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Industrialized Timber Building Systems For An Increased Market Share – A Holistic Approach Targeting Construction Management And Building Economics

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Abstract

Because modern timber construction has developed in recent years from a traditional niche market towards an industrialized business, a large number of designers, entrepreneurs and investors are beginning to demand comprehensible basics in building and construction in general. Advancements of recently developed timber products and their application within the prefabrication process require construction management processes to be standardized and unified. These processes then need to be scientifically proven with cross-company references. Apart from technical developments, especially in terms of cost savings and standardization of building procedures, professionalization also plays a fundamental role in providing practical application for a long term success in the market.

The current demand for the mass appeal of timber is accompanied by various economical key factors in addition to the question of technical standardized system components. These standardized components provide long term stability regarding costs, consistent quality, construction management optimization and sustainability.

According to current expert surveys and cost investigations undertaken within this research paper, the integration of a consistent data workflow during the planning, production, and installation process allows for a significantly shortened construction period with major on-site cost reduction as well as for a sustainable approach to delivering a holistic construction management system for timber. Within this research field, the identified criteria and surveyed fundamentals are used to create general construction management methods for the branch. Additionally the applicability was analyzed consistently to determine future potential and generate appropriate and integral timber building systems.

Modern timber construction methods are especially suitable for prefabrication because of the material-specific properties, its sustainable performance, the possibilities in prefabrication and easier assembly under dry construction conditions. For this reason a high productivity combined with excellent quality in short installation periods provides verifiable arguments for best practice examples in the area of construction management of modern timber building systems.

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Keywords: Timber construction, prefabrication, professionalization, standardization, cost reduction, sustainability, expert survey, cost analysis, performance

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1. The holistic approach

Because modern timber construction has developed in recent years from a traditional niche market towards an industrial and large scale business, many decision makers are demanding extensive construction management and building economics basics for this specific material which have been scientifically verified and can be used to operate their business and carry out projects. Therefore, in addition to recent technical developments with a special focus on cost reduction and standardization of workflows, professionalization in the branch is an absolute necessity and plays a fundamental role in ensuring practical usability. The demand for the mass appeal of timber as a main building material is accompanied by the topic of technical system components, business economics key factors in the field of costs, and constant quality and optimization in construction management to provide long term stability. The central theme of a holistic and comprehensive industry and system investigation demands a clear structure on liability and a decision matrix in the implementation of timber construction projects. Therefore the question of standardized processes and production systems and their applicability in timber construction as well as existing process chains are at the forefront of the development and work on the recurring questions of system efficiency. Associated information interfaces need to be developed and implemented to ensure that the procedures are carried out appropriately. The research project "Industrialized timber construction – development & optimization of technical and economical timber construction system for the industrialized building with timber", which provides the basis for this paper, was started in 2012/2013 at the Institute of Construction Management and Economics at Graz University of Technology and should provide basic information on this topic. This will offer industry professionals guidance in making successful decisions regarding industrialized timber construction from a building economic aspect point of view [1].

1.1. Point of departure – why now?

Modern timber construction, which is characterized by constant growth nationally and internationally, has evolved considerably in recent years, especially in technical terms. Numerous product innovations have helped timber grow from infancy to a well-established timber system on the market which can be implemented for the majority of large-scale buildings and which is radically different from the conventional timber construction known for centuries. Therefore, it is a logical conclusion and necessity that construction-related studies and construction management optimizations follow the technical developments.

The gaps in timber construction in terms of construction management or business economic aspects should be minimized and used to help to generate a benefit for this building system. The background and input parameters for usual costing systems within special timber construction systems are not as well established as they are for traditional building materials such as steel and concrete [2]. With the help of investigative studies, research projects, information focusing and appropriate communication tools, it is the main objective of the research field to generate a knowledge basis, apart from practical experience without cross-company reference, and form a respectable background on data which forms a reliable guide for construction with timber and managerial decisions.

