

PAPER • OPEN ACCESS

## Adaption of construction management aspects and building economic principles to prevent cost overruns in modern timber construction

To cite this article: J Koppelhuber and M W Bok 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **800** 012030

View the [article online](#) for updates and enhancements.

# Adaption of construction management aspects and building economic principles to prevent cost overruns in modern timber construction

J Koppelhuber<sup>1\*</sup>, M W Bok<sup>1</sup>

<sup>1</sup> pm holzbau – Sporgasse 11, 511a, 8010 Graz, Austria

\*Email: koppelhuber@pmholzbau.at

**Abstract.** The timber construction industry is subject to continuous development and steady modernisation worldwide. This leads to a compelling necessity regarding highly industrialised and standardised processes – both technological and economical – along the value chain of today's timber construction. Within this field innovative materials and products (such as cross laminated timber – CLT) in combination with a deeply rooted systematic approach are used to create large span and multi-storey timber structures. The results are displayed in an increased use of (partially) automated machines and production plants, novel (semi-)prefabricated components as well as complex software solutions. However – next to numerous technical researches – numerous aspects within construction management and building economics require intensive investigation. Since the influencing factors from economical point of view have been criminally neglected over the past decades it becomes apparent that aspects such as cost planning and estimation, invitation and call for tender as well as cost calculation of timber construction projects demand comprehensive research. Therefore, an outstanding and all-encompassing investigation has been carried out over the past 6 years in Austria at the University of Technology in Graz [1] to identify, develop and implement building economic principles and relating tools focussing exclusively on timber construction. Therefore, the emphasis was set on the development and practical implementation of timber-specific solutions in order to avoid cost overruns and hidden costs during design, construction and use. Possible approaches to solve this lack of economical and operational instruments in timber construction are discussed in this paper.

## 1. Introduction

The evolution of timber constructions in the 21<sup>st</sup> century is primarily driven by technological advancements on product level and its production methods. Meanwhile, the principles of building economics regarding cost planning, cost calculation and invitation and call for tenders have not been adapted adequately to this rapid technological development. Practical tools specially adapted for the timber construction sector have received insufficient attention resp. have been neglected entirely for a long time. This results in a flagrant information deficit, based on the combination of a lack of reliable data and a largely missing processing of the few existing findings and parameters for the construction companies, developers, architects as well as other parties involved along the construction and design process.

A sole transfer of universal principles and values from conventional concrete and masonry construction into timber construction is only possible to a limited extent. Because of company-significant demands and industry-specific requirements as well as the fact of a completely contrary



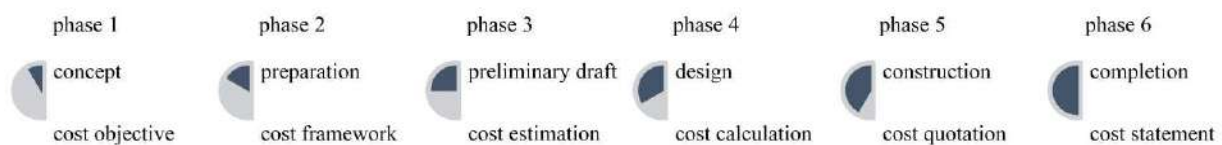
production and building process, the development and establishment of independent procedures and implementation tools is necessary.

However, the timber construction industry is – due to the latest developments in recent years as described below – on a continuous path to liberate itself from its infancy regarding building economics and to carry out a holistic professionalization from a contractual perspective. In addition to numerous other issues such as the ongoing debates concerning the overall design process and the long-term strategic challenge to find a way out of the so called “price war” within the construction industry, the topics of cost planning, tendering and cost calculation need to be solved in the near future.

In the following passages the status quo (SQ) for economic aspects within the timber construction industry regarding especially these three thematic fields is presented and feasible solution approaches (FSA) are discussed. Current developments which have already begun or are still pending as well as their potential long-term impact on the industries are subsequently described.

## 2. Aspect I – budgeting / cost planning

Austrian Standards International which publishes all Austrian Standards as public national institutions divides the planning of construction costs (as part of the quality, cost and time triangle) in six subdivisions following the Austrian Standard OENORM B 1801-1. Within the cost sequences specific cost management tasks need to be carried out for each stage of the construction and by becoming more precisely the further the project is developed. These stages of budgeting are depicted in the following figure.



