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STATUS QUO OF AUSTRIAN TIMBER CONSTRUCTION SECTOR

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ABSTRACT: The application of industrialized timber in large-volume buildings is considered as one main strategy promoting sustainability in the construction sector. Austrian timber construction ecosystem is mainly conformed by small and medium sized enterprises (SMEs) that are mostly limited to single and multiple housing projects and it is rarely represented in multi-storey buildings. Within a five days' workshop, 19 experts from research and practice including SMEs, discussed the challenges and potentials, and specially the implication of SMEs, by the completion of those, exchanging experiences and expertise. The workshop was inductive coded looking for factors affecting the design and construction process, in which seven categories were defined containing 33 overall concepts with 105 factors embedded. Further, a SWOT analysis was conducted, in which over half of all factors are conflicts, mostly related to the coordination of the team along the process, mainly caused by the lack of an integrated design approach. Highly positive rated are those aspects related to greater levels of prefabrication, while general rising awareness together with political support represent relevant opportunities, and common prejudices a threat. This overview of the sector may help further research to develop strategies focused on handling internal factors to exploit opportunities and minimize threats.

KEYWORDS: Multi-storey timber buildings, off-site construction, design and construction process, SWOT Analysis

1 INTRODUCTION

Construction sector has been performing widely unsatisfactorily along decades. While productivity [1], digitalization, profitability and customer satisfaction remain low, risks, claims, fragmentation, insolvencies, and budget, and time overruns arise [2]. Its ecological and environmental impact has become also an issue, as it is responsible for 32% of the waste generated annually [3] and the largest producer of CO_2 emissions worldwide [4], being a large part of these a result of cement production [5]. A shift in construction sector, including processes and working methods, is expected in an early future, in which the introduction of new materials and the promotion of the digitization, the industrialisation and the automation will play a major role as a response to combination of higher sustainability requirements, increased cost pressure and a general shortage of skilled workers [2]. Industrialized timber construction is seen as an attractive ecological, economic and social solution to reshape the sector and assess its significant impact, especially in terms of resource efficiency, comfort and carbon emissions together with their atmospheric concentration [6–10]. This disruptive solution is gaining interest from various stakeholders, meaning great chances to take the lead in upcoming years, but also large concerns related to the lack of experience of new entrants. Due to its multi-layered character and own value and supply chain, planning and building with timber involves different actors, approaches and expertise [11, 12], and yet there exists no common understanding about interdependences what leads to inefficient collaboration and large conflicts meaning higher costs, time overruns, tension and dissatisfaction [13]. Previous studies have shown higher concerns in the production and assembly phase of a industrialized timber construction than in the acquisition and design phase [14]. Timber construction companies in Austria are small and scattered, and the structure of the industry is very fragmented and locally organized [15]. Its traditional approaches and its average sizes lead to mostly small projects. For example in 2019, 65% of all new buildings were residential and with one or two apartments, while just 11% had three or more apartments [16]. Nevertheless, a growing trend towards multi-storey timber construction can be appreciated within the last years [17], where the involvement of small and medium-sized enterprises

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(SMEs) is very challenging. On the one hand, this small size reduces the competitiveness of those companies in the completion of large-volume residential constructions in comparison to their larger competitors on the market. On the other hand, through this regional supply chain and fragmented structure, local value is added and resilience in crises is ensured. In addition, the global monopoly positions of large companies should be reduced to the detriment of local companies in order to facilitate a social balance. This study deals with the identification and analysis of factors affecting the completion of multi-storey timber buildings, specifically from the point of view of SMEs.

2 METHODOLOGY

This explorative study was developed based on two previous projects, a series of round tables organised by *MAGK Architekten* and *ecoplus Bau.Energie.Umwelt Cluster NÖ* named *Holz.System.Bau* [18], and a multi-case qualitative analysis based on experts' interviews [14], where the main barriers against timber use in large-volume constructions were analysed and strategies were discussed. This specific workshop called *Holzbau 4.0* was developed and run by the Vienna University of Applied Sciences in cooperation with *ecoplus Bau.Energie. Umwelt Cluster NÖ,* and funded by the Austrian Agency for the promotion of research *FFG* (*Österreichische Forschungsförderungsgesellschaft*). The five days' workshop was recorded, documented and inductive coded within several iterative rounds. Additionally, a SWOT analysis was run, in which the defined codes were classified as Strengths, Weaknesses, Opportunities and Threats. Figure 1 represents the overall process of this study with its steps from data collection to analysis and findings.