1.2. The chance of timber construction systems

The topic of timber construction systems, in the broader sense "industrial building with timber", and the possibilities of systematization and rationalization in the construction industry have always been a topic of discussion. Technological developments, the acute housing shortage after the world wars and the technical possibilities of serial prefabrication of individual construction and design elements have allowed planners and developers, especially during the last several decades, to develop new approaches to integrate the ideas of industrialized building components in conventional construction processes.

Although initial attempts of modular prefabrication and systematic manufacturing were performed more than 100 years ago, automated building processes are hardly established in Central Europe nowadays, regardless of the construction system or building material used. The emphasis in this analysis is thus based on the prefabrication of modern industrialized timber construction, which is characterized by its light weight and easy process ability during

prefabrication. Positive examples provide evidence of the steady development of industrial buildings with this construction material. However, the realized objects are still prototypes. Additionally, the experts interviewed in the survey provided later in this paper believe that a useful form of industrialization which uses system components and is consistently implemented is required for successful substitution in building processes.

2. Strategy for research approach

It is a key task in timber construction to establish an integrated building system that performs not only by joining single elements but also by implementing an industrialized building method using system components in an optimized construction management process, taking the specific conditions into account.

2.1. Constraints and topics

For this paper the following main topics are considered to be relevant to generate a holistic approach [1]:

- Industrialized building with timber

  Research is continuing on this core issue regarding the extent to which the subject of an integrated industrialization of production processes in timber systems allows industrialized construction and how this potential can be used and optimized in future.

- Modularity in timber construction

  The topic of modularity in construction is considered by the investigation of the technical expansion within a building as well as by prefabrication of entire 2D-elements and 3D-modules using fundamentally unchanging components with a high prefabrication grade in which timber is the dominating production factor.

- Construction management in timber construction

  The research investigates the usual methods in construction and tries to create an overall concept for a possible information loss-free operation. Due to the complexity and number of interfaces, implementing a planning overview of timber construction includes mainly work scheduling, logistics and construction techniques.

- Turnkey building with timber

  The research question is also raised regarding the extent to which a merging of the expertise within the turnkey branch and timber skills is necessary and productive and how far it is possible for these aspects to be combined without sacrificing already established systems.

The goal of the research presented here is therefore to outline a holistic approach to a system solution for timber construction which is technically and economically optimized. This includes an intensive investigation on decisive factors in construction management as well as an optimization in terms of influences on building economics in large scale timber buildings.

2.2. Methodologies of research

To generate verified and widespread data within this research project, three methods of data collection were used. Firstly, an adapted methodology of REFA [3,4] was applied on site to obtain facts and figures which relate directly to construction management and building economics considerations. Secondly, expert surveys were conducted to obtain appropriate answers on an extensive questionnaire regarding construction management themes. Thirdly, extensive cost analyses on existing and upcoming projects were performed to determine cost breakdowns in conjunction with prefabrication.

The methodology of REFA as well as the results conducted on site are not included within this description. Additionally, the cost analysis undertaken on specific timber construction project is not part of this paper.

2.3. Expert survey on industrialized timber construction

Existing literature on specific topics regarding prefabrication within the construction management aspects investigated needed to be compared and verified by experts. Therefore accurate data and reflections on industrialized building systems with their advantages, constraints, and challenges in future were investigated with particular emphasis on timber construction methods and systems. To generate considerable data, an expert survey was conducted from November 2014 to February 2015 [5]. Within this survey 28 experts were involved who came from various disciplines such as architecture and engineering, construction, SME, public and private investment as well as the field of research and development. The results from this survey where then compared to the existing and comparable literature on these topics to verify the accuracy of the expert statements.

3. Construction management and building economic aspects

A large variety of timber products developed recently and the manufacturing processes required include general construction management aspects, such as modularity and prefabrication, turn-key building systems, reliable cost calculations and analysis, adequate integral planning tools as well as the existing discussion on the topic of interfaces between the trades involved. These themes formed the basis for questions in the expert survey included here.

