2020

MASTER'S THESIS

HANA REMEŠOVÁ

UNIVERZA NA PRIMORSKEM
FAKULTETA ZA MATEMATIKO, NARAVOSLOVJE IN INFORMACIJSKE TEHNOLOGIJE

MASTER'S THESIS
(MAGISTRSKO DELO)

DIFFERENCES IN CONSUMER PREFERENCES FOR UNWEATHERED AND WEATHERED WOOD
(RAZLIKE V PREDNOSTNIH IZBIRAH POTROŠNIKOV PRI NESTARANEM LESU IN LESU, IZPOSTAVLJENEM OKOLJSKIM DEJAVNIKOM)

HANA REMEŠOVÁ

UNIVERZA NA PRIMORSKEM
FAKULTETA ZA MATEMATIKO, NARAVOSLOVJE IN INFORMACIJSKE TEHNOLOGIJE

Master's thesis

(Magistrsko delo)

Differences in consumer preferences for unweathered and weathered wood

(Razlike v prednostnih izbirah potrošnikov pri nestaranem lesu in lesu, izpostavljenem okoljskim dejavnikom)

Ime in priimek: Hana Remešová

Študijski program: Trajnostno grajeno okolje, 2. stopnja

Mentor: doc. dr. Michael Burnard

Somentor: doc. dr. Anna Sandak

Koper, september 2020

Ključna dokumentacijska informacija

Ime in PRIIMEK: Hana REMEŠOVÁ
Naslov magistrskega dela: Razlike v prednostnih izbirah potrošnikov pri nestaranem lesu in lesu, izpostavljenem okoljskim dejavnikom

Kraj: Koper
Leto: 2020
Število listov: 68 Število slik: 7 Število tabel: 19
Število prilog: 2 Št. strani prilog: 4
Število referenc: 79
Mentor: doc. dr. Michael Burnard
Somentor: doc. dr. Anna Sandak

UDK: 630*83(043.2)
Ključne besede: fasada, les, staranje lesa, estetika, preference potrošnikov, modifikacija, obdelava
Izvleček: Z izboljšanjem energetske učinkovitosti stavb so materiali odgovorni za vse večji delež vplivov gradnje na okolje. Les je bio material, primeren za različne gradbene namene, vključno s fasadami. Videz lesa se spremeni, ko je izpostavljen vremenskim vplivom. Razvoj modifikacije lesa prinaša nove materiale, ki delujejo dobro funkcionalno in estetsko, kadar so izpostavljeni zunanjim razmeram. Izvedena je bila raziskava za ugotavljanje razlik v potrošniških preferencah med nestaranim in staranim modificiranim lesom. Anketiranci so po ogledu vzorcev ocenili in razvrstili 6 parov modificiranih lesnih materialov (tako staranih kot nestaranih). Rezultate smo primerjali med materiali in pogoji. Dodatne lastnosti materiala (barva, razlike v sijaju in hrapavosti), skupaj z demografskimi podatki, so bile upoštevane kot dejavniki, ki potencialno vplivajo na preference potrošnikov. Razlike med materiali so bile ugotovljene pri ocenah vseh različic materialov (nestaranih, staranih in obeh). Sprememba barve med staranimi in nestaranimi vzorci je bila povezana z oceno materiala: ocene so se izboljšale, ko so bile spremembe barv majhne ($\Delta E < 2$), medtem ko so se zmanjšale, ko so bile spremembe barv velike ($\Delta E > 12$). Manj velika sprememba barve ($6 < \Delta E < 12$) ni povzročila pomembnih sprememb v ocenah. Ocene anketirancev in razvrstitve posameznih materialov so bile različne, kar se je odražalo v visoki stopnji variabilnosti. Vremenske razmere in z njimi povezane estetske posledice morajo upoštevati projektanti, gradbeniki in arhitekti. Priporočljivo je vključiti preference potrošnikov v razvoj novih fasadnih materialov in pri razvoju ciljati na tiste dejavnike, ki pri oblikovanju novih materialov in postopkov najbolj vplivajo na preference potrošnikov.

Key document information

Name and SURNAME: Hana Remešová
Title of the thesis: Differences in consumer preferences for unweathered and weathered wood

Place: Koper
Year: 2020
Number of pages: 68 Number of figures: 7 Number of tables: 19
Number of appendices: 2 Number of appendix pages: 4
Number of references: 79
Mentor: assist. prof. Michael Burnard, PhD
Co-Mentor: assist. prof. Anna Sandak, PhD

UDC: 630*83(043.2)
Keywords: Façade, wood, weathering, aesthetics, consumer preferences, modification, treatment
Abstract: As the energy performance of buildings improves, materials are expected to cause a greater share of the environmental impacts of construction. Wood is a bio-based material suitable for different construction purposes, including façades. The appearance of wood changes when exposed to weather. Development in wood modification brings new materials that perform well both functionally and aesthetically when exposed to outdoor conditions. To assess the difference in consumer preferences between unweathered and weathered modified wood, a survey was conducted. Respondents rated and ranked six pairs of modified wood materials in both unweathered and weathered conditions after viewing material samples. The results were compared between materials and conditions. Additional material properties (colour, gloss and roughness differences) along with demographic data were considered to understand which factors influence consumer preferences. Differences between materials were found in ratings of all sample conditions (unweathered, weathered and both). Colour change between weathered and unweathered states was associated with material assessment: they improved when colour changes were small ($\Delta E < 2$), while they declined when colour changes were large ($\Delta E > 12$). High colour change ($6 < \Delta E < 12$) resulted in no significant change in assessments. Respondent ratings and rankings to individual materials were diverse, resulting in a high degree of variability. Weathering and its aesthetic consequences should be considered by designers, builders and architects. It is recommended to include consumer assessment into new façade materials development and target those factors that influence consumer preferences the most when designing new materials and processes.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

CoV – coefficient of variation
therm. – thermally
mod. – modified

ACKNOWLEDGEMENTS

I gratefully acknowledge European Commission for funding the InnoRenew project (Grant Agreement N° 739574) and the Slovenian Research Agency (ARRS) ARCHI-BIO project (BI/US-20-054). I also acknowledge the CLICKdesign project, which is supported under the umbrella of ERA-NET Cofund ForestValue by the Ministry of Education, Science and Sport (MIZS) - Slovenia; The Ministry of the Environment (YM) - Finland; The Forestry Commissioners (FC) - UK; Research Council of Norway (RCN) - Norway; The French Environment & Energy Management Agency (ADEME) and The French National Research Agency (ANR) - France; The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS), Swedish Energy Agency (SWEA), Swedish Governmental Agency for Innovation Systems (Vinnova) - Sweden; Federal Ministry of Food and Agriculture (BMEL) and Agency for Renewable Resources (FNR) - Germany. ForestValue has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773324.

My deepest thanks to my mentor Mike for his endless patience, kindness and support, and for his profound knowledge. To my mentor Anna who found time for me in her busy schedule. To Andreja and Matt and all the people making the study program possible.

I thank Vaclav, Kelly, Amy, Lea, Dean, Liz and countless others from the InnoRenew CoE who always helped me and made me feel welcome. I also thank to my friends from the APZ UP who eased me into the life in Slovenia.

Finally, I would like to thank my friends and family; to my parents who supported me throughout my studies and my brothers who were always there for me.

1 INTRODUCTION

In this thesis, people's preferences towards weathered and unweathered wood used for façades are studied. Recognized factors influencing consumer relationship towards wood in the built environment are discussed. Since appearance seems to have the biggest influence on wood assessment and since wood exposed to the outside undergoes changes caused by weathering and other degradation processes, wood structure and decay mechanisms are presented. The perspective of future development for the building industry is covered, enhancing the importance of use of bio-based materials. New and creative ways of improving wood and other natural materials' performance to enable its use in the built environment are also briefly discussed.

1.1 SUSTAINABILITY IN THE BUILT ENVIRONMENT

The construction industry is a huge consumer of resources, raw materials and energy. In the last three decades, there has been a sequence of meetings and agreements regarding climate, importantly the Paris agreement implemented in 2016. The need to reduce greenhouse gas emissions was recognized, and construction – being one of the main contributors while consuming substantial amounts of energy – is an area in which improvements towards sustainability are to be made [1] [2]. Following that, in 2019, European Green Deal was introduced [3]. It recognizes climate changes and environmental degradation as an existential threat that is supposed to be overcome by transforming the EU into an economy with zero net emissions of greenhouse gases by 2050, with economic growth decoupled from resource use and with inclusivity. With still-growing needs for further development and construction, it is clear that the ecological consequences of the construction industry need to be reduced, making construction more sustainable and appropriate for cascade-economy principles both in new construction and refurbishments. Sustainable development is an umbrella term with ununified definition, depending on point of view [4]. In Brundtland's widely cited definition, 'sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs' [5]. The main aspects of sustainability, so-called "triple bottom line", are environmental, economic and social [6]. With amount of fossil fuels and other depletable resources being finite, it is only reasonable to focus on renewable materials and energy sources [7]. Sustainable construction principles are seeking to minimize construction environmental impact, aspire to have a closed material loop and get incorporated into nature after the end of service life. The discussion includes need for resources and energy during material extraction, processing, transport, the construction process itself, service life of the structure and its deconstruction. Obviously, that is not simple to assess, and since it is not possible to include all inputs, the scope of analyses often differs. Exact definition and content of sustainable development and "Green Building" representing an effort to achieve its ideal practice have evolved over years [8].

1.2 ASSESSMENT METHODS IN CONSTRUCTION

Adding to national and European legislation, other assessment methods have been developed to guide and recognize sustainable construction. The main two globally used sustainability assessment methods are BRE Environmental Assessment Method (BREEAM) and Leadership in Environmental and Energy Design (LEED). BREEAM is an environmental assessment method setting up a standard for environmental design through set benchmarks more demanding than the regulations. The method is motivating builders to develop and adopt new sustainable solutions and helps them to be recognized and appreciated by both users and the public. A scoring system is adopted that is easily understandable and straightforward and results in certification reflecting the performance of a given project against set standards; however, these might differ regionally. The LEED rating system was founded in the United States as a voluntary national standard for achieving high-performance, sustainable buildings. The points are awarded in categories related to environment, with a material and resources section supporting use of renewable materials [1].

1.3 RENEWABLE MATERIALS IN CONSTRUCTION

Bio-based materials are renewable, available world-wide, easily adapted and biodegradable, with wood being in the forefront of renewable materials used in construction. Not only does its stock steadily grow without direct human intervention but it helps mitigate climate changes via sequestering carbon from the atmosphere, incorporating it into its structures. When the wood is burned or decayed, carbon is released back to nature as a part of the carbon cycle. Clearly, when wood is utilized in construction or for other non-disintegrating purposes the cycle is prolonged, lowering the amount of CO_2 in the atmosphere. It is available for harvest throughout the year and its future stock is generally known [7]. It is assumed that with improving energy performance of buildings – the EC directive (2010/31/EU) requiring all buildings to be nearly zero-energy buildings by the end of 2020 – the distribution of environmental impacts will shift from being caused mainly due to the use of the house to materials used for its construction [9]. Use of natural materials in construction is conditioned on the knowledge of involved professionals about natural material properties and their proper use in construction and by acceptance of those materials by consumers. Data and good-practice examples must be available to achieve not only better understanding and acceptance but also to change builders' preferences for bio-based materials [1]. However, with the recent awakening of awareness about climate change and global sustainability issues, a shift of perception of bio-based materials in construction is being observed.

1.3.1 Non-wood biomaterials used in construction

Starting with non-wood organic materials, bark and cork are other parts of trees that can be utilized, but their use in the construction sector is rather limited, mainly to insulation materials. Flax, being amongst the strongest natural fibres, presents a problem due to its sensitivity to many factors influencing its growth and properties. Shives from the stalk are used to create a flaxboard, similar to a particleboard, fibres are used as reinforcement in cement or plaster. Hemp fibre has excellent mechanical resistance and low density. It is used for biocomposites and insulation materials as well as a reinforcement. Lime-hemp mixture called hempcrete is used as a plaster material. Similar to flaxboard, a particleboard can be made out of the hemp stalk shives. Straw has a long history of being used in construction. Nowadays, strawbales can form the insulation layer of a house or even serve as a load-bearing system. Development of prefabricated wood-straw panels makes a straw-based construction more acceptable by the public. Possibilities of bamboo and rattan fibres in construction are being explored.

Reed has been used as thatching for centuries, and if correctly applied, it is believed to last for as long as 50 years although it is generally much less [1]. None of the other discussed non-wood bio-based materials serve exposed to outdoor conditions since they are susceptible to damage and decay (unless as composite with plastic matrix); however, they can be protected by other natural materials such as mud or lime. Living plants can be featured in construction and the built environment, too. Green walls are vertical elements requiring specific support and watering systems, with growing substrate also spread vertically. Installation of such a wall might be demanding but results in lower wall temperature in summer and additional insulation in winter, while shading and moistening the adjacent street area. Such an approach can be applied to roofs, again with specific demands on the load-bearing structure, creating so-called green roofs that have added advantage in dealing with stormwater [10]. If the soil or substrate for the façade-covering plants is only located at the bottom of the structure, it is called green façade. The installation and maintenance of plants that are climbing on a structure is, however, costly [11].

1.3.2 Wood as a construction material

Wood is an organic material broadly used in construction. It has been utilized for centuries and, after being supressed by stone and later on steel and concrete during the last few hundred years, comes back to the forefront as an answer to current need for an affordable, versatile, renewable organic material [1]. Wood grows on its own, sequestering carbon from the air and utilizing it as a construction material for its tissues. That means lowering the amount of greenhouse gases in the air, which is one of the main challenges in the modern sustainability efforts of slowing down climate change. Wood is biodegradable; once it is decomposed by burning or natural processes, the carbon returns to the cycle. The longer the wood can stay in its solid form, the longer the carbon is bound in solid material instead of forming carbon oxides in the air. Wood can be modified to change its properties or transformed into elements of bigger forms than a single stem or in layers as thin as several millimetres, which can be used in different shapes and forms or converted to chemicals. With proper construction and treatment, it can last for hundreds of years – the oldest still-standing wood structure is a temple built in the 7th century. The use of wood in construction can be repetitive since undamaged elements from deconstructed buildings can be easily reused or transformed into another valued product [12]. In Europe, softwoods are mostly used for construction due to their high strength-to-weight ratio, availability and machinability. However, the mix of species in the forest is, partly due to climate change, transforming towards prevalence of hardwood species. That will force the wood-processing industry to adapt in the future [8].

Nowadays, solid wood is used for structural elements, light frame constructions, beams, columns, bridges, ceilings, floors, façades, etc. It tends to be used in residential buildings rather than non-residential ones. In smaller non-residential buildings, wood has proven successful, but it is avoided in large ones, mainly due to fire safety concerns, building code restrictions and inexperience of both designers and builders [13]. In order to achieve better performance and better utilize woody material otherwise considered as waste, engineered wood products were created and innovations continue to develop in this area. Cross laminated timber (CLT) was developed in an attempt to produce a high-quality product out of a lower-quality material. Layers of timber are glued together in perpendicular direction, with an odd number of layers ensuring the outer layers have the same orientation. That allows for a solid panel that can span considerably in two dimensions, overcoming the solid wood issue of having substantial dimension in one direction only. CLT has also increased dimensional stability and can be easily and efficiently prepared for construction while allowing for individual changes. Together with changing legislation, CLT is playing a major role in multi-storey, wood-based construction, soothing concerns regarding wood-based construction, stability and fire safety. In such applications, CLT tends to be used together with other materials, including glulam, another engineered wood product in which planks of timber are glued parallel to each other to form a structural composite beam. Wood-based panels typically consist of wood parts of various sizes (veneers, particles, fibres) glued together and hardened by heat, forming either separate panels or infinite mat that is cut to appropriate dimensions. Plywood, formed out of layered wood veneers, is typically used for flooring, sheathing, ceilings, cladding or furniture. Particleboard is formed out of glued wood particles, resulting in a panel with somewhat uniform properties that is typically coated or laminated and used for flat parts of furniture or wall and floor panels. Oriented strand board is made of strands or wafers of timber glued together. It is often a substitute for plywood – usually as structural panels in floors or walls. Other applications include packaging, I-joists and even as aesthetical elements. Fibreboard is a panel formed of wood fibre connected by glue. Based on its density, it can be used for insulation, flooring, furniture or façades [1]. Even smaller particles of wood powder or flour are combined with matrix materials like plastics or resins to create wood-plastic composites (WPCs). The exact rates and materials of both basic components to obtain desired properties are still being researched, but it is obvious there are many uses for the still-new product, including façades. For some uses, it offers significant benefits, but if competing with other products, the incorporated plastic presents an environmental drawback [11].

1.4 FAÇADES

Façades are a building element that separates inside from outside, like the body's skin, providing barrier from moisture, dust and UV, helping regulate inner temperature and interacting with its environment [11]. For proper façade function, both structural and aesthetic requirements must be met. Façade hugely influences the overall appearance of the building; its purpose is to present the building to its surroundings [14]. To ensure a stable and comfortable environment, façade must block from, mute or channel the influence of the outside environment, dealing with different weather, changes of temperature and humidity and specific requirements for each climate zone. Distinct environments require not only particular material use but also influence choice of shape and orientation of the building and the layout of building features including windows, overhangs, blinds, etc. In the past, façade was just a result of material used for the wall itself, which tended to be mud, timber or stone. Later on, the façade was an indicator of dwellers' wealth and importance, resulting in more intricate, decorated finishes. With other means to show economic status, buildings' purpose changing, time spent indoors prolonging, technical developments and growing demands on comfort, façades are nowadays a complex part of building design [11].

