Sioux City Bus Stops—Flat Fab

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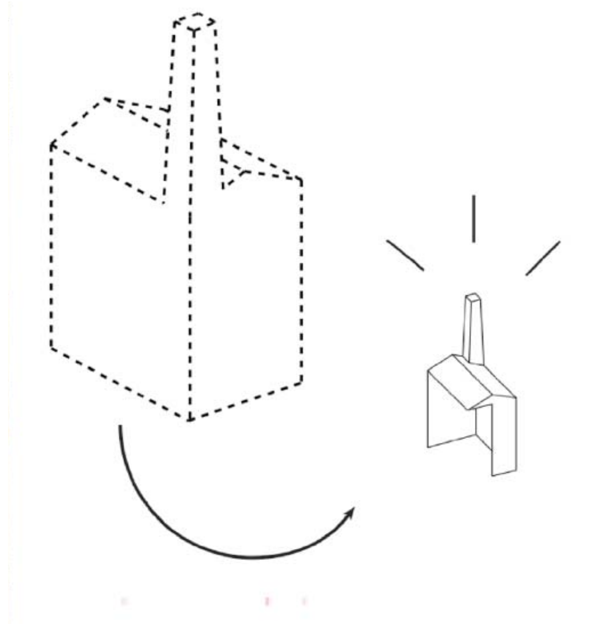
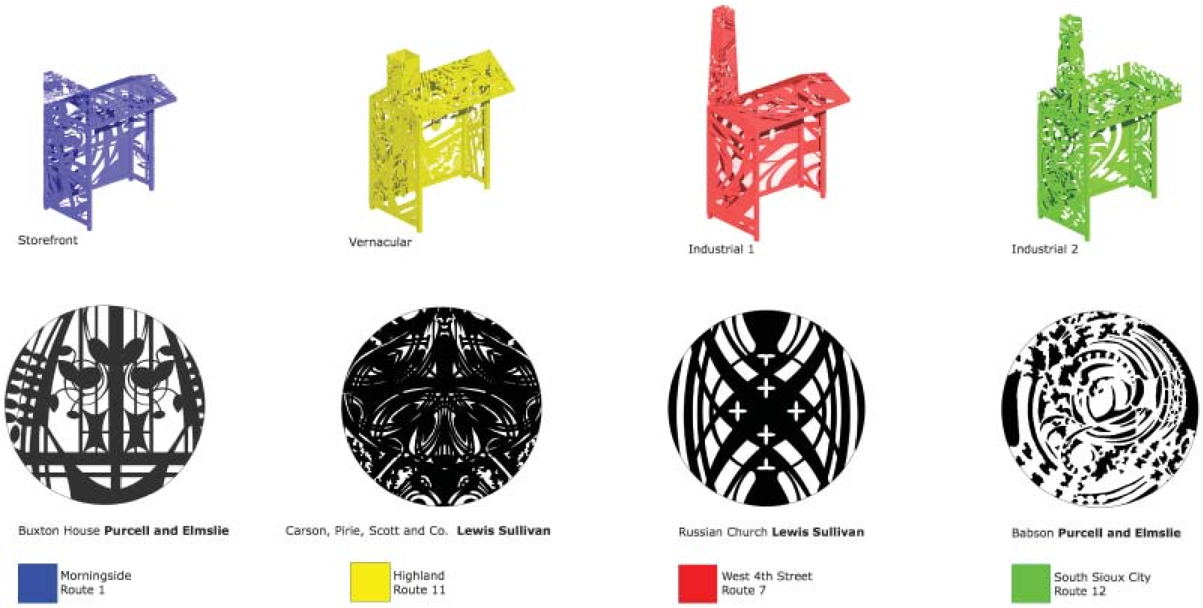


New Bus stop **Scaled and Replaced**

The study of flatness[1] in architecture has a particular place within the expanding discussion of digital fabrication and its relationship to the built environment. This paper suggest that while both the additive and subtractive methods of rapid prototyping have crucial roles to play in the design process it is the various scaled operations of two-dimensional CNC cutting that offer closer ties to conventional construction methods. The following offers an apology for this method in the form of two bus stops that where designed for Sioux City Iowa in the summer of 2007. This text describes the background to the project and then presents the design and fabrication process as an aligned methodological transference from the model to full scale. It explores aspects of mass customization and the potential role of sheet steel parametric modeling software in producing further variants of the project. It reflects on further improvements to the design process with particular consideration of the morphology of digital models. It concludes by suggesting that the flat-cut technique has a consequence upon both formal and textural properties of architecture that should be consciously embraced as a language that offers direct communication with readily available modes of digital fabrication.