3.1. Industrialized timber construction and modularity

To generate an industrialized building system, various industrialized functions from the stationary industry must be transferred into the decentralized systems of the construction industry. The word “prefabrication” is generally used in the context of building in series and building in systems, which include mainly production and construction with 2D-elements and 2D- or 3D-modules. Industrialized construction encompasses therefore a production of different building elements in an industry setup that is not subject to changes in weather [6].

Often it is assumed that building in systems is the typical building style of the 1960s, with its unification in repetitive multi-storey concrete buildings spread all over middle Europe. To achieve an economical advantage in comparison to other building materials at that time, the building components were standardized and produced in high quantity and always implemented in the same way. In contrast to that, the introduction of the principles of lean production formed the leading production system which then changed the process completely [7].

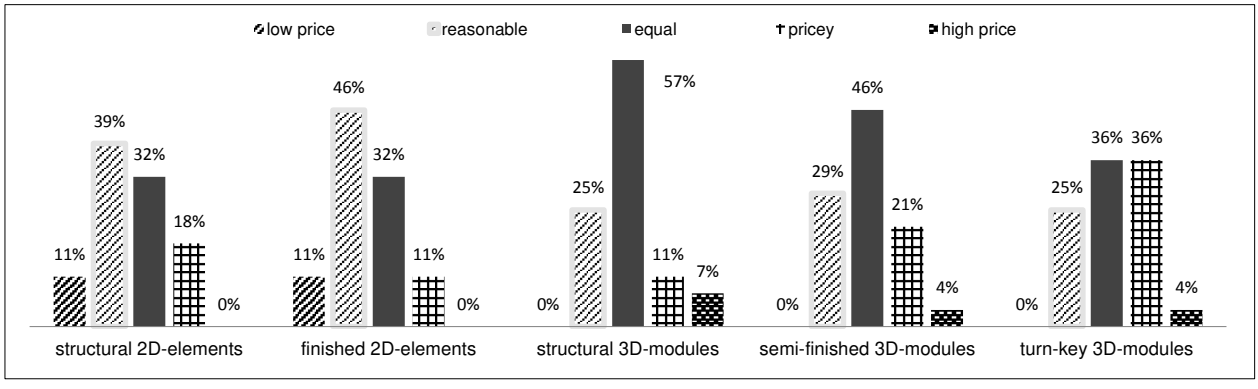

Fig. 1. Expert survey cost comparison of traditional to industrialized building systems [5].

Industrialized building systems are formed by a combination of 2D-elements and 3D-modules; the proportion of elements to modules in each combination depends on the particular circumstances. The impact factors have the opportunity to develop traditional building components into industrialized building components and systems without losing the advantages and significance of the individual tasks while also generating a greater benefit by using an intelligent combination of the planning and production factors [8]. This was found out in the expert survey by identifying the cost influence and chances using a higher grade of prefabrication within the finishing works. The expert opinions see a significant benefit in using prefabricated 2D-elements and 3D-modules; however, finalized turn-key 3D-modules are still indicated with higher costs although they do show very large potential in the upcoming years.

3.2. Construction management and prefabrication in timber construction

Compared to various international research projects, the expert surveys also indicate that prefabricated building systems show a positive trend and constant growth within the coming years. Multi-storey residential and commercial buildings in particular as well as intra-urban and inner-city developments with industrialized building systems offer great advantages and a prosperous future for construction.

Certainly the reasons for using industrialized timber building systems are not directly related to the material. The following figures obtained through the expert survey show that prefabricated building systems offer greater advantages, especially when it comes to quality reasons, as well as lower general building costs on site and easier production system under dry and constant conditions. An accurate production method as well as fast manufacturing and short installation time on site comprise the main benefit by implementing more industrialized building systems within the general construction industry.