**Figure 1.** Budgeting in six stages of cost planning referring to the OENORM B 1801-1[2]

The cost objective and the cost framework of a project, which represent the first two stages within the cost planning procedure, as well as their consistent compliance are decisive in the pursuit of a positive project completion. The responsibility for an accurate cost planning and monitoring lies in the hands of the contracting authority resp. the planning representative of the client. Different interests of the builder, the authorized designers or the local construction supervision often result in an opportunistic behaviour towards the building contracts. The cost calculation within the cost planning process (conducted by the contracting authority in the design phase) must be distinguished to the calculation of the construction costs (conducted by the contractor during the tender process) described in chapter 4.

### 2.1. Status quo in the timber construction industry

Timber construction companies increasingly offer in many cases a high added value on the market in comparison to general contractors or even as design and build-contractors. This is especially necessary when large-scale multi-storey construction projects are realized primarily with timber. Therefore, timber construction must prove itself technically but above all financially to the competitors building with concrete. A comparable and sound cost planning is therefore without any alternative.

Due to insufficient or non-existing cost indicators within the budgeting cost estimations (phase 3 preliminary draft), cost calculations (phase 4 design) and cost quotation (phase 5 construction) for timber constructions is often inadequate, less resilient and generated on the wrong basis. The missing data leads directly to the circumstance that a neutral and conclusive cost comparison between timber structures and conventional structures is rarely possible in practice. At this stage the costs of a timber construction are mainly estimated from literature sources generated outside the industry mainly not timber-specific and not reflecting the current technical innovations at the product level. A temporary solution is often a superficial cost planning based on internal empirical values and rough estimations. Only in a few cases adequate cost parameters on a neutral and technical accurate basis are available. The result is a strongly

distorted and unjustified budgeting in which timber structures are often portrayed as financially disadvantageous.

Furthermore, most construction projects are designed to be realized with reinforced-concrete, bricks or other conventional building materials. Timber construction companies therefore frequently have to offer their value proposition as alternative, which consequently provokes additional costs as the design is not timber specific and their inadequate. This focus on a certain construction method in early project phases complicates a valid cost comparison on a neutral basis.

An additional complication is the unequal quality expectations regarding different construction methods. Experience have shown that a higher level of quality standards is more often required in timber structures than compared to conventional concrete structures. The average timber construction provides a higher equipment standard than other building methods (e.g. wood-aluminium windows and doors instead of PVC-products, parquet instead of laminate, shingles instead of thin plaster, wood-fiber-insulations instead of EPS-insulation, etc.). Often cost planning based on empirical data does not exclude the cost of interior components and design elements, which contributes to the common misconception regarding the economic efficiency of timber constructions.

#### STATUS QUO (SQ) – BUDGETING / COST PLANNING

- insufficient cost indicators and parameters on a neutral on a technical accurate basis
- construction method requires a specific design process and cost estimation
- cost comparison of structures is not on an equal equipment standard

**Figure 2.** SQ budgeting – cost planning phases in timber construction

#### 2.2. Feasible solution approaches for the timber construction industry

Following these facts, it is of considerable importance to pursue the goal of providing the key decision-makers in the cost planning process with comprehensive and (company-)neutral cost indicators, figures and parameters which are in line with the current state of the art.

Furthermore, a cost comparison between different building materials and/or construction methods must be based exclusively on the shell construction to eliminate unequal demands regarding interior elements and equipment features from the equation. The wall, ceiling and rooftop elements as well as other structural components distinguish certain construction methods from each other, while must finishing elements of the expansion as well as the equipment are not construction specific. All elements such as windows, doors, facades, roof coverings, floors, building services (heating, air conditioning, ventilation, sanitary provisions) and electrical wires are therefore not to be considered in the original cost comparison of the building material / construction system / construction method. These will only be included in the overall calculation at the time of the final cost calculation, which enables a neutral cost comparison based on an equivalent with respect to analogousness referring to statics and building-physics (same static function, deflection, heat transition coefficient, sound insulation and fire protection etc.). Without these measurements timber construction methods cannot be assessed on a neutral base and fair arrangement. The current conditions deprive developers and architects of a real alternative to conventional construction methods and unfairly hinders the progression of environmentally friendly construction methods.

