Modularisation in Housing

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Modularisation in Home Construction

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PREFACE TO THE SECOND EDITION

Increased attention to the modularisation approach within the construction industry has sparked the interest of experts and led to further company analyses in Germany and abroad. The theoretical foundations for a product configurator are being developed and implemented in a prototype. A film was produced to summarise and illustrate the virtual flow of the value chain in modular home construction. Beginning with the planning stage in the product configurator, the film illustrates all process steps on the construction site, from element production to module assembly, all the way to the finishing phase. Considerations and insights gained during discussions with experts have been incorporated into this edition.

Munich, 18 May 2015

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PREFACE TO THE FIRST EDITION

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The need for affordable housing is increasing globally and demanding the construction of high-quality, low-cost housing in less time than was previously possible. Conventional building methods that predominantly use steel and concrete, and decentralised added value at the building site, are quickly reaching their limits of effectiveness. This mostly occurs due to unstable and fluctuating quality assurance, and the difficulty of coordinating the various building trades involved. In addition, several regions increasingly find themselves without a sufficient number of trained professionals. Modularisation in home construction offers an approach to face the challenges posed by building projects. Modular housing intelligently combines standardised lightweight modules allowing builders to erect residential buildings in industrialised production and assemble a weatherproof shell within a day. This study presents a scientific foundation and positioning of modularisation in home construction.

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Munich, 10 January 2015

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0 Summary

Growing global demand for affordable housing is becoming an increasingly critical factor in the economic and social development of many countries due to steady population growth and progressive urbanisation. Especially emerging economies such as India, China, Russia and Brazil, as well as South East Asia, are feeling the effects as the need for housing continues to surge. Developments regarding income distribution play a central part because emerging economies predominantly need affordable housing. Current mega-projects have shown that conventional steel and concrete housing construction is of limited effectiveness in this sector. The challenges in building projects of this type are coordinating the services of contracting partners and sub-contractors, dealing with shortages of important resources, and yet continuously optimising process efficiency. Modularisation of the product and the production processes allows builders to offer a high degree of versatility and variety while better managing internal complexity. As in the case of the industrialisation of production in the automotive industry, there is considerable potential to be realised here. This study shows that modern lightweight design, in combination with modular construction and production, is capable of overcoming the challenges of the conventional building industry and of constructing individual homes efficiently, flexibly and at low cost, yet with high quality standards.
The following questions need to be addressed:

1. What modularisation principles can be applied to housing construction?
Modular system construction distinguishes between the principles of

skeleton, element and room module construction which are usually installed in combination. The deciding factor is the degree of industrial prefabrication which varies greatly depending on which construction principle is used. Modularisation is one way to raise the degree of industrial prefabrication. The modules for housing construction need to be mapped in a structured matrix, a hierarchical relationship of materials, elements, modules, and clusters, which defines the interrelations among the individual elements in terms of a hierarchical order. The elements in this system can be combined, expanded, re-used, and are easy to assemble. They are joined by means of homogeneous interfaces and assembled into unique buildings. Elements constitute more complex modules based on a geometric order that determines the positioning of braces, walls, or room modules. Although architectural flexibility is bound by certain specifications, individual room constellations can be created by combining different modules, projecting a sense of highly customised building structures. To benefit from the cost advantages of modularisation in housing constructions, builders must follow the given matrix structures. The learning and scaling effects resulting from modular building concepts will allow builders to not only produce better quality homes, but to build them in less time and at a lower cost.

2. How can multi-faceted customer preferences be systematically integrated into modularisation in home construction?
The selection of interfaces in modular home construction requires in-depth knowledge of customer preferences. With a modular mindset, questions of actual needs, additional requirements, and the customer’s willingness to pay can be addressed precisely. The combinability of

modules decreases the number of components required overall, while at the same time increasing the proportion of customised products. The price of a modular home is competitive in all relevant markets, and it can be intelligently supplemented by a variety of equipment options. Analysis has shown that certain elements have proven to be indispensable as customers insist on including them and are therefore willing to pay for them. In residential construction, different architects can develop completely different homes based on a limited number of elements. Customer preferences are generated during the planning process by means of a digital product configurator. This targeted aggregation and provision of information results in a more efficient performance process. Building Information Modelling allows the builder to reveal cost reduction potentials along the entire value chain, and in itself represents an important competitive advantage. The ability of modular production to adapt to changing conditions within defined boundaries permits flexibility in room design combined with a high degree of prefabrication, which offers quick adaptation of production methods in response to changes in customer requirements given at short notice.

