2006-126: THE EFFECTS OF COMPUTER AUTOMATION ON THE DESIGN DEVELOPMENT PROCESS IN ARCHITECTURE

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The Effects of Computer Automation on the Design Development Process in Architecture

Abstract
Computer automation and information technology has changed the design development process in architecture. Students no longer use a transparent, linear design process facilitated through the craft of hand drawing. Instead, the design process has become increasingly fragmented and hidden through the use of this new technology. The dilemma we face as educators is: one, how to teach and assess this new process in the context of existing ideas of how students experience and acquire design knowledge, and two, how to prepare students who will work in a profession that is increasing embracing the use of this new technological process for economic reasons. This paper outlines characteristics of this new design process and examines the effects in a Construction Design course. Student survey data is presented showing student behavior along with other examples to support the theory. Recommendations for new assessment are offered. This topic should have broad appeal for anyone teaching a design development course that seeks to prepare students for the profession.

Introduction

Throughout history, handcrafted processes have been transformed by technology into new and different processes. Technological changes affect the very nature of an activity, our perception and understanding of it. As processes are transformed, some skills become obsolete, other aspects of the process become hidden, particular activities become more focused, new skills developed and knowledge acquired. It should then come as no surprise that technology, as later defined, is now transforming the design development process in architecture.[1]

The design development process in architecture was originally a handcrafted process that involved a pencil, tracing paper, and drafting equipment. It started with exploratory layout sketches followed by a linear series of overlays, one on top of the other, with tracing paper. The entire process produced a refined design solution for assembling and constructing building components. Each component and assembly in the design process was hand drawn by the designer. Through this act, a level of knowledge and ownership of the process was obtained. The process began to change with the introduction of CAD (Computer Aided Design) drawing. The perception of scale changed and the pencil was substituted with a mouse in this paperless drafting platform. Recent advances in CAD automation software[2] coupled with computer information technology systems have combined to further transform the design development process in architecture from the original handcrafted process.

The result of this new design process is one that has become increasingly fragmented and hidden through the use of this new technology. Design automation reduces the designer to observer by hiding the process rather than having one see and experience it. The coping and pasting of components into the design solution further removes the designer from coming to know, on some level, parts of their solution. Both of these technological features combined challenge and question our basic understanding of ownership of the design process itself. The dilemmas we face as educators are many. What is the new design process? What knowledge is and is not relevant? What does ownership mean? How do we teach and assess this new process in the context of existing ideas and faculty experiences of how do students traditionally acquire design knowledge? How do we prepare students for work in today's profession that is increasingly embracing the use of this new technological process for economic reasons?

This paper will apply a series of existing theories developed from the post World War II period to the pre CAD period of the 1980's to explain technological changes and apply them to computer automation design process of today. These ideas will help to develop a theory to understand this new design process. It will outline characteristics of this new design process and present a framework to examine the effects in a Construction Design course. Student surveys and supporting data are presented. Recommendations for new assessment are offered. The larger goal of this paper is to obtain feedback for a more serious journal length article.

Theoretical Background

There is a substantial body of theoretical work that explains how technological changes affect and transform handcrafted processes. Many of these theories were developed during the nineteenth and twentieth centuries to explain the effects of the Industrial Revolution. Until recently, the design process itself has remained relatively unchanged because no new technology has transformed it. This paper examines the very narrow effects on how technology changes a particular design process; design development, also known as construction design or working drawings. It will build on a theoretical framework of established ideas to explain and develop a new understanding. Three important works are used in this paper: (1) Siegfried Giedion's Mechanization Takes Command[3] for the historical lessons learned from mechanization, (2) Peter McCleary's article, "Some Characteristics of a New Concept of Technology"[4] for ideas on how we experience technology and (3) Christopher Alexander's work on contextual appropriateness and fit,[5, 6] along with my own writings.