Initially, internal environment was adjusted by natural means of ventilation and heat and moisture exchange through the envelope. However, that requires considerable effort from the inhabitant and might not achieve desired impact. Passive means respective to needs of specific climates were developed, such as overhangs blocking direct sun radiation in hot climates and added insulation in colder climates. Introduction of HVAC systems led to air-tight building envelopes where the internal conditions of temperature, humidity and air circulation were set up and regulated as desired. However, certain shortcomings emerged – from moulds growing in air duct to inability of occupants to influence their environment. Mixed-mode systems compromise on the latter by opening the façade in certain periods of the year: if the outdoor conditions are favourable, windows are opened; if not, air-conditioning is utilized. Lately, adaptive façades have been introduced: the façade changes some of its properties and functioning based on outdoor conditions [11].

1.4.1 Wooden façades

The main advantage of natural materials is their renewability and recyclability. Their drawback is their flammability and relationship with water, which they bind in their structure. Certain levels of moisture lead to dimensional changes and allow for biological attacks. The susceptibility to decay and degradation by biotic and abiotic factors is a point of concern when discussing wood as a façade material since façade is the part of the building exposed to outdoor conditions. It is advised to avoid long-term wetting of the structure by following the so-called 4 Ds: deflection, drainage, drying and durability of used materials. However, when used properly, wooden elements are known to last decades to hundreds of years. Natural materials are generally appreciated by building users; however, aesthetic appreciation evolves and is individual. As façade is usually seen as whole, an aesthetical quality specific for wood is not only its colour and texture but also the direction and rhythm of the cladding. Wood colour is in shades of yellow, orange and brown, which changes with time into pale shades of those and to grey. The uneven colouration caused by ageing and weathering is usually not appreciated although sometimes it is desired or even produced intentionally [11]. In some cases, reclaimed wood in good state has been re-used as façade, decreasing the environmental footprint and adding a story to the building [15] [16].

For some applications, gloss of material – meaning how reflective a material is from a certain angle – is considered. Although wood isn't generally considered a glossy material, some coatings or finishes can result in rather reflective material.

Roughness, as a set of height differences of the profile of an object, seems to be the dominant factor in tactile perception of a material. It is also related to other parameters of well-being, like acoustic, olfactory or socio-cultural comfort [17]. Not only is there an inevitable natural unevenness caused by wood anatomy, but wood can be purposely sculpted to decorative elements. Notably, such carved elements tend to be easily damaged by weather since more wood vessels are open and thus unprotected [11]. Measurement of roughness, on wood surface specifically, is complicated and doesn't have one generally accepted approach. Roughness can be described in statistical height descriptors, texture parameters, probability descriptors or other analytical approaches [18]. However, in the research where tactually perceived roughness was compared with measured data, R_a (arithmetic average deviation from a mean line) was used previously [19] [20]. The mean line is defined as a line area between which and the profile above equals area between the line and the profile below [21].

1.5 WOOD

1.5.1 Wood structure

Wood is an organic material that consists of carbon, oxygen and hydrogen forming major components known as lignin, cellulose and hemicellulose. The cellulose is a polysaccharide arranged in amorphous and crystalline forms, forming small fibral structures called microfibrils. Lignin is an amorphous polymer the encapsulates and connects the fibrils. Each of the components is represented differently in different layers of the wood cell wall. Wood cell wall comprises layers called middle lamella, primary wall and secondary wall. Heavily lignified middle lamella interconnects wood cells, and its mass is provided by each of the concerned cells. Primary wall is a thin layer with random orientation of cellulose microfibrils, often undistinguishable from middle lamella. Secondary wall consists of three layers, second of which is the thickest and most influential in the overall properties of the cell wall. Of all the wood cell wall layers, secondary wall has the lowest share of lignin and highest share of cellulose. Wood cells formed from these chemicals are organized in concentric bands. Different cells have different functions, all of them intertwined to allow for the tree to grow and prosper. This is often omitted when viewing wood as a construction material. When looking at a transverse section of wood, it consists of a pith, heartwood, sapwood, vascular cambium, inner bark and outer bark when going from the middle to the outside. Outer bark serves as mechanical protection of the inner bark, which transports products of photosynthesis from leaves to the growing parts of the tree and roots. Vascular cambium is a thin layer where cells of both inner bark and sapwood are produced. Sapwood has living cells forming tissues transporting water or sap from roots to leaves, storing it, and also tissues with a mechanical function. On the edge between sapwood and heartwood cells chemicals known as extractives are produced that are stored in the dead cells of heartwood and often give it different, darker coloration together with modified resistance; the mechanical function remains despite the dead cells. The very centre, the pith, is a tissue from early growth of the tree from before the wood was formed. Tree species can be generally divided into softwoods and hardwoods distinguished by botanical characteristics and distinctive tissue organization. Within those, each species has characteristic elements that differentiate it from the others. Nevertheless, each individual tree's structure is unique, resulting in the high degree of variability of wood as a material [12].

1.5.2 Wood and water relationship

As any living organism, wood contains water, which remains in timber to some extent. Wood is hygroscopic due to hydroxyl groups present in its cell walls. Its moisture content is balanced with the humidity of the outer environment (typically relative humidity of air – RH). When RH is changing, the moisture content of wood is adjusting appropriately, resulting in volumetric changes together with changes in mechanical, elastic and thermal properties. However, only a limited amount of water can be incorporated in wood cell walls (bound water). This limit is called the fibre saturation point (FSP), exceeding which results in liquid water present in lumens (free water) of the wood cells that doesn't contribute to dimensional changes. Due to the angle of microfibrils in the secondary layer of the cell wall, the dimensional changes are biggest in lateral planes. Longitudinal changes occur but are minimal. When in a humid environment, the wood swells to reach its equilibrium moisture content; correspondingly, the wood shrinks in a dry environment [12].

1.5.3 Wood degradation

Wood is an organic material susceptible to damage. There are biotic and abiotic factors that result in chemical and, subsequently, also visual or mechanical changes. Biological degradation occurs in processed wood when environmental conditions enable presence and growth of biotic agents of wood degradation (such as bacteria, mould, stain, decay fungi, insect or marine borers), and the element is not protected against it. Mould and stain are limited to wood element surface changing its colour, which typically lowers the value of a material or product. There are many species of decay fungi, and they are mostly differentiated by the mechanism of decay to brown-rot fungi, white-rot fungi and soft-rot fungi. Brown-rot decomposes cellulose and hemicellulose and white-rot degrades lignin; fungal decay compromises mechanical and aesthetical properties of wood. Wood-damaging insects create holes in wood – which is a source of nutrition or a habitat – resulting in mechanical weakening. Commonly, decay caused by one type of wood decay organism enables for easier attack of others. Abiotic factors account for weathering and fire [12].

1.5.3.1 Wood weathering

Weathering is degradation of wood exposed to outdoor elements including sunlight, rain, snow, wind, heat, cold and temperature changes, etc. The surface of wood exposed to outdoor conditions withstands changes in relative humidity and temperature, causing swelling and shrinking of wood, abrasion by airborne particles and solar radiation and its UV component (photodegradation). The UV radiation's energy chemically changes the structural components of wood. The colour of wood is induced by presence of chromophore groups in extractives, which are degraded by energy of the visible sunlight spectrum and results in colour fading. Consequently, changes of wood colouration indoors are only caused by chemical degradation of extractives by visible spectrum of light since UV light is filtered by glass in windows. While wood indoors fades in colour, outdoor elements' colour turns toward grey. Unlike lignin, the chemical by-products of UV-imposed degradation are water-soluble and washed out by rain. Remaining polysaccharides, cellulose and lignin are white-grey in colour. The grey colour is also enhanced by the presence of blue-stain fungi. At the early stages of weathering, the colour change progresses more rapidly in heartwood since it's richer in extractives than sapwood [12].

Having said that weathering influences the surface, it is not limited to visual changes. Through repeated wetting and drying coupled with heat or frost, the wood surface cracks and exposes the yet-intact part to weathering. Weather-stressed wood can be easily colonized by wood decay organisms if other conditions are favourable for their growth [12].

1.5.3.1.1 Photodegradation

Wood consists mainly of polysaccharides and lignin, respectively carbon, oxygen and hydrogen, forming structures and connected by different chemical bonds. These bonds, having different properties and strength, can be dissipated if involved chemicals absorb sufficient energy. Solar radiation reaching Earth's surface is (from a certain point of view) a stream of particles – photons – of different energy and wavelength. The photon energy is inversely proportional to wavelength. The part of radiation with the shortest wavelength (between 295 and 400 nm) is UV radiation; therefore, its photons have the highest energy. Visible spectrum radiation ranges from 400 to 800 nm, and infrared radiation ranges between 800 and 3000 nm. Randy & Rabek [22] in Rowell [12] introduce chemical bonds commonly present in lignin and wood itself and their necessary dissociation energy which ranges between 231 and 540 nm. Naturally, the highest energy provided by solar radiation is that of 295 nm wavelength. In order to break a bond, the radiation energy must be absorbed by some component of wood. Absorbed energy can be depleted in different ways, one of them being dissipation of heat (not degrading by itself but might enhance the degradation [23]) while others involve chemical reaction. Indeed, many chemical bonds incorporated in wood dissociate with radiation of the UV spectrum and part of the visible spectrum [12]. Accepted energy results in forming of free radicals, which react further with oxygen in the atmosphere. The oxidation results in lignin degradation. The products of lignin degradation are rinsed by rain. While lignin itself is considered hydrophobic, its degradants are water-soluble.

Since middle lamella is highly lignified, photodegradation occurs primarily in this wood cell wall layer, leading to wood cells separation. In microscale, lignin binding the microfibrils is degrading and leads to fibrils loosening and detaching. In macroscale, latewood with thicker cell walls and, therefore, thicker secondary walls are significantly more resistant than earlywood. Therefore, surface of photodegraded wood with distinguished earlywood and latewood gets rough. Similarly, wood with higher density degrades slower [12].

1.5.3.2 Wood and fire

A big risk connected to use of wood in construction is its combustibility. Heated up, wood thermally degrades and releases gases that are flammable. The degradation slowly starts in temperatures around 225 °C, when the hemicellulose component begins to decompose. It is mostly decomposed by the time the temperature reaches 325 °C. The cellulose decomposes within a short temperature range above 370 °C. The lignin starts to decompose at temperatures around 200 °C but remains rather stable. Released gases, mixed with oxygen and heated to ignition temperature, burn [12]. It is obvious that bio-based materials aren't a priori resistant to fire.

Fire resistance is the capability of material to withstand fire. Within Europe, there are requirements for a specific time for which a load-bearing structure of a building must remain intact. For the thermal degradation of wood, there must be sufficient temperature, oxygen and volatile gases. Flammable building elements can be covered by non-combustible elements or treated with fire retardants that either make combustion less likely, lower the amount of flammable volatiles released during fire or create a separating barrier between the material and the air – a source of oxygen. Interestingly, fire can be used for increasing aesthetic and durability properties of wood as proven by the Shou Sugi Ban technique. Burning a wood element chars on its surface, creating a layer of charcoal that functions as an insulator to the wood underneath. Load-bearing structures are commonly designed with increased cross section to ensure its stability during designed time of fire resistance [11].

1.5.4 Wood protection

Wood can be protected by design or by treatment/modification. Design solutions focus on ensuring decay organisms don't have adequate conditions for life, meaning keeping access of oxygen, temperature and humidity either below or above the range necessary for decaying organisms. Wood species are of different durability, so part of the design process should be a choice of a material adequate to the exposure conditions. Knowledge of wood and its behaviour in relation to influences that are expected to impact the element during its service life is important, as is proper and educated manipulation and installation on the construction site. Out of the above-mentioned conditions, it is common practice to use moisture as the limiting factor and keep it under the level favourable by wood-decaying organisms. Therefore, it is recommended to keep the water away from the structure, and if that is impossible, to drain the water away and dry the natural material as soon as possible. Commonly used techniques are roof overhangs, separation between wooden elements and structures with higher moisture (concrete, stone wall), distancing wooden elements from the ground or covering them to limit the amount of reflected rainwater, end-grain protection by design or coating, sufficient roof angle and façade shaping, spacing of planks to allow for water drainage, etc. [1]. If protection by design is insufficient, other protection methods should be used.

1.6 WOOD TREATMENTS AND MODIFICATIONS

As organic material, wood undergoes dimensional instability, biotic and abiotic decay, flammability and combustibility. That is natural – wood degradation is part of tree life cycle – but when using wood as product or material, stability and endurance are preferred. To achieve desired characteristics, wood components and, therefore, its properties can be modified. However, to be able to change them, they have to be understood first. All the above-mentioned degradation processes evoke either mechanical damage or chemical decomposition reactions that can be eliminated or slowed down. Wood can be protected from both abiotic and biotic factors by modification that changes its overall durability or by coating that either creates a barrier between the insect or fungi spores or includes biocides either terminating the wood decay organisms or inhibiting their ability to procreate. Note that some of the existing solutions can be unsuitable for ecological or economic reasons. Other potentially cheap and non-toxic treatments do not translate into required properties or durability. It is important to consider sustainability and impact not only of production and service life but also disposal. While active modification changes the chemical nature of the material, passive modification influences the properties without chemical alteration of the wood itself. Not every interaction between a chemical agent and wood is considered a chemical modification. Intake of a chemical that impregnates cell walls but doesn't necessarily react with cell wall components is considered to be impregnation modification [7] [12].

1.6.1 Chemical modifications

Chemical modifications are herein understood as a chemical reaction between wood component and a chemical reagent forming covalent bond. Formed bond should be strong enough to withstand natural degrading processes. The treating chemical must contain a reagent that will bind with the chosen reactive part (often hydroxyl group) of wood. The outcome cannot be toxic to humans and toxicity of the process should be limited. The chemical should have a low enough boiling point to enable removal of excess reagent. It is necessary to utilize rather lower temperatures if the treatment takes time; on the other hand, if the treatment requires high temperature, the reaction time should be very short [12]. In any case, the temperature shouldn't exceed 170 °C as wood degrades quickly in higher temperatures [24] in [12]. The reagent needs to be able to reach the reactive chemical sites; therefore, it is favourable if the chemical is capable of swelling the wood structure. It is advisable that the chemical and resulting compound are hydrophobic. All that said, the treated wood should not lose the desirable properties – its strength, workability, odour, colour and electrical resistance should not be compromised. Naturally, the process should be as simple as possible, including removing excess or by-product chemicals [7] [12].
Choice of modification is based on desired properties.

1.6.1.1 Acetylation

Acetylation of wood (see Formula 1) typically uses acetic anhydride in liquid form [12]. There had been experiments with wood acetylation using ketene gas that doesn't produce any by-product, but properties of such treated wood were unsatisfactory. Esterification of accessible hydroxyl groups in the cell wall produces acetic acid as a side product. Since it is a single site reaction and no polymerization occurs, weight gain can be directly translated in number of reactions. Acetylation reduces the hygroscopicity of wood, resulting in lower dimensional changes. Modified wood presents good resistance to both white-rot and brown-rot fungi, and it is somewhat resistant to termites and marine organisms. Effects of weathering are reduced to a half in surface erosion and depth of its operation. There is some retardation in photochemical changes: acetylated pine is reported to start turning grey in two years of outside exposure as opposed to one year for unmodified wood [12]. Acetylated wood is produced commercially under the tradename Accoya® [25].

wood-OH + CH_3-C(=O)-O-C(=O)-CH_3 → wood-O-C(=O)-CH_3 + CH_3-C(=O)-OH

Formula 1: Acetylation. Acetic anhydride bound to hydroxyl groups in wood result in acetylated wood and acetic acid by-product [12].

1.6.2 Impregnation modification

Chemical agents acting in impregnation modification either polymerize within the cell wall or, after diffusing in the cell wall in soluble form, reacting with subsequent treatment to form an insoluble compound. Practices mentioned in the chapter “1.6.1 Chemical modifications” (0) regarding toxicity, treatment temperature and speed and resulting wood properties apply here equally. It is important to note that penetration of cell walls is a process based on diffusion and, therefore, on degree of cell wall swelling, size of chemical molecules and time but not on applied pressure. However, pressure might be applied to ensure penetration of the chemical agent throughout the element. Molecules too big to penetrate the cell wall might form a barrier on the surface of lumen, which protects the cell wall from degrading agents but tends to fail after some time [7].

1.6.2.1 Furfurylation

Furfurylation is a process of wood impregnation with furfuryl alcohol – an organic compound typically derived from biomass waste. With applied moderate pressure and heat, furfuryl alcohol binds to available hydroxyl groups of the cell walls and polymerizes into furan polymers that cause permanent partial swelling of the cell wall. That results in limited dimensional changes, which are further reduced by decreasing the number of available hydroxyl groups. Note that the exact modification mechanics is still being discussed. Wood modified by furfurylation has improved stiffness and hardness, dimensional stability and resistance to biotic decay. Its colour is darkened but fades and turns silver when exposed to outdoor weathering. The toxicity of furfurylated wood during production, service and end of life is reported to be very low, even outperforming untreated wood in ecological toxicity testing. The treatment is used commercially under trade name Kebony® [7] [25].