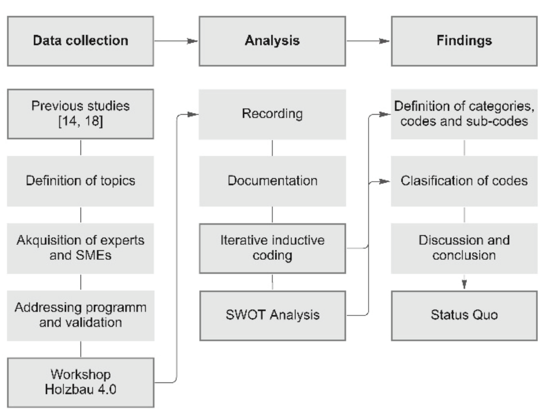

Figure 1: *Overview of the project*

2.1 DESCRIPTION OF THE WORKSHOP

The five days-workshop aimed to offer an exchange platform where to discuss the status quo of the industry with its barriers and opportunities. Once the overall topics were defined, participants were purposive sampled. Experts from science and practice including SMEs were selected to participate actively in the workshop. Several previous cooperative rounds were organized to address specific topics, goals and working methods, in alignment with the needs of all 19 participants, conformed by three researchers and seven planners with an average experience of 20 years, and nine professionals with key roles from six SMEs, including carpentry and timber components, glass construction, pluming, roofing, and lean management (Table 1).

Table 1: *Summary of participants within the workshop*

Area of expertise	N° participants
Research	3
Architectural design	5
Specialist consultants	2
SMEs employees	9

The workshop combined theoretical inputs and practical application in form of a cooperative project exercise with group discussions and reflexions, and was organized around the following five thematic blocks:

1. Team and process
2. Business models and cooperation processes
3. Systemisation and digital tools
4. Prefabrication and logistics
5. Equal opportunities

The first unit addressed a common understanding of an expected change in construction sector and its processes due to digitization and automation, exploring new ways of thinking, and establishing a common vision about the innovativeness, resilience and competitiveness of SMEs. Within the second unit, various business models and cooperation processes were explored, including legal framework and specific logistical, technical and digital aspects and requirements for large-volume timber buildings. The focus of the third unit was on systemisation, standardisation and digital tools for collaborative work. Design and production planning were compared in terms of level of information, development and detail, while several digital tools for design and production were explored, including their interfaces, working processes and information exchange. Building services and their standardization were extensively explored, together with prefabricated wall-elements and volumetric modules. The fourth unit was dedicated to production, prefabrication and logistics, where best practice examples were discussed, and methods based on Lean Management and efficient logistics were explored, together with their application to design, production and assembly. Topic of the last unit was equality and fair opportunities encompassing different social and political aspects, like funding, anti-discrimination, and laws. To conclude, feedback was collected, and a networking round offered to ease possible future cooperation.

To practically assess the acquired knowledge, participants were divided in two teams for an interdisciplinary and

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cross-company teamwork to analyse two different existing multi-storey residential buildings and collaboratively develop a new planning and construction process, aligning trades, identifying interfaces and players, and optimising tasks with milestones and deliverables. Both projects were alike in terms of volume, construction and height, but different in the financing type, being one private and the other one public with their corresponding focus, process model and tendering as shown in Table 2.

Table 2: *Description of both projects*

	Project A	**Project B**
Approach	Private	Public
Focus	Individuality	Fixed budget
Quality	High-Tech	Low-Tech
Process model	Cooperative	Traditional
Time of tendering	Irrelevant	Fixed

Besides exploring suitable cooperative planning and building systems and its intrinsic high competence level, other soft aspects like trust, willingness to work together and innovative ways of thinking were discussed.

3 FINDINGS

3.1 QUALITATIVE ANALYSIS

The five days' workshop was analysed qualitatively through an iterative process of coding and categorizing. Excerpts representing relevant factors affecting the correct and efficient design and construction of multi-storey timber buildings were referred into sub-codes and further organized into codes and overall categories. A total amount of 105 sub-codes were identified and structured into 33 codes and seven categories according to their content and relations. The distribution of categories and their codes is shown in Figure 2.

The category *team and process* is the one with the highest amount of codes with seven, followed by the categories of *product and performance*, *mind-set of the industry* and *competence and expertise* with six codes each (Figure 3). *State of the industry* has five codes and the categories with the fewest numbers of codes are *awareness* with two, and *politics and funding* with one. Attending to the sub-codes embedded in each code the relevance of the categories remains the same, being the only difference the higher amount of sub-codes by the category *state of the industry* with 15 in relation to the ones by *competence and expertise* with 13. Therefore, the same structure remains, being *team and process* the one with the highest amount of sub-codes with 25, followed by *product and performance* with 19, and *mid-set of the industry* with 17. The categories *awareness* and *politics and funding* encompass 11 and five each.