Lessons from Mechanization

Siegfried Giedion's 1940's work is important here because there are parallels between the effects of CAD and computer automation, in parts of the design process now, and the lessons he learned when complicated handcrafted processes are transformed through mechanization during the Industrial Revolution. Giedion argues that the mechanization process requires three things: (1) the understanding of the steps of hand movement, (2) standardization of components and (3) the assembly line [linear] process. First is the notion of movement. Understanding movement allows one to understand the steps that lead to the division of a process.[7] The medieval handcrafted process was a continuous singular process versus the modern mechanization which is a divided process. The design development process is now divided through the use of CAD and computer automation. Second is the standardization of components. Building components have becomes highly standardized as a result of mechanization. When CAD became the drawing platform for design, the natural process was to standardize information. The result is standardized blocks of details and assemblies that are then copied and pasted into the design development solution. This information is no longer designed by the architect, rather it is selected from a library of standardized assemblies; like an old catalogue of standard mechanical parts. We will see this trend continued in the design process where design solutions will become more and more standardized through the use of technology. Third is the linear assembly line. The assembly line becomes the time synchronous process by which the sub processes from the divided act and standardized components come together to form the solution. If a desired design solution is known and the outcome is predictable, then CAD automation now has the capacity to do this linear form of design easily and in real time. We may not be conscious of this because of the effects are slowly creeping into the design process but this is part of the larger paradigm of modernism. It started with the Industrial Revolution and is now continuing through the computer and information technology revolution.

Experiencing Technology
Peter McCleary's article is important because it describes how we experience and perceive the effects of technological transformation. His article specifically applies to architectural technology and not the design process itself; the article is also pre CAD. He discusses three technological factors that affect how we view and respond to architectural form: (1) transparency and opacity; (2) amplification and reduction; and (3) appropriateness to and appropriation of context. The first two concepts are elegantly presented and relate to this paper's theory. The third concept could be used here but instead we will rely on Christopher Alexander's work. McCleary gives a simple example of how technology transforms the process of cutting the grass transforms the process, "My grandfather cut the grass with the short-handled sickle; my father reduced the stress in his back by using the long-handled scythe; I experienced the cutting of grass with a hand-driven lawnmower; my daughter encounters the characteristics of grass with a fuel-powered (or self propelled) hand-guided mower; her child will use a lawn-tractor where the experience is driving and not of cutting; my great-grandchildren will, in all likelihood use, if anything, an automaton or mechanical goat." The transparent experience of cutting grass by hand becomes completely opaque by the technology of the mechanical goat. Although McCleary uses a different example of the "tele" (i.e., telephone, telescope, television) to explain amplification and reduction but we could apply it to the grass cutting example also to highlight this space time idea.[8] Aspects of the mechanical goat's function are amplified (i.e., how to turn it on, how long does the battery last, etc.) while the time and space proximity to the grass and experience of cutting it is reduced. Parallel concepts here can be applied to CAD automation and the copy and paste function in the design development process.

Contextual Appropriateness
Christopher Alexander's theory states that we should measure design in terms of how appropriate the form fits the context.[9] His binary fit and misfit test and reliance on analysis of patterns for appropriate contextual fit are some of the foundations of his architectural theory. His theory is not explicitly intended for application at the level of building system component design or this technological issue, but it can be. It is used here as the basis for analyzing copied components or automated design solutions for fit into the larger system. Students will often use almost any solution whether or not it is appropriate because the copy or automate function is quick and easy. Other than unawareness, there is a seduction factor of a perfect technological solution in front of them and their inability to challenge it. This issue of contextual fit is now an important part of the design development decision making process.

Recent Work
Over the past three years I have written about issue of design automation and the dilemmas we face as educators in the referenced articles.[10, 11, 12] Common to these articles is the growing conflict between industry and academia in the increasing use of automation. This argument is

based on the following premise. "Certain cognitive design processes will be completely automated by technology thus rendering specific types of knowledge obsolete. In the same token, certain types of knowledge used as building blocks for learning can only be gained by using obsolete technology. Herein lies the dilemma, industry is moving toward one type of technological platform [automation] for economic reasons that academia cannot use for pedagogical ones. The secondary issue is that the automation process reduces the designer to observer similar to the way a worker was reduced to observer in the Industrial Revolution with a mechanized process."[13] The conclusion is that technology has divided the act of design itself into one of design creation and the other of design analysis through automation.[14] The result is certain types of design will now be automated and the thought process for students will be to analyze the end solution or product as a design analysis act. TABLE 1: Comparison of Computer Automation vs. Human Value Judgment (see Appendix) has been provided predicting what aspects of design are likely to be automated and what are not.

