# Digital Design-Build

Ryan E. Smith
University of Utah
College of Architecture + Planning
375 S 1530 E Rm 235
Salt Lake City, Utah 84112-0370
E-mail: rsmith@arch.utah.edu

## ABSTRACT

**This paper is concerning a new methodology for design-build education based on digital design and fabrication. This is being examined through a recently developed community service learning studio at the University of Utah, College of Architecture + Planning. As digital design processes that lead to digital manufacturing and fabrication become more widely implemented into the making of buildings in standard practice, students who engage in this learning will be better equipped to become leading practitioners in the art of building.**

## 1. INTRODUCTION

Architectural education in many institutions across the country recognize the need for students to develop an awareness of the physical aspects of architecture, that of the making of buildings. Design-build programs in schools of architecture focus on serving communities with student labor by means of recycled, off the shelf or found construction materials. Auburn and more personally Utah's rural programs are some examples. Although these programs are positive in helping student engage in a social act and learn valuable lessons about traditional construction, they do not address the changing nature of architectural design in contemporary practice, that of digital design and off-site fabrication of buildings. The Digital Design-Build Service Learning Studio at the University of Utah, College of Architecture + Planning is therefore, rooted in teaching and researching methods of digital design and construction practice.

Fig.1 University of Utah, College of Architecture + Planning Rural Studio – Bluff, Utah (Professor Hank Louis)

At the foundations of digital design and manufacturing, or CAD/CAM in architecture is the principle of off-site fabrication. Benefits of prefabrication include increased speed of construction, better constructability, liability reduction, increased precision and quality control, as well as increased recyclables. In addition, similar to the focus of the current design-build educational models, this process, by means of digital practice has the potential to put architects back in control of the building process as the master builder. Although computer aided design and manufacturing has primarily been associated with elitist architecture, the implementation of digital design-build has the potential to create a better product for less money than conventional construction in mainstream design and construction practice.

Wherefore, the goal of this research is to investigate the process of digital design and fabrication, its pros and cons with respect to cost, time, constructability, and whether architecture based on this notion is limited in its formal qualities. In addition to practice issues, the studio will be a evaluated in its effectiveness over time as a learning model in architectural education. The process is explored by means of teaching, meaning the students with the aid of professors are developing projects that probe explorations in CAD/CAM. The projects are therefore, real world projects with a client, a site, and a budget. Currently, the Utah Transit Authority (UTA) is funding a project in which students develop designs, drawings, pricing, and lead times for digital manufacturers, in order to build prototypes for construction. The process is documented in preparation for a report that evaluates the project and recommends a design and construction based on the research discoveries. The project will be built in town as the first in a series of shelters for the Bus Rapid Transit (BRT) system. The model will be evaluated and repeated with modifications for a future shelter project for the University of Utah Campus Shuttle system in connection with the Campus Facilities and Planning Department. Additional projects being sought for subsequent years include student union demountable booths, as well as other small pavilions and buildings on campus and in the community. Funding for the program is provided by the client organizations and additional support is being sought from parametric software developers for testing in the digital design-build program and manufacturers who are working to emerge in mainstream building practice. Funding is also being requested from the Lowell Bennion Campus Service Learning Center at the university once service learning designation is awarded to the studio course.

## 2. CASE EXAMPLE

### 2.1 Work Description

The work conducted on a project in the Digital Design-Build Studio is broken into the following three phases: Design Competition, Design Development, and Prototype Construction.

For UTA the initial design commenced with a three week design competition. The competition was introduced as an initial meeting with the client representative, a project manager at UTA to establish the goals, expectations, and programmatic requirements for the project. Students worked in teams of three or four with their studio professors on urban analysis and architectural design. A presentation was then made of the schematic designs to a jury consisting of representatives from UTA and the college in order to select teams whose projects respond most appropriately and innovatively to site and program while utilizing a CAD/CAM intention. The top three winning teams are now participating in the following phases of development of the project.