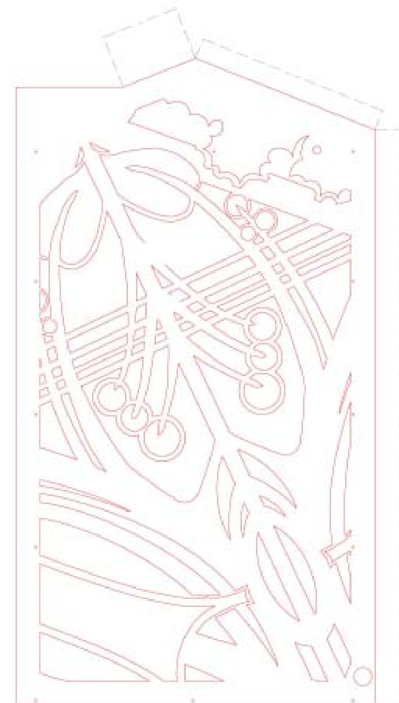


BACKGROUND

In this case those formal and textural qualities were in the vanguard of design priorities at the beginning of the scheme (as much as it is possible to list design considerations in terms of importance). The project was initially generated in discussion with a number of Sioux City public agencies that included the Chamber of Commerce and Downtown Partners along with key contributions from various steel production companies[2]. After the schematic design had been agreed the project was presented to the first year graduate students of Iowa States Architecture program as the focus for the summer session of the "Service Learning" course. The project was then developed in detail and constructed by the students under the guidance of the studio instructor. The whole course lasted eight weeks.

The key considerations of this design center on the role of the bus stop within the physical and cultural context of downtown Sioux City. As architect Nathan Kalaher points out the city has experienced an ongoing "erasure" of the center between 1930 and 2003 and is still witnessing a depletion of its building stock[3]. Downtown areas are thinning out as former industrial warehouses are being demolished. This project responds to this context by mimicking those absent building typologies in quasi-historical scaled down forms. Proposals are presented as a chimera of what once existed and now reappears in a new form. The two we selected were "Smoke Stack Industrial" and "Storefront" which were chosen from a range of other reduced profiles. These forms where functionally adapted to the role of a bus stop to give shelter and provide good sight lines for the bus driver looking for waiting passengers (hence the bite out of the front left hand corner and missing leg). Another facet of this contextual reflection appears in the detail and decoration of the buildings elevations. All sides of the building are indiscriminately tattooed with abstractions of Prairie Style decoration that were generated

Panel I-B Panel I-C



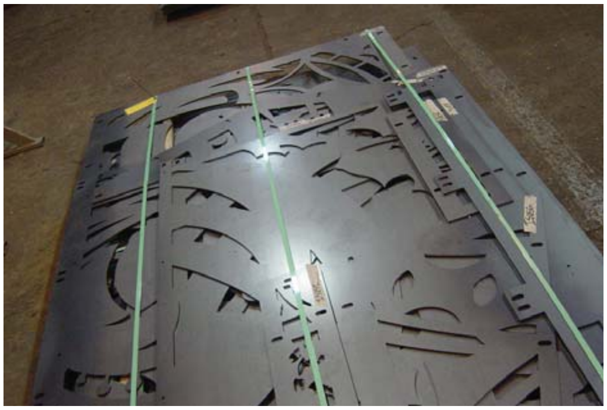
Panel I-E

from proximate sources. One appropriates from Steele / Purcell Elmslie's Woodbury Court House and the other from Louis Sullivan's Babson House[4] which were then collaged onto the form in a manner that externalizes and brings them to the close attention of the daily bus traveler. The final consideration in terms of these contextual links is the use of sheet steel as the main construction material. Of the remaining industries within Sioux City steel fabrication is one of it most vibrant. The city is often described as "Midwestern rust belt" claiming four large steel fabrication plants each making extensive use of CNC laser and plasma cutting capabilities. It is this constructional aspect of the project that forms the focus of this text and speculation on the flat-cut nature of mainstream digital fabrication.[5]