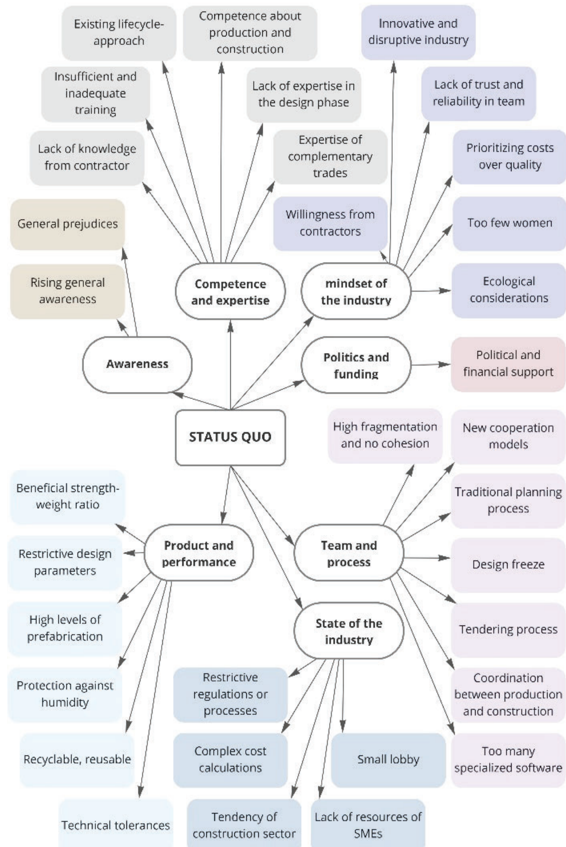

Figure 2: *Relation of codes and categories*

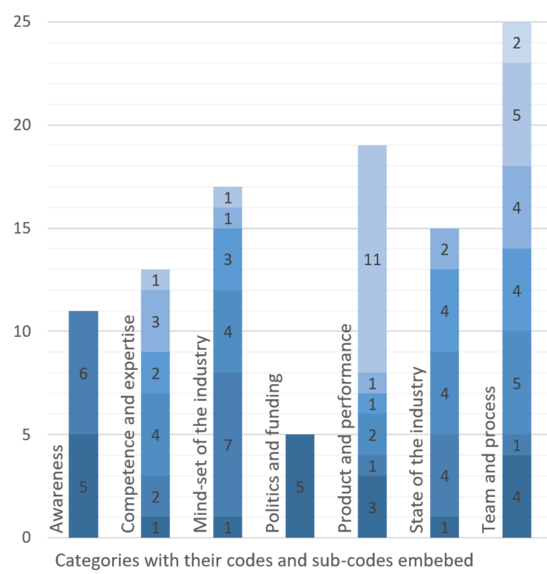

Figure 3: *Categories with their embedded codes and sub-codes*

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3.1.1 Awareness

This category refers to the consciousness of general society related to the capabilities and properties of timber applied to large volume construction and encompasses two codes with overall 11 sub-codes as represented in Table 3.

In common terms there exists a great deal of mistrust and scepticism towards industrialized timber constructions, based mainly on general prejudices of inadequate performance related to cost efficiency, fire protection, noise insulation, structural response and durability. Nevertheless, a changing attitude and a rising general awareness about more sustainable procedures have been recognized. The ecological and healthy properties of timber supports this shift as a response to the rising resource scarcity, the higher carbon emissions and the new social and economic requirements of the sector and society.

Table 3: *Sub-codes and codes in the category "Awareness".*

Awareness (2) (11)	
General prejudices (5)	**Aw1**
· Too expensive · Fast combustion · Not enough noise insulation · Lack of durability · Little structural resistance	
Rising general awareness (6)	**Aw2**
· End of fossil energy and materials · Ecological properties of timber · Aesthetics and comfort · New generation, new requirements · Resources scarcity · Shared economy incl. platforms	

3.1.2 Competence and expertise

Due to its multi-layered character, its material properties and its different value and supply chain, planning and building with timber implies specific approach and competence, which are different from those widely used within mineral constructions. Related to this issue, six codes with 13 associated sub-codes were defined and are represented in Table 4.

A common lack of knowledge and expertise was found from the side of the contractor, complementary trades and planners. Due to their little experience, contractors refuse to build with timber, while the lack of expertise of complementary trades implies higher mistakes rate on site and therefore higher coordination efforts to avoid them or minimize their impact. General architects and engineers also lack competence related to the higher complexity of large industrialized timber constructions, mainly due to insufficient and inadequate training, where little know-how is found as well in common architectural and engineering trainings, as in specialized. On the contrary, there exists a recognisable competence of manufacturers and construction companies about production and construction, and a beneficial lifecycle-oriented approach.