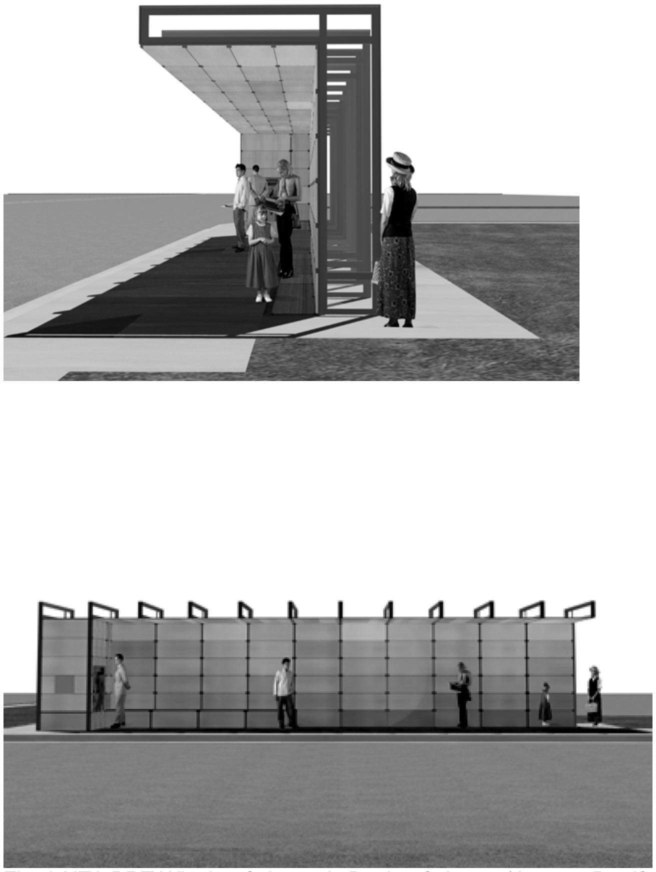

Fig. 2 UTA BRT Winning Schematic Design Scheme (Jensen, Bradford, Newbold, Sumsion)

The students are currently participating in the latter end of the second phase of work consisting of construction documents, pricing, and construction process development and planning. This phase involves meeting bi-monthly with the client representative or group and engaging a structural consultant and other consultants as deemed necessary. The process is lead by a steering team made up of experienced designer/fabricator professors. The student team members have been given responsibilities in conjunction with the roles of the professors, namely: the project leader who acts as a manager of the team by keeping track of responsibilities, maintaining the schedule, interacting with consultants and reporting bi-weekly to the professors; the modeling leader who is primarily responsible for developing the digital models, and the pricing leader who is responsible for interacting with fabricators and contractors. Each group has developed the project including locating fabricators, beginning digital ready files for fabricators, and establishing a construction methodology and associative price in preparation for prototyping. After the pricing data is gathered a decision will be among the teams as to which design responds to the issues budget, speed of construction, durability, and constructability. A design will then be chosen for building the prototype.

Digital ready files are being produced in phase two in preparation for fabrication of parts or wholes for construction. In the third phase, students will observe the fabrication of parts at the fabrication shop. The components will be transported and assembled at a predetermined site. The construction will be supervised by professors. The prototype with its pricing data and lessons learned, will be evaluated in a report as a model for implementation on the 3500 South corridor for design/construction by UTA.

## 2.2 CAD/CAM

The dialectic of form making to physical making of architecture is explored in this studio. The question of what determines form is difficult to evaluate. In the process of digital design and fabrication projects issues of software platforms capability may determine form. In other projects the manufacturing technology available is only utilized in so far as it is a step in accomplishing the desired design objective. This latter traditional method of producing architecture continues to disassociate design from production. Rather, in the digital design-build studio the goal is to explore the methods of manufacturing and fabricating for building as the impetuous for design and form making. In short, the software and manufacturing technology informs and may even drive the design process. Students therefore learn of the importance of understanding the tools necessary to fabricate and produce buildings. In order to foster this knowledge students are taken to CNC (Computer Numerical Control) fabrication shops including digitally driven laser/water jet cutting, 5-axis milling, tube and pipe bending. These processes are evaluated and explored for their potentials in form making such as testing them against forming surface, plane, and or volume. The design process then yields a product that relies on the technology available.