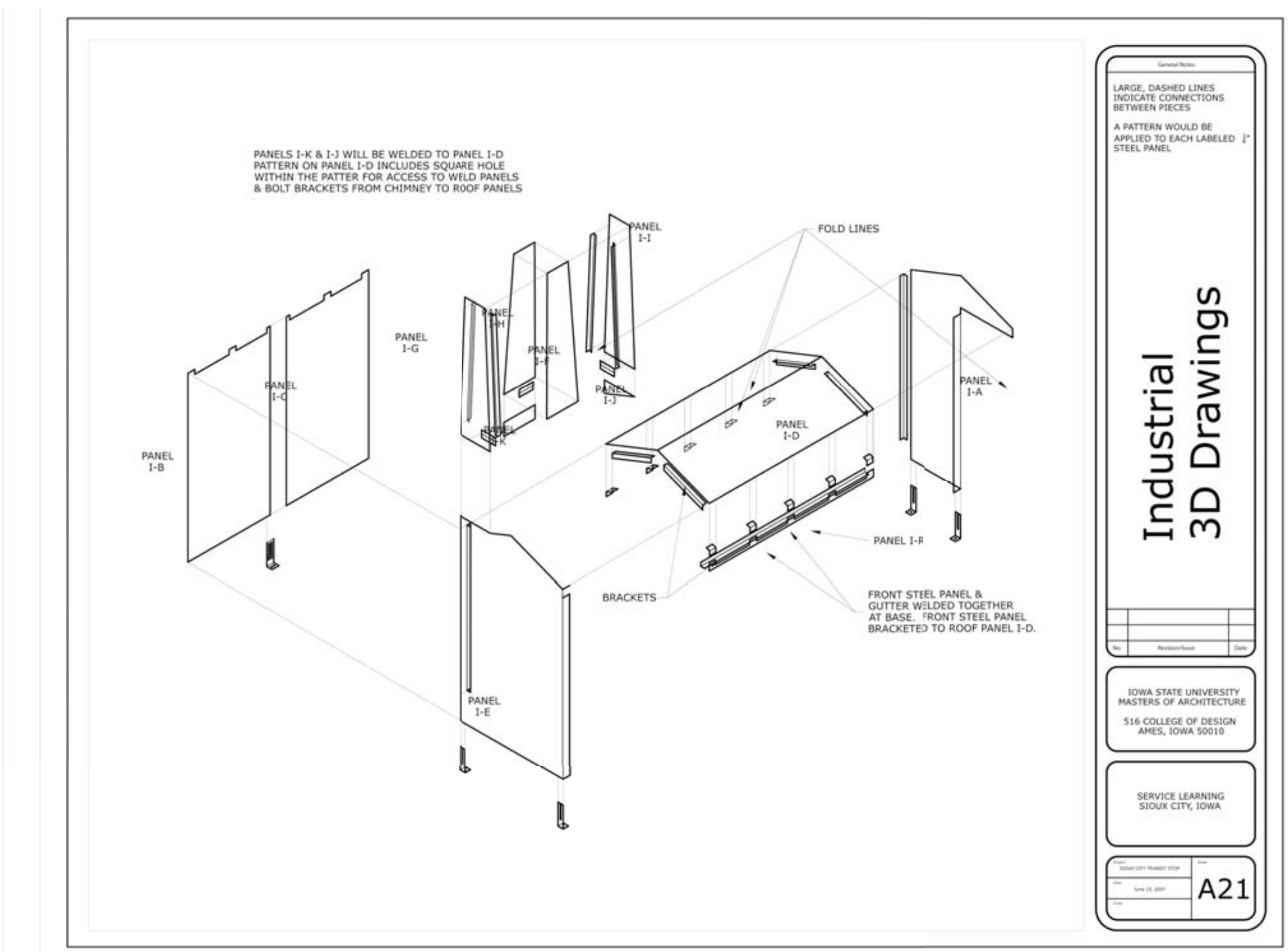
In part this speculation is based around the likeness between the design method and the fabrication technique. The key issue here is that the stock of the design model is manipulated in almost the exact same way as the full-scale stock. The consequences of design decisions can be more effectively simulated especially when full-scale stock sizes are replicated in scale and with a similar material. This relationship cannot be applied to the additive process of the three types of 3D printers wherein the full scale construction method is drastically different both in terms of the material and in the manner in which is cast. This may be contested. At present professor Behrokh Khoshnevis is producing a 1:1 3D printer designed to produce concrete buildings called the "Contour Grafter[6]. However the issue of digital fabrication in architecture can be roughly categorized in two ways: Those that we can use today and those that we cannot. While both aspects of this discipline require extensive consideration in architecture it is the former that is focus of this paper. The following offers a detailed account of the construction process evaluated in terms of this "likeness" of production methodology.