Numerous construction surveys following the systematic of REFA have been undertaken by the author within his former function as scientific researcher at the Institute of Construction Management and Economics (BBW) at University of Technology in Graz (Austria). They have shown that timber construction can be identified as cost neutral in identical circumstances [3][4][5]. This applies to timber frame construction, solid timber construction (CLT) as well as timber-concrete-composite constructions (TCC). Additional soft facts, such as lower wall thicknesses (and therefore a greater floor space), shortened construction times (earlier building utilization or rental/sale income) and less CO<sub>2</sub>-emissions

(avoidance of potential carbon taxes) are additional aspects, which will also have to be considered financially in the future.

### FEASIBLE SOLUTION APPROACHES (FSA) – ASPECT II BUDGETING / COST PLANNING

- collection and aggregation of accurate cost indicators and parameters in a neutral and up-to-date database
- definition of component properties (equal static and building physic) instead of specific structures
- promotion of a cost estimation and cost comparison based exclusively on the shell construction

**Figure 3.** FSA – budgeting / cost planning in timber construction

### 3. Aspect II – invitation and call for tender

In accordance with the fundamental principle "a good project requires a good tender" the question occurs how to translate a sound design into a complete tender dossier to provide the best possible basis for a contractual framework which prevents cost overruns, construction time extensions and legal disputes. The underlying tendering process plays an essential role in achieving a smooth transition from design to construction in the traditional design-bid-build project delivery method (figure 4) and helps to avoid the previously mentioned undesired monetary, temporal and legal impacts on the overall project.



**Figure 4.** Six stages of the tender process in the design-bid-build project delivery method

Especially in private / commercial tenders an additional negotiation stage between the submission of tender and the procurement procedure is quite common. Furthermore, a complete, transparent and resilient tendering process is highly important between contractor and subcontractor as well as between contracting authority (client or authorized architect) and bidders (design and build contractors or general contractors). The previously stated budgeting procedure shown as cost planning sequence (especially the cost calculation by the contracting authority) sets out a precise presentation of the technical specifications, components and services to be produced as well as the expected circumstances for the construction works. The latter must be recognizable in quality and quantity to allow a precise construction cost calculation by the bidder.

In order to take the aforementioned facts into account the contracting authorities in Austria have relied on the federal government's standardised specifications in form of standard texts for tenders for the entire construction (LB-HB) for the past decades, which covers approximately 80% of all construction works carried out in the general building sector. The descriptions are in a textually precise and comprehensive manner and pursue the principle that building services are to be clearly, completely and neutrally describable.

#### 3.1. Status quo in the timber construction industry

Due to the rapid product innovations, the continuously adaption of new detail solutions and modern connection methods as well as the ever-increasing performance levels in timber construction the aged carpenter specific group of technical specifications included in the LB-HB had to be updated significantly to adapt to the state of the art. The newly released version of the LB-HB 021 (officially released by the Austrian government in December 2018 [6]) includes an up to date timber specific

description and extensively recreated group of technical specifications (the so-called LG 36) for the entire timber construction industry. This allows a comprehensive and detailed technically adequate tender in timber construction due to a completely different structure sectioned in components (wall, ceiling, roof, etc.) as well as in vertical and horizontal layers (support structure, insulation, interior clothing, facade, etc.). General and particular technical specifications in a standardised way enable both the contractor and the contracting authority to tender as well as calculate according to a clear scheme and provide a structure similar to the widespread tender procedure of the conventional construction methods. It also saves time and costs, because it allows the bidder to provide a detailed cost calculation of the individual items quickly and effectively.

While the reworked standardised specifications for timber construction in Austria is a first step into the right direction other countries with a lower market share of timber buildings lack comparable procedures for a timber-adequate tender process which leads to an unlevel playing fields on the international level. Cross-border standards (e.g. Eurocodes) which represent the state of the art in timber construction in a technical way are currently not available for an international standardised tender referring to contractual topics.