Students of architecture learn software programs quickly and efficiently. Many students are excellent modelers on the computer, however have not learned to harness the skill into design, having utilizing three dimensional modeling programs for visualization only. The studio presents opportunities to apply specific software applications to the design intention. Many different software packages are available, however vary in their function. There exist 5 general groups of parametric modeling environments in computer aided design, namely, concept renders such as Sketch-up and Form-Z, animation programs such as Maya, entity based programs such as Vectorworks or AutoCAD, component based software otherwise known as building information modelers such as Revit and ArchiCAD, and finally design development modelers such as SolidWorks in the industrial design arena and in architecture, CATIA.[3] The digital-design build studio encourages students to experiment with software applications that meet the design intentions based on the abilities of the fabricators. CATIA is a powerful platform that offers great advantages for integrated design in building information modeling environment that can act as a database of information represented in a variety of mediums, graphically being just one, however is difficult to learn in a short semester-long studio.[4] Proactively, the students will continue to learn software packages in the future, and as the studio evolves year to year, the platforms will become more sophisticated. It is the intention of the studio therefore to utilize and test software capabilities according to design intentions.

[3] Shodek, Bechthold, Griggs, Kao, and Steinberg. Digital Design and Manufacturing. Wiley Publishers 2005. Ch. 10 Fundamentals of Digital Modeling

[4] Ghery Technologies has developed an architectural version of CATIA called Digital Project that offers a more user friendly environment.

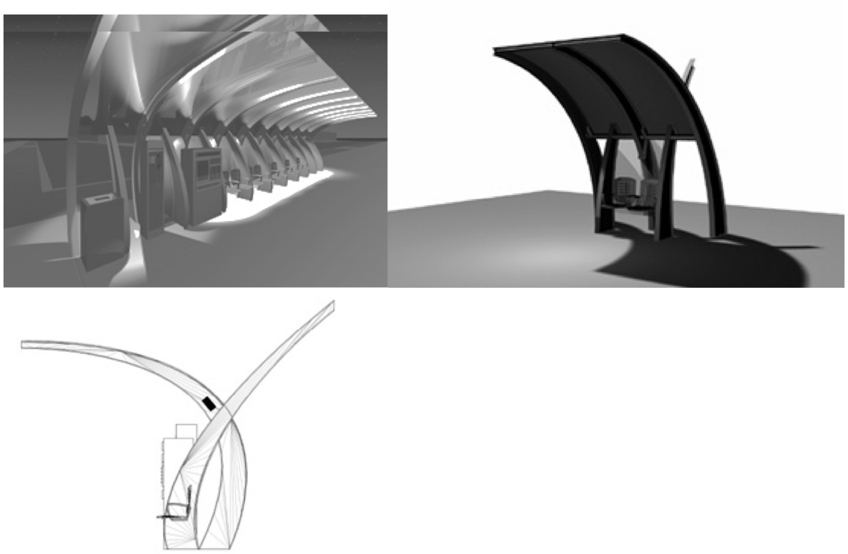

Fig. 3 Initial design concept (concept render), construction module (Entity Based), digital development of steel components for fabrication (Design Development Modeler)

2.4 Practice Training

In addition to learning issues of software and fabrication students also learn real life lessons concerning professional practice such as the realities of client and consultant interaction. For example, in the UTA project, students in meetings with the structural engineer are evaluating issues in relation to design, similar to an office environment. In a recent report from one of the groups, the leader stated after a structural consultant meeting, “We have to make compromises on things that do not matter so much and take a stand with things that do. We have to let go of the randomness of the columns for an ordered chaos of grided columns on angled cants, but we are maintaining their dimension and profile. Although tube steel is not the best profile for making a moment connection, the tube profile happens to be the most economical.” Students are also learning about continued interactions with the client after a schematic design is approved or competition is won through bi-monthly development meetings. On list of things to do before next client meeting, one group noted a task list in their bi-weekly report as follows: “understand what the client ‘needs’, refine lighting scheme/talk to lighting consultant, contact fabricator for fabrication options, work on thermal expansion scheme on glass to frame, rework structural details according to engineer’s suggestions…” Lessons learned concerning practice issues in this experience are invaluable in aiding young architects in becoming leaders in the art of building.