Table 4: *Sub-codes and codes in "Competence and expertise".*

Competence and expertise (6) (13)	
Competence about prod. and constr. (1)	**Co1**
· High competence of manufacturers and constr. companies	
Insufficient and inadequate training (2)	**Co2**
· Lack of know-how in conventional training · Lack of specialized trainings	
Lack of expertise in the design phase (4)	**Co3**
· Related to common planers · High complexity of specific software · Overestimation of own competence · Underestimation of complexity	
Existing lifecycle-approach (2)	**Co4**
· Interdisciplinary multi-layered character · Lifecycle costs approach	
Expertise of complementary trades (3)	**Co5**
· High mistakes rate related · Higher coordination effort on site · Lack of competence or expertise	
Lack of knowledge from contractor (1)	**Co6**
· Little knowledge and experience	

3.1.3 Mind-set of the industry

In this category, those aspects related to the attitude or way of thinking of the construction sector are referred, encompassing six codes and 17 sub-codes (Table 5).

Table 5: *Sub-codes and codes in "Mind-set of the industry".*

Mind-set of the industry (6) (17)	
Green washing (1)	**Mi1**
· Use of timber as marketing	
Innovative and disruptive industry (7)	**Mi2**
· Towards open mind-set, ready for new · Open-source databases (projects / network) · Rising number of small start-ups · Rising number of young experts · Little speculation · Transfer of Lean concepts · Rising number of independent planning eng.	
Lack of trust and reliability in team (4)	**Mi3**
· No transparency / communication · Lack of trust and reliability in design team · Lack of trust between SMEs · Silo thinking and lack of cooperation of SMEs	
Prioritizing costs over quality (3)	**Mi4**
· Criteria within arch. competitions · Criteria within tendering processes · Conventional investments' criteria	
Too few women (1)	**Mi5**
· Too few and with no key roles	
Willingness from contractors (1)	**Mi6**
· Rising willingness	

Although the rising willingness of contractors to build with timber is remarkable, conventional investment criteria based primarily on prioritising cost over environmental or health benefits make its actual implementation difficult, as it occurs within architectural competitions and tendering processes. At the same time, the misuse of timber as “green washing” represents a threat that must be kept under control. Focusing directly on the timber industry, its innovative character was highlighted, with the transfer of concepts from other industries as well as disruptive start-ups, open-source platforms, young experts and independent planning engineers playing a role, but in which women are too rare and with no key positions, and a general lack of reliability between players is found.

3.1.4 Politics and funding

Only one code with five sub-codes comprehends this category, where current topics related to political and financial support were addressed (Table 6).

The great environmental impact of construction sector has led to the development of several political initiatives to promote and accelerate a shift from a mineral-based and resource-intensive sector towards a bio-based and resource-saving one, including circular economy and re-densification as a reaction of current shortage of urban space and resources, with timber playing an important role. Existing European initiatives to promote sustainable building methods were discussed as examples for their application in further countries, including the French government's requirement to use at least 50% wood and other bio-based materials in all new public buildings [19]. Additionally, carbon fees and financial support for circular bio-based constructions help to minimise the use of carbon intensive materials.

Table 6: *Sub-codes and codes in “Politics and funding”.*

Politics and funding (1) (5)	
Political and financial support (5)	**Po1**
· Carbon (CO_2) fees · Financing of bio-based construction · Reinforcement of re-densification · Fix % of timber in public financed projects · Rising awareness towards circular economy	

3.1.5 Product and performance

This category contains the higher amount of codes with six and sub-codes with 19 (Table 7) after the category *team and process*, and refers to the characteristics of timber as construction material.

Recyclability was highlighted as highly advantageous, as was the strength-to-weight ratio, which allows great degrees of prefabrication and therefore higher material efficiency and quality due to industrialised production processes, reliable stock-keeping, cost and time calculation, as well as shorter overall project time due to optimised assembly work on site with less coordination efforts and parallel work in the factory. Further benefits of prefabrication include the construction of mock-ups to run different tests and the possibility of tracking the whole supply and production chain. At the same time, specific parameters related to production, transport, assembly and structural performance influence the design. Particular attention must be paid to tolerances to other materials and moisture protection, especially on the construction site and for building elements, but also when planning the building services and the façade.

