

Chapter 66

Direct Building Manufacturing of Homes with Digital Fabrication

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ABSTRACT

Architecture, engineering, and construction industries maintain a long standing desire to enhance design communication through various forms of 3D CAD modeling. In spite the introduction of Building Information Modeling (BIM), designers and builders expect varying amounts of communication loss once construction has started due to indirect construction techniques or hand based methods to manufacture buildings. This is especially true for houses and small structures, buildings that makeup the core of villages and suburbs. Unfortunately, paper documentation and reading 3D CAD models on screen continue the trend of indirect production defined in most manufacturing industries as error. The emerging application of CAD/CAM within design and construction industries provides hope for elevated communication between design and building. With CAD/CAM, it is possible to manufacture buildings of all types and sizes directly from CAD files similar to mass produced artifacts, thus reducing complexity in communication between parties. This chapter is presentation of one process of direct manufacturing from CAD and the emerging possibilities for small building production using digital fabrication. The chapter will focus on houses to illustrate the potential of direct manufacturing of buildings from CAD data.

1. INTRODUCTION

For centuries, architects and builders have pursued systematic ways to design and deliver homes at low cost in production and high quality in output. New arguments around home production are di-

rected at machine based manufacturing of buildings opposing common handcraft construction techniques (Kiernan & Timberlake 2005). This process, typically described as prefabrication, is a century old, westernized system of home production in factories by assembly of large units with cranes on site. It has survived many decades of reinvention while also struggling for

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broad acceptance as a worldwide industrialized system of building production (Davies 2005). In particular prefabrication has not caught on in developing countries or as a means to produce low cost housing in westernized environments.

This chapter argues prefab is complex in production maintenance, it suffers from the limitations of space and skilled labor, both impede the number of modules produced daily when demand for prefabricated homes is high. These factors also jeopardize the financial security of each manufacturer when unit sales are low. Also noted is the high cost of factory startup and operations curtailing new ventures within impoverished countries and states.

Digital fabrication or CAD/CAM is emerging as the next method of building delivery with built examples as experimental and exotic structures (Sass 2006) (Iwamoto 2008). It is a low cost, high precision manufacturing from CAD data commonly used today for furniture manufacturing. Specific to home construction one benefit of digital fabrication is that it can expand the range of production beyond the local contractor. With digital production manufacturers of metal, stone, plastic and wood based trades can fabricate components anywhere and at anytime. Manufactured components can be delivered to the project site or factory supporting assembly only production systems with low skilled labor. Digital fabrication of components assures component assemblies with few discrepancies between the digital representation in CAD and the physical artifact. As a production system it allows for replication and recombination of digital models potentially supporting mass customized home manufacturing (Duarte 2005). Best is that digital fabrication can increase the efficiency of Building Information Modeling (BIM) by empowering *direct building manufacturing* from CAD based product models (Eastman 2008).

The grand challenge for *direct building manufacturing* will be discovery of new process pathways that bridge the physical divide between 3D

building information models and machine data. This limitation stems from industry maintenance in hand tooling and assembly with handheld machinery as the core production method. For wood framed housing the standard material is dimensional lumber processed with standard tools such as power saws, screwdrivers and nail guns. Power tools and dimensional lumber do not take advantage of the efficiency of CAD modeling or CAD/CAM machinery. Precise machine cutting of is often difficult without special machine setups and rigging, the industry of wood framed housing maintains a need for highly skilled crafts people.

The aim of this chapter is to provide a context for digital fabrication as a mode of building production from a design by presentation of a process with two built examples. The chapter starts by presentation of industrialized manufacturing as the background for our home product manufacturing goals (Section 2). Next, past methods of controlled home manufacturing is presented illustrating the limitations and error in construction leads to higher cost and lower quality construction (Sections 3-5). Digital fabrication is presented as a method of production along with an explanation of its limitations (Sections 6-7). Materializing Design is systematic way to compute a design model for digital fabrication along with illustrations of the transformation process (Sections 8-9). The chapter ends by discussion on next steps as they related to the integration of other building systems such as plumbing, electrical, solar, etc.

2. INDUSTRIALIZED MANUFACTURING

As we stand at the threshold of new demands for energy-efficient green homes, we are also faced with the need for advanced systems that control design and home delivery. More than ever before, consumers expect new homes to perform in ways similar to mechanical products like automobiles, computers, and airplanes. Demands for increased

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