3. How can home technology solutions and interfaces to the infrastructure be modularised?

The home of the future places a multitude of demands on the design of intelligent home and network technology. Due to energy-saving concerns, automatic controls of ventilation, shading, and heating systems have become mandatory components in virtually all new buildings. The modules and their interfaces must therefore satisfy energy-related, architectural, and technical specifications. In order to ensure a kind

of “plug-and-play capability” of the modules between home technologies and infrastructure, modularisation in home construction defines a framework of conditions clearly assigning delineated areas of responsibility and making use of interfaces. Standardised interfaces are a prerequisite to ensuring that modules will be combinable, reusable, and expandable, as well as being easy to assemble and disassemble. In home construction, the connection to the infrastructure is established via the building foundation. After the base plate is poured and has hardened, construction of the building can begin. Before the modules are permanently anchored in place, the various electrical installations, sewer and heating pipes, as well as water lines are laid through the openings provided in the modules and connected to one another by means of standardised interfaces. Assembly time and qualifications required of construction staff on site can thus be reduced to the lowest necessary extent, while quality and productivity indicators are increased at the same time.

4. How can modular home construction optimise time, costs and quality without sacrificing the flexibility expected by the customer?
Based on the modular product, success factors are also greatly affected by production. An increase in the degree of prefabrication to over 80 % allows builders to reduce the time required to finish a home to a few weeks from the time of placing the order to handing over the keys. This reduction is achieved by the modular product, the reutilisation of existing planning services, and the application of lean production principles. Production principles such as those used by the automotive industry result in the consistent identification and elimination of waste, reduced

lead time and precipitate the simultaneous lowering of costs. The materials sector offers distinct saving potentials, as the use of pre-cut and pre-assembled components significantly reduces the amount of waste and scrap produced on site. Furthermore, the industrial process makes modular construction up to ten times more precise than conventional building methods. On site, precision in the cm-range is possible, while components produced at the plant can be exact within the mm and µm range. This level of precision leads to a high degree of consistency and process quality. In addition, the processes are performed under industrial conditions according to the manufacturer's specifications which is especially relevant in the use of fillers, glues, and paints. Central control of individual building trades also guarantees that there will be no delays in the production sequence and that pre-determined lead times will be met. The employment of a continuous quality management system throughout the entire building project ensures the quality of production and the work performed on site. Despite the defined production processes, customers can still flexibly change their product right up until the "design freeze" without precipitating additional production operations or incurring additional costs. With the modular product structure, customers can expand or adjust their homes even after the establishment of a structure.

5. What modularisation principles can be applied at the plant for home construction?

Owing to the modern design of production facilities, manufacturers can reutilise existing planning services not only for the product but for production as well. In modularising the plant, all resources, processes,

and structures needed for a functioning plant are standardised, so they can be used again in building new production facilities. This standardisation includes not only production lines, but also plant buildings, lot size, infrastructure links, staff qualifications, and the IT environment, making it possible to select and develop new production facilities much more quickly. The plants are scalable in terms of the degree of automation, capacity, and also the degree of prefabrication of the houses according to the requirements of the new location. Due to the scalability of the modules, the new facility can be adapted to the local circumstances. The use of tried-and-proven systems and processes shortens the run-up phase of the new location, which boosts its productivity. Beyond that, the organisation can fall back on existing lessons learned about the systems and processes, which also help to increase productivity. This becomes particularly noticeable in machine maintenance, as the plant can draw on structured experience and know-how from the past in case of a system failure, and this knowledge is not limited to one facility alone but can be applied to all facilities built according to the modular plant concept.

6. What modularisation principles are applicable on the building site?
The modularisation approach is particularly applicable to the layout planning of the construction site. The pre-defined basic matrix of the home modules allows the builder to present layout modules that can be selected and combined by means of a site layout modular system offering computer-assisted planning. Due to the high degree of prefabrication, sequences and processes on the construction site are much leaner. Where virtual modelling in conventional building fails due to

the high level of complexity, modularisation of the construction site makes illustration in the 5D model – 3D model plus building progress and costs – possible. By means of a building set and computer- assisted modelling, modularisation integrates the sequences on site more firmly into the building data modelling system. The lean and transparent processes on site help to minimise errors. In addition to layout planning, site infrastructure can also benefit from the implementation of modularisation principles. Required machinery such as desalination systems, power generators, or hoists are provided on site in modules that can be combined as required. They can be selected even during the planning stage from the layout module system. Furthermore, modularisation guarantees a high level of versatility of the site, allowing for the rapid and flexible response of the builder to any changes.

7. How does service modularisation contribute to home construction?
Apart from the product, customers expect additional services, much as they might expect their automobile dealership to offer financing when they buy a car. This development can be applied to modular home construction. By using services strategically in the form of hybrid service packages, these additional offers can represent additional value and allow the builder to stand apart from competitors with a more individualised product and additional services. This differentiation potential can in turn increase the benefit to the customer and promote customer loyalty. The effect can be further enhanced by allowing the customer to freely combine the services independently of one another. Apart from the basic service, product-oriented supplementary services successfully complement the service package and create further scaling effects.

Such supplementary services may include maintenance, insurance, consulting, financing, security, interior design, energy, supply, IT, wellness, health, full building service, property management, clearing and demolition, and landscaping. The options for reutilising these modules, the high individualisation potential of the services, and the independent development of individual service modules are further implications of modularisation. More added value can be created by offering the services in the form of packages. Offering additional services opens up new business sectors to construction businesses, which will ultimately lead to further innovations in the building industry. Possible new business sectors may include property financing, module licensing, after sales services, module sharing, module rentals, and a market for used modules.