The most recent article advocates the increasing role of contextual fit as part of this new design analysis component and a change in assessment to reflect that shift.[15] The new contribution made in this paper is not proving that this is occurring or arguing the nuts and bolt of which CAD programs do what. It puts forward an explanation of what the designer is experiencing, as described by a set of characteristics, when we automate parts, the design experience and integrate other technological functions that affect our experience.

Ownership

One of the dilemmas we face as educators is the issue ownership. Specifically, what work did the student do, what work was automated and what work was copied and pasted into the design solution? Design solutions, unlike term papers, are not cited. Both historically and culturally, architects claim ownership of a design by the act of drawing even though ideas, styles and entire building types are freely borrowed. The act of drawing also becomes a way that architects come to know all aspects of their designs. The automation, copy and paste features reduce the designer to observer. Some sociologists would argue that a loss of ownership maybe the cause of alienation and resistance. Marx defined alienation as occurring when individuals become estranged from the products of their work.[16] This could include the loss of meaning, control, individual creativity and ownership of their own labor. Marx also says that there has to be a dimension of exploitation, of which there is little evidence of that occurring to academia, so one wonders if this is occurring in the workplace.

Theory

The theory developed here explains, by using a series of characteristics, how this new technology changes the design experience. If we understand this, then we can answer the relevant pedagogical questions of what types of knowledge and skills should our students have? How do we assess this new design process? The characteristics of this technological experience presented are as follows: (1) singular vs. divided; (2) transparent vs. hidden; (3) magnified vs. reduced; (4) discovery vs. outcome; (5) contextually implicit vs. explicit; (6) individual vs. shared ownership. The TABLE 2: Experience Between Handcrafted Design Process vs. Technological Design Process (see Appendix) is presented here as an informal compilation of ideas to show the alignment of these characteristics also.

Singular vs. Divided

Technology is dividing the design process. Architecture, unlike engineering, has remained primarily a singular process and craft oriented profession. The notion of a divided process seems foreign to a culture that celebrates our popular architectural heroes as individual artists. Architecture has only one professional degree versus many in engineering because neither science nor technology has changed the core process of design until now. CAD automation by default is creating a divided and fragmented design process. The designer doesn't have to use the technology but given the economic pressure[17] and surety risk[18] of professional practice, the CAD choice will nearly always be selected. Design is now a shared or divided process between technology and the individual. Giedion's theory of mechanization becomes increasingly applicable and foretelling for design automation; dividing the act, standardizing components and automated linear assembly process.

Transparent vs. Hidden

CAD automation has hidden parts of the design process. We still teach freshmen hand drawing not because we think the skill of drafting is important but because we recognize the importance of thinking through the process of plan, section, elevation, and axonometric without the mediation of technology. Thinking with just a pencil in many ways is an extension of our fingers and hands and in this sense is completely transparent. McCleary's example gives us a clear idea of how technology mediates our experience and transforms the process so the parallels applied seem clear to us in the design development process in architecture. An example of CAD design automation here is the auto-roof design featured on Autodesk® Architectural Desktop 3.3. See FIGURE 1: Time Comparison of Automated Design verses Handcrafted Process in the Appendix for an example of this. If the footprint of the building is known and the type of roof characteristics desired, a three-dimensional design is automatically produced with the click of a mouse. The roof design experience is completely hidden from the designer, along with the knowledge to actually do it.

Magnified vs. Reduced

The technology is also changing what designer's experience by magnifying certain aspects of the design process while reducing other aspects. The components within a design are increasingly being reduced by either the automation or the copy and paste process. The connections between components are being magnified. Most of the time a designer now spends is in the solving of connections between the components. The zoom command has also magnified the scale at the connection level beyond what is traditionally experienced in the pencil and paper process. In this sense, the space time idea that McCleary alludes to is also experienced by the designer.

Discovery vs. Outcome

The drawing process was rich in discovery, explaining why designers still like to draw in diagram. CAD technology in many ways is changing this experience for the designer also. CAD automation along with copy and paste are selections that produce an instant outcome rather than a process of discovery through drawing. CAD can be used as a powerful three-dimensional discovery tool but in the design development process it remains two-dimensional, moving toward an outcome, rather than a discovery based process.