PATTERN

The final arrangements for the external patterns where agreed after a lengthy process of trying alternatives. These patterns were generated from photographs and hand drawings of existing Prairie school designs. The range of these alternatives were then quickly tested by scanning these drawings as black solid shapes on white background and autotracing them in Illustrator to



produce a set of polylines. These lines then formed the basis of the scaled down laser cut models. This process allowed us to quickly test the levels of transparency and topological continuity of the panels. The "autotrace" command could be used to produce a filled surface that can be moved around to test its integrity both as a digital model and then as a laser cut panel of the model. The method was used to analyze all the surfaces and make sure that all patterns held together. From our various choices we produced a number of models (in addition to the texture mapped renderings) used in presentations to the clients and fabricators and upon which we made or final choices. These illustrator drawings served to initiate one aspect of our discussions with both State Steel and Missouri Valley Steel about the problems with laser cutting. Initially it was hoped that these autotraced drawings would go straight to the fabricators for the final cutting although when the actual cut times where simulated using the companies NestPRO software they were considered to be too long. This testing process allowed us to get closer to the most efficient method of line quality and to iron out any unnecessary pause point during the laser cutting process. It transpired that the best line production would be an Autocad polyline that was generated from initial spline drawings and then converted to a polyline. In addition to this all acute angled junctions needed to filleted with a radius of no less that .02 inch in order for the



laser cutter to cut the junctions without burning. The final cutting including the panel profiles had a travel distance of approximately 4000 ft at a rate of 100 inches/min with a total cut time around 8hrs for all panels.

The issue of flatness became apparent again when we began to work on structural alternatives. Both steel companies advised us on the appropriate dimensions for their steel supplies that were principally to do with the nominal thicknesses, grain direction and overall dimensions. However the maximum steel sizes were ultimately conditioned by the 7x9 bed size of the laser cutter. All panel sizes needed to be within these proportions or capable of being efficiently nested as multiples within these proportions. Again this was something that we could simulate quickly on the laser cutter as save fabrication time. However these considerations had even greater effect on the structural solution of the project.

Initially the designs had been based on a frame and panel system that was generated from studies of existing aluminum bus stops. This meant that the panels could be thin and non-structural. However we began to think that this might have a limitation on the longevity of the proposal. After our initial proposals to the Chamber of Commerce and open session of Sioux City Council we were encouraged to develop them as prototypes for more stops and other cities within the region. Additionally the steel companies were suggesting that they could be a flat pack system that could be delivered and assembled locally. As a consequence we changed the structural system to a folded plate method and made the decorative panels integral to the structure. The new system was to be entirely cut from sheet steel and connected with brackets. The panels were connected through tapped holes that were secured with 1/2’” dia. #20 threaded stainless steel hex-headed security bolts. This system required further analysis of the topological continuity of the panels and their lateral strength that was in effect a form of cross bracing disguised within the pattern. Additional strength was generated from the right angled folded plate panel ends and in the pitched roof form. In both cases all two dimensional laser cutting needed to be done in advance and that those patterns needed to have a solid border along the fold lines. Once they were laser cut they then folded using a 200-

ton NC press brake for accurate bend angles. Panel sizes also needed to respect the brake opening and accessibility issues. As the brake is predominantly used with steel these issues translated back to the design models and simulated with the laser cut chipboard model panels.

The preference for the flat pack version was also conditioned by the painting options.

At one point during the transition to the flat pack version we had considered a fully welded version. This proposal had more of a “one off “ quality to it but was considered to be a safer bet both structurally and in terms of avoiding the complexity of designing and positioning the threaded holes and corresponding slotted holes. This version would then imply that the welded whole would have to be sprayed in an autobody shop by hand and not without some difficulty (especially within the chimney on the smokestack version). In effect this meant that the bus stops were considered more as artworks than a system for potential mass production. It seemed that, for pedagogical, reasons it was important to pursue them as a hybrid of a customized and mass produced system. This was furthered by the encouraging support from Sioux City Council for further versions. This issue extended to the painting options.

Our second alternative for paint was through a company called Fimco who have a manufacturing facility also in Sioux City. A large proportion of their work includes the mass production of components for ag equipment that includes an extensive powder coating facility. The design of the flat pack bolted version was also influenced by this system and essentially aligned with ag equipment component production methods. In addition to the panel size restriction of the laser cutting bed we were also restricted by the size of the 5′x102″ throat of the shot blasting booth, the charging and spraying booth and the infrared heating run all of which were arranged in sequence along a hanging conveyor system. At one point we had been analyzing the possibility of getting the fully welded version through. However this was restricted by the booth throat area and also because this painting system was most effective on objects that had no hidden or internal faces. Therefore our pre-assembled pieces could be more effectively painted using a system that was designed to provide a specification that would withstand all weather exposure. In this respect the most vulnerable parts of the project were the sharp edges of the pattern in that the paint would thin along the edges. This problem was reduced by the shot-blasting phase of the painting, which would effectively round these edges giving a more even coverage. This alignment with the industrial process even extended to the paint finish and solved our anxieties about the right color. Although Fimco's were happy to source color options for us the plant mainly ran on bulk cans of stock ag colors of black and the emergency colors red, yellow, green and blue. Frimco's spay schedules are arranged around large batches of components of the same color. We felt that these colors were especially appropriate not only for production reasons but also because they would have some contextual link to the agricultural foundation to Sioux City. The built versions were the blue and the yellow although future versions would incorporate the full range.