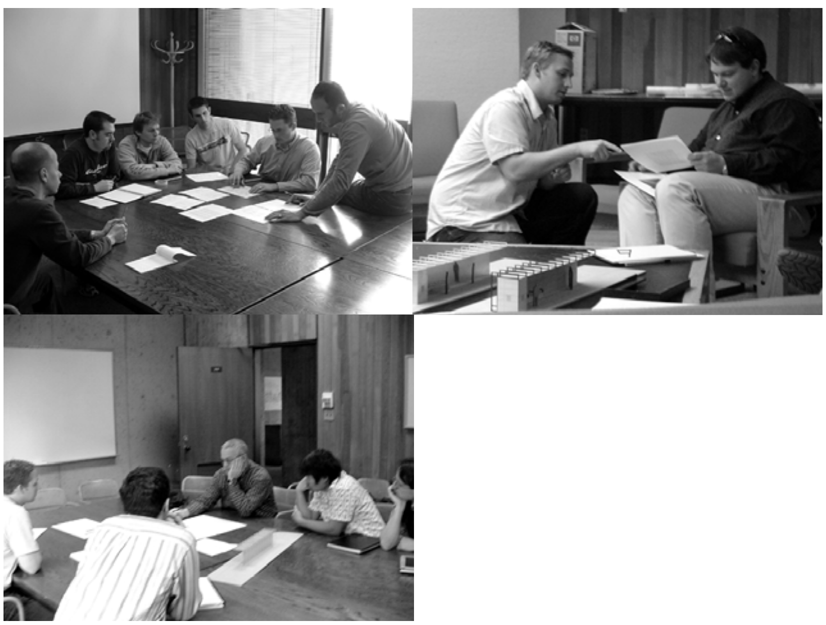

Fig. 4 Student team meeting with professors, student team leader meeting with client, student team meeting with structural consultant.

A vital role of the architect is with respect to serving the community at large. Although the projects in the digital-design build studio are client driven, the design-build projects are also related to important community and civic issues. For example, for the Utah Transit Authority, the design calls not only for a sophisticated shelter design, but one that considers ticketing machines, integral signage, and accommodations for twenty waiting riders per stop. The issues of design range from traffic analysis, urban design, landscape, graphics, and iconology of the bus system itself. The issues addressed through the studio help in teaching students the importance of design as a social and ethical responsibility.

## 3. LESSONS LEARNED

### 3.1 Conclusions

The outcomes of the Digital Design-Build Service Learning Studio are beneficial for students, the community, and the profession of architecture. First, students learn about the realities of practice through the lens of a real world project that is built. The scale of the projects is such that students are able to experience similar phases of a design project in the profession at an increased pace. Therefore, the students learn the skills necessary to become instrumental on a design team. Students also develop a sense of obligation to the community as the projects work to foster an attitude of education as part of practice. The community benefits from the service learning class by having their programmatic needs met. In addition, under the digital design-build methodology, community groups have projects built that surpass traditional practice models trough producing a better end product at a potentially lower cost, in a shorter amount of time, while engaging in a process of supporting public education of young architects. The profession benefits from the studio in producing knowledgeable and skilled designers in the digital design and fabrication arena.

Construction in the U.S. is relatively cheap in materials costs and expensive in labor costs. In traditional models of design-build education students are hence often exploited as cheap labor to accomplish construction projects for the benefit of the community. The digital design-build studio utilizes students as a means of education in the manner in which they will be practicing, that of design development. The students then engage in construction by means of development and observation without being used for labor. As a new model for architectural education, the Digital Design-Build Studio address all aspects of architectural education and practice and combines them into one concentrated and integrated experience that teaches client interaction, programming, site planning, consultant interaction, management, and construction administration.