1.6.3 Thermal modification

Thermal modification is currently the most commercially used modification of wood [7]. The wood is exposed to temperatures usually between 180 °C and 260 °C. Hemicellulose is the least resistant to increasing temperature. Crystalline regions of cellulose degrade in temperatures between 300 and 340 °C. Amorphous regions of cellulose are less resistant. Lignin is considered the most thermally stable of the three basic wood components.
Increased temperature induces changes in wood components, resulting in reduced hygroscopicity, limited dimension changes and improved resistance to biotic degradation and weathering [26]. On the other hand, thermally treated wood displays reduction in strength, impact toughness and modulus of rupture; it is more brittle, less resistant to abrasion and has a dark colour. Although colour stability of thermally treated wood is reported to be improved, once exposed outside, its colour will fade [27], [28]. Both mass loss and volumetric shrinkage occur during thermal treatment, typically resulting in lowering of specific gravity. Better colour stability during weathering in comparison with untreated wood is reported [27] [29], but specific changes and resulting properties depend on the chosen method of thermal modification [7].

1.6.4 Surface modification

It is sometimes difficult to ensure uniform penetration of treatment agents to the bulk of material. Creating a reaction on the surface of the material covered and protected by a given chemical makes it much easier for both agent application and its removal at the end of service life. It is complicated to provide surface protection from UV radiation without concealing the wood structure because transparent coatings, even if UV-stable themselves, don't protect underlying wood from the UV radiation consequences, which – together with mechanical damage or shrinking and swelling – result in coating system failure. Surface treatments changing the wettability of the wood surface or making it hydrophobic exist. Other treatments ensure better glue bonding or improve resistance against degrading agents. Wood surface finishes tend to be oils, waxes, coatings or stains with the main purpose to prolong the service life of a given element. Despite this general purpose, particular formula, colour, application and need for maintenance differ. Durability and longevity of the treated surface depend not only on the treatment agent's properties but also on the application and wood surface and the compatibility between the agent and the wood [7] [11].

1.6.5 Hybrid modification

Both bulk and surface modifications change some of the wood properties. In some cases, it was found useful to combine the treatments and utilize two or more processes together. Mainly bulk treatments providing better dimensional stability combined with surface coating, which, consequently, isn't stressed by wood shrinking and swelling and promise prolonged service life. Such an example is coated acetylated wood or waxed thermally treated wood. On the other hand, it must be noted that some treatments aren't compatible [11].

1.7 NATURAL MATERIALS IN BUILT ENVIRONMENTS

About 55 % of people globally live in urban areas [30], and people spend over 80 % of their time indoors [31]; therefore, obviously, the built environment greatly influences human well-being and health. As mentioned in the chapter "1.3 Renewable materials in construction" (0), sustainable construction principles aim to reduce its environmental impacts. Restorative environmental design (RED) adds an anthropocentric aspect to sustainable building principles by incorporating focus on occupants' health. Restorative environment aspires to shift the paradigm from minimizing environmental impacts to restoring human connection with nature [32]. According to Kaplan [33], nature fulfils the characteristics of restorative environment such as being away, fascination, extent and compatibility. Since people don't tend to go out and seek nature, the idea is to reverse course and bring nature into the built environment [34]. Natural components such as exposed wood or stone, water features, plants and indoor gardens or nature-imitating structures can be implemented well in houses, offices and their surroundings. Updating the RED concept with ergonomic interventions led to REED, restorative environmental and ergonomic design. Furthermore, human beings' innate affinity towards nature, a tendency to relate to life and lifelike processes called biophilia, in connection with the built environment, translates into biophilic design [35], [36]. This design paradigm shifts the building sustainability from only green principles to include human well-being. It relies on the link between nature and human well-being and therefore requires consideration of environmental issues as well. Natural materials have a positive effect on human health, health care, learning, stress relief and work efficiency [36] [37] [38].
By using natural materials, natural forms and connection with nature, biophilic design can bring real sustainability into the built environment, exceeding "environmentally friendly" buildings that might currently be remarkable for their energy efficiency or cutting-edge technology but will inevitably turn obsolete. It is doubtful that current environmental measures will be enough of a reason in the future to restore such structures. Because of that, biophilic design should be combined with low environmental-impact methods. Natural materials are one of the attributes of the "environmental features" element recognized in biophilic design. Biophilic design suggests people prefer natural materials over artificial ones because of observed weathering, which also provides a sense of time [36].

1.8 CONSUMER PREFERENCES FOR WOOD

In business, consumer satisfaction is of a high importance. However, defining satisfaction is a tricky issue. Based on Giese & Cote [39] there are three general components of satisfaction: a) an emotional or cognitive response; b) a respond related to a particular focus such as a product or consumption experience; c) relevance to a particular time. The emotional aspect shows people adopt feelings toward a product of different intensity. According to Giese & Cote [39], the meaning of the focus is that it "identifies the object of a consumer's satisfaction" and typically compares its performance to some general or specific standards (not necessarily of the product itself). It is argued that satisfaction is related to the after-purchase time, and it can change over time. Having that said, satisfaction is subject to a "chameleon effect", having different meanings for different respondents. Also, different consumers show preferences towards different products [40]. Consumers' preferences are influenced by aesthetics, cost, perceived quality and material of a product.

Wood and wood products are generally perceived as "natural", "reliable", "healthy" and "environmentally friendly" and are enjoyed by users [41] [42]. Broman [43] claims wood surface should be harmonious, clean and fresh looking to attract people's interest. He also reports that questions about overall look of the wood are more relatable to respondents than questions about specific features. "Vividness", "evenness" and "contrast" were among verbal descriptors of wood found useful by Manuel et al. [44].

In the last decades, there has been growing need to determine durability and service life of materials, components, installations, structures and buildings due to environmental and economic issues [45]. The understanding of wood labelling starts influencing the decision patterns of consumers. There is a share of consumers who prefer tropical wood products and are willing to pay extra for it if it is eco-labelled. However, if a product is not certified, a bigger share of consumers (coming from temperate zones) prefers wood originating in temperate zones, showing concern about sustainability issues concerning tropical wood harvesting and its transport [46]. Perhaps thermally treated wood or other wood modifications employing locally certified wood and environmentally-cautious approaches that result in wood with properties comparable to tropical species can solve this issue. Environmental labelling doesn't seem to overweight other aspects of a wood product when being chosen but can contribute to the decision [47] [48], and consumers seem to be willing to pay about 5% more for an eco-labelled product [49]. Added to that, research of Cai and Aguilar [50] shows consumers value domestic origin of manufactured wood products and, if possible, prefer manufacturers with higher corporate social responsibility ratings. Nonetheless, aesthetics seems to be playing the main role in consumers' choice of wooden products (although that might differ for different regions and different purposes) [51] [52] [53] including wood façades, in preference of which aesthetics was found to play a bigger role than service life, price and maintenance interval [54]. With wood exposed to the outer environment, its appearance changes, which in turn changes consumers' opinion about it.

1.9 PERCEPTIONS OF WOOD IN THE BUILT ENVIRONMENT

In consumers' relationship to wood, vision and touch play an important role. Evidence exists that there is a relationship between perceptual and affective properties of wood [55]. According to the research, utilizing haptic assessment of wood while preventing visual assessment of natural finishes is connected with positive emotional ratings, such as "comfortable" or "pleasurable", as opposed to coated surfaces that induce assessments of "irritation" and "discomfort". There doesn't seem to be significant difference in emotional touch perception between softwoods and hardwoods, specifically pine and oak [56]. On the other hand, Bumgardner and Bowe [57] argue there is a difference in psychological effect of a wood product based on wood species used, seeing darker wood as expensive and formal and lighter wood as inexpensive, casual and modest. Interestingly, they also report a difference between how a wood species is thought of and the real reactions on a correspondent wood sample, which shows major importance of how a wood species or a wood treatment is presented, marketed and perceived.

It was reported that modified wood was preferred over untreated wood and can be preferred over other materials in indoor use where both visual and tactile perception are utilized [58]. According to the results of Nyrud and Høibø [59], Norwegian consumers preferred aged materials over fresh ones for wooden decking. All exposed specimens of the four materials (pine pressure treated with organic biocides, pine pressure treated with copper and boron, furfurylated pine and untreated larch) achieved higher mean preference rating than unweathered specimens. Interestingly, the mean rating for fresh materials was below neutral (average 4.33 out of 9 points on a Likert scale for all materials) while mean rating for decking exposed to weather was above neutral ranking (5.20/9).

1.10 FUTURE TRENDS IN FAÇADE MATERIAL SELECTION

A significant part of overall maintenance cost of a building is spent on a façade [60]. Wooden façade structures get exchanged due to their aesthetics and subjective perception rather than due to their functional state [61], so pairing up their aesthetic and functional performance might help to avoid extra costs for early replacement. Due to efforts of researchers within the project BIO4ever, a prototype software tool is being developed that will help to model and predict aesthetic service life of exposed wood elements, namely façades. In BIO4ever, an extensive amount (120) of differently treated samples was observed and measured prior, during and after degradation caused by weathering. Coupled with weather measurements from the ASHRAE 2013 database, the goal was to predict changes in bio-based façade materials' aesthetics as a function of time and exposure as well as provide life cycle assessment calculation with special emphasis on the service life phase, making a useful tool for architects, investors, builders and other stakeholders [62]. The choice, maintenance and

replacement of material can only be planned reasonably if technical parameters (based on comprehensive data about material properties) and human factors (acceptability of the appearance) are involved [63]. The work of BIO4ever is continued with a project called CLICKdesign where different models (decay, moisture, insects, aesthetics) are combined into a software tool.
This leads to the question: does seeing fresh and weathered material change people's opinion about façade materials?

2 OBJECTIVES

The purpose of the research was to assess people's perception about wood, namely the difference between assessment of fresh and weathered wood materials intended for use as a façade. Associated goal was to identify if any of the recorded demographic parameters (age, gender, living environment), measured parameters of the materials (colour, roughness, gloss and their change) or additional information about materials (cost, lifespan, needed maintenance) influenced the assessment.

3 HYPOTHESES

Based on the objectives, three hypotheses were formed to address the difference between new and weathered material assessment, evaluating influence of aesthetics of the weathered material on overall material assessment and assess the influence of demographic parameters on overall material rating.
H1: Consumer preferences for weathered and unweathered wooden façade materials of the same type will differ.
$H1_0$: There is no difference between consumer preferences for weathered and unweathered wooden façade materials of the same type.
H2: Knowing the weathered appearance of a material will change consumers preference for material selection.
$H2_0$: Knowing the weathered appearance of a material will not change consumers preference for material selection.
H3: Consumer preferences for weathered and unweathered wooden façade materials do not differ based on their age, gender or living environment.
$H3_0$: There is a difference between consumer preferences of weathered or unweathered wooden façade materials based on age, gender or living environment.

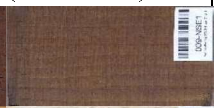
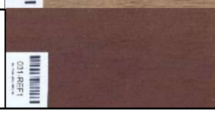
4 MATERIALS AND METHODS

For the purposes of this research, samples of treated and untreated wood were selected in unweathered and weathered state. Their colour, roughness and gloss were measured. To gather data to address the issue, a survey was conducted where potential consumers rated treated and untreated wood samples in unweathered and weathered states.

4.1 MATERIALS

Six pairs of unweathered and weathered materials were chosen: three of them were softwoods (pine, *Pinus radiata*) and three were hardwoods (oak, *Quercus sp.*). A variety of treatments was represented, including no treatment, thermal modification, thermal modification in vacuum, furfurylation and acetylation. Similarly, the samples represented a range from little visual change due to weathering to substantial visual change due to weathering. The naturally weathered samples were exposed to outdoor conditions for 15 months at south exposure on the rooftop of a building in San Michele all’Adige, Italy (46°12′N 11°8′E, 210 meters above sea level, warm and temperate climate with above-average precipitation [64]). All samples were randomly assigned letters from A to L to enable their identification by respondents without revealing anything specific about them.

Table 1: Overview of wood materials

wood species	treatment	fresh	weathered (15 months)
pine	thermal modification + treatment with water borne penetrating oil		
oak	thermal modification in vacuum + wax		
oak	no treatment		
pine	acetylation + coating		
oak	thermal modification in vacuum		
pine	furfurylation		

Materials were obtained in collaboration with the ARCHI-BIO project BI/US-20-054, ARRS: Perception and performance assessment in bio-based architecture.

The visual reference presented in this paper was obtained by scanning with a HP Scanjet 2710 (300 dpi, 24 bit).
Expressions “fresh” or “new” throughout the paper mean “unweathered” samples.

4.2 METHODS

4.2.1 Roughness

Roughness was measured using LEICA DCM8 paired with LEICA Map Premium software. Considering the complexity of the roughness of wood, R_a (arithmetic average deviation from a mean line) was selected as a measure as in other previous research [19] [20]. The R_a reported for each specimen is the mean of three roughness measurements taken on different locations on the face of the specimen.

4.2.2 Gloss

Five random spots on the sample surface gloss were measured parallel to fibre direction with an REFO 60 glossmeter (2007, Dr. Lange, Düsseldorf, Germany) with incidence angle of 60° as adequate for materials with low gloss. The mean value for each specimen is reported.

4.2.3 Colour

Ten random spots on the sample surface were measured with a colorimeter, obtaining data in CIELAB colours L*a*b* form. The DataColor approach is considered as an industrial standard when controlling quality or characterizing colour of surface.
The instrument was calibrated with white and dark references and measurement conditions and colour computation variables were set. After positioning the probe over the measured surface, the measurement was executed. The light source used for computation of the CIELAB colour coordinates was D65, the viewing angle was 10°. The mean of the ten measurements of each sample was used to calculate colour values and difference between weathered states, using the formula below with L_1, a_1, b_1 and L_2, a_2 and b_2 representing three colour dimensions of two different colours in CIELAB colour space.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

Formula 2: Colour difference formula in CIELAB colour space [65]

4.2.4 Survey

The purpose of the research was to assess people's perception about wood. For that, a questionnaire was created and presented to respondents individually since previous research suggests questionnaires can be used for assessment of people's perceptions towards aesthetical properties of wood [43].

4.2.4.1 Questionnaire

A questionnaire was developed in English then translated to Slovene and Czech (see Appendix A: Qestionnaire). Respondents were free to choose the version that suited them most. The first page provided general information about the survey, data protection and instructions, and it served as the informed consent agreement. Those respondents that agreed to continue were presented with the set of fresh specimens and asked to specify what they would use the material for from the following choices: Construction (mechanical support), Furniture (visible material), Façade (external building envelope, including partial covering), Indoor flooring, Outdoor flooring (terrace), Fences, Doors, Windows/window frames, Shutters, Other use or Nothing/no use, out of which one or multiple answers were to be chosen. After that, it was explained that the materials are meant for façade. Questions two, three, four and six were all asking respondents to assess the likelihood of use of each material as their own house façade based on an adapted 7-point Likert scale ranging from extremely unlikely (1) to extremely likely (7) – see Figure 1; but each of those questions differed. Questions two and three asked "How likely would you be to use each of the presented materials for a façade of your home?" for separately presented fresh and weathered samples, respectively. Question four asked "Knowing how the wood looks when new and after it has been weathered for 15 months, how likely would you be to use each of the presented materials for a façade of your home?" while pairs of both fresh and weathered samples of all materials were presented. Question number 4 was "How would you rank the materials based on how likely you would use them for a façade of your home?" with both weathered and fresh sample present. Question 6 was mimicking question 4, but additional information about cost, necessary maintenance and lifespan was added (Table 2).

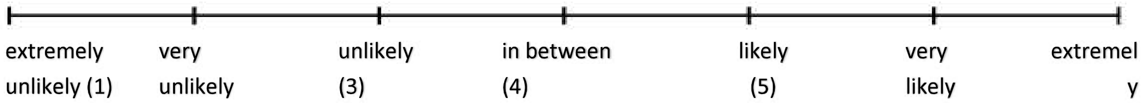


Figure 1: Likert scale used in the questionnaire

Table 2: Information provided for material assessment in question 6

materials	material cost per house* (EUR)	lifespan	maintenance
thermally modified pine	12.000	30 years	none
thermally m. oak + vacuum + wax	7.200	30 years	none
untreated oak	4.200	30 years	none
acetylated pine + coating	12.000	50 years	repainting every 6 years
thermally modified oak + vacuum	6.000	30 years	none
furfurylated pine	14.400	30 years	none

* a house with 120 m^2 of wooden façade is considered

Finally, demographic data were collected by asking about respondents' age range, gender, living environment and occupation (questions 7-10):

7. Please state your age:
a) 18-25
b) 26-37
c) 38-50
d) 51-64
e) 65+

8. Please state your gender:

9. Please characterize your living environment:
a) urban
b) suburban
c) rural

10. Please state your occupation:
a) student: ……………… (field of study)
b) working
non-working

As recommended by Brace [66], the questionnaire was planned to take less than 30 minutes to avoid respondent fatigue.

4.2.4.2 Delivery

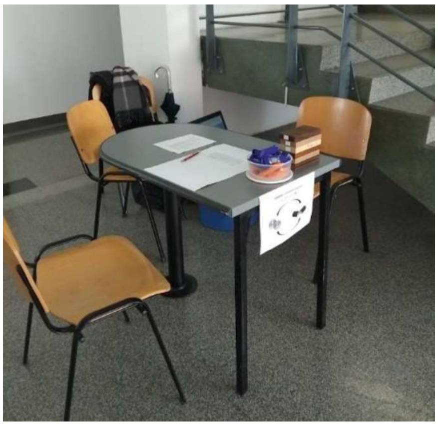


Figure 2: Research setup

The survey was completed individually. Respondents were given papers with the survey questions in the language they chose. Their answers were given orally with the researcher typing them in. The setup involved a table on which questionnaire papers and samples were laid with two chairs on the opposite sides for the respondent and the researcher. Chocolates were offered as a respondents' reward and people were invited for participation by personal invitation, over social media and by signs placed around the building.