Contextually Implicit v. Explicit
The total experience of a continuous process of drawing a component in preparation for making the connection fit has changed. The handcrafted process was singular and contextual fit was implicitly discovered. Because the CAD process can develop several solutions instantly versus the handcrafted evolutionary process, the discovery as we know it has changed to analysis of contextual fit. In pre CAD design development, architects would check their work for errors. Today there are few errors in the design solution. Looking for these errors is like checking for a spelling mistake. What we need to check for is the appropriateness of fit. The real question we should ask students is does this instant solution properly fit the micro and macro design patterns? Alexander's work gives us a philosophy and binary methodology for testing and proving the goodness of fit.

Individual vs. Shared Ownership
Although not as important in practice, the issue of ownership or authorship becomes very important in academia because of its connection to assessment. Since student work is not cited in design, the question of how did a student come up with this is important. Couple this with the design functionality of CAD, educators are challenged as to just what the student has done and what knowledge or experience they have gained from the process; this is equivalent to assessing an individual on a team or group project. A secondary issue is how or even if, students can take ownership of this design process? How do they come to know it or should they just take responsibility for the management of the process? More studies need to be done in this area but clearly the technology has changed their experience and is raising important pedagogical questions of authorship as well as ownership.

Supporting Data
Survey
A three-page blind survey was given to the Construction Design students at the conclusion of their first ten-week design development project for a large residence. Although the survey was not designed specifically for this paper, it does show characteristics of this new technological experience. See Results of Student Behavior Survey in the Appendix. The survey first asked students a series of questions on how they designed or generated components of their project that ranged from standardized manufactured components to complete assemblies. It then asked a series of questions about the use of the design automation features and how they reviewed, analyzed or just accepted the computer generated solution. The survey also asked a series of questions on how students spent their time, what choices they made in terms of the selection of copied or automated material and how much time they would invest before they changed their strategy if they could not find the correct solution.

Process Comparison
A comparison between a handcrafted design process and automated design process for a hip roof design only reveals the time differential; it takes a fifteen to twenty times longer to design by hand and there always exist the possibility for error. See FIGURE 1: Time Comparison of Automated Design verses Handcrafted Process in the Appendix. It is impossible to know what the designer is really thinking but we can deduce the following: The automated design renders the designer as observer who selects the outcome rather than discovers it. The designer of the automated solution may or may not have the craft, empirical or theoretical knowledge to design

the solution. Since the CAD solution is nearly certain to be technically correct, the only knowledge the designer needs to have is the CAD skills to make the correct outcome choice.

Analysis of Data
The following design behaviors can be concluded using the data available. One, students will select the technological solution available over taking the time to do handcrafted solutions as indicated from the survey. This selection indicates that the design process experience has become divided or fragmented. Two, the survey also shows us that time spent on design analysis, the explicit contextual fit characteristic, is a separate design act. Three, we can also infer that based on the Process Comparison in Figure 1 that the designer will select an outcome process versus discovering the solution through the experience of the design process because of speed and accuracy. One wonders if the overall creative process of design is increased or decreased in other areas because the joy and confidence of designing easy stuff is apophatic and the more challenging design is kataphatic.[19]

Assessment Recommendations
Design is a process and the process is everything academia so how do we assess students pedagogically? Unless one has a full understanding of the changes in the design process as the result of technology, assessment will not properly reflect student work. This paper presents a series of characteristics that will act as a guide for future assessment. First, assessing student work will be much more akin to assessing a team project because there are no citation standards for design drawings so ownership is difficult to establish as we know it. The team is the student and CAD platform. The recommendation is to hold the student solely responsible for all of the design regardless of how it is developed. In this sense students also act as managers. Second, the contextual analysis and fit of components becomes important because herein lies the decision of appropriateness. CAD can produce hundreds of design solutions but only one will be the best for that context. Embodied in the selection of the best solution contains the type knowledge and pattern making skills students need to have to be successful. That is a different type of knowledge than that required for the handcrafted discovery process of design. Third, design development is usually never taught with much student writing. Faculty should think of introducing a journaling process so that students can record their decision making narratives. Combined with informal weekly interviews, these may be important tools for seeing beyond the instant and error free design solutions to assess the real process behind student thinking.