While the rapid technological progress in the timber industry is accountable for its sharp increased market share it aggravates the development of timber-specific solutions. National and international standards and regulations as well as implementation tools in the timber building industry must be updated continuously to keep up with the technological advancements. Due to well-filled order books timber construction companies often do not have the time, interest and/or motivation to deal with advancements in the field of building economics and construction management. This results in a loss of opportunities, time and money plus a risk of legal consequences as well as an exclusion during the tender process because of insufficient tender documents or inadequate formulations.

#### STATUS QUO (SQ) – TENDER PROCESS AND PRINCIPLES

- standardised specifications for timber construction are adjusting to the traditional procurement
- international and national standards and regulations often do not represent the state of the art
- limited usage of building economic and construction management tools by timber companies

**Figure 5.** SQ – tender process and principles in timber construction

### 3.2. Feasible solution approaches for the timber construction industry

In order to achieve a comprehensive and nevertheless detailed tender incorporating timber construction methods the use of the previously described standard specification for building construction is vital to allow little to no possibility of additional cost claims and construction time extensions. A neutral tender regarding building material (with technical objectives regarding static and building physics as suggested in chapter 2.2) as well as a timber-specific tender must describe the technical specifications, components and services adequately with enough detail to allow a precise construction cost calculation by the contractor.

Due to the ascent of timber construction companies from a regional niche to global players international standardisation of products, services and technical components as well as a timber-compatible tendering process are overdue – if not worldwide at least pan-European. This development is imminent to provide sustainable and innovative construction methods like timber with an equal chance to succeed.

The usage of such standardised tender concepts and economical tools within the tender process in all construction projects also means to deviate from the mostly contradictory, company-specific tender texts and preliminary remarks that have been widespread in the timber industry for decades. Thus, a product- and company-neutral tender in timber construction is possible, which in turn allows a solid, detailed and comprehensible construction cost calculation as well as a specific cost determination without a high risk premium due to insufficient clarity resulting from inadequate design and non-standardised contractual specifications.

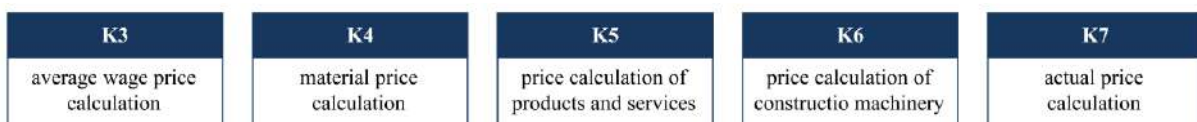
Ultimately, this step towards standardised tendering in timber construction also forms the basis for a continuous compliance with the previously cost framework that lasts until the project is completed and does not result in a contractual framework far from reality – which is often recognizable in modern construction industry. Although extensive use of standardised specifications for building construction requires a trial period of familiarization for the contracting authorities it also offers the certainty of ensuring unambiguous comparability of all offers and reduces the contract risk by eliminating inadequate formulations and contradictions in the tender. In the end, this also effects the price of the bidder, because the contractor also experiences a minimization of the contract risk as a result of a standardised call for tender, which becomes part of the construction contract.



**Figure 6.** FSA in tender process in timber construction

#### 4. Aspect III – cost calculation of construction

The calculation of construction costs resp. prices by the bidder / contractor is clearly regulated in Austria by standardized cost calculation form sheets (K-sheets) following the Austrian Standard OENORM B 2061 [7]. This cost determination is based on the tender documents which has a position regarding the building material as well as the construction method and is nationwide uniformly executed with calculation forms depicted in figure 7.



**Figure 7.** Cost calculation forms for the determination of construction prices acc. to Austrian Standard

Associated auxiliary sheets support the calculation of construction costs resp. prices. The national standard provides additional information relating to the correct structure of the cost calculation and deals with clear presentability as basis for a review procedure regarding the appropriateness of the construction cost submitted in the tender.

This calculatory framework is used in the award procedure as a fundamental criterion in the comparison of tenders and is mandatory in public construction projects in accordance with the federal procurement law (Bundesvergabegesetz BVergG [8]). A detailed construction cost calculation according to this scheme is also recommended for private and commercial construction projects to ensure the formal correctness and appropriateness of the submitted tender.