4.2.4.3 Sampling

The research was conducted in Slovenia and the Czech Republic with a sum of 74 participants using convenience sampling. The research was located on the grounds of the Faculty of Mathematics, Natural Sciences and Information Technologies of the University of Primorska due the amount of people within the building and walking by. However, because of the COVID-19 restrictions it was prohibited to carry out with that setting. Therefore, people were contacted and questioned individually. In the Czech Republic, a place well visited by the community was chosen. The research was conducted in Slovenia in March and June 2020 and in the Czech Republic in May 2020. The respondents were informed about the purpose of the research, use of provided data and protection of their personal information. Each respondent confirmed their content with data use and their protection with a signature while they were informed about a possibility to leave in any given moment.

4.2.5 Data analysis

The collected data include demographic data, ratings on Likert-like scales, which are converted to numerical values, and rankings. The rating data are ordinal; variables with ordered categorical scales. They can be ordered but distances between categories are not necessarily defined [67]. The values only help with orientation on the scale but the distances between each of them are not the same in a mathematical sense. This type of data should generally not be analysed using statistical tests that rely on assumptions of equal variance and normality. Therefore, for hypotheses 1 and 2 the Wilcoxon signed rank test, which returns a point estimate for the difference in parameters along with non-parametric 95 % confidence intervals, was used to paired responses between questions. For hypothesis 1, assessments of fresh samples obtained in question two and assessments of weathered samples obtained in question three were compared. For hypothesis 2, rating of fresh samples from question 2 and rating of coupled samples from question 4 were used. For hypothesis 3, ordinal regression was fit using proportional log odds regression in R (version 4.0.2) [68] using the MASS package (version 7.3-51.6) [69]. Ordinal regression returns the log odds of the coefficients in the model, which can then be used to predict the probability that a new respondent would select each item on the Likert scale used in the questionnaire. Two models were fit, one with demographic data and one without. No demographic data was found to be significant and there was no significant difference in the variability explained between the models. Accordingly, the simpler model without demographic data was used. In the

exploratory analysis, another ordinal regression model was fit to determine the impact of the difference material properties (roughness change, colour change, gloss change) between unweathered and weathered states.
For all tests, the threshold for statistical significance was set at $\alpha < 0.05$. P-values for the Wilcoxon signed rank tests were adjusted for multiple comparisons using the False Discovery Rate method of Benjamini & Hochberg [70]. All Wilcoxon signed rank tests were paired two-sided tests.

5 RESULTS

5.1 MATERIAL PROPERTIES

The roughness, colour and gloss of samples were measured. R_a, the roughness indicator, was lowest in the acetylated pine with coating, reaching a value 1.28 (±0.48) µm for fresh specimen and 1.43 (±0.27) µm for weathered specimen, being also the material which roughness changed the least during the exposure. With respect to the standard deviation, fresh specimens of thermally modified pine, waxed oak thermally modified in vacuum and untreated oak were rougher than coated acetylated pine, oak thermally modified in vacuum and furfurylated pine.
Lightness (L*) of fresh materials ranged between 30 and 36 for pine samples and 55 to 68 for oak samples, meaning all modified fresh pine samples were darker than oak samples. All materials got lighter during the weathering except for acetylated and coated pine, which lightness remained the same. Despite the treatment, the lightness of all oak materials after the 15 months of outside exposure was almost the same, ranging between 73 and 77. On the green-red scale (a*), data of all specimens were within the positive (red) values with the acetylated and coated pine having the highest values. The redness of weathered samples was lower for some materials and higher for others, but all the materials remained in the red part of the spectrum. All the materials were well in the positive (yellow) part of the blue-yellow scale (b*), with values ranging between 9 and 31.

Table 3: Mean roughness measurements of parameter R_a of samples

roughness parameter R_a		
material	fresh specimen (µm)	weathered specimen (µm)
thermally modified pine	7.82 (±4.10)	10.25 (±3.36)
thermally mod. oak + vacuum + wax	5.09 (±2.85)	16.57 (±9.45)
untreated oak	5.88 (±1.38)	32.99 (±23.13)
acetylated pine + coating	1.28 (±0.48)	1.43 (±0.27)
thermally modified oak + vacuum	2.84 (±0.99)	36.43 (±2.29)
furfurylated pine	3.12 (±0.56)	16.71 (±3.52)

Table 4: Mean colour and gloss measurements of fresh samples

	fresh specimens			
colour	L*	a*	b*	gloss
thermally modified pine	30.20 (±0.78)	8.55 (±0.42)	9.40 (±0.60)	1.40 (±0.24)
therm. mod. oak + vacuum, wax	58.20 (±0.68)	8.38 (±0.17)	30.68 (±0.45)	1.92 (±0.12)
untreated oak	68.48 (±0.43)	6.91 (±0.11)	20.41 (±0.28)	2.52 (±0.12)
acetylated pine + coating	36.19 (±0.79)	11.81 (±1.02)	16.66 (±1.32)	31.76 (±0.45)
thermally mod. oak + vacuum	54.93 (±0.51)	6.01 (±0.21)	17.13 (±0.30)	4.22 (±0.19)
furfurylated pine	32.64 (±0.28)	8.82 (±0.19)	9.44 (±0.41)	5.30 (±0.40)

Table 5: Mean colour and gloss measurements of weathered samples

	weathered specimens			
colour	L*	a*	b*	gloss
thermally modified pine	37.03 (±0.35)	8.99 (±0.15)	14.97 (±0.29)	1.40 (±0.09)
therm. mod. oak + vacuum, wax	76.80 (±0.86)	3.86 (±0.41)	16.86 (±0.56)	2.92 (±0.13)
untreated oak	75.01 (±1.86)	5.60 (±0.90)	17.85 (±2.16)	5.16 (±0.35)
acetylated pine + coating	36.19 (±0.35)	12.49 (±0.46)	15.63 (±0.66)	24.96 (±0.50)
thermally mod. oak + vacuum	73.09 (±0.59)	5.02 (±0.23)	15.02 (±0.58)	5.04 (±0.14)
furfurylated pine	48.43 (±1.07)	8.18 (±1.32)	17.69 (±2.03)	4.10 (±0.33)

Interestingly, after weathering the yellowness of samples was very much levelled with all materials ranging between 15 and 18. The gloss of all fresh materials was similar except for acetylated and coated pine gloss, which was substantially higher than the gloss of the other specimens in both fresh and weathered state (Table 4 and Table 5).

Table 6: Differences in colour, gloss and roughness of materials from fresh to weathered state

materials	colour difference ΔE	gloss difference	roughness difference (μm)
thermally modified pine	8.84	0.00	2.43
thermally modified oak + vacuum + wax	23.61	-1.00	11.48
untreated oak	7.33	-2.64	27.11
acetylated pine + coating	1.94	6.80	0.15
thermally modified oak + vacuum	18.33	-0.82	33.59
furfurylated pine	18.04	1.20	13.60

Although slightly, gloss of all oak specimens increased from fresh to weathered samples and gloss of all pine specimens decreased. Overall change of colour was minimal in acetylated and coated pine material (1.94) and low for untreated oak and thermally treated pine samples; change of colour of oak thermally treated in vacuum and furfurylated pine was somewhat lower than the change in colour of oak thermally treated in vacuum and waxed, which was the highest with ΔE equal to 23.61 (Table 6).

Based on overall colour change assessment criteria of Barcík et al. [71], the colour change of acetylated coated pine can be considered small ($\Delta E < 2$), the colour change of thermally modified pine and untreated oak high ($6 < \Delta E < 12$) and colour change of both thermally treated oaks and furfurylated pine is considered as two different colours altogether ($\Delta E > 12$).

Notably, the gloss of all oak materials receded during weathering while it increased or did not change in all pine materials. The acetylated material has the smallest colour change while its gloss changed the most.

R_a changed the most during weathering of the samples of untreated oak and oak thermally modified in vacuum (Table 3). It must be noted, however, that the roughness of weathered untreated oak sample has high level of variability. The roughness of coated acetylated pine and thermally modified pine didn't noticeably change.

5.2 SURVEY

5.2.1 Observed results

There were 74 completed questionnaires in both Slovenia and the Czech Republic, with 40 and 34 respondents respective to each country; 44 of those identified as male, 29 as female, 1 as a non-binary gender; 30 respondents characterized their living environment as suburban while urban and rural living environments were listed 22 times each. Among participants were 29 students, 44 workers and 1 non-working person (Table 7).

Table 7: Demographic results

age					gender	
18-25	26-37	38-50	51-64	65+	M	F
32	19	16	7	0	44	29

living environment			employment status		
urban	suburban	rural	student	working	non-working
22	30	22	29	44	1

Given various options about what respondents thought was the purpose of the material presented, the main suggested purpose was furniture, indoor flooring and doors and windows (Table 8). Only two respondents thought collected materials as a set were of no use while 21 participants considered them for a façade use.

Table 8: Suggested use of presented materials

purpose	frequency
Furniture (visible material)	65
Doors	48
Indoor flooring	47
Windows/window frames	46
Fences	36
Outdoor flooring (terrace)	30
Shutters	28
Façade (external building envelope, including partial covering)	21
Construction (mechanical support)	15
Other*: …………………	8
Nothing/no use	2

*Purposes listed as "Other": musical instruments, indoor art, mobile phone covers, picture and mirror frames, dishes, stacks for vineyards.

Table 9: Mean ratings on Likert scale for fresh and weathered sample and both samples

materials	fresh sample	weathered sample	both samples
thermally modified pine	3.93 (±1.86)	3.99 (±1.70)	4.61 (±1.58)
thermally modified oak + vacuum, wax	4.30 (±1.56)	3.43 (±1.53)	3.03 (±1.38)
untreated oak	3.73 (±1.61)	3.22 (±1.44)	3.15 (±1.51)
acetylated pine + coating	3.14 (±1.93)	3.88 (±2.07)	4.28 (±2.02)
thermally modified oak + vacuum	4.51 (±1.46)	3.82 (±1.46)	3.70 (±1.48)
furfurylated pine	4.22 (±1.69)	3.96 (±1.67)	3.50 (±1.57)

When presented with fresh samples only, oak thermally modified in vacuum achieved highest average rating of 4.51 (±1.46) on 7-point Likert scale. The least favoured was the coated acetylated pine scoring 3.14 (±1.93). However, the scoring of materials changed rapidly when the respondents were assessing weathered specimens. None of the average assessments was higher than 4 – expressing neutral relationship – meaning all materials were on average unlikely to be used. Thermally modified pine and furfurylated pine were the ones obtaining the highest values while untreated oak was liked the least. The shift in assessment between fresh and weathered samples can be observed in Figure 4. The shift of assessments between fresh samples and both samples can be observed in Figure 3, showing the same direction, meaning that when weathered material was liked less than original material, the rating of both samples together was even lower, and vice versa. Interestingly, assessment of coated acetylated pine improved considerably while both thermally treated oak materials received much lower rating. When both samples of a material were presented, the highest average rating, 4.61 (±1.58), was achieved by thermally modified pine. Together with coated acetylated pine, rated on average 4.28 (±2.02), these two were the only materials assessed between neutral and likely evaluation, while the other four materials were averaged between neutral and unlikely. The lowest mean overall assessment (3.03 (±1.38)) was awarded to oak thermally modified in vacuum and waxed (Table 9).

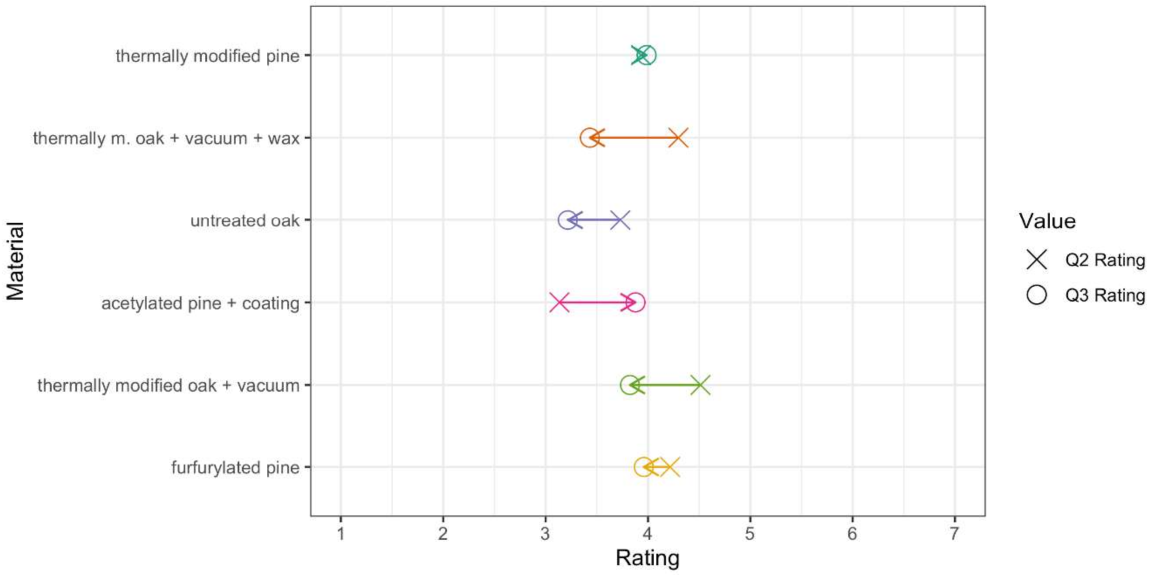


Figure 3: Average ratings of fresh (question 2) and weathered samples (question 3) with arrow pointing towards the rating of the weathered sample

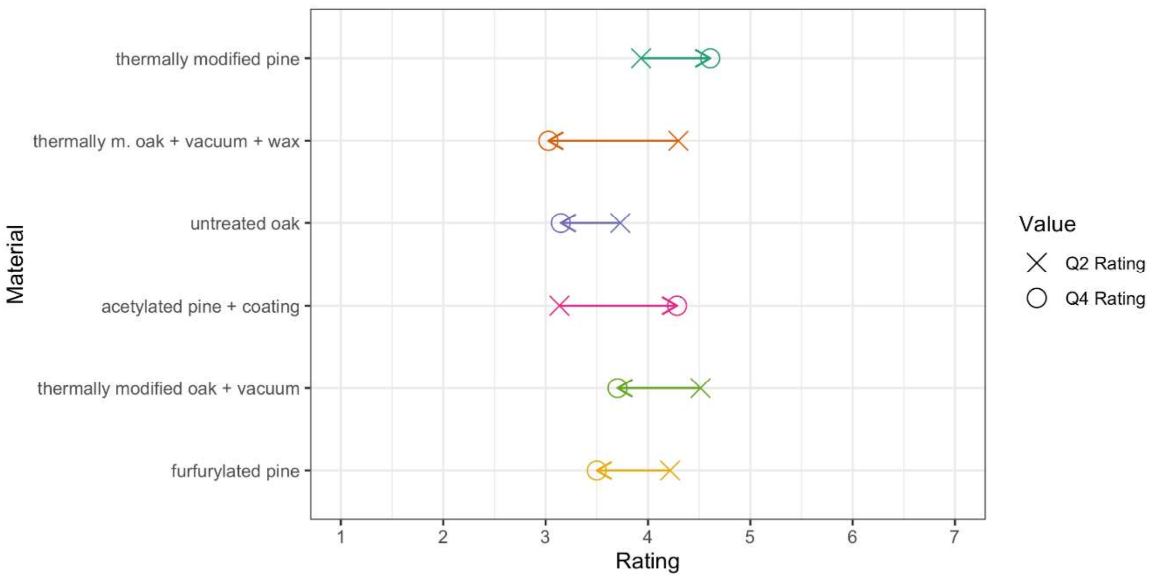


Figure 4: Average ratings of fresh sample (question 2) and both samples (question 4) with arrow pointing towards the rating of both samples

High standard deviations (CoV between 0.32 and 0.65) for all assessed values show that respondents' opinions on the materials varied. The highest variation of dispersion of values was for the coated acetylated pine, which seemed to trigger either positive or negative reaction.

Table 10: Mean and consequent ranking of materials

materials	average rank	consequent rank
thermally modified pine	2.78 (±1.73)	1
thermally modified oak + vacuum + wax	4.03 (±1.30)	5
untreated oak	4.11 (±1.51)	6
acetylated pine + coating	3.24 (±2.11)	3
thermally modified oak + vacuum	3.19 (±1.36)	2
furfurylated pine	3.66 (±1.65)	4

In the ranking task, the best ranking material was the thermally modified pine with average rank 2.78 (±1.73). The second-best scoring material was the oak thermally modified in vacuum with 3.19 (±1.36), followed by acetylated coated pine with 3.24 (±2.11). As in other questions, the standard deviation of acetylated pine was the highest, meaning highest dispersion of answers. The furfurylated pine placed fourth with average rank of 3.66 (±1.65), rank of waxed oak thermally modified in vacuum was 4.03 (±1.30) and the last in ranking was untreated oak with a rating of 4.11 (±1.51).