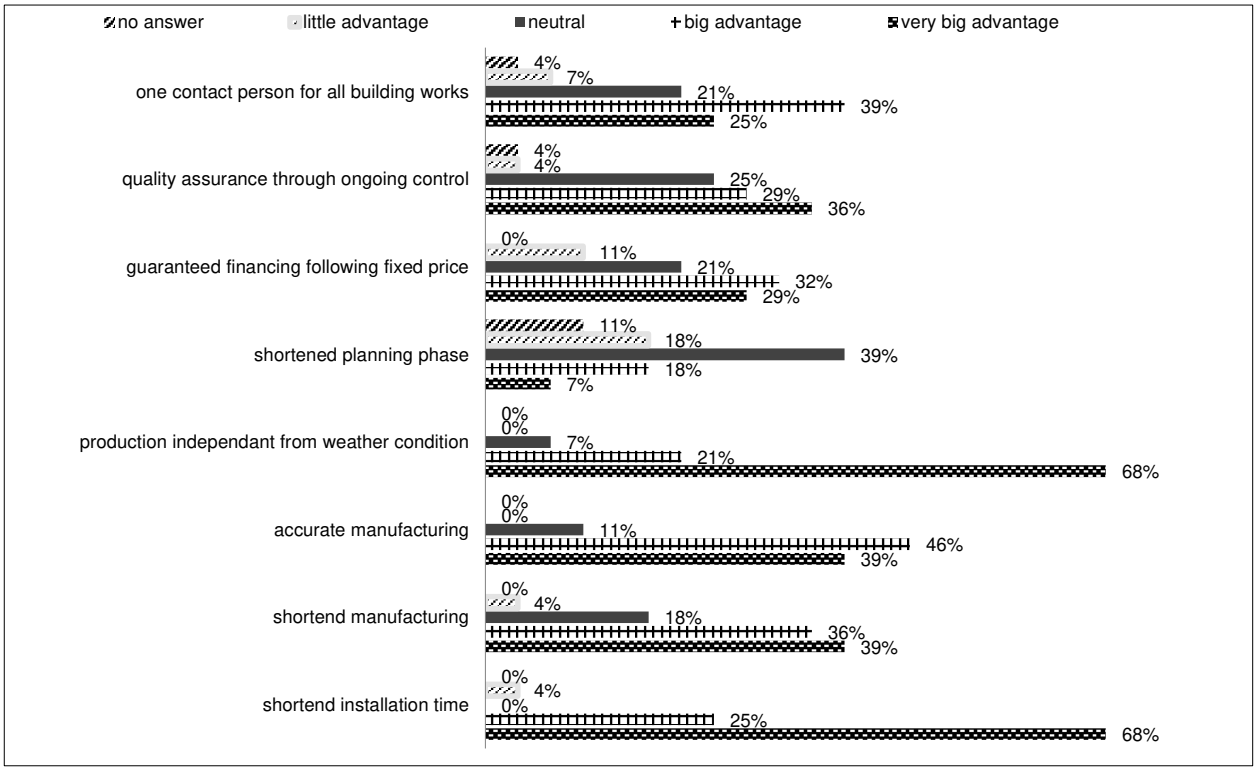

Fig. 2. Expert survey advantages of industrialized compared to traditional systems [5].

3.3. Turnkey systems in timber construction

The prefabrication grade in general offers a wide range for interpretation. There is a misleading lack of understanding even in specific literature and expert-opinion surveys on various economic results generated through the grade of finishing works within the prefabrication process. However the expert survey conducted as part of the research discussed here indicates a constant increase of this market, especially in the case of timber construction systems with a high grade of prefabrication [9]. The system also includes 3D-modules with a high grade of prefabrication as well as 2D-elements with almost finished internal as well as external surfaces.

