

fertighauscity5+

Typological and technical study
of multi-storey timber-based buildings in city centres
focusing on prefabrication and user participation

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1. Research objectives

Living in the city has many advantages. But anyone wishing to custom-plan and design their living space will be faced with quite a problem, because end users of urban multi-storey housing tend to have very little influence on the design. Owner-builders who opt for a detached single-family house for own occupancy, on the other hand, can usually custom-design their home. Households wishing to build property, many of them dedicated city dwellers, consequently move to the suburbs.

Our research team has therefore developed a concept for buildings that are up to 5 floors high, which allows room for custom design. Its key element is bespoke production with a self-build component. Following amendment of the building codes in the German states, timber construction, which is highly flexible and allows construction types other than detached single-family homes, can now be used for timber-based urban housing projects. We have focused on timber construction systems, because they offer considerable potential with regard to prefabrication, construction time, and flexible production. This can be of particular benefit in multi-storey construction. But although the new model building code and the model directive for timber construction have created the necessary legal framework for this type of construction, owner-builders, planners and construction companies still have reservations and feel uncertain about how to actually apply them. This is partly because there are no concepts for a technical implementation of the legal requirements.

Owner-builders want to be able to specify their individual planning requirements and also enjoy the benefits of industrialised production. The implementation of housing projects in the city centre requires a concentration of financial resources. Homeowners' associations or housing cooperatives could function as umbrella organisations. A homeowners' association in this sense would be an association of different owner-builders who, instead of each building a separate home in the suburbs, together implement a housing project in the city centre. There is thus a need for new models of high-density housing, yet there are no sound concepts for implementing the related construction tasks. In this context, the "*fertighauscity5+*" (5-storey urban prefab) can be identified as a new key planning task for city centre homeowners' associations. The following housing types would be suitable:

- New houses with up to five(+) floors based on solid timber, post-and-beam, or timber-frame construction (multi-unit housing)
- Infill housing in the form of addition of extra floors to existing housing (maisonette and penthouse types)

- Prefabricated extension or conversion modules for house conversions or modernisation (energy efficiency refurbishment)
- Urban multi-storey terraced housing (townhouses)

This research project focuses on new timber-based buildings with up to 5 floors, since we consider them the construction task with the greatest potential for development. In our concept, the key focuses are user participation and bespoke production. At present more time is required in the "*fertighauscity5+*" concept for planning and implementation than in a traditional project, but this should be made up with flexible production technologies and integrated coordination tools.

Especially in view of the current climate debate, the use of wood, a renewable resource, is an important factor in the reduction of CO₂ emissions. The "*fertighauscity5+*" will be implemented as a "passive house" with heat recovery. Its flexibility and adaptability to different users' lifestyles make this type of construction exemplary in terms of sustainability and durability.

2. Implementation

"*fertighauscity5+*" is a joint research project of TU Braunschweig in cooperation with partners. The project was developed over a period of 12 months. The individual cooperation partners worked separately on the topic, compiling and coordinating their findings in working meetings. Their different areas of expertise are outlined below.

TU Braunschweig – IIKE – Institute for Industrial Building and Construction Systems Design

Architecture teaching and research at IIKE focus on industrial building and, in the field of construction systems, on prefabrication and industrialised construction processes.

TU Braunschweig – IGS – Institute of Building Services and Energy Design

Teaching areas at the institute comprise technical building equipment, hygrothermal aspects of building physics, the passive and active use of solar energy, and the energy design of buildings and housing developments.

TU Braunschweig – IBMB – Institute of Building Materials, Concrete Structures and Fire Protection

Fire protection research at IBMB focuses on fundamental research aimed at describing the outbreak and impact of fires and the fire behaviour of building materials, and at determining the strength and deformation behaviour of structures in the event of a fire.

O.Lux Holzbau, Roth

From its two sites in Roth and Georgensgmünd, O.Lux can provide a complete range of timber-based products and services, including the implementation of complex architectural projects. In its workshops, O.Lux can produce large-format wall, floor and ceiling modules in any weather. The company's state-of-the art production facilities are fully automated and computer-controlled.