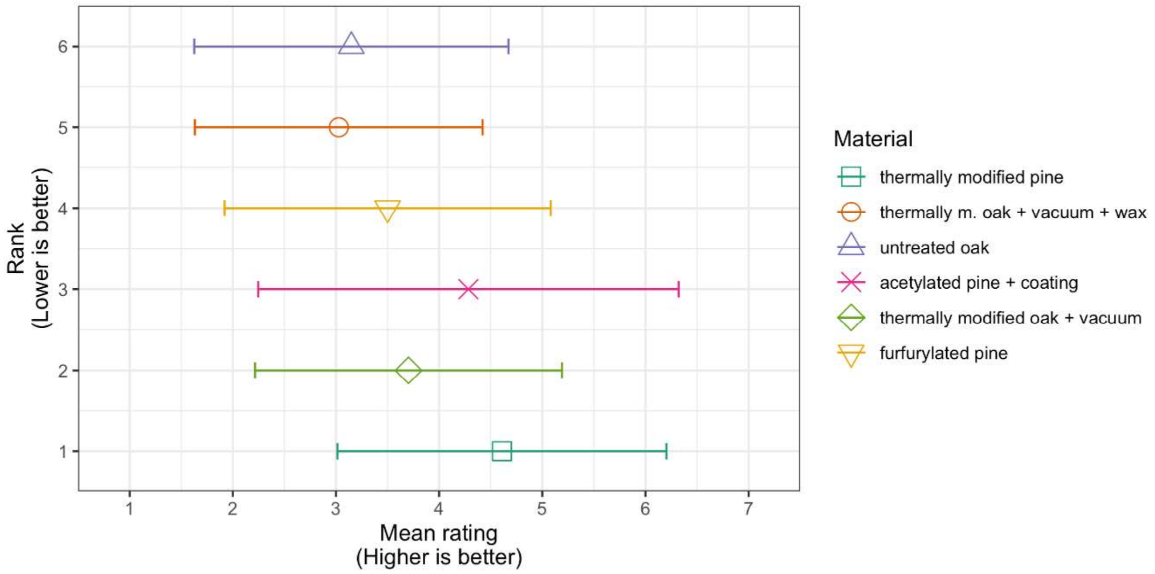


Figure 5: Ranking of materials (question 5) compared with rating of materials (question 4)

High standard deviations and, in this case, consequently, high coefficients of variation suggest peoples' opinions were not unified. That is also suggested by comparison of results of the ranking with results of the previous task, the assessment of both samples of all materials based on a Likert scale (Figure 5). It was observed that the rankings and rating for materials were negatively correlated, as expected (Kendall's tau: -0.53, $p < 0.001$). However, two materials didn't follow this trend. Thermally modified oak was ranked second but obtained third highest rating. Conversely, acetylated pine was ranked third but was the second highest rated material. Apparently, respondents' observations were so variable that their opinions manifested differently in two different tasks.

Table 11: Material information provided in the questionnaire

materials	material cost per house* (EUR)	lifespan	maintenance	assessment
thermally modified pine	12.000	30 years	none	4.12 (±1.73)
thermally m. oak + vacuum + wax	7.200	30 years	none	4.05 (±1.50)
untreated oak	4.200	30 years	none	4.09 (±1.71)
acetylated pine + coating	12.000	50 years	repainting every 6 years	3.41 (±2.03)
thermally modified oak + vacuum	6.000	30 years	none	4.47 (±1.41)
furfurylated pine	14.400	30 years	none	3.15 (±1.62)

* a house with 120 m^2 of wooden façade is considered

The most favoured material after informed assessment was oak thermally modified in vacuum scoring 4.47 (±1.41). Thermally modified pine, oak thermally modified in vacuum and waxed and untreated oak ended up with similar mean rating close to neutral, but slightly positive, assessment. Average assessment of acetylated pine was second lowest and, again, the opinions about this material were the most diverse. The least likely material to be used as a façade of a family house was furfurylated pine. The shift between uninformed and informed assessment of materials can be observed in Figure 6. Apparently, the three more

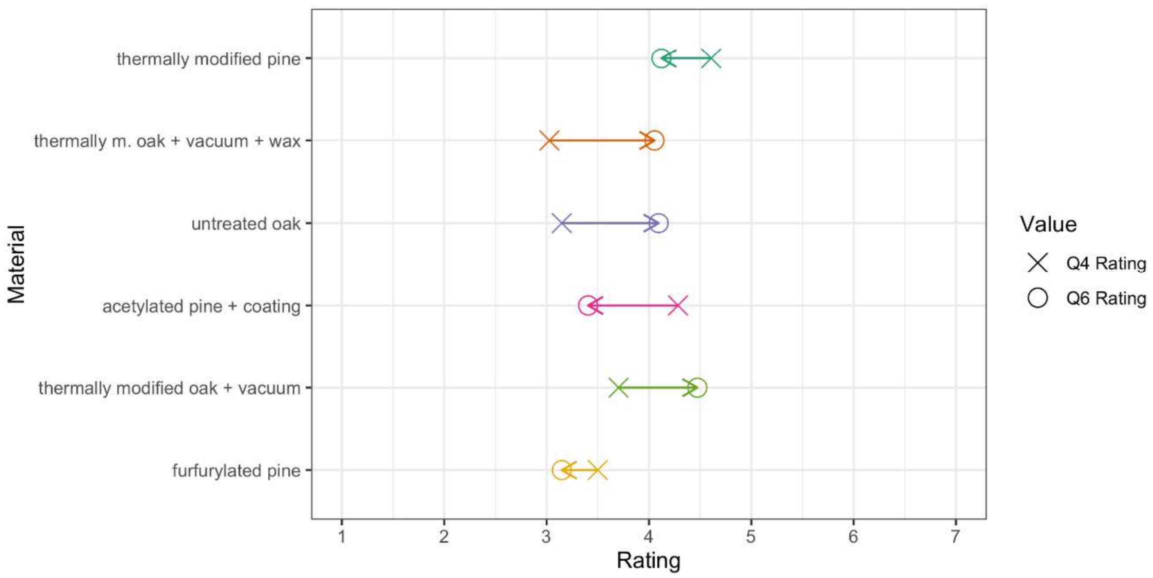


Figure 6: Average shift in responses from uninformed (question 4) to informed (question 6) assessment of materials

expensive materials, incidentally pine, experienced a drop in likeliness while rating of the three less pricey materials substantially increased. Since the price of thermally modified pine and acetylated pine were the same, and the price of furfurylated pine even higher, the biggest negative shift of assessment of acetylated pine can be explained by necessary maintenance, despite its longer expected lifespan.

5.2.2 Analytical results

In addition to the observed data, several hypotheses were tested, and an exploratory analysis was performed on data outside the scope of the planned hypothesis testing.

5.2.2.1 Hypothesis testing

H1: Consumer preferences for weathered and unweathered wooden façade materials of the same type will differ.

$H1_0$: There is no difference between consumer preferences for weathered and unweathered wooden façade materials of the same type.

To assess this hypothesis, results of assessment of separate fresh materials (survey question 2) and separate weathered materials (survey question 3) were used in Wilcoxon signed rank test. The results suggest that there wasn't a statistically significant difference in the ratings of fresh and weathered sample of thermally modified pine and furfurylated pine. Estimated change of assessment for these two materials was 0 and decrease by 0.5, respectively. Both thermally modified oak materials and acetylated pine show significant change in assessment, but rating of both oaks decreased between fresh and weathered sample while rating of acetylated pine increased. Assessment of the two samples of both untreated oak materials was significantly different but estimated shift was only -0.5, same as for furfurylated pine (Table 12).

Table 12: Results of Wilcoxon signed rank test between rating of fresh sample (question 2) and weathered sample (question 3)

materials	estimate	statistic	adj. p-value	95% conf. interval
thermally modified pine	0.000	739.500	0.640	-0.500 to 1.000
thermally modified oak + vacuum + wax	-1.500	279.000	0.000***	-1.500 to -0.500
untreated oak	-0.500	546.000	0.036*	-1.500 to 0.000
acetylated pine + coating	1.500	668.000	0.000***	1.000 to 2.000
thermally modified oak + vacuum	-1.000	386.500	0.004**	-2.000 to -1.000
furfurylated pine	-0.500	606.500	0.197	-1.000 to 0.000

significance indicators:
* p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

Therefore, hypothesis 1 was rejected for thermally modified pine and furfurylated pine while it wasn't rejected for the rest of the tested materials.

H2: Knowing the weathered appearance of a material will change consumers preference for material selection.

$H2_0$: Knowing the weathered appearance of a material will not change consumers preference for material selection.

To address hypothesis 2, Wilcoxon signed rank test was performed with data of assessment of fresh samples (question 2) and assessment of both samples (question 4). The adjusted p-value was less than 0.05 for all materials, meaning there was significant difference between fresh sample and both samples assessments (Table 13). Estimated shift in assessment of thermally modified pine and acetylated pine is positive, which indicates that the appearance of the weathered sample or appearance of both samples together among the other materials made respondents increase their rating. The highest estimated negative shifts were for both thermally treated oak materials.

Table 13: Results of Wilcoxon signed rank test between rating of fresh sample (question 2) and both samples (question 4)

materials	estimate	statistic	adj. p-value	95% conf. interval
thermally modified pine	1.000	1193.500	0.005**	0.500 to 1.500
thermally m. oak + vacuum + wax	-1.500	319.000	0.000***	-2.000 to -1.000
untreated oak	-0.500	502.000	0.015*	-1.500 to 0.000
acetylated pine + coating	2.000	984.500	0.000***	1.000 to 2.500
thermally modified oak + vacuum	-1.500	315.000	0.000***	-2.000 to -1.000
furfurylated pine	-1.000	516.500	0.006**	-1.500 to 0.000

significance indicators: * p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

H3: Consumer preferences for weathered and unweathered wooden façade materials differ based on their age, gender or living environment.

$H3_0$: There isn't a difference between consumer preferences of weathered or unweathered wooden façade materials based on age, gender or living environment.

Two models were fit based on ratings of both samples (question 4). First, the dependent variable (sample ratings) were regressed against material type, gender, age group and region. No significant influence of age group, gender or living environment was observed, so the second model was fit against only the material type. The models were compared using ANOVA. The residual deviance difference was not significant (Likelihood ratio test, p = 0.57), so the simple model was used.

Table 14: Ordinal regression summary output of material ratings when viewing both fresh and weathered samples (question 4). Values are proportional log odds. Named rows are material coefficients; rows with number pairs are intercepts between the ratings

coefficient	value	std. error	t-value	p-value
thermally modified pine	0.300	0.305	0.983	0.326
thermally modified oak + vacuum + wax	-1.368	0.308	-4.447	0.000***
untreated oak	-1.264	0.309	-4.085	0.000***
thermally modified oak + vacuum	-0.647	0.303	-2.133	0.033*
furfurylated pine	-0.891	0.307	-2.903	0.004**
1|2	-2.953	0.274	-10.790	0.000***
2|3	-1.777	0.247	-7.195	0.000***
3|4	-0.732	0.237	-3.091	0.002**
4|5	0.080	0.234	0.341	0.733
5|6	0.983	0.240	4.102	0.000***
6|7	2.212	0.278	7.950	0.000***

significance indicators: * p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

According to the model based on acetylated and coated pine, its rating in question 4 wasn't significantly different from thermally modified pine and somewhat significantly different from oak thermally modified in vacuum (Table 14). The utilized model indicates that highest probability of choosing a given rating by next random person is to have ratings 5-6 for thermally modified pine and 4-5 for acetylated pine. Those are the only two materials that most probable rating is above average assessment. Most likely rating for waxed oak thermally modified in vacuum and also for untreated oak is between 2 and 3, for oak thermally modified in vacuum and furfurylated pine is 3-4 (Table 15).

Table 15: Values are the probability of new respondent to select a given rating for one of the materials based of materials based on the ordinal regression model of ratings of both samples (question 4)

rating on Likert scale	Extremely Unlikely	Very Unlikely	Unlikely	In between	Likely	Very likely	Extremely likely
thermally modified pine	0.04	0.07	0.15	0.18	0.22	0.21	0.13
thermally modified oak + vacuum + wax	0.17	0.23	0.26	0.16	0.10	0.06	0.03
untreated oak	0.16	0.22	0.26	0.16	0.11	0.07	0.03
acetylated pine + coating	0.05	0.10	0.18	0.20	0.21	0.17	0.10
thermally modified oak + vacuum	0.09	0.15	0.24	0.20	0.16	0.11	0.05
furfurylated pine	0.11	0.18	0.25	0.19	0.14	0.09	0.04

5.2.2.2 Exploratory analysis

In the exploratory analysis, some additional analyses not covered in hypotheses testing were done.

Based on Wilcoxon signed rank test, assessments of weathered samples (question 3) and of both samples (question 4) were significantly different in case of thermally modified pine with adjusted p-value > 0.001, still significantly different for furfurylated pine, waxed oak thermally modified in vacuum and acetylated pine. No significant difference was found between assessment of weathered sample and both samples of untreated oak and oak thermally modified in vacuum (Table 16).

Table 16: Results of Wilcoxon signed rank test between rating of weathered samples (question 3) and rating of both samples (question 4)

materials	estimate	statistic	adj. p-value	95% conf. interval
thermally modified pine	1.000	847.000	0.000***	1.000 to 1.500
thermally m. oak + vacuum + wax	-1.000	344.500	0.010**	-1.000 to 0.000
untreated oak	0.000	480.000	0.492	-0.500 to 0.000
acetylated pine + coating	1.000	394.500	0.012*	0.000 to 1.500
thermally modified oak + vacuum	0.000	450.000	0.781	-1.000 to 0.500
furfurylated pine	-1.000	287.000	0.004**	-1.500 to 0.000

significance indicators: * p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

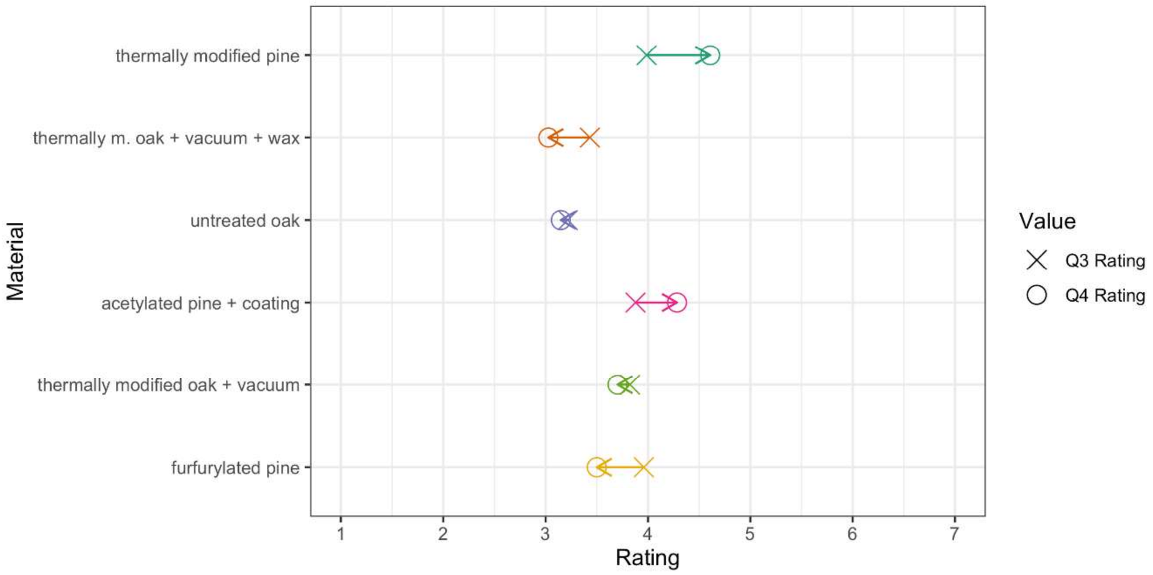


Figure 7: Average shift in responses from weathered sample (question 3) to assessment of both samples (question 4)

As apparent from Figure 7, the biggest shift between weathered assessment and assessment of both samples was for thermally modified pine. Together with acetylated pine, those two shifts in rating were positive. Average shifts of assessment of waxed oak thermally modified in vacuum and furfurylated pine were negative while for untreated oak and oak thermally modified in vacuum the assessments did not change significantly.

To evaluate the joint impact of additional information about cost, maintenance and lifespan, Wilcoxon signed rank test between uninformed rating of both samples (question 4) and informed rating of both samples (question 6) was performed. The adjusted p-value was less than 0.001 for all oak materials and for acetylated pine, which means there is a significant difference between their uninformed and informed ratings. For thermally modified pine, adjusted p-value was 0.029, meaning its uninformed and informed assessment was significantly different but less so than the previously mentioned materials. The adjusted p-value of furfurylated pine suggests no significant difference in medians of ratings based on provided information about materials was found (Table 17).