Conclusion
This paper should challenge the reader because what is proposed is a real transformation in the design development process. How do we test this theoretical idea and can we prove it? What does it mean for us as educators? Is this in-fact happening and are these the correct characteristics of a new process? How do we start the investigation? There are several methods that we can use to investigate whether or not these new characteristics are transforming the design process? The first is a standardized examination of how much students know between old and new knowledge, methods and skills. This would be used to confirm the characteristics of transparent vs. hidden and magnified vs. reduced. The differential between the knowledge, methods and skills acquired will be evident. The second method is by objective observation. One could count the times something is designed from scratch, copied and pasted or design automated in the process. This would be used to test the characteristics of singular vs. divided

and individual vs. shared ownership. The third method is by subjective observation, using experienced design professionals who were originally trained to design with a pencil and paper. The characteristics of discovery vs. outcome and contextually implicit vs. explicit can be verified using this method.

The idea that aspects of the design process are entirely hidden is unsettling to us as educators. How do students really obtain knowledge from a particular type of craft based knowledge with technology hiding the process? Does this type of knowledge simply become obsolete or is it somehow transformed into another type of knowledge? When do we discard obsolete knowledge or obsolete processes? Are these decisions first made in political economies of academia or the profession; do we educate students or train them? What is the future roll of a handcrafted design process and is it still important for intuitive discovery? Unfortunately, this paper is a starting point of discussion, raising many more questions than giving answers.

End Notes

1. Design development is also known as construction design. It is the part of design that focuses on how buildings will be constructed based on the broad architectural ideas.
2. Other papers as referenced discuss various software programs, capabilities and functions. This paper will not cover that ground and will remain primarily at the conceptual level.
3. Giedion, S., Mechanization Takes Command: a contribution to anonymous history (New York: Oxford University Press 1948).
4. McCleary, P., “Some Characteristics of a New Concept of Technology,” Journal of Architectural Education 42, no. 1 (Fall 1988) pp. 4-9.
5. Alexander, C., Notes on the Synthesis of Form (Cambridge: Harvard University Press 1964)
6. Alexander, C., A Pattern Language: towns, buildings, construction (New York: Oxford University Press 1977)
7. Adam Smith refers to this as a “*division of labor*” in his 1776 his masterpiece work, An Inquiry into the Nature and Causes of the Wealth of Nations.
8. McCleary’s space time idea is more complicated than what is presented here but for brevity, the description has been simplified.
9. Alexander’s theories are widely known on contextual fit so this description is purposely very brief.
10. Betz, J., "*Design Automation: a forecast for the architectural profession*," Hammer Magazine, 8:10, October 2003.
11. Betz, J., "*Epistemology, Technology and Organization: the affects of change in architectural design*," Proceedings of American Society for Engineering Education (ASEE) Annual Conference, Nashville, TN, June 2003.
12. Betz, J., "*Automation Takes Command: toward a design typology*," Proceedings of American Society for Engineering Education (ASEE) Spring Regional Conference, Kean University, NJ, April 2003.
13. Ibid.
14. This division of labor theory parallels the divisions caused by modernism and mechanization as defined by Emile Durkheim (1857-1917). Although more than one hundred years later, it is argued here that computer automation is an extension of modernism and further divisions are occurring from technology.
15. Betz, J., “Copy, Insert and Automate in the Design Process: Where's the Thinking and Learning? Proceedings of American Society for Engineering Education (ASEE) CIEC Conference, Savannah, GA, February 2005.
16. Marx, K., "Economic and Philosophical Manuscripts," In Karl Marx Selected Writings, (Paris) ed. David McLellan. New York: Oxford University Press (1844) 1977.
17. Gutman, R., Architectural Practice: A Critical View. New York: Princeton Architectural Press 1988.
18. Blau, J., Architects and Firms: A Sociological Perspective on Architectural Practice. Cambridge: The MIT Press 1984. The idea of “Daedalean Risk” in architectural practice is a central theme in this book.
19. The ideas of apophatic and kataphatic is usually used when describing forms of spiritual prayer. In this case, I’m applying it to mean that some design processes allow us to listen (apophatic) while others give us the chance to speak (kataphatic) and that this give and take is a form of what I term “design breathing.”