Table 7: *Sub-codes and codes in “Product and performance”.*

Product and performance (6) (19)	
Protection against humidity (3)	**Pr1**
· Complex planning of building services · Protection of the façade · Protection of building elements and site	
Recyclable, reusable (1)	**Pr2**
· Recyclable, reusable	
Restrictive design parameters (2)	**Pr3**
· Raster (uneconomical free forms) · Transport requirements	
Technical tolerances (1)	**Pr4**
· Between concrete and timber	
Beneficial strength-weight ratio (1)	**Pr5**
· Beneficial strength-weight ratio	
High levels of prefabrication (11)	**Pr6**
· Higher production quality · High industrialized production · Material efficiency (excl. CLT) · Mock-up (simulation and technical proof) · Reliable cost estimations after tendering · Reliable stock planning · Reliable time estimation · Parallel work on-site and in the factory · Tracking (RFID / QR-Code) · Assembly site (shorter construction time) · Less trades on site (less coordination)	

3.1.6 State of the industry

Aspects related to the current situation of the industry, including its capacities and developments, are assigned to this category, which encompasses five codes and 15 sub-codes as represented in Table 8.

In general, there are restrictive or inadequate regulations or procedures that make the use of timber difficult, especially with regard to fire protection or maximal height, and their different local specifications, but also the material-neutral character of most architectural competitions and the required technical proofs for specific construction elements and connections, before and after tendering. One way to force the needed adjustment of those is seen in the move of the construction sector towards a digitally connected, product-based approach, in which timber can play a main role due to its increasingly digital and industrialised manufacturing. Nevertheless,

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the timber sector has a small lobby with little influence on policies and a general low willingness of decision-makers to build with timber, partly due to the higher complex cost estimation before tendering and a lack of planners and reference projects, as well as an own timber oriented network. Also at the construction side, very few companies can act as general or total constructors and accomplish large timber constructions, as the ecosystem consists mainly of labour-overloaded SMEs with inadequate infrastructure and low financial strength and bank confidence.

Table 8: *Sub-codes and codes in "State of the industry".*

State of the industry (5) (15)	
Complex cost calculations (1)	**St1**
· Complex and not standardized	
Restrictive regulations or processes (4)	**St2**
· Material neutral arch. competitions · Technical proof of each solution · Restrictive regulations (fire, height…) · Lack of common standards (fire, noise…)	
Small lobby (4)	**St3**
· Acquisition of projects through own network · Small pool of partners · Lack of influence in policies · Little predisposition of decision-makers	
Lack of resources of SMEs (4)	**St4**
· Lack of financial capacity · Lack of infrastructure · Too few companies as general or total constr. · Resistance to adaptation (overloaded)	
Tendency of construction sector (2)	**St5**
· Towards product-based construction · Towards industry 4.0 (Smart/Virtual Factory)	

3.1.7 Team and process

This category has the highest number of both, codes with seven and sub-codes with 25 (Table 9), and includes aspects related to the coordination of stakeholders within design and construction along the course of a project.

The small and fragmented structure of SMEs limits cohesion due to locally organised logistics and own internal systems, resulting in an overwhelming repertoire of solutions that cannot be combined, and makes cooperation difficult, for which they often have to work as sub-constructor. The traditional linear planning process separates design and construction and therefore limits the inclusion of timber expertise in early design stages, including designers, manufacturers and suppliers. This results in complex and elaborate tendering processes with few bids, where details and joints have to be adapted, leading to an unnecessarily higher design workload forehand and extra redesign efforts after the tender. This planning process also complicates an interdisciplinary approach and the involvement of other disciplines such as building services, which reduces the required greater definition for the correct application of prefabrication. Several international cooperation models were discussed as examples of how to overcome this separation, which should be digitally supported, for what there are still too many incompatible specific software on the market. Another aspect to take into account is the need for a design freeze, where no late decisions or accompanying planning are possible, and therefore, an early inclusion of users' wishes is necessary. After the design freeze and tenders, the production line and construction site with their specific suppliers, capacities and delivery times must be coordinated including the combination of different elements, their transport and store logistics.

Table 9: *Sub-codes and codes in "Team and process".*

Team and process (7) (25)	
High fragmentation and no cohesion (4)	**Te1**
· Close systems and platforms (logistics) · Too many possible solutions · Lack of combination of 2D and 3D prefabrication · Traditional construction process (sub-constructor)	
New cooperation models (1)	**Te2**
· Alliances (UK, USA and Canada)	
Traditional planning process (5)	**Te3**
· No interdisciplinary approach · High influence of financing type to the process · Late inclusion of timber competence in design · Lack of prefabrication of building services · No inclusion of manufacturers and suppliers in the design (detailing)	
Design freeze (4)	**Te4**
· Early involvement of end-user (wishes, goals) · Late decisions (end-users, contractor, planners…) · Earlier higher definition · No accompanying planning possible	
Tendering process (4)	**Te5**
· Complex and elaborate tendering · Redesign after tendering (in-house systems) · Over-processing (interface between arch. to prod.) · Reduced bids, higher resources (redesign)	
Coord. between prod. and constr. (5)	**Te6**
· Higher logistics related to transport · Store capacity and time (logistics) · Different delivery times · Coordination between timber and concrete constr. · Coordination between prod. and constr. capacity	
Too many specialized software (2)	**Te7**
· Incompatibility between software · Open BIM still works like file transfers	

3.2 SWOT ANALYSIS

After coding and categorizing all identified factors, a SWOT analysis was carried out, checking that the sub-codes were also related to the character of the labelled code and ensuring coherence. Figure 4 represents all factors characterized as strengths, weaknesses, opportunities and threats, including codes and sub-codes.