BWK – BauWohnberatung Karlsruhe

The BWK advice service in Karlsruhe (BWK) provides assistance with the management of small-scale and large-scale housing projects and with defining the objectives in the complex process of homebuilding for own occupancy. BWK helps with knowledge transfer, and the creation of sustainable administrative, legal and process frameworks, such as the formation of a homeowners' association. It also provides advice regarding the personalised design of floor plans, open space planning and space allocation.

External experts for the research project

Dipl. Ing. Ute Rustemeyer, Federal Office for Building and Regional Planning

Prof. Brian Cody, University of Graz, Austria – IGE – Institute for Buildings and Energy

Dirk Kruse, WKI, Wilhelm Klauditz Institute, Braunschweig

Prof. Andreas Löffler, HfT Stuttgart, Dept. of Environmental Architecture & Building Technology

Prof. Nikolaus Nebgen, HAWK, Faculty of Civil and Construction Engineering

3. Summary of findings

3.1 Findings

Our joint research work has yielded possible variants of 5-storey prefabricated timber-based houses. With the design of a prototype that is suitable for all locations and can be used anywhere in Germany, we could show their viability from the planning stage to construction details, providing both written documentation and illustrations.

"*fertighauscity5+*" is designed to allow a wide range of different user groups to custom-design their future living space as much as possible and already at the planning stage. At the same time, it offers the benefits of industrialised prefabrication at both the planning and the construction stages. "*fertighauscity5+*" will thus be a 5-floor prefabricated, yet tailor-made home. Our research takes account of several factors that are central to the building of bespoke properties. A systematic planning process has been designed, which simplifies decision-making processes for owner-builders.

BWK – The BWK advice centre in Karlsruhe focused on two areas of the "*fertighauscity5+*" integrated research project. It took on the "virtual" role of the future occupants throughout the development process. Based on established models, BWK also distinguished a number of clearly defined socioeconomic target groups to whom the "*fertighauscity5+*" would be of particular interest. For three of these target groups, BWK developed specific planning, implementation and participation matrices, which provide sound assistance in defining a project profile to both planners and owner-builders. One of the aims was to speed up the process for the owner-builders, another to enhance the quality of planning, design and construction. BWK also investigated the option of integrating commonly used software-based planning configurators in a participation-focused planning process. The findings show that it is possible to offer custom housing using standardised processes, which is in line with the major economic trend of "mass customization".

IGS – Regarding technical installations, the Institute of Building Services and Energy Design focused on developing simple, modular components that would allow a high level of prefabrication, while providing great flexibility in the design and use of living spaces. The concept provides for a vertical supply line system via a central prefabricated shaft. The individual floors are connected to the central shaft via a defined interface. To give the design greater flexibility, the supply lines are then distributed through a horizontal media girder. Almost like on a printed circuit board, a wide range of different room configurations can thus be taken into account at the planning stage, and prefabricated. The energy use standards of the passive house were taken as the minimum requirement for the "*fertighauscity5+*". These standards are common in the market and they can be achieved with little additional cost. The concept also requires integration of a heat recovery ventilation system. IGS investigated different shaft positions, air conduction variants and system configurations. Key considerations in the development of the different variants were economic and energy efficiency throughout the building's life cycle, and the highest possible level of prefabrication for all system parts and technical equipment. Development of the façade included an analysis of passive solar energy use. This required a calculation of the optimum total window area based on orientation and glazing quality. The team also studied the impact of integrating loggias and the relationship between illumination and daylight autonomy.

IBMB | O.Lux – A building's supporting structure has a major impact on its quality and appearance. Today, a multitude of timber construction methods are available, each of them with its specific advantages. This makes it all the more important to focus on the requirements of the property to be planned, while also designing an energy-efficient building. In the development of a supporting structure for the "*fertighauscity5+*", the different requirements

resulted in a combination of construction methods. IBMB and the company O.Lux together developed a framework for implementing the designs created in the "*fertighauscity5+*" project. By implementing the supporting structure in the form of a skeleton-frame construction, the major requirements of a typical timber building can be met.