Table 17: Results of Wilcoxon signed rank test between uninformed rating of both samples (question 4) and informed rating of both samples (question 6)

materials	estimate	statistic	adj. p-value	95% conf. interval
thermally modified pine	-1.000	446.000	0.029*	-1.000 to 0.000
thermally modified oak + vacuum, wax	1.500	1191.000	0.000***	1.000 to 2.000
untreated oak	1.500	1093.000	0.000***	1.000 to 2.000
acetylated pine + coating	-1.500	157.000	0.000***	-2.000 to -1.000
thermally modified oak + vacuum	1.000	1341.000	0.000***	0.500 to 1.500
furfurylated pine	-0.500	721.000	0.068	-1.000 to 0.000

significance indicators: * p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

While the colour difference and roughness difference varied, the gloss difference was left on the same level throughout because the ordinal regression model showed that its impact is insignificant. The values for the levels were based on measured data of real samples of materials used in this research. Wherever constant value of an objective parameter was used (gloss change, part of colour change, part of roughness change), they were derived from first quartiles of measured data. The results presented in Table 19 indicate that with low change of all objective parameters from fresh to weathered state of wood there is slightly higher probability of a respondent choosing positive rating than negative rating. Provided that the gloss change and roughness change stay low, increase in colour change to the middle level (10) leads to slightly higher probability of choice of negative assessment. High level of colour change (20) results in probability of 0.5 of a negative assessment while the probability of a positive assessment is only 0.3. With colour difference and gloss difference fixed on value indicating first quartile of measured data, low values of roughness difference (2.5) result in equal probability of a negative or positive rating. With roughness difference increasing to intermediate levels, positive assessment is a little less probable than negative assessment, which is comparable to a situation with constant roughness and mid-level colour change. Roughness difference on a high level means the probability of negative rating is higher by 0.13 than the probability of a positive rating, but the probabilities of negative assessment are lower than when the extreme difference is of colour.

Table 18: Ordinal regression with colour difference, gloss difference and roughness difference based on average ratings of both samples (question 4)

coefficient	value	std. error	t-value	p-value
colour difference	-0.030	0.010	-2.440	0.015*
gloss difference	0.040	0.040	0.940	0.349
roughness difference	-0.020	0.010	-1.650	0.098
1|2	-2.850	0.280	-9.990	0.000***
2|3	-1.700	0.260	-6.520	0.000***
3|4	-0.690	0.250	-2.760	0.006**
4|5	0.080	0.250	0.330	0.743
5|6	0.950	0.250	3.740	0.000***
6|7	2.160	0.290	7.390	0.000***

significance indicators: * p-values between 0.01 and 0.05
** p-values between 0.001 and 0.01
*** p-values < 0.001

Table 19: Probability of new respondent to select a "likely" or "unlikely" rating using modelled objective parameters of the materials based on the ordinal regression model of ratings of both samples (question 4)

Δ E	gloss difference	roughness difference	probability of unlikely assessments (rating 1, 2, 3)	probability of likely assessments (rating 5, 6, 7)	difference in probabilities
2.5	-1.0	5.0	0.38	0.43	0.05
10.0	-1.0	5.0	0.43	0.38	-0.06
20.0	-1.0	5.0	0.51	0.30	-0.21
7.5	-1.0	2.5	0.41	0.40	0.00
7.5	-1.0	10.0	0.43	0.38	-0.06
7.5	-1.0	20.0	0.47	0.34	-0.13

6 DISCUSSION

It must be addressed that for the purposes of this research, only six pairs of wood materials with different treatments were chosen. There exist hundreds of other possible wood-based façade solutions, colour and weathering that are dependent on the original material, modification, possible surface treatment, position on the building, exposure, etc. These results are only based on used materials, but some assumptions can be taken beyond and applied generally.

Exploring hypothesis 1 about different assessment between weathered and fresh samples, it was noted that, based on Wilcoxon test, the thermally modified pine and untreated oak ratings weren't statistically significantly different while the others differed. That can be explained by low colour change between fresh and weathered samples of the two materials, which, as concluded before, is significant. However, the lowest colour change was recorded in acetylated pine, yet there was a statistically significant difference between the weathered and unweathered ratings for this material. The inconsistency can be explained by the initial value of rating of acetylated pine, which was the lowest of all fresh materials. That means that while big change in colour significantly decreased rating of weathered material, low change in colour either didn't change or slightly improved material assessment. This is supported by the exploratory ordinal regression of ratings against material properties where colour change was found to have significant effect on consumers' evaluation of a material. Manipulating the colour change from low to high level, the probability of a positive rating decreased by 0.13 (and the probability of negative assessment increased by 0.13). An analogous shift in change of roughness, which is from low change of roughness to high change of roughness, resulted in change of rating by 0.06. Is it a little or is it significant? It depends on a point of view. From the research or assessment point of view, the distance between ratings on Likert scale is lowest around the middle of the scale where the values are used more often by people and some of them get almost interchangeable with people expressing close-to-neutral opinions. However, if any of the more extreme ratings are used in this context, it expresses strong opinion about a given material. From a purchase point of view, it doesn't matter "how unlikely" a person would be to use the material; it only means that the purchase won't happen. Therefore, if a material is found negatively rated by consumers it might be reasonable to adopt measures to improve the rating to positive spectrum, and if a material is viewed positively, further improvements of its assessment by consumers won't make a difference between purchase or no purchase (but perhaps between a purchase of that material and a rival). In that case, even a shift in probability as small as 0.1 can mean a change of buyer perception from negative to positive. Based on our findings, focusing on material improvement in terms of colour stability during weathering is more influential on consumers' opinions than focusing on minimizing roughness change.

There were significant differences between all the fresh samples' ratings and ratings of both samples. That suggests stronger influence of the look of the weathered samples on the overall score. That assumption is further supported by the fact the average assessment of all the fresh samples was "farther" from assessment of both materials than assessment of weathered samples. This may be potentially very important because façade materials tend to be selected based on "new state" of materials, and the future – weathered – look is omitted [63]. It should be noted, though, that the weathered look didn't explain the overall score for all materials –

in fact, four of the six materials had significantly different assessment of weathered sample and both samples. That suggests there is more to the overall assessment than just separate looks of fresh and weathered samples. Nonetheless, the appearance of weathered wood is an important parameter in forming one's opinion about a wood material meant for outdoor exposure. Designers and architects should reflect on that and include the weathering process in their planning and presentations of products and designs. Software tools are being developed to help with the material weathering performance prediction, which is going to not only help to better plan the construction and maintenance of the building but can induce trust in consumers who are going to see what they get.

Stating that a shift from assessment of a new material to assessment of weathered material sets a trend towards the overall assessment, whether positive or negative, should be further observed and verified. However, it might mean that when consumers are pleasantly surprised by the weathered look of a material, their overall rating will increase. But if the weathered look disappoints, the overall assessment will be even lower. In this experiment, that was the case for both thermally treated oak materials, which were the two most appreciated materials among new samples. But the weathered samples were not liked by the respondents, and the rating of the weathered and unweathered samples together was much lower. Since thermally modified oak is a new material being developed, an improvement of weathered appearance should be considered before entering the market.

Research by Jošt et al. [72] suggests that in the last ten years Slovenian customers, preferring wooden furniture, are considering colour and price prior to environmental attributes at the time of purchase. Information about price changed respondents' opinion significantly in five out of six materials, and the extent of changes of assessment was similar to the extent of changes of assessment between assessment of fresh and weathered material. That indicates price might have about as strong an influence as colour change, leaving producers with a choice of colour stabilization in exchange for higher price. For furfurylated pine, additional information didn't result in significant change of assessment ($p = 0.068$). That is noteworthy since the price of furfurylated pine was the highest of all examined materials, and based on the observed results, price is an important role in material assessment (Figure 6). The three most expensive materials were pine. The estimated shift in assessments of both acetylated pine and thermally treated pine was negative, -1.5 (95% confidence interval: -2.0 to -1.0) and -1.0 (95% confidence interval: (-1.0 to 0.0), respectively. The strong decrease in ratings of acetylated pine with or without information is probably influenced by information about maintenance and lifespan as argued in the observed results (chapter 5.2.1 Observed results0). Therefore, it can be assumed that the negative influence of cost (meaning lowering the rating based on high cost) is weaker than positive influence of cost (increasing the rating based on low cost).

Nicholls and Roos [73] report aesthetics of wood products is highly important while price was of intermediate importance and environmental parameters were of low importance. They were, however, assessing attitude of wood manufacturers instead of end-users.

Appearance was the most important attribute of wood products ratings reported previously [51] [52] [53]. It can be debated whether façade, as an outdoor element, has less design importance to people than furniture or items they are surrounded by inside. The influence of lifespan and maintenance were hard to assess because most studied wood materials shared the same parameters. Still, if we assume longer lifespan is a positive attribute, then need for maintenance seems to induct rather strong negative consequences on assessment. Because the role of price on façade material choice seems to be of bigger influence than in other wood-based materials, future research focusing on the influence of cost, lifespan and maintenance would be appropriate. The environmental cost, which wasn't covered within this thesis, would be another interesting parameter influence on façade material preference that should be assessed.

In the study of Kaputa [74], wood was found to be preferred by consumers as a furniture material. Furniture was also the most mentioned use of all wood materials presented in this study. That might mean people readily connect wood to furniture since wood and wood-like furniture is very common, as it is for doors and window frames. Wood used in construction as a static member or as a façade is less common in Slovenia [75] and the Czech Republic [76] and, therefore, not seen as a viable use. In the Norwegian study of Nyrud and Høibø [59], overall rating of new materials was below neutral and overall assessment of weathered materials was above neutral. In this study, respondents were overall slightly unlikely to use wood as a façade for their house, both in unweathered and weathered state. It may be that our built environment is keeping us so far from thoughts of nature that natural building elements will trigger concerns about maintenance and longevity rather than about connection to nature. It is debated that while biophilia is an inherent biological drive, it is relatively weak and must be supported by one's learning and culture to manifest [34]. Therefore, we consider probable that respondents' natural affinity towards wood was overdriven by their cultural and social views of what material is appropriate for a house façade. However, after seeing both states of the materials and being informed about material cost, lifespan and maintenance, four out of six materials were on average rated neutral or positive. So, for architects or homeowners seeking to implement biophilic design, a natural and renewable material like wood could be a compelling option if price and performance were suitable.

That is a positive message to wood façade producers because – as shown previously – improvements in material properties can be done to increase the likelihood of materials to be regarded positively. Having that said, people might have an even better opinion about other façade materials, so wooden material products must be well presented and marketed because people's consciousness about products forms strongly their opinion [57].

Assessing the rating task (question 5), a fairly strong negative correlation (Kendall's tau: -0.51, $p < 0.001$) was found between its results and results of assessment question 4. Negative correlation was to be expected because the more positive an opinion about any sample, the higher the assessment and the lower the rank. The two outliers from the perfectly correlated results were untreated oak and acetylated pine (see Figure 5). Both were ranked lower than their rating from question 4 suggested. That might mean that direct comparison between materials can somewhat differentiate from absolute assessment of individual materials. Therefore, it is suggested that producers developing or improving their façade material product not only include consumer assessment in the process but have it assessed in comparison with other available materials. Secondly, an inconsistency of individual respondents was observed – it is recognized that asking questions about matters people rarely think of in their normal life might result in weakly founded data [66]. The ranking was included to make respondents differentiate materials that they might give equal rating to. Another reason might be the variety of responses: despite evaluating consequent ranking based on average ranking, all average positions are within variation of each other bounded by their standard deviation, so no solid conclusions can be drawn. Nevertheless, it is notable how high the standard deviation is in all of the respondents' answers with the coefficient of variation ranging from 0.31 to 0.65. It shows that individual likings and preferences are various, as previously stated by Manuel et al. [40]. The highest coefficients of variation in all but one material-related questions were observed in coated acetylated pine. It triggered rather stronger opinions, whether positive or negative ones. Its appearance was distinctly different from the others (notably lower roughness, notably higher gloss). However, to discover demographic or other reasons for this contradiction is a task set for further research. If those reasons are understood, they can be utilized in targeting potentially interested buyers or process modifications to produce materials with different properties. Generally, the findings about the role of demographic factors on wood assessment differ [40] [77] [78]. In our research, no difference in preferences between gender, age groups or people living in different environments was found. The influence of occupation remains unaddressed in this thesis because respondent occupation was not recorded (only the status of student, employed or unemployed was recorded). Further research with a respondent group of likely buyers might bring different results. This research was conducted among people with no particular interest in choosing or purchasing a façade because the objective was to assess whether there generally is a difference between perception of weathered and unweathered wood materials.

7 CONCLUSIONS

Out of six tested façade materials, people's rating of four of them differed between unweathered and weathered states. With the two materials with indifferent assessments, high colour change ($6 < \Delta E < 12$) was observed. Respondent assessments improved when colour change was small ($\Delta E < 2$), while it declined when colour change was large ($\Delta E > 12$).

There was a significant difference between assessment of all fresh samples and coupled samples. So, when people have more information about what a façade will look like after weathering, their opinions change. Also, four out of six materials exhibited significant difference between the weathered sample assessment and the assessment of both samples, which suggests other factors are influencing people's overall judgement of wood appearance. Nonetheless, the weathered rating of all materials was closer to their overall rating than the rating of fresh materials was. Weathering and its aesthetic consequences need to be considered by designers, builders and architects – software tools might be available to help with that in the future.

Despite being conducted in countries with a rather small share of wood construction, the mean assessment of all materials with provided information about cost, maintenance and lifespan was slightly positive. This is a good sign for the producers indicating wood is being accepted as a façade material.

Reactions of respondents to individual material were diverse. Different people have different preferences – what are they based on or related to should be researched in the future. Opinions varied the most about coated acetylated pine.

Producers and manufacturers of wood façades should consider improvements in colour stability of their products during weathering. Larger colour changes between fresh and weathered states of materials produced more negative assessments of the material. Similarly, distinct change in roughness also negatively influences consumer opinion, but this relationship seems to be less powerful than the one based on colour difference.

It is advisable to incorporate consumer assessment of products in their new and weathered state into development of new wood façade materials before releasing on the market. While rating tasks can reveal whether the material is likely or unlikely for a respondent to purchase, ranking tasks enable comparison with rivalling products.

8 POVZETEK NALOGE V SLOVENSKEM JEZIKU

8.1 UVOD

V tej nalogi so preučene preference ljudi do staranega in nestaranega lesa, ki se uporablja za fasade. V nadaljevanju razpravljamo o prepoznanih dejavnikih, ki vplivajo na odnos potrošnikov do lesa v grajenem okolju.

Gradbena industrija je velik porabnik virov, surovin in energije. Prepoznava se potreba po zmanjšanju toplogrednih plinov in gradnja (odgovorna za velik negativni doprinos) je področje, na katerem je treba izboljšati trajnostni razvoj [1] [2]. Ob vedno večji potrebi po nadaljnjem razvoju in gradnji je očitno, da je treba zmanjšati njene ekološke posledice, s čimer bo gradnja postala bolj trajnostna [8].

Domneva se, da bodo z izboljšanjem energetske učinkovitosti stavb - uredba ES (2010/31 / EU), ki zahteva, da bodo do konca leta 2020 vse stavbe skoraj nič energijske stavbe - okoljski vplivi namesto zaradi uporabe stavbe povzročeni predvsem s strani materialov, uporabljenih za njeno gradnjo [9].

Les raste sam, odvaja ogljik iz zraka in ga uporablja kot gradbeni material svojih tkiv. To pomeni, da zmanjša količine toplogrednih plinov v zraku, kar je eden glavnih izzivov pri sodobnih prizadevanjih za trajnostni razvoj. Les je biološko razgradljiv; ko se razgradi z gorenjem ali naravnimi postopki, se ogljik vrne v cikel. Dlje kot lahko les ostane v prvotni obliki, dlje se ogljik veže v trden material, namesto da v zraku tvori ogljikove okside. Les lahko spreminjamo tako, da spreminjamo njegove lastnosti, ali ga spremenimo v elemente večjih oblik ali v zgolj nekaj milimetrov debele plasti; lahko ga uporabljamo v različnih oblikah ali pretvorimo v kemikalije [12].

Fasada je gradbeni element, ki ločuje znotraj od zunaj, posnema funkcijo telesne kože, zagotavlja oviro pred vlago, prahom in UV žarki, pomaga pri uravnavanju notranje temperature in estetsko vpliva na okolje. Za zagotovitev stabilnega in udobnega okolja mora fasada preprečiti, utišati ali kanalizirati vpliv zunanjega okolja in se spopasti z različnimi vremenskimi vplivi, spremembami temperature in vlažnosti ter specifičnimi zahtevami vsakega podnebnega območja [11].

Dovzetnost bioloških materialov za propadanje zaradi biotskih in abiotskih dejavnikov je zaskrbljujoča pri lesu kot fasadnem materialu, saj je fasada tisti del stavbe, ki je izpostavljen zunanjim razmeram. Vendar pa lahko ob pravilni uporabi lesni elementi trajajo desetletja ali stoletja. Uporabniki stavb navadno cenijo naravne materiale, vendar se estetsko cenjenje razvija in je individualno. Barva lesa je v odtenkih rumene, oranžne in rjave, ki sčasoma bledijo in sivijo. Neenakomerna obarvanost, ki jo povzročajo staranje in vremenski vplivi, ponavadi ni cenjena, čeprav je včasih zaželena ali celo namenoma umetno povzročena [11], les pa se lahko tudi reciklira [15] [16].

Kot vsak živ organizem tudi les vsebuje vodo, ki do neke mere ostane v lesu. Les je higroskopen, njegova vsebnost vlage je uravnotežena z vlago zunanjega okolja. Ko se vlaga spreminja, se vsebnost vlage v lesu ustrezno prilagodi, kar povzroči volumetrične spremembe, skupaj s spremembami mehanskih, elastičnih in toplotnih lastnosti. Otekanje in krčenje nista edini težavi lesnih elementov; obstajajo tudi biotski in abiotski dejavniki, ki povzročajo kemične in posledično tudi vidne ali mehanske spremembe. Biološka degradacija se v predelanem lesu pojavi, kadar okoljski pogoji omogočajo prisotnost in rast biotskih povzročiteljev razgradnje lesa [12].