Strengths and weaknesses refer to positive and negative internal aspects respectively. In contrast, opportunities and threats picture external factors that affect positively and negatively each. The amount of global internal aspects (strengths and weaknesses) is four times higher than the external ones (opportunities and threats). Analysing the proportion of positive and negative factors, the sector is represented with a two times higher amount of negative aspects (including weaknesses and threats), than overall positive factors (strengths and opportunities). Figure 4 represents the distribution of all codes and embedded sub-codes according to their character. Weaknesses embody over half of all factors, while strengths only around 1/5 of all factors, and opportunities and threats 1/6 and 1/17 each. That means that the sector is highly aware about its own issues and should develop strategies and set objectives to exploit own strengths and address own weaknesses with its current resources and capabilities, since its control over internal factors is higher than over external ones. These last ones can be influenced or at least anticipated, in order to avoid or minimize their impact, or to take advantage from them, but not fully controlled. All strengths, weaknesses, opportunities and threats are described in detail in the following sections.

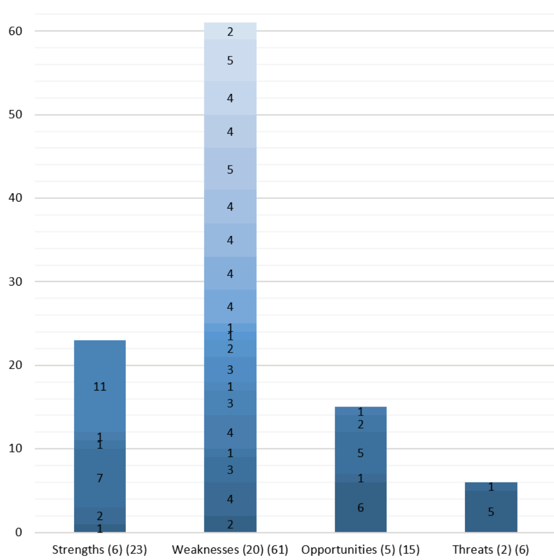

Figure 4: Summary of all codes and their embedded sub-codes classified according to the SWOT analysis.

3.2.1 Strengths

Table 10 shows a summary of all strengths, including their sub-codes, ranging from one to 11, with an average of 3.8, and representing around 1/5 of all factors with six codes and 23 sub-codes.

The high expertise about production and construction from manufacturers and construction companies together with the existing lifecycle-approach of the industry represent two strengths regarding *competence and expertise*, what ensure an efficient and effective erection of large timber constructions. Related to the *mind-set of the industry*, its innovative and disruptive character is a positive and significant factor with seven sub-codes that supports relevant improvement potential, while the recyclability and beneficial strength-to-weight ratio of timber represent two strengths related to the *product and performance*. Its consequent higher workability and greater prefabrication levels have the highest number of sub-codes with 11, being therefore the most discussed factor and the best-rated strength.

Table 10: *Codes identified as Strengths.*

Strengths (6) (23)	
Co1	Competence about prod. and const. (1)
Co4	Existing lifecycle-approach of the industry (2)
Mi2	Innovative and disruptive industry (7)
Pr2	Recyclable, reusable (1)
Pr5	Beneficial strength-weight ratio (1)
Pr6	High levels of prefabrication (11)

3.2.2 Weaknesses

Weaknesses encompass over half of all identified factors with 20 codes and 61 sub-codes ranging between one and five with an average of 3.3 (Table 11).

One of the most relevant weaknesses is the traditional linear planning process, which together with the lack of expertise in the design phase and reliability within the team, caused by inadequate specific training, constrain the right definition of industrialized constructions and their required design freeze. By separating design and construction, an integrated design is impracticable, where the amount of incompatible specialized software is also a problem. Mineral-oriented regulations, which have not been adapted to industrialised constructions mainly due to the small lobby of the sector, limit an earlier and correct assessment of timber buildings. Further, the high fragmentation and lack of cohesion of the industry make tendering processes complicated with complex cost calculations, fewer offers and re-design efforts, where also the prioritizing of cheapest offers over quality plays a negative role. Another major conflict is the coordination between production and construction, needing higher logistics, which may be caused by the lack of resources and infrastructure of SMEs. Although prefabrication was the most highly rated strength, the specific design parameters related to material properties and production and transport measures, and the consideration of technical tolerances to other materials are disadvantageous. Protection of the elements and the site from rain and moisture, together with increased coordination efforts on site due to the lack of experience of the complementary trades, represent further disadvantages.