8. What are the effects of modular home construction on order handling and organisation?

In order handling, orders for modular home construction are generated by the customer by means of a product configurator. The configurator lets the customer, aided by planners and architects and under consideration of regional regulations, design a house and have all essential data like costs and delivery date calculated. The proper involvement of authorities such as the building supervisory board or trade supervisory board is the responsibility of the design planner or the project coordinator. The use of the configurator allows for the quick generation of a proposal and flexible adjustments of the model. The model then serves as a basis for building and logistical plans, as well as machine data records and parts lists for the subsequent stages of order handling. Further ad-

vantages of using the configurator are a lower complaint rate and better recording of customer requirements and needs. The integration into order handling and into the standardised interfaces between the building data modelling system and the ERP system results in better communication among all parties involved in the project. The required supplier matrix includes suppliers of structural components such as steel profiles or gypsum fibreboards, and those of other installations like kitchen and bath fixtures. After the modules are manufactured, there is a drying and hardening phase and subsequently the commissioning, transport and final assembly of the modules with special equipment at the construction site. Parallel to the manufacture of the modules, the foundation is prepared and connected to the local infrastructure. This phase can be carried out by the module manufacturer or a subcontractor. Unlike with conventional building methods, the inclusion of in-kind contributions by the investor is rather unsuitable for modular home construction, as it would significantly increase the complexity of the industrial production process. One option for offering them nonetheless is the delivery of modules according to the "core and shell" principle, comparable with the conventional "building shell" including installation work, where the interior finishing is the customer's in-kind contribution. The use of a configurator in order handling improves the flow of information among all parties involved, which can significantly reduce the time required for the project.

9. What are the possible applications and market potentials for modular home construction?

Systematic modularisation and industrialisation open up new appli-

cations for the home building sector such as residential development, planned densification and special structures. Due to the prevailing technical and economic conditions, multi-family homes built with lightweight steel construction modules are particularly suitable for satisfying the growing demand for housing. To optimise cost factors, these homes need to be developed using a defined stepped fixed cost structure. In Europe, modular home construction can increasingly be used in residential development projects to help satisfy the demand for subsidised housing. Densification can be carried out to create more living space in existing older buildings in inner cities through adding storeys or finishing attics. There are also applications for modular construction in special construction projects such as hospitals, schools, or care facilities. The great advantage here is the ability to satisfy different utilisation requirements with minimum effort. Market potentials for modular construction appear to vary according to geographical regions. In the regions examined for this study, the worldwide market potential for modular home construction is estimated to be about €520bn by 2020. The largest potential markets are China, the USA and Turkey. In these countries, a market share of over 70% is deemed possible by 2050. China, the USA and Turkey present market potential by 2050 of around €1.8tn, €1.6tn and €419bn respectively. Modular home construction may reach a market share of 70% in Russia in order to satisfy high demand. India will also play a major part in the years to come when relevant political reforms have been implemented. The German market for modular home construction is expected to see moderate growth and may represent up to 32% of the entire German home construction market by 2050.

10. What is the level of feasibility of modular home construction?

The feasibility of modular home construction is evaluated from three perspectives: the customer's perspective, the economic perspective, and the corporate perspective. For the customer, modular construction should provide the greatest possible benefit at a significantly lower cost than a conventional building. With respect to the various customer needs such as shelter, individuality, sustainability, financial relief and predictability, modular home construction helps to improve the standard of living. The cost advantages of this building method will allow the proportion of home ownership among households to increase from currently 20% to around 50% because even relatively low-income earners will be able to invest in their own home. The economy will also experience positive effects. Governments will be able to provide subsidised housing at significantly lower cost and effort. In addition, they can profit from increased consumption and higher tax revenues as citizens and companies will have up to 13% more disposable income due to their monthly savings on living expenses. Companies can benefit from modular construction in terms of costs, time, quality assurance, and flexibility. Although modular construction represents higher initial investments for companies, e.g. for production buildings, manufacturing systems or site equipment, this investment should be amortized within two years assuming the enterprise runs at full capacity. In addition, companies can benefit from premium-priced products created by the combination of basic and supplementary modules. Further potential for revenue rests in offering services which unlock new business opportunities for companies and contribute to the realisation of new growth potentials.

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Manfred Grundke studied mechanical engineering at the University of Applied Sciences of the German state of Rhineland-Palatinate in Bingen. His professional career began at the Federal Office for Defence Technology in Koblenz before he moved to Feinmechanische Werke (Precision Engineering) in Mainz, where he became the leader for the development of aeronautical systems in 1989. After being entrusted with several other positions during his career, Manfred Grundke joined Mannesmann Rexroth AG in 1997, where he held positions as a Member of the Board and subsequently Chairman. In 2008, he became a Managing Partner at Gebr. Knauf Verwaltungsgesellschaft KG.

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