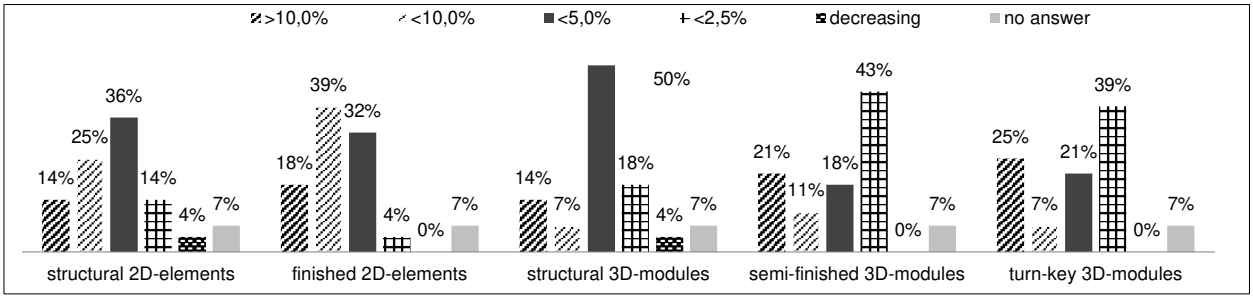

Fig. 3. Expert survey on market development of industrialized timber building systems depending on the grade of finishing works [5].

The operation processes required during the construction of timber buildings include mostly complex procedures and sequences, which need to be identified in-depth to ensure financial success. This is especially the case in terms of turnkey systems when a high grade of prefabrication is set and many trades are involved in the project at the same time. As described, these processes include an intensive planning phase with a high level of detail in an early planning stage [10]. These processes can also be carried out before the cost impacts of late changes rise significantly. The deeper the influences of turnkey systems become in a project, the more preparatory work is of major interest. This is because the grade of prefabrication can only be ensured by appropriate and extensive work preparation for all trades involved. This includes the planning of the production, the charts on expected time and construction progress, the setout of the required building site equipment on site, the planning of all necessary resources as well as the cost calculation implementing all these circumstances [11]. However, not only the processes themselves but also the interaction between these constraints and the interfaces need to be arranged accurately. This is especially true for prefabricated turnkey timber solutions.

3.4. Planning and tendering process of industrialized timber construction systems

The discussion of planning systems, level of detail and the simple question “who is responsible for developing which detail and drawing?” as well as the question of responsibilities are ongoing not only in the timber industry, but in construction as well. As various timber products have been developed over the last few years, a vast lack of knowledge has appeared not only in construction but also during the planning and tendering stage. The majority of current timber constructions are designed by specialized designers and technicians who often work in-house in the timber industry. However many of these designers and planners, as well as the general planning community with their standard education and training on conventional building systems, cannot comply with and meet the required level of detail for an appropriate timber solution. This offers a significant opportunity for a specialized planning industry to develop new and simple integral planning systems and tools which have a great potential for market developments in the future. On the other hand, the existing large variety of new materials, building systems, possible details in the connections as well as building physics and entire timber building systems run the risk of failure by incorporating too much variability for simple planning tasks. The more complex a 3D-system is, the higher the risk when implemented.

As a result, the implementation of existing and newly developed integral planning systems and tools, such as building information modeling (BIM), is required for the entire timber construction industry in future [12].

The substantial increase in complexity within the construction industry and especially in the timber sector has a profound impact on the economic success and presents challenges as well as restricting constraints. The fact that newly developed building materials and products have a rather low level of trial and error and compound the risk when implemented in today's building systems can be especially high. The number of interfaces has increased rapidly in recent decades as numerous trades and business have entered the construction market. The level of detail is far higher than 10 to 15 years ago when many details were solved on-site and the simple question of how a new system should be implemented in conventional buildings did not exist. Today's mostly complex CAD-CAM systems offer the chance to reduce risk and failure through too many interfaces. In many cases just-in-time deliveries of products, systems and services need to be implemented in standard structural elements. These offer a great opportunity on one hand, especially cost wise. However, the majority of costs nowadays are generated by building services engineering instead of structural components and levels of detail [13].