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Table 11: Codes identified as Weaknesses.

Weaknesses (20) (61)	
Co2	Insufficient and inadequate training (2)
Co3	Lack of expertise in the design phase (4)
Co5	Expertise of complementary trades (3)
Co6	Lack of knowledge from contractor (1)
Mi3	Lack of trust and reliability in team (4)
Mi4	Prioritizing costs over quality (3)
Mi5	Too few women (1)
Pr1	Protection against humidity (3)
Pr3	Restrictive design parameters (2)
Pr4	Technical tolerances (1)
St1	Complex cost calculations (1)
St2	Restrictive regulations or processes (4)
St3	Small lobby (4)
St4	Lack of resources of SMEs (4)
Te1	High fragmentation and lack of cohesion (4)
Te3	Traditional planning process (5)
Te4	Design freeze (4)
Te5	Tendering process (4)
Te6	Coordination between prod. and constr. (5)
Te7	Too many specialized software (2)

3.2.3 Opportunities

The five opportunities with their 15 sub-codes are shown in Table 12 with an average of 3.0., and representing 1/6 of all factors.

The main opportunity is the general increase in awareness, which can expand the collective pressure to accelerate the sector's shift towards more sustainable strategies that reduce embodied carbon and store carbon in buildings while forests sequester it. Political and financial support is seen as a major opportunity to support this transformation by promoting bio-based solutions. The tendency of construction sector from design-oriented to product-oriented is also considered as a chance to promote prefabrication, what together with a perceived higher willingness of contractors and the implementation of new cooperation models represent relevant opportunities for the right design and construction assessment of large timber constructions.

Table 12: Codes identified as Opportunities.

Opportunities (5) (15)	
Aw2	Rising general awareness (6)
Mi6	Willingness from contractors (1)
Po1	Political and financial support (5)
St5	Tendency of construction sector (2)
Te2	New cooperation models (1)

3.2.4 Threats

Threats summarize the fewest amount of factors with only two codes and six sub-codes, as shown in Table 13, and representing around 1/17 of the total discussion.

Common prejudices like insufficient fire protection or noise insulation represent the most threatening aspect that affect the wider implementation of timber in large constructions with five embedded sub-codes, where a better communication of its benefits could help. At the same time, its misuse as the so-called green washing could be enormously disadvantageous, and therefore should be avoided and coherently implemented.

Table 13: Codes identified as Threats.

Threats (2) (6)	
Aw1	General prejudices (5)
Mi1	Green washing (1)

4 DISCUSSION

Locating all strengths, weaknesses, opportunities and threats in their corresponding categories, an overview of the status quo of the timber sector with its positive and negative factors is shown in Figure 5.

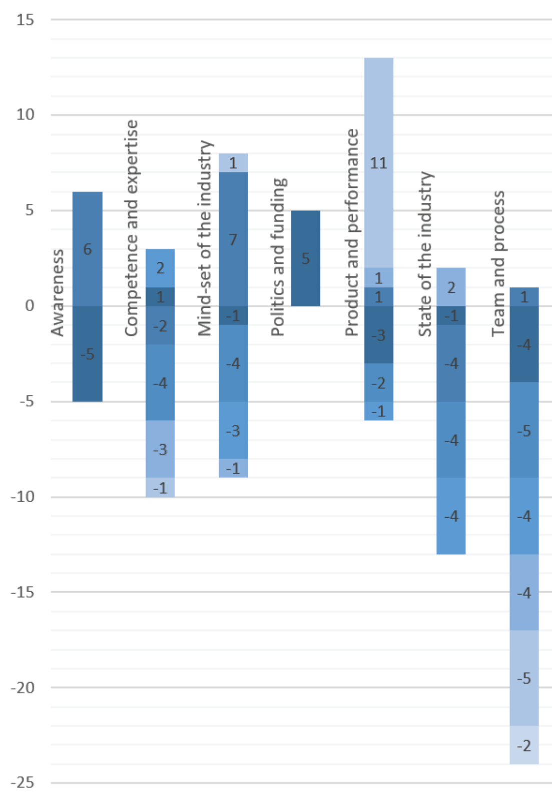

Figure 5: Positive and negative aspects related to their categories

Team and process, *product and performance* and *mind-set of the industry* were the most discussed categories with the highest number of codes and sub-codes as shown in Figure 3. *Team and process* account the greatest number of both codes and sub-codes with seven and 25, being all of them except one classified as weaknesses what makes it the most conflictive category. Only the application of new cooperation models is seen as an opportunity to overcome all the weaknesses in this category, which are mainly caused by the traditional lineal and fragmented planning process with its separation of disciplines constraining a coordinated and cooperative working method with a design freeze and making tendering processes complicated.