##### 4.1. Status quo in the timber construction industry

Nowadays timber is much more than just a construction material for single-family houses and agricultural buildings. Timber frame constructions as well as solid timber (and hybrid) constructions are, due to its elegance in construction, architectural diversity and ecological benefits, increasingly used for multi-storey housing and office buildings as well as large-scale public buildings such as educational institutes, sport facilities and administration offices. To enable timber construction companies to act as general contractors a complete and comprehensive cost calculation according to the national code as well as pan-European normative requirements is inevitable. This leads to the fact that all detailed cost

calculations are carried out and fully disclosed in the case of deepened cost resp. price appropriateness reviews.

Therefore, it is no longer sufficient in today's timber industry to calculate solely to the level of unit prices for individual advertised positions, but to deal in detail with the connection details, processes and the expected circumstances on site and in relation to other trades including all cost factors as well as a transparent and resilient documentation of the cost determination process. This form of a detailed cost calculation – as it is custom in conventional mineral construction methods for decades – is finding its way also into timber construction, since without it an excretion of the tender process is the inevitable consequence.

Thus, it is up to the timber construction companies to carry out a sound and valid calculation, which is verifiable and plausible for the contracting authority or the authorized person responsible for the deeper tender evaluation. As such the cost calculation of timber constructions do not give a cause for an exclusion in the procurement process.

The detailed cost calculation must be divided (as depicted in figure 7) into wages, materials, products and external services as well as construction machinery and equipment. Since industrialized timber constructions have a high share of material costs in comparison to the labor or wage costs, the economic calculation tools also need to be adapted to this specific situation. However, due to varying suppliers (semi-finished parts and prefabricated structural elements), the entrepreneur itself can have little to almost no influence on the production processes of construction components, which makes a detailed and all-encompassing cost calculation even more complicated.

On the other hand, the assembly works on a construction site are found to be relatively consistent due to manageable assembly crews of only three to five skilled workers (mostly carpenters). However, they do differ in reliance to the degree of prefabrication, the complexity of the components and the quality of the work done by other subcontractors (e.g. in case of a reinforced concrete building core).

These circumstances lead to the fact that the cost resp. price determination of timber construction works must be conducted more accurately and a complete renunciation from an exclusive assessment from the gut must be enforced to ensure a realistic assessment of the overall construction costs. This development is highly depended on auxiliary and timber-specific cost calculation tools to encourage the use of standardized cost calculation forms and a substantiated cost database which represents the current state of the art on the product level.

#### STATUS QUO (SQ) – COST CALCULATION

- insufficient cost calculations restrict the market access for timber construction companies
- high degree of prefabrication limits the possibility of holistic cost calculations
- calculation guidelines and tools depicting the timber constructions state of the art are missing

**Figure 8.** SQ – cost calculation in timber construction

#### 4.2. Feasible solution approaches for the timber construction industry

Although the experience of established entrepreneurs is theoretically a good foundation for an initial construction cost resp. price assessment. However, they are hardly able to withstand any appropriateness test and are not transparent for external reviewers in any way. Consequently, it is necessary to implement a standard costing (pricing) index and calculative scheme in the timber construction industry in which each process is specified according to the same schemes as in other trades. This leads to a comparable and comprehensible cost calculation in which only individual cost approaches as well as the quantities must be adapted between various construction projects. The calculation process itself remains the same.

In the past years standardized cost calculation approaches were rigorously collected and published in the course of construction process (acc. to REFA analysis – see chapter 2). The objective of such studies is to generate a well-founded database for the cost calculation of timber construction companies. In the process, a large amount of data can be collected and scientifically substantiated. Cost indices are



derived from observations and can be used in individual calculations. The result of several research projects is currently being implemented in a specific cost calculation software (especially for Austria) – which follows the structure and positions of the timber-specific technical specifications in the new LB-HB.

