UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Developing an Integrated Design Support Framework to Enable Mass-Customisation in Multi-Storey Timber Building Projects

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under the supervision of
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Alireza Jalali Yazdi declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Built Environment, Faculty of Design, Architecture and Building at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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To my parents, for all their support and unconditional love

This is a thesis by compilation

Declaration of Publications

The following publications, which have arisen from the research for this thesis, are listed below:

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Abstract

The building industry has adopted mass-customisation (MC) strategies to address efficiency issues associated with the customised nature of this sector. Multi-storey apartment buildings constitute a large segment of the Australian building sector, which possesses significant potential for MC. MC aims to provide choices for heterogeneous apartment demands in a prefabricated construction context. It intends to deliver marketable building products at a competitive cost close to mass-produced buildings. To maximise their benefits, mass-customisation strategies must be implemented from early design stages by developing a custom product that can be efficiently manufactured, transported and assembled onsite. Implementation of general design rules, such as guidelines provided by Design for Manufacture and Assemble (DfMA), at the early design stages can enable the mass-customisability of the final building product. Implementing such generic DfMA rules is challenging, particularly due to the mathematical complexity of the building design problem. To successfully address this challenge, a systematic and automatic approach is necessary for exploring different design alternatives. However, the literature is slim in proposing a practical solution to optimise the design for MC. Such an optimisation platform must incorporate offsite manufacturing processes and efficient onsite assembly and installation operations into the design process.

This research introduces a design support framework that enables MC of multi-storey buildings by incorporating both offsite manufacturing and onsite assembly requirements. The framework consists of three main components: (1) a design optimisation model to maximise standardisation while maintaining architectural flexibility, (2) a framework for transferring the optimisation results to a digital design platform, and (3) an onsite installation optimisation model for crane scheduling to avoid the formation of bottlenecks in assembling mass-customised components. Due to their increasing market uptake, and their high potential for customisation, Cross-Laminated Timber (CLT) buildings are chosen as the case studies for the implementation of MC strategies. The mass-customised building designs were automatically generated and thoroughly explored using evolutionary algorithms. The optimal design solutions were visualised on a Building Information Modelling platform and then were used to generate an accurate bill of quantities for factory production. Results of the case studies showed that up to a 20% decrease in the CLT waste and a 10% decrease in the installation, delays are achievable by adopting the proposed methodologies. The outcomes of this research can be used by the building industry to achieve mass-customised designs that result in minimal waste during manufacture and a more productive onsite installation.

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