Contrary, the second most discussed category, *product and performance*, is the one with the highest amount of strengths with three codes and 13 sub-codes which encompass aspects related to the recyclability and workability of timber and its associated higher levels of prefabrication. At the same time, three codes with six sub-codes were classified as weaknesses, which relate to the restrictive design parameters due to off-site construction and their correlated technical tolerances to other materials and the necessity of rain and moisture protection of the elements and the site.

Mind-set of the industry may be the most controversial category, being the third most discussed and sharing equally positive and negative sub-codes. Its innovative and disruptive character is seen as a great strength with seven sub-codes that could help against weaknesses by increasing trust in the team, and fostering gender equality, as well as rewards based on quality rather than on the cheapest offer. Further, a perceived increase in the willingness of contractors to build with timber is seen as a great opportunity to implement its use, but in a coherent way and no as green washing, what is considered a threat.

State of the industry is the second most conflictive category after *team and process*, where only one code with two sub-codes are classified as opportunities, and four codes with 13 sub-codes as weaknesses. Many regulations are not aligned with industrialized construction, which limit common standards and increase complexity, making the sector unattractive, which therefore consists on few overburdened experts lacking resources and infrastructure. The tendency of the sector from a design-based and labour-intensive construction site towards a product-based assembly site is seen as a chance to force the required adjustments and ease the completion of industrialized large timber constructions.

The third most conflictive category is *competence and expertise*, where two codes with three sub-codes are rated as strengths, while four codes with 10 sub-codes as weaknesses. There exists a lack of adequate specific training in architectural and engineering degrees, leading to very few competent designers or rather little expertise in design, and conflicts at the interface with construction. Parallel, complementary trades lack of experience causing greater coordination efforts on site due to higher risks. On the contrary, construction companies and manufacturers have remarkable knowledge regarding production and construction that should be exploited and transferred, together with the holistic design approach of experts covering the lifecycle of buildings and materials.

The category *awareness* encompasses equal number of codes and sub-codes classified as opportunities and threats. The rising general awareness about reducing carbon emissions and using more sustainable materials should be exploited, while general prejudices minimized.

The least discussed but most highly rated category is *politic and funding*, since its single code with five sub-codes are classified as opportunities. This category covers policy and financial support to move from lineal constructions with carbon-intensive materials to circular buildings with bio-based materials.

5 CONCLUSIONS

A wider use of timber within large-volume construction is seen as a disruptive ecological, economic and social solution to mitigate the great environmental impact of construction sector, while increasing wellbeing, productivity and promoting circular economy. On the one hand, its bio-based nature reduces carbon emissions, absorbs it from the atmosphere and stores it in the long term, while on the other hand, its renewable character and beneficial strength-to-weight ratio alleviates the scarcity of resources and the lack of urban space respectively. It also promotes higher productivity and resource efficiency thanks to its greater levels of prefabrication and advanced industrial production logistics. These characteristics imply different actors, processes and expertise than for mineral constructions, leading to a multitude of errors, inefficiencies and misunderstandings. This study takes a close look to the factors affecting the right definition and completion of large-volume timber constructions with a special focus on the production and construction side by implying SMEs with their expertise and experience. A five days' workshop was organized with 19 experts from science and practice including SMEs employees with key roles, where challenges and chances of their implication in the completion of multi-story timber buildings were discussed. The explorative study was inductive coded, where 105 factors were identified and labelled into 33 more generic concepts and organized into seven categories. Further, a SWOT analysis was run, in which the recognized strengths, weaknesses, opportunities and threats were located in their corresponding categories. The coordination of the team along the process to achieve an integrated design, which supports the right assessment of prefabrication, represents a major conflict, while prefabrication itself with their corresponding benefits is considered the greatest strength of the sector. Cooperation models supported by the tendency of construction sector towards a product-based approach are seen as opportunities to overcome this prominent barrier and exploit this strength. A general rising awareness together

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with political support to move away from carbon intensive materials represent another relevant opportunity, while common prejudices related to insufficient fire protection constitute a main threat. Further research may use this overview of the status quo of the sector to develop strategies and set objectives, in which internal strengths can be used to exploit external opportunities (SO strategies), as well as to avoid or minimize the impact of external threats (ST strategies). At the same time, internal weaknesses can be overcome by exploiting external opportunities (WO strategies) while minimizing external threats (WT strategies).

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