Ultimately, there is the possibility in timber construction – following the example of various other trades in the past – to conduct a sound and valid cost determination. This facilitates the market access of timber construction companies regarding large-scale public projects and encourages cost optimizations throughout a detailed cost calculation. It is inevitable for an overall cost reduction to examine every cost center. If these sub-processes are also calculated and a full-cost calculation is carried out at the beginning of every project, it is possible for the entrepreneur to be competitive and ensure a necessary monetary surplus. Ecological attributes are the drivers for the development of timber constructions, but ultimately the price of a system decides on its selection.

### FEASIBLE SOLUTION APPROACHES (FSA) – ASPECT III – COST CALCULATION

- implementation of a standard costing index and calculative scheme for timber constructions
- conduction of empirical studies to derive state of the art cost parameters
- cost optimization of timber construction based on full-cost calculations

**Figure 9.** FSA – cost calculation in timber construction

## 5. Current developments and long-term impact

In addition to these three essential facts – cost planning, tendering and cost calculation – another topic is directly related to the developments inside timber construction: Building design as advance input and building contract law as legal consequence. Above all, the topic of planning resp. design in timber construction has been the focus of numerous considerations and (research) projects for several years. Due to the increasing volumes and complexities in timber construction as well as the often-ambiguous situation between the various architects and specialist designers, it seems to be necessary to define unambiguous performance profiles or detailed descriptions of the scope of work for all parties concerned. These would ensure clarity regarding the responsibilities and areas of competence of architects, structural engineers, building physicists and designers of technical services as well as timber construction companies and enable smooth cooperation between all of them along with the client and/or investor. Ultimately, it is about the question of who plans what, when and with which level of detail and how these services are adequately remunerated according to the actual effort within each construction project. The timber-specific advancement of design services is of considerable importance, because early completion of construction drafts is highly important to enable prefabrication and short construction times.

In order to guarantee clear and adequate responsibilities, to define interfaces and to specify the timber-specific contents of the individual planning stages, a comprehensive performance profile is currently being prepared at the Graz University of Technology (BBW – Prof. H. Lechner) together with the author [9]. This is done in accordance with the Austrian service phases of LM.VM.2014 (also written by Prof. H. Lechner) as well as the German HOAI (also written by Prof. H. Lechner) and serves as a fundamental basis for a clear distribution of competencies of the designers specifically in timber construction and for a fair payment solution for everybody involved.

Numerous other issues regarding construction management, building economics and building contract law are currently being considered in timber construction, as they form the basis together for making timber construction more successful and sustainable in the economic sense. These include topics of organization (process engineering, work preparation, production planning, logistics etc.), of economic optimization and cost calculation (further calculation approaches and databases, comparative evaluation of procedures, cost analyzes based on completed buildings, etc.) as well as areas of timber construction

contracting and personnel development. Ultimately, this is going to lead to a restructuring process across the borders of the timber construction industry as well as beyond the product and technological level. New strategic innovations and business models are going to challenge the prevailing corporate strategies and push the whole construction industry into a higher productivity and greater sustainability. Due to the technical achievements in recent years and the supplementary economic tools, construction data and innovations regarding corporate management the use of timber construction will accelerate even further soon.

This development is sustained, inter alia, through a systematic and modular approach to timber construction. With consistent specification from a technical point of view and extensive implementation in the construction companies as well as planning departments, timber system construction is going to allow the widespread use of timber in a way which has seemed impossible up to now. This is possible, because the higher productivity resulting from the increased usage of modular timber systems can radically reduce costs and thus the comparison of construction methods and especially structural materials is tilting more and more in the favor of the construction material timber.

At this point it must be noted, that the presented scenario can only be realized if the timber industry ignores the prevailing lethargy of the construction industry and the blatant deficits regarding labor productivity as well as the degree of digitization are solved. Only this development enables the possible for timber to succeed over other construction materials – in addition to the ecological benefits – in terms of costs in the long term. The goal must be to reduce construction costs drastically, especially in the area of affordable housing. At the same time, it is important to consider the global ecological developments and to assume responsibility for the numerous environmental and ecological-social problems in the construction industry. Timber construction can play a leading role in the evolution of construction from an ecological as well as an economic point of view if there is a consistent implementation of building management approaches and strategic tools. A technologically outstanding product alone is not enough to survive in the business world of the 21st century – not even in the construction industry [10].