PARAMETRIC VERSIONS

Working both with the steel companies and Fimco gradually pushed the project in the direction of the flat panel system. The realization of this project became more conditioned by industry standard production techniques. Part of the reflection of this project also considers the way in which the design process might further the notion of mass customization while retaining a practical understanding of its effect on production information and fabrication techniques. In this respect it was the earlier stages of the design that should be considered more widely especially in the light of advanced methods of digital morphogenesis.

The next set of proposals for these bus stops retains the repertoire of forms based on the idea of "absent typologies" (a four-square with chimney and a warehouse). In effect each one would be unique in its form and decoration while it would retain the basic construction and fabrication methods. However the uniqueness of these forms would present a certain amount of additional design work which would need careful consideration to be effective in terms of practice. While the first version did generate a number of digital models all the production drawings were done in two dimensions using Autocad. In retrospect this system would have been considerably quicker using a parametric modeling program like Solidworks or ProENGINEER and then generating cutting drawings from an accurate three-D model. Solidworks in particular is advanced in its sheet metal modeling capabilities. Models generated in this program are produced using the Parasolid modeling kernel that generate parametric drawings that be easily modified for different geometries, hole patterns and types of bend. This program also specializes in fully documented production level drawings for NC bending and laser cutting software applications. In effect Solid works unfolds a three-D model and generates a dimensioned cutting pattern with all hole and bending information including bend factors, tapping information and bolt schedules[7]. Drawings developed outside the programs primitives like our decoration patterns can be brought in as dxfs and included in the cutting sequence. A more effective use of parametric modeling programs would enhance the role of "digital morphogenesis"[8] as the alternative to the traditional duality of physical models and orthographic drawings. The alignment of scaled and full-scale laser cutting fabrication would then ensue without drastically changing the effect of the final outcome.

CONCLUSION

While this project was predicated on the extensive use of laser cutting techniques this came, in part, from an interest in typologies and decoration along with the desire for an intentional sense of flatness. As the project developed so to did the desire for yet more flatness. Both the cutting and bending process became important methods by which the familiarity of the typology and decoration were estranged via this flattening

techniques.[9] In this way the laser cutter turned out to be particularly appropriate to these aims. The sense of compression of architecture towards an infinitely thin surface is part of its commentary and intentional aesthetic. In part this method is indebted to Venturi's play on the overtly flat signification of cutout elements of his buildings.[10] While much of VSB's work pre-empted use of CNC cutting in its detail and language it also provided important lessons on the economy of expression in architecture i.e. the flat, vertical surfaces of the building provides the most effective register for architectural communication. Today these expressive opportunities can be explored by architects more cheaply and quickly with advanced methods of fabrication. While digital fabrication supports a wide range of architectural outcomes it is interesting to note that most of them have distinct period of being in a state of flatness after which they are formed or bent into the appropriate shape. This period of flatness is implied both in the developable surface and in the double-curved surface a like. It is also present in the lateral and bi-directional sectioned structure. These bus stops look for another application to this understanding of flatness. They are considered in terms a particular aspect of digital fabrication from the design process through to completion. They suggest that a rigorous analysis of the alignment of digital fabrication with contemporary methods of production will help widen its use within the built environment. In this case with a sense of flat cut architecture coming as it does from the most effective and readily available means of digital fabrication.

ENDNOTES

1 Edward R. Tufte. Envisioning Information – Escaping Flatland P.14

2 Full team was comprised of Sioux City Chamber of Commerce, Downtown Partners, Siouxland Transit, State Steel, Missouri Valley Steel and Fimco.

3 "Sioux City – A Potential History" - Masters thesis Nathan Kalaher.P.48

4 Carried out with George Elmslie. It is not clear how much of this design is attributed to Sullivan and how much to Elmslie. See Louis Sullivan and George Grant Elmslie by David Gebhard

The Journal of the Society of Architectural Historians, Vol. 19, No. 2. (May, 1960), pp. 62-68.

5 Majority of these drawings were carried out in collaboration with students of ISU graduate program "summer service learning"

6 Behrokh Khoshnevis is a professor of Industrial & Systems Engineering and Civil & Environmental Engineering, and is the Director of the Center for Rapid Automated Fabrication Technologies (CRAFT) and Director of Manufacturing