Abiotski dejavnik, ki vpliva na lesne konstrukcije, ki so izpostavljene zunanjim vplivom, so vremenski vplivi - počasna razgradnja lesa, ki je izpostavljen vremenskim vplivom, kot so sončna svetloba, dež in sneg, veter, toplota, mraz in temperaturne spremembe. Površina lesa, ki je izpostavljena zunanjim razmeram, vzdrži spremembe relativne vlažnosti in temperature, kar povzroča otekanje in krčenje lesa, abrazijo delcev, ki se prenašajo v zraku, in predvsem sončno sevanje ter njegove UV-komponente (fotodegradacije). Energija UV-sevanja kemično spreminja strukturne sestavine lesa. [12].

Les v gradbeništvu je treba zaščititi predvsem s pravilnim dizajnom. Trajnost se lahko poveča s kemično ali toplotno obdelavo, bodisi s globinsko obdelavo bodisi z ustvarjanjem sloja na površini [7].

Kemične modifikacije vključujejo tvorbo kovalentne vezi med lesno komponento in kemičnim reagentom. Primer takšne spremembe je acetilacija. Impregnacija pomeni, da kemična komponenta ali polimerizira znotraj celične stene ali prodre do celične stene in se tam strdi. Predstavnik procesa polimerizacije je furfurilacija. Toplotna modifikacija les izpostavi temperaturam med 180 °C in 260 °C. Zvišana temperatura povzroči spremembe v sestavnih delih lesa, kar pomeni zmanjšano higroskopičnost, omejene spremembe dimenzij in izboljšanje odpornosti proti biotski razgradnji. Včasih je težko zagotoviti enakomerno prodiranje obdelovalnega sredstva v globino materiala. Če pride do reakcije na površini materiala, prekritega in zaščitenega z dano kemikalijo, se s tem olajša tako nanos sredstva kot tudi njegovo odstranjevanje ob koncu življenjske dobe. Na površini lesa so ponavadi olja, voski, premazi ali lazure, katerih glavni namen je podaljšati življenjsko dobo danega elementa. Hibridne modifikacije uporabljajo dva ali več različnih zgoraj omenjenih mehanizmov [7] [11] [25].

V poslu je zadovoljstvo potrošnikov zelo pomembno, vendar je opredelitev zadovoljstva težavno. Zadovoljstvo je podvrženo „kameleonskemu učinku“, ki ima različen pomen za različne anketirance. Prav tako različni potrošniki izkazujejo preference do različnih izdelkov [40]. Zdi se, da ima estetika glavno vlogo pri izbiri lesenih izdelkov s strani potrošnikov [42] [43] [44]. Čeprav označevanje okoljskih dejavnikov najbrž ne pretehta vloge estetike pri izbiri lesenega izdelka, lahko prispeva k odločitvi [47] [48]. Pri odnosu potrošnikov do lesa igrata pomembno vlogo vid in dotik. Bumgardner in Bowe [57] trdita, da obstaja razlika v psihološkem učinku lesenega izdelka, glede na uporabljeno vrsto lesa in razliko med predhodnim dojemanjem lesne vrste in dejanskimi odzivi ob izpostavitvi vzorcu lesa. Predstavitev in marketing lesne vrste ali obdelave lesa ima pomembno vlogo pri zaznavanju materialov.

8.2 CILJI IN HIPOTEZE

Namen raziskave je bil oceniti človekovo zaznavanje lesa, in sicer razliko med ocenjevanjem staranih in nestaranih lesnih materialov, namenjenih za uporabo kot fasada. Povezan cilj je bil ugotoviti, ali se z oceno povezuje kateri koli od zabeleženih demografskih parametrov (starost, spol, življenjsko okolje), izmerjenih parametrov materialov (barva, hrapavost, sijaj in njihovo spreminjanje) ali dodatnih informacij o materialih (stroški, življenjska doba, potrebno vzdrževanje).

Na podlagi ciljev so bile oblikovane tri hipoteze za obravnavanje razlike med ocenjevanjem nestaranega in staranega materiala, vpliv estetike danega materiala na celotno oceno materiala in povezanosti demografskih parametrov z oceno materiala.

H1: Preference potrošnikov za lesne fasadne materiale iste vrste se bodo razlikovale med staranimi in nestaranimi različicami materialov.

H2: Poznavanje staranega videza materiala bo spremenilo preference potrošnikov pri izbiri materiala.

H3: Preference potrošnikov za starane in nestarane lesne fasadne materiale se ne razlikujejo glede na njihovo starost, spol ali življenjsko okolje.

8.3 MATERIALI IN METODE

Izbranih je bilo 6 parov nestaranih in staranih materialov. Predstavljeni so bili različni načini obdelave, vključno brez obdelave (hrast), toplotna modifikacija (bor), toplotna modifikacija v vakuumu (2 × hrast, eden od njih voščen), furfurlacija (bor) in acetilacija (bor). Izbrani vzorci so predstavljali različne vizualne spremembe tudi zaradi vremenskih vplivov. Naravno vzorčeni vzorci so bili 15 mesecev izpostavljeni zunanjim razmeram na jugu strehe stavbe v San Michele all'Adige (Italija). Izmerili smo hrapavost, barvo in sijaj vseh vzorcev. Grobost je bila izražena z R_a. Barva je bila ocenjena v sistemu CIELAB. Sijaj je bil izmerjen vzporedno z vlakni s 60° vpadnim kotom.

Namen raziskave je bil oceniti človekovo percepcijo lesa. V ta namen je bil izdelan vprašalnik, ki je bil anketirancem predstavljen posamično (glej Appendix A: Questionnaire). Odgovori so bili podani ustno raziskovalcu, ki jih je vnesel v računalnik. Anketiranci so ocenjevali verjetnost uporabe najprej nestaranih in nato staranih vzorcev lesa za fasado družinske hiše po lestvici s 7 točkami (od 1 - zelo malo verjetno do 7 - zelo verjetno). Zatem so ocenjevali materiale, ko so bili obenem predstavljeni tako nestarani kot starani vzorci materiala. Materiale so udeleženci nato rangirali med 1 in 6 in jih nato ponovno ocenili, tokrat z dodatnimi informacijami o posameznih stroških materialov, njihovi življenjski dobi in potrebi po vzdrževanju. Nazadnje so bili zbrani demografski podatki z vprašanji o starosti anketirancev (na podlagi starostnih skupin), spolu, življenjskem okolju in poklicu.

Zbrani podatki so vključevali demografske podatke, ocene na 7-točkovni ocenjevalni lestvici, ki se pretvorijo v numerične vrednosti, in range. Podatki iz ocenjevalne lestvice so ordinalni: spremenljivke z zaporednimi kategorijami. Pri analizi smo uporabili Wilcoxonov test in ordinalno regresijo. Za hipotezo 1 so bile primerjane ocene nestaranih vzorcev, pridobljene v drugem vprašanju, in ocene staranih vzorcev, pridobljene v tretjem vprašanju. Za hipotezo 2 sta bili uporabljeni oceni nestaranih vzorcev iz drugega vprašanja in ocena staranih vzorcev iz četrtega vprašanja. Za hipotezo 3 je bila izvedena logaritemska ordinalna regresija v R (različica 4.0.2) [68] z uporabo paketa MASS (različica 7.3-51.6) [69]. Regresija vrne logaritem obetov koeficientov v modelu, ki jih lahko nato uporabimo za napovedovanje verjetnosti, da bo nov anketiranec izbral določeno postavko na 7-točkovni lestvici, uporabljeni v vprašalniku.

8.4 REZULTATI

Objektivne lastnosti materiala so se med vremenskimi vplivi spreminjale. Na podlagi splošnih meril za oceno barvne spremembe predlaganih s strani Barcíka in sod. [71], se lahko sprememba barve acetiliranega premazanega bora dojema za majhno ($\Delta E < 2$), sprememba barve toplotno modificiranega bora in neobdelanega hrasta za visoko ($6 < \Delta E < 12$) ter sprememba barve tako toplotno obdelanih hrastov kot furfuritiranega bora se lahko razume kot dve različni barvi ($\Delta E > 12$). Zlasti sijaj vseh hrastovih materialov se je med vremenskimi vplivi zmanjšal, medtem ko se je pri vseh borovih materialih povečal ali se ni spremenil. Acetilirani material ima najmanjšo barvno spremembo, najbolj pa se je spremenil njegov sijaj. Sprememba hrapavosti je bila od 0,15 µm (premazan acetiliran bor) do 33,59 µm (hrast, toplotno spremenjen v vakuumu).

Tako v Sloveniji kot na Češkem je bilo izpolnjenih 74 vprašalnikov, v katerih je bilo 40 in 34 anketirancev v vsaki državi. 44 od teh se identificira kot moških, 29 kot žensk, 1 pa kot nebinarni spol. 30 anketirancev je svoje življenjsko okolje označilo za primestno, medtem, ko je bilo mestno in podeželsko bivalno okolje izbrano po 22-krat. Med udeleženci je bilo 29 študentov, 44 delavcev in 1 nezaposlena oseba. Anketiranci so največkrat menili, da so bili razstavljeni lesni vzorci namenjeni izdelavi pohištva, notranjih talnih oblog ter vrat in oken. Le dva anketirana sta mislila, da predstavljeni materiali niso koristni. 21 udeležencev je videlo možnost uporabe materialov za fasado.

Če je bil predstavljen samo z nestaranimi vzorci, je hrast, toplotno spremenjen v vakuumu, dosegel najvišjo povprečno oceno 4,51 (± 1,46) na 7-točkovni ocenjevalni lestvici. Najmanj favoriziran je bil premazani acetiliran bor, ocenjen s 3,14 (± 1,93). Vendar se je ocenjevanje materialov hitro spremenilo, ko so anketiranci ocenjevali starane vzorce. V tem primeru nobena od povprečnih ocen ni bila višja od 4, ki je izražala nevtralno mnenje - kar pomeni, da je bilo v povprečju malo verjetno, da bo katerikoli od materialov uporabljen. Ko sta bila hkrati predstavljena tako starana in nestarana različica materiala je toplotno modificiran bor prejel najvišjo povprečno oceno, 4,61 (± 1,58). Ta dva materiala sta bila, skupaj s premazanim acetiliranim borom ocenjenim s 4,28 (± 2,02), v povprečju ocenjena med 'nevtralno' in 'verjetno', medtem ko so bili drugi štirje materiali v povprečju ocenjeni z 'nevtralno' in 'manj verjetno'. Najnižja povprečna skupna ocena (3.03 (±1.38)) je bila podana hrastu, ki je bil toplotno obdelan v vakuumu in povoščen.

V nalogi rangiranja je bil najboljše ocenjen toplotno modificiran bor s povprečnim rezultatom 2,78 (± 1,73). Material z drugim najvišjim rezultatom je bil hrast, toplotno spremenjen v vakuumu s 3,19 (± 1,36), ki mu je sledil acetiliran bor z rezultatom 3,24 (± 2,11). Furfurilirani bor je bil na četrtem mestu s povprečno oceno 3,66 (± 1,65), rezultat voščenega hrasta, toplotno spremenjenega v vakuumu, je znašal 4,03 (± 1,30), zadnji na lestvici pa je bil neobdelan hrast z oceno 4,11 (± 1,51). Visoka standardna odstopanja in posledično visoki koeficienti variacije kažejo, da mnenja ljudi niso bila enotna.

Za obravnavanje hipoteze 1 smo uporabili Wilcoxonov test, s katerim smo primerjali odgovore iz drugega in tretjega vprašanja. Glede na rezultate so se ocene nestaranih in staranih vzorcev statistično značilno razlikovale, razen za termično modificiran bor in furfurilirani bor. Od bistveno različnih premikov se je pozitivno spremenila le ocena acetiliranega bora. Za obravnavanje hipoteze 2 je bil izveden Wilcoxonov test, ki je primerjal ocene nestaranih vzorcev (vprašanje 2) z ocenami obeh vzorcev (vprašanje 4). Popravljena p-vrednost je bila za vse materiale manjša od 0,05, kar pomeni, da obstaja statistično značilna razlika med ocenami nestaranih vzorcev in obeh vzorcev. Spremembe toplotno spremenjenega bora in acetiliranega bora so bile pozitivne, kar kaže na to, da so na podlagi videza staranega vzorca ali videza obeh vzorcev (skupaj z drugimi materiali) anketiranci zvišali oceno. Najbolj negativni premiki so bili opazni pri obeh toplotno obdelanih hrastovih materialih. Hipotezo 3 smo obravnavali z ordinalno regresijo na podlagi odgovorov iz vprašanja 4 (ocen parov vzorcev). Noben izmed preučenih demografskih podatkov ni imel statistično značilne vloge. Ko so bili materiali opremljeni z informacijami o njihovih stroških, vzdrževanju in življenjski dobi, se je njihova ocena bistveno spremenila, razen pri furfuliziranem boru. Cena je bila glavni dejavnik.

Na podlagi ocen iz vprašanja 4 je bil ustvarjen ordinalni regresijski model, ki je kot prediktorje uporabil spremembo barve, hrapavosti in sijaja. Edini dejavnik, ki je povzročil statistično značilne spremembe, je bila barvna razlika, razlika v hrapavosti pa se je le bližala statistično značilni vlogi.

8.5 DISKUSIJA

Ugotovljeno je bilo, da sprememba barve zaradi vremenskih vplivov pomembno vpliva na ocenjevanje materialov lesenih fasad. Tudi sprememba verjetnosti za določene oceno, ki znaša le 0,1, lahko pomeni spremembo kupčeve percepcije iz negativne v pozitivno. Če potrošniki negativno ocenjujejo material, bi bilo smiselno sprejeti ukrepe za izboljšanje njihovih ocen. Glede na naše ugotovitve je osredotočanje na izboljšanje materiala v smislu stabilnosti barve med vremenskimi vplivi bolj vplivno na mnenja potrošnikov kot osredotočanje na zmanjšanje sprememb hrapavosti.

Med ocenami vseh nestaranih vzorcev in ocenami obeh vzorcev so bile statistično značilne razlike. To kaže na močnejši vpliv videza staranih vzorcev na skupno oceno. To je lahko zelo pomembno, saj se fasadni materiali navadno izberejo na podlagi videza, ko so novi (nestarani), prihodnji (starani) videz pa se ne upošteva [63]. To bi se moralo odražati v oblikovanju in razvoju izdelkov. Dobra ponazoritev zgoraj opisanega so na novo razviti toplotno obdelani hrastovi materiali, uporabljeni v tej raziskavi, katerih nestarani vzorci so bili udeležencem zelo všeč, medtem, ko je bila ocena staranih vzorcev in obeh vzorcev hkrati precej nižja.

Zdi se, da cena vpliva na dojemanje anketirancev več, kot je običajno zabeleženo [46] [79]. Zahtevano vzdrževanje materialov je negativno vplivalo na oceno.

Koeficient variacije je bil v ocenjevalnih nalogah visok (0,31 - 0,65), kar kaže, da so mnenja različnih anketirancev različna.

8.6 ZAKLJUČEK

Od šestih preizkušenih fasadnih materialov so se ocene štirih med njimi razlikovale med nestaranim in staranim stanjem. Med oceno vseh nestaranih vzorcev in vzorcev v paru se je pojavila statistično značilna razlika. Oblikovalci, gradbeniki in arhitekti morajo upoštevati vremenske vplive in njihove estetske posledice - v prihodnosti bodo morda na voljo programska orodja, ki jim bodo pri tem pomagala. Pri razvoju novih fasadnih materialov je treba vključiti tudi oceno potrošnikov staranega lesa.

9 REFERENCES

[1] D. Jones and C. Brischke, Performance of Bio-based Building Materials, Elsevier, 2017.

[2] I. Z. Bribián, A. V. Capilla and A. A. Usón, "Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential," *Building and Environment,* vol. 46, no. 5, pp. 1133-1140, 2011.

[3] E. Commission, "A European Green Deal: Striving to be the first climate-neutral continent," 11 December 2019. [Online]. Available: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. [Accessed 31 July 2020].

[4] B. Hopwood, M. Mellor and G. O'Brien, "Sustainable Development: Mapping Different Approaches," *Sustainable Development,* pp. 35-52, 2005.

[5] WCED, "Our Common Future," Oxford University Press, New York, 1987.

[6] J. Elkington, Cannibals with Forks: the Triple Bottom Line of 21st Century Business, Oxford: Capstone, 1997.

[7] C. A. Hill, Wood Modification: Chemical, Thermal and Other Processes, Chichester: John Wiley & Sons Ltd, 2006.

[8] M. Kitek Kuzman and A. Kutnar, Contemporary Slovenian Timber Architecture for Sustainability, Springer, 2014.

[9] B. Peuportier, Eco-conception des bâtiments et des quartiers, Paris: Presses de l'Ecole des Mines, 2008.

[10] K. L. Getter and D. B. Rowe, "The Role of Extensive Green Roofs in Sustainable Development," *Hortscience,* vol. 41, no. 5, pp. 1276-1285, 2006.

[11] A. Sandak, J. Sandak, M. Brzezicki and A. Kutnar, Bio-based Building Skin, Singapore: Springer, 2019.

[12] R. M. Rowell, Handbook of wood chemistry and wood composites, Boca Raton, Florida: CRC Press, 2005.

[13] J. O'Connor, R. A. Kozak, C. Gaston and D. R. Fell, "Wood use in nonresidential buildings: Opportunities and barriers," *Forest Products Journal,* vol. 54, no. 3, pp. 19-28, 2004.

[14] G. Z. a. A. Faraguna, Evolutionary Optimization of Facade Design: A New Approach for the Design of Building Envelopes, Springer: London, 2014.