IBMB – The institute presented the building authority regulations for multi-storey residential buildings with a height of between 7 and 13 m and a timber-based supporting structure. Major construction requirements include a fireproofing of the supporting timber structure with a non-flammable cladding, and the use of non-flammable insulation materials with a melting point > 1000 °C. Examples of existing multi-storey buildings in Germany illustrate the applicability of the model building code, while also indicating areas where real-life projects deviate from the code. Such areas are, for instance, requests for reduced fireproof cladding, the use of flammable insulation materials and non-fireproofed solid timber parts in some areas.

As part of the "*fertighauscity5+*" research project, fire tests were carried out on different fireproof claddings affixed with a variety of fasteners. The fireproof cladding was also assessed in terms of its bracing properties. The team's findings show the capabilities and limitations of optimising fireproof cladding and thus provide a good starting point for improvements in specific areas. The use of flammable insulation materials (e.g. made from renewable raw materials) in timber panel constructions, or of non-fireproofed solid timber modules are the subject of ongoing and completed research projects at IBMB. The aim of the "*fertighauscity5+*" project was to meet the fire safety requirements of the MBO model building code, to ensure the building designed would qualify for a standard fire certificate rather than requiring special certification.

O.Lux – O.Lux clearly illustrated the production stages, ranging from planning to manufacturing, packaging, and building, as well as developing a project-specific detailed plan and the logistics for "*fertighauscity5+*".

IIKE – In its part of the research project, IIKE developed flexible floor plans specifically for the bespoke prefabrication of a 5-storey timber building, as well as indicating suitable timber construction systems. The findings from this research led to the development of a prototype. The innovative aspect of this research project lies in the provision of a structure for developing residential buildings in the city centre that allow integration of the end users' specific requirements while also benefiting from industrialised production. These residential buildings are suitable for all locations and can be used for infill housing, as detached houses, or in terraced housing. The flexible design means not only customized floor plans but also different façade models can be offered. "*fertighauscity5+*" offers the target groups identified for this research project a level of influence and participation that is tailored to their specific needs. Considering

the surrounding area is another key factor in the development of prefabricated housing for the city centre. It is, in fact, the very reason why to date many city dwellers have opted for a custom-built home in the suburbs. The "*fertighauscity5+*" design consequently aims for a balance between private and communal areas.

3.2 Outlook

In a next step, we aim to test the viability of the "*fertighauscity5+*" concept, in a model project at a specific city centre site. We will look particularly at the target group models and their individual needs regarding participation and marketing.

Any real-life housing project requires clearly defined interfaces and planning parameters, which the planner defines and the client can select. These interfaces need to be considered individually and adapted for every target group. Moreover, every real-life project requires a project-specific schedule. This should take the form of a checklist and visualise the housing project for the user, from the first planning steps to final occupancy, clearly showing responsibilities, costs and deadlines. Although at present more time is required for planning and implementation than in a traditional project, this should in the long term be made up with flexible production technologies and integrated coordination tools.

A timber building is not identifiable as such from the outside, because all critical structural components are protected by non-flammable materials. It would be worthwhile researching to what extent the use of visible timber parts on the interior, for the supporting structure, or for the façade would affect users' identification with their timber home. Under the model building code, façades for class 4 buildings must be made from materials that are difficult to ignite, which excludes timber. And although timber can be treated with flame retardants to make it difficult to ignite, the substances currently available are not weatherproof and can thus not be used on the exterior of a building. There are ongoing research projects studying the prevention of floor-to-floor firespread, with the aim of finding ways of using normally flammable building materials, including untreated timber, for the façade.

From a fire-safety perspective, the current version of the model directive for timber construction does not permit exploitation of all timber construction options. Some of the guidelines for construction are rather conservative. Provided certain criteria were met, however, the guidelines could be made more flexible. With a view to widening the area of application for the "*fertighauscity5+*" concept, it might be worth considering whether even timber-based buildings with more than 5 floors would meet the objectives of the model building code.