed into the acquisition of skills from historical sources.

**Prefabricated wooden buildings** are a part of contemporary architecture. Industrial production of wooden structures creates an opportunity to implement standard and unique projects by saving time and resources. In recent years, separate public building projects with prefabricated wooden structures have been created in Latvia, however, most of the wooden buildings manufactured in Latvia are exported.

Almost all of the **new wooden building materials** are produced in Latvian, but in the local architectural projects they are used relatively little. In the construction of both private and public buildings in Latvia most often traditional rather than innovative wood construction solutions are used. Most of new wooden building materials are exported because they cannot compete with other building materials in the domestic market in terms of costs.

Architecturally complex buildings that are up to 18 storeys high are built from wooden structures. These projects are implemented as **experiments, innovations or pilot projects** where the designers cooperate with the manufacturer and builder of wooden structures. Demonstration projects are essential as they encourage other public and private clients to use wooden structures.

In recent decades, some larger-scale wood construction projects have been implemented in Latvia, however, the total volume of wooden buildings is small compared to other countries. During the last decades in Latvia **same larger-scale wooden structure projects** have been implemented, however, the total amount of wooden buildings is small compared to other countries. Each implemented wooden construction project is unique in its own way in the context of contemporary Latvian architecture, and several have gained recognition at the European level as well.

The **building codes** for the design of wooden buildings play an important role in the creation of new projects of wooden architecture. In recent years, construction standards in Latvia have been changed and amended several times, however, regulations in certain areas are contradictory. At present, the norms are not arranged in the system to help Latvian designers to ensure a healthy and safe environment.

In some countries, a **promotion system** has been set up at national level to increase construction with wood. The forestry and wood industry sectors organize the education of designers and the public, the construction of pilot projects of wooden architecture, and the awarding of the best projects. In Latvia, the promotion of wooden construction takes place by organizing separate activities supported by the industry.

The choice of construction material in architectural projects takes place at an early stage, or the decisions made at this stage significantly affect the choice of material. The choice of wood as a building material is influenced not only by the socio-economic situation, but also by **knowledge and experience of all participants** involved in the construction process. In Latvia, the participants of the construction process do not have sufficient knowledge and experience in using wood as a building material.

In many architecture projects, the choice of wooden structures has been made at the beginning of the project. It had been due to the projects being in cooperation with wood material manufacturers or as the result of educating investors and designers, as well as purposeful innovation projects, however, the **decisive role in the choice of wood as a building material** has been played by the customer. In Latvian wooden architecture projects, the desire of some customers to use natural materials or innovative solutions has also played an important role, but wooden constructions are still not an obvious choice.



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