## 6. Conclusion

The liberation of its economical infancy has begun in the timber industry a few years ago and is now leading to a continuous change in the industry towards a holistic construction process management. This includes all construction and management related areas, which – in addition to all the technical achievements – provide the basis for a continuous development of timber construction. The construction material timber and thus the underlying companies can develop out of a niche market into global players and initiate a new age of building. Numerous measures were and are set out now in order to create the armament, which makes it possible for timber construction companies to realize a lot more than just lighthouse projects and to be dismissed as nice to have in an ecological point of view. Regardless of the construction method – timber frame constructions, solid timber constructions and timber hybrid constructions – the target must be to conquer the mass market. This is especially true regarding multi-storey housing, office buildings, public buildings such as schools, libraries and governmental buildings as well as industrial buildings. The presented developments in the fields of construction management and building economics in the form of standardized processes and tools for cost planning, tendering and cost calculation ultimately serve the big picture and are necessary steps to further professionalize and legitimize timber construction. They are the indispensable foundation of the successful implementation of the building material timber.

## References

- [1] Koppelhuber J 2018 *Bauprozessmanagement im industriellen Holzbau – Ableitung eines Bauprozessmodells zur Prozess- und Bauablaufoptimierung im Holzsystembau (Building Process Management in Industrial Timber Construction Defining a Model for the Optimisation of Building Processes and Construction Sequences in Timber System Construction)* Dissertation, TU Graz (Graz: University of Technology)
- [2] Austrian Standard Institute 2015 *OENORM B 1801-1 Bauprojekt- und Objektmanagement Teil*

- 1: Objekterrichtung (Project and object management in construction — Part 1: Object construction)* (Vienna: Austrian Standard International)
- [3] Heck D Koppelhuber J 2014 *Tagungsband 1. Forum Holzbau trifft Bauwirtschaft – Kosten und Kalkulation im Holzbau 27.03.2014*, TU Graz (Graz: University of Technology)
- [4] Heck D Koppelhuber J 2015 *Tagungsband 2. Forum Holzbau trifft Bauwirtschaft – Bauwirtschaftliche Optimierungsansätze im Holzbau 29.04.2015*, TU Graz (Graz: University of Technology)
- [5] Heck D Koppelhuber J Wall J 2017 *Tagungsband 3. Forum Holzbau trifft Bauwirtschaft – Bauwirtschaftliche Ansätze in der Ausschreibung, Kalkulation und Kooperation im Holzbau 12.05.2017*, TU Graz (Graz: University of Technology)
- [6] BMDW Bundesministerium für Digitalisierung und Wirtschaftsstandort *Standardisierte Leistungsbeschreibung Kennung: HB Version 021 (Ausgabe 31.12.2018)* <https://www.bmdw.gv.at/> (Vienna: BMDW Bundesministerium für Digitalisierung und Wirtschaftsstandort)
- [7] Austrian Standard Institute 1999 *OENORM B2061 Preisermittlung für Bauleistungen 1999 (Determination of price in building and construction – General principles)* (Vienna: Austrian Standard International)
- [8] Bundeskanzleramt Österreich 2018 *Bundesgesetz über die Vergabe von Aufträgen (Bundesvergabegesetz 2018 – BVergG 2018) – BGBl. I Nr. 100/2018 idgF.* (Vienna: Bundeskanzleramt Österreich)
- [9] Lechner H Koppelhuber J release planned for 2020 *Planung und Bauaufsicht für Holzbauten – Leistungen der Holzbauplanung (PREFAB)* Fachbücher Planung und Bauen Institut für Baubetrieb und Bauwirtschaft TU Graz (Graz: University of Technology)
- [10] Bok M 2019 *Geschäftsmodelle im industriellen Holzbau – Ableitung strategischer und technologischer Parameter anhand einer visionsorientierten Geschäftsmodell-Systematik (Business Models for Industrialized Timber Construction – Derivation of Strategic and Technological Parameters on the Basis of a vision-oriented Systematic)* Masterthesis Institut für Baubetrieb und Bauwirtschaft TU Graz (Graz: University of Technology)