4. Conclusion – developments and tendencies

The industrialized timber building division, which differs significantly from traditional carpentries by the implementation of automated production and prefabrication methods, has been continuously developed in recent decades by introducing technical developments on the material level as well as computer-based manufacturing processes. [14].

The high potential of timber construction systems lies in the short installation period required on site in comparison to existing conventional and traditional building systems used nowadays. The prefabrication of 2D-elements and 3D-modules in particular provides many arguments for a widespread use of timber as the main structural material. However, because of a lack of knowledge in this area, the cost impacts are still commonly used as arguments against timber as the leading material as these costs are hardly quantifiable and ratable in comparison to conventional building systems.

4.1. Potentials of prefabricated timber construction

Even though timber as a leading construction material has a high potential for pioneering tasks, especially when implementing turnkey strategies by transforming the technical advantages of a material into an integral building system [8], the positive trend in the last 15 years can be expanded further. This is proven by various investigations and literature as well as the expert survey incorporated in this research project. However, in addition to the technical and material sector, more effort is required in the building economic fields [15]. In order to professionalize the entire branch, the planning and management process requires a particularly high planning reliability, a better quality assurance with a wider standardization of building components in sum and in detail, and standardized system components for general applications.

The constantly rising demand for timber buildings helps to develop a comprehensive and detailed prefabricated timber construction system in conjunction with neutral cost studies [16]. This in turn creates a benefit from the effects of an industrialized construction as well as from an adaptation of building regulations. Therefore this helps to create an additional step towards professionalization and industrialization in the building industry by implementing turn-key concepts in order to generate meaningful construction management tools to allow ecologically friendly material to become a widely used standardized building system.

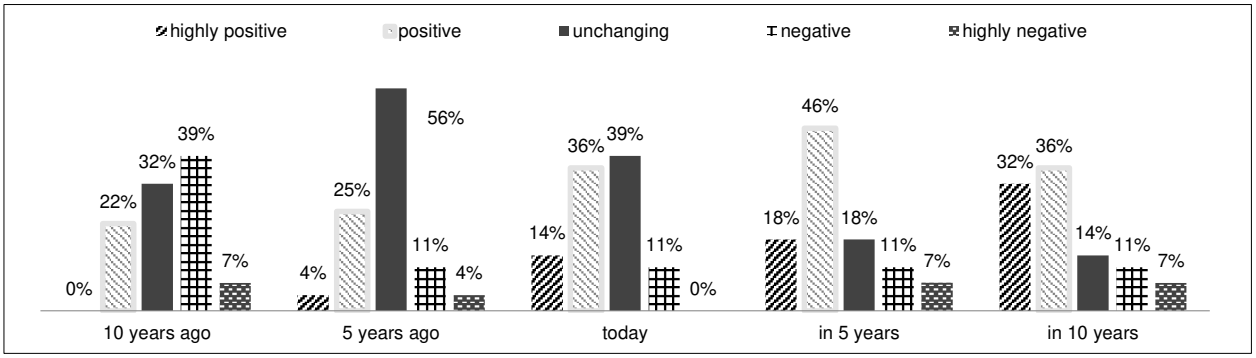

Fig. 4. Expert survey potential of modular timber building systems [5].

The high potential of timber construction can be spotted mostly in the short period of installation required on site. Additionally, less site installation equipment means smaller areas are required for temporary storage. Apart from non-influenceable weather conditions, the installation time is mostly affected by the grade of prefabrication, the lifting facilities, and the installation performance of the team on site. However, these arguments are not commonly used as they are difficult to quantify and rate. This is because it is difficult to assign responsibility for cost factors and time-influencing circumstances among the collaborating companies and their interfaces. Timber has a very high potential to become a widely used integral building system, especially when turnkey strategies are implemented. To extend the successful development even further, much more effort is required also within the scientific community, not only in the technical sector but more than ever in the construction management and building economic segment to allow this useful and ecologically friendly material to become a widely used building system.

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