20. Betz, J., "*Automation Takes Command: toward a design typology*," Proceedings of American Society for Engineering Education (ASEE) Spring Regional Conference, Kean University, NJ, April 2003. (Note: this chart is presented to show which design processes will most likely become automated and which ones will not.)
21. Betz, J., "Copy, Insert and Automate in the Design Process: Where's the Thinking and Learning? Proceedings of American Society for Engineering Education (ASEE) CIEC Conference, Savannah, GA., February 2005. (Note, this survey data was originally published in this referenced paper to show student behavior. It is presented again here to reinforce the theory.)

Appendix

TABLE 1: Comparison of Computer Automation vs. Human Value Judgment [20]

Computer Automation - Design Analysis	Human Value Judgment - Design Creation
Theoretical/Philosophical Operating Model	
● Applied science	● Creative/Interpretive art
● Causal model	● Ideal model (*as defined by Max Weber*)
● Linear decisions	● Multidirectional decisions
● Solves a common problem	● Tells an individual story
● Strictly rational	● Can be irrational
● Modernist approach	● Post-Modernist approach
Mode of Production	
● Standardized assemblies	● Highly varied assemblies
● Universal application	● Particular application
● Modular system	● Non-modular system
● Mass produced components	● One-of-a-kind prototype
Design Solution	
● Predictable solution	● Unpredictable solution
● Low creativity	● High creativity
● Scientific reason and process	● Literary reason and process
● Hard logic (cost, function, need)	● Soft logic (cultural, aesthetic, want)
● Right and wrong solution	● Good, better and best solution
● Analysis based defense	● Verbal argument defense
● Easy to measure	● Difficult to measure
● Apolitical	● Political

TABLE 2: Experience Between Handcrafted Design Process vs. Technological Design Process

Handcrafted Design Process - Drawing	Technological Design Process – CAD
Hand Drawing	**Automation**
● Design process transparent – no technique	● Design process hidden – technique
● Singular step-by-step design process	● Divided / fragmented design process
● Designer active participant in entire process	● Designer active observer in parts of the process
● Designer discovers the solution with overlays	● Designer selects the solution outcome
● Craft knowledge of drawing important	● Empirical knowledge of components important
● Contextual fit integrated into the process	● Contextual fit analyzed as separate step
● Solution checked for errors, not fit	● Solution analyzed for fit, not errors
● Components and connections are equal	● Components reduced / Connections magnified
● Standardized solution not predetermined	● Standardized solution predetermined
● Individual ownership (the process)	● Shared ownership (the process)
● Knowledge of entire process important	● Knowledge of parts of the process important
Hand Tracing	**Copy & Paste**
● Component known through drawing	● Component known through viewing
● High level of ownership (the components)	● Low level of ownership (the components)
● Components and connections are equal	● Components reduced / Connections magnified
● Sense of design scale	● Loss of design scale

● Contextual fit integrated into the process	● Contextual fit analyzed as separate step
● Work not easily shared and transferred	● Work easily shared and transferred

Results of Student Behavior Survey[21]

Seventeen students took the survey. Before they were give the survey, the instructor defined the three processes of initially generating information and the three methods of thinking about and using the information thereafter in their design. These definitions were also noted on the top of the survey for reference. Students were then asked the following questions verbatim and gave the following compiled responses:

1. **Please answer the following window detail questions:**
   A. How did you initially generate an Andersen Window detail?
      0% Automate; **58.8%** Copy; **41.1%** Copy parts; **0%** Create
   B. How did you fit the head and sill of this detail into your wall detail?
      0% Analyze only; **0%** Develop only; **5.9%** Integrate only; **76.5%** Analyze & Integrate; **17.6%** Just copied and pasted into the wall detail without modifying
2. **Please answer the following first floor sill/floor/stud wall intersection detail questions:**
   A. How did you initially generate a first floor sill/floor/stud wall intersection detail?
      0% Automate; **5.9%** Copy; **5.9%** Copy parts; **88.2%** Create
   B. How did you fit this detail into your wall section?
      0% Analyze only; **47.1%** Develop only; **5.9%** Integrate only; **41.1%** Analyze & Integrate; **5.9%** Just copied and pasted into the section without modifying
3. **Please answer the following wall detail questions:**
   A. How did you initially generate an entire wall detail?
      0% Automate; **5.9%** Copy; **17.6%** Copy parts; **76.5%** Create
   B. How did you fit this detail into your building section?
      0% Analyze only; **29.4%** Develop only; **17.6%** Integrate only; **52.9%** Analyze & Integrate; **0%** Just paste in without modifying
4. **Please answer the following building section questions:**
   A. How did you initially generate an entire building section?
      5.9% Automate; **0%** Copy; **17.6%** Copy parts; **76.5%** Create
   B. How did you coordinate this section into your project?
      0% Analyze only; **41.1%** Develop only; **5.9%** Integrate only; **47.1%** Analyze & Integrate; **5.9%** Just paste in without modifying
5. **What would your first choice be in initially generating a manufactured product detail if you have access to the Internet or typical details from the Architectural Graphic Standards CD?**
   0% Automate; **94.1%** Copy; **5.9%** Create
6. **What would your first choice be in initially generating a site built detail if you have access to the Internet or typical details from the Architectural Graphic Standards CD?**
   0% Automate; **70.6%** Copy; **29.4%** Create
7. **What would your first choice be in initially generating a unique site built detail if a company can't manufacture this item?**
   5.9% Automate; **17.6%** Copy; **76.5%** Create;
8. **Please answer the following roof plan questions:**
   A. How did you initially generate the roof plan?
      47.1% Automate (3-D); **0%** Copy; **52.9%** Create
   B. If you checked <u>create</u>, how did you first verify the plan was correct?
      88.9% Professor review; **0%** Peer review; **11.1%** Automate & compare; **0%** None of the above
   C. If you checked <u>automate</u>, how did you first verify the plan was correct?
      87.5% Professor review; **12.5%** Peer review; **0%** Didn't check; **0%** None of the above
9. **Please answer the following elevation questions:**
   A. How did you initially generate an elevation?
      5.9% Automate (3-D); **0%** Copy; **94.1%** Create
   B. If you checked <u>create</u>, how did you first verify the elevation is correct?
      56.3% Professor review; **12.5%** Peer review; **18.75%** Automate & compare; **12.5%** None of the above
   C. If you checked <u>automate</u>, how did you first verify the elevation is correct?

100% Professor review; **0%** Peer review; **0%** Didn't check; **0%** None of the above

10. **How much time <u>would</u> you spend trying to find a detail to copy or download before you would create it (say the detail would take 1.5 hrs. to create)?**
    11.8% Create from the start; **64.7%** 0-30 min.; **11.8%** 30-60 min.; **11.8%** 60-90 min.; **0%** more than 1.5 hrs.
11. **How likely are you to use an available detail that works but is not your first choice versus spending the time to create one?**
    11.8% Very likely; **52.9%** Likely; **29.4%** Not likely; **5.9%** Not very likely
12. **How likely are you to use an automated design solution that works but is not your first choice versus spending the time to create one?**
    5.9% Very likely; **52.9%** Likely; **41.1%** Not likely; **0%** Not very likely
13. **What percentage of time on the last project did you spend initially generating information by?**
    11.8% Automating; **24.6** Copying; **63.7%** Creating; (= <u>100</u>**%** Total)
14. **What percentage of time on the last project did you spend thinking about and using information by?**
    22.4% Analyzing; **47.9%** Developing; **29.4%** Integrating (= <u>100</u>**%** Total)
15. **How valuable was working in teams to collect information?**
    17.6% Very valuable; **41.1%** Valuable; **23.5%** Not valuable; **17.6%** Not very valuable
16. **How valuable was working in teams for peer review?**
    29.4% Very valuable; **64.7%** Valuable; **5.9%** Not valuable; **0%** Not very valuable

FIGURE 1: Time Comparison of Automated Design verses Handcrafted Process