[15] A. Griffiths, “Dezeen: Reclaimed windows and doors form facades of Collage House by S+PS Architects,” 1 May 2016. [Online]. Available: https://www.dezeen.com/2016/05/01/s-ps-collage-house-reclaimed-window-door-facade-mumbai-india/. [Accessed 31 July 2020].

[16] K. McKnight, “Dezeen: Birdseye Design clads Vermont dwelling in salvaged wooden boards,” 3 April 2017. [Online]. Available: https://www.dezeen.com/2017/04/03/birdseye-design-clads-vermont-dwelling-in-salvaged-wooden-boards/. [Accessed 31 July 2020].

[17] V. Kotradyová, “Material Surface Features in Body Conscious Spatial Design,” *International Journal of Contemporary Architecture ”The New ARCH“,* vol. 2, no. 2, pp. 38-44, 2015.

[18] J. Sandak and N. Martino, “Wood surface roughness – what is it?,” 2015.

[19] S. Wongsriruksa, P. D. Howes, M. Conreen and M. Miodownik, “The use of physical property data to predict the touch perception of materials,” *Materials & Design,* vol. 42, pp. 238-244, 2012.

[20] W. M. Bergmann Tiest and A. M. Kappers, “Haptic and visual perception of roughness,” *Acta Psychologica 124,* pp. 177-189, 2007.

[21] B. Bhushan, “Surface Roughness Analysis and Measurement Techniques,” in *Modern Tribology Handbook, Two Volume Set*, Boca Raton, CRC Press, 2000, p. 1760.

[22] B. Ranby and J. F. Rabek, Photodegradation, photooxidation and photostabilization of Polymers: Principles and Applications, London: John Wiley & Sons, 1975.

[23] D. Hon, “Photochemical degradation of lignocellulosic materials.,” in *Developments in Polymer Degradation-3*, Essex, Applied Science Ltd., 1981, pp. 133-139.

[24] A. J. Stamm, Wood and Cellulose Science, New York: The Ronald Press Co., 1964.

[25] G. I. Mantanis, “Chemical Modification of Wood by Acetylation or Furfurylation: A Review of the Present Scaled-up Technologies,” *Bioresources,* vol. 12, no. 2, pp. 4478-4489, 2017.

[26] R. Herrera, J. Sandak, E. Robles, T. Krystofiak and J. Labidi, “Weathering resistance of thermally modified wood finished with coatings of diverse formulations,” *Progress in Organic Coatings,* vol. 119, pp. 145-154, 2018.

[27] N. Ayadi, F. Lejeune, F. Charrier, B. Charrier and A. Merlin, “Color stability of heat-treated wood during artificial weathering,” *European Journal of Wood and Wood Products,* vol. 61, no. 3, pp. 221-226, 2003.

[28] T. Syrjänen and E. Kangas, "Heat treatment of wood in Finland," Doc. No. IRG/WP 00-40158, 2000.

[29] R. Herrera, A. Arrese, P. L. d. Hoyos-Martinez, J. Labidi and R. Llano-Ponte, "Evolution of thermally modified wood properties exposed to natural and artificial weathering and its potential as an element for façades systems," *Construction and Building Materials 172,* pp. 233-242, 2018.

[30] UN Department of Economic and Social Affairs, "World Urbanization Prospects 2018," 2018. [Online]. Available: https://esa.un.org/unpd/wup/Download/. [Accessed 9 June 2020].

[31] N. Klepeis, W. Nelson, W. Ott, J. Robinson, A. Tsang, P. Switzer, J. Behar, S. Hern and W. Engelmann, "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants," *Journal of Exposure Analysis and Environmental Epidemiology,* vol. 11, pp. 231-252, 2001.

[32] V. Derr and S. R. Kellert, "Making Children's Environments "R.E.D.": Restorative Environmental Design and Its Relationship to Sustainable Design," in *Proceedings of the 44th annual conference of the environmental design research association*, Providence, Rhode Island, 29 May–1 June 2013, 2013.

[33] S. Kaplan, "The restorative benefits of nature," *Journal of Environmental Psychology,* pp. 169-182, 1995.

[34] S. Kellert, Building for life: designing and understanding the human-nature connection, Washington, DC: Island Press, 2005.

[35] E. Wilson, Biophilia, Cambridge, Massachusetts: Harvard University Press, 1984.

[36] S. R. Kellert, J. Heerwagen and M. Mador, Biophilic design: the theory, science and practice of bringing buildings to life, Hoboken: Wiley, 2008.

[37] V. Kotradyová and B. Kaliňáková, "Wood as material suitable for health care and therapeutic facilities," *Advanced Materials Research,* vol. 1041, pp. 362-366, 2014.

[38] M. D. Burnard and A. Kutnar, "Wood and human stress in the built indoor environment: a review," *Wood Science and Technology,* vol. 49, no. 5, pp. 969-986, 2015.

[39] J. Giese and J. Cote, "Defining Consumer Satisfaction," *Academy of Marketing Science Review 4,* pp. 1-27, 2000.

[40] A. Manuel, R. Leonhart, O. Broman and G. Becker, "Consumers' perceptions and preference profiles for wood surfaces tested with pairwise comparison in Germany," *Annals of Forest Science,* vol. 72, no. 6, pp. 741-751, 2015.

[41] T. Pakarinen, "Success factors of wood as a furniture material," *Forest Products Journal 49(9),* pp. 79-85, 1999.

[42] T. A. Guzel, "Consumer Attitudes toward Preference and Use of Wood, Woodenware, and Furniture: A Sample from Kayseri, Turkey," *Bioresources,* vol. 15, no. 1, pp. 28-37, 2020.

[43] O. Broman, "Means to measure the aesthetic properties of wood," Lulea University of Technology, 2000.

[44] A. Manuel, R. Leonhart, O. Broman and G. Becker, "How do consumers express their appreciation of wood surfaces? Norway spruce floors in Germany as an example," *Annals of Forest Science,* vol. 73, no. 3, pp. 703-712, 2016.

[45] P. Hovde, "The Factor Method For Service Life Prediction From Theoretical Evaluation to Practical Implementation," in *Proceedings of the 9DBMC International Conference On Durability of Building Materials and Components*, Brisbane, Australia, 2002.

[46] F. X. Aguilar and Z. Cai, "Conjoint effect of environmental labeling, disclosure of forest of origin and price on consumer preferences for wood products in the US and UK," *Ecological Economics 70,* pp. 308-316, 2010.

[47] R. C. Anderson and E. N. Hansen, "The impact of environmental certification on preferences for wood furniture: a conjoint analysis approach.," *Forest Products Journal 54(3),* pp. 42-50, 2004.

[48] V.-S. Osburg, S. Appelhanz, T. Waldemar and M. Schumann, "An empirical investigation of wood product information valued by young consumers," *Journal of Cleaner Production,* 2015.

[49] K. Veisten, "Potential demand for certified wood products in the United Kingdom and Norway," *Forest Science,* vol. 48, no. 4, pp. 767-778, 2002.

[50] Z. Cai and F. X. Aguilar, "Consumer stated purchasing preferences and corporate social responsibility in the wood products industry: A conjoint analysis in the U.S. and China," *Ecological Economics,* vol. 95, no. 95, pp. 118-127, 2013.

[51] H. Bigsby, C. Rai and L. Ozanne, "Determining consumer preference for Furniture Timber," *Journal of Forest Products Business Research,* 2005.

[52] B. U. B. R. Lihra T, "Mass customisation of wood furniture as a competitive strategy," *Int J Mass Customisation 2,* pp. 200-215, 2008.

[53] T. Ramananantoandro, M. F. Ramanakoto, A. H. Rajemison and F. Eyma, "Relationship between density and aesthetic attributes of wood and preference of Malagasy consumers," *Annals of Forest Science,* vol. 70, no. 6, pp. 649-658, 2013.

[54] E. O. R. G. I. Rametsteiner, Europeans and wood: What Do Europeans Think About Wood and its Uses? A Review of Consumer and Business Surveys in Europe, Warsaw: Ministerial Conference on the Protection of Forests in Europe, 2007.

[55] W. Fujisaki, M. Tokita and K. Kariya, "Perception of the material properties of wood based on vision, audition, and touch," *Vision Research,* vol. 109, pp. 185-200, 2015.

[56] S. R. Bhatta, K. Tiippana, K. Vahtikari, M. Hughes and M. Kyttä, "Sensory and emotional perception of wooden surfaces through fingertip touch," *Frontiers in Psychology,* vol. 8, p. 367, 2017.

[57] M. Bumgardner and S. A. Bowe, "Species Selection in Secondary Wood Products: Implications for Product Design and Promotion," *Wood and Fiber Science,* vol. 34, no. 3, pp. 408-418, 2002.

[58] D. Lipovac, M. D. Burnard and A. Kutnar, "Perception and evaluation of modified wood," in *Proceedings of 9th European Conference on Wood Modification*, Arnhem, 2018.

[59] A. Q. Nyrud and O. Høibø, "Evaluating customer preference for wooden deck materials with age effects," in *Scandinavian Forest Economics No. 42*, Lom, 2008.

[60] E. Teo, "An Assessment of Factors Affecting the Service Life of External Paint Finish on Plastered Facades," in *10DBMC International Conference On Durability of Building Materials and Components.*, Lyon, 2005.

[61] A. Aikivuori, "Critical loss of performance—what fails before durability," in *8th International conference on durability of buildings materials and components*, Vancouver, Canada, 1999.

[62] A. Sandak, J. Sandak, M. Petrillo, P. Grossi and M. Brzezicki, "Performance of modified wood – Bio4ever project - how to convince people to use bio-based building materials?," in *COST Action FP1407 WG1 and WG4 meeting: Wood modification in Europe: processes, products, applications*, Firenze, 2018.

[63] A. Sandak, J. Sandak, M. Petrillo, P. Grossi and M. Brzezicki, "A simulation tool for the façade aesthetic appearance – BIO4ever project approach," in *COST TU1403 "Adaptive Facades Network"*, Lucerne, 2018.

[64] Climate-data.org, “Trento Climate (Italy),” [Online]. Available: https://en.climate-data.org/europe/italy/trentino-alto-adige-suedtirol/trento-1117/. [Accessed 31 July 2020].

[65] G. Sharma, Digital Colour Imaging Handbook, Boca Raton: CRC Press, 2003.

[66] I. Brace, Questionnaire design: how to plan, structure and write survey material for effective market research, second edition, London: Kogan Page, 2008.

[67] A. Bryman, Social Research Methods (4th Edition), New York: Oxford University Press, 2012.

[68] R Core Team, “A language and environment for statistical computing,” R Foundation for Statistical Computing, Vienna, Austria, 2020. URL https://www.R-project.org/.

[69] W. N. &. R. B. D. Venables, *Modern Applied Statistics with S. Fourth Edition.,* New York: Springer, 2002. ISBN 0-387-95457-0.

[70] Y. a. H. Y. Benjamini, “Controlling the false discovery rate: a practical and powerful approach to multiple testing,” *Journal of the Royal statistical society: series B (Methodological),* vol. 57, no. 1, pp. 289-300, 1995.

[71] Š. Barcík, M. Gašparík and E. Razumov, “Effect of temperature on the color changes of wood during thermal modification,” *Cellul Chem Technol,* vol. 49, pp. 789-798, 2015.

[72] M. Jošt, V. Kaputa, M. Nosáľová, A. Pirc Barčić, I. Perić and L. Oblak, “Changes in Customer Preferences for Furniture in Slovenia (Promjene sklonosti kupaca namještaja u Sloveniji),” *Drvna industrija 71,* pp. 149-156, 2020.

[73] D. L. Nicholls and J. Roos, “Lumber attributes, characteristics, and species preferences as indicated by secondary wood products firms in the continental United States,” *European Journal of Wood and Wood Products,* vol. 64, no. 4, pp. 253-259, 2006.

[74] V. Kaputa, A. P. Barčić, H. Maťová and D. Motik, “Consumer Preferences for Wooden Furniture in Croatia and Slovakia,” *Bioresources,* vol. 13, no. 3, pp. 6280-6299, 2018.

[75] M. Kitek Kuzman, K. Lähtinen and D. Sandberg, “Initiatives Supporting Timber Constructions in Finland, Slovenia and Sweden.,” in *IUFRO 2017 Division 5 Conference "Forest Sector Innovations for a Greener Future"*, Vancouver, Canada, 2017.

[76] Committee on Forests and the Forest Industry of the UN Economic Commission for Europe, “Market statement of the Czech Republic,” UN Economic Commission for Europe, Committee on Forests and the Forest Industry, Vancouver, Canada, 2018.

[77] S. A. Bowe and M. Bumgardner, “Species Selection in Secondary Wood Products: Perspectives From Different Consumers,” *Wood and Fiber Science,* vol. 36, no. 3, pp. 319-328, 2004.

[78] D. Nicholls and M. Bumgardner, “Evaluating selected demographic factors related to consumer preferences for furniture from commercial and from underutilized species,” *Forest Products Journal,* vol. 57, no. 12, pp. 79-82, 2007.

[79] M. Bumgardner, D. Nicholls and G. H. Donovan, “Effects of species information and furniture price on consumer preferences for selected woods,” *Wood and Fiber Science,* vol. 39, no. 1, pp. 71-81, 2007.

APPENDICES

Appendix A: Questionnaire

Welcome! This study is part of a master's thesis in the Sustainable Built Environments study program at UP FAMNIT. The supervisor of this project is assist. prof. Michael Burnard.
By participating, you agree to allow your responses to be used for research purposes (in publications or scientific presentations) and placed in a data repository. Only your anonymized data will be used and shared. Your responses will not be directly connected with your identity. No other use of your data is authorized and your personal information will not be shared unless required by law. Your rights are protected by the European Union's General Data Protection Regulation and Slovenian law.
Participation is voluntary. You can leave at any time or withdraw your answers by contacting ha.rem@seznam.cz or michael.burnard@iam.upr.si.
Should you have any questions, please ask the researcher.
You will be presented with cards with instructions and questions. Tell your answers to the researcher. Please try to answer by referring to numbers and letters.
When assessing the presented materials, consider the top surface only.

1. **What would you use the presented wood for? Think about all the specimens as a set, not individually. You may select more than one use for the set.**

a) Construction (mechanical support)
b) Furniture (visible material)
c) Façade (external building envelope, including partial covering)
d) Indoor flooring
e) Outdoor flooring (terrace)
f) Fences
g) Doors
h) Windows/window frames
i) Shutters
j) Other: …………………
k) Nothing/no use

The presented specimens have been treated or modified by different methods. These materials were designed to be used as a building façade. Imagine you are choosing between different wood types for a façade of a family house.

2. **How likely would you be to use each of the presented materials for a façade of your home?**

(specimens A, B, C, D, E, H)

extremely unlikely (1)	very unlikely (2)	unlikely (3)	in between (4)	likely (5)	very likely (6)	extremely likely (7)

The following presented specimens are a set of treated or modified wood that was exposed to outdoor weather for 15 months. Weathering is an inevitable natural process resulting in changes to the appearance of wood and its properties. Most changes occur within the first 12 months of service.

3. **How likely would you be to use each of the presented materials for a façade of your home?**

(specimens F, G, I, J, K, L)

extremely unlikely (1)	very unlikely (2)	unlikely (3)	in between (4)	likely (5)	very likely (6)	extremely likely (7)

The presented specimens are pairs of the same material with one new specimen and one weathered specimen (15 months). The pairing is as follows:

new specimen		weathered specimen
A	-	I
B	-	L
C	-	F
D	-	K
E	-	G
H	-	J

4. **Knowing how the wood looks when new and after it has been weathered for 15 months, how likely would you be to use each of the presented materials for a façade of your home?**

(materials AI, BL, CF, DK, EG, HJ)

extremely unlikely (1)	very unlikely (2)	unlikely (3)	in between (4)	likely (5)	very likely (6)	extremely likely (7)

5. **How would you rank the materials based on how likely you would use them for a façade of your home?**

(materials AI, BL, CF, DK, EG, HJ)

(the most likely to use) 1. ………..
2. ………..
3. ………..
4. ………..
5. ………..
(the least likely to use) 6. ………..

specimens	**material cost per house* (EUR)**	**lifespan**	**maintenance**
AI	12.000	30 years	none
BL	7.200	30 years	none
CF	4.200	30 years	none
DK	12.000	50 years	repainting every 6 years
EG	6.000	30 years	none
HJ	14.400	30 years	none

** a house with 120 m² of wooden façade is considered*

6. **Knowing how the wood looks when new and after it has been weathered for 15 months as well as the information about cost, maintenance and lifespan, how likely would you be to use each of the presented materials for a façade of your home?**

(materials AI, BL, CF, DK, EG, HJ)

extremely unlikely (1)	very unlikely (2)	unlikely (3)	in between (4)	likely (5)	very likely (6)	extremely likely (7)

7. **Please state your age:**
   a) 18-25
   b) 26-37
   c) 38-50
   d) 51-64
   e) 65+

8. **Please state your gender:**

9. **Please characterize your living environment:**
   a) urban
   b) suburban
   c) rural

10. **Please state your occupation:**
   a) student: ……………… *(field of study)*
   b) working
   c) non-working

Thank you for your participation!

Appendix B: Anonymized data

Remesova, Hana, & Burnard, Michael. (2020). Data cleaning and analysis for the Master's thesis: DIFFERENCES IN CONSUMER PREFERENCES FOR UNWEATHERED AND WEATHERED WOOD (Version 1) [Data set]. Zenodo. http://doi.org/10.5281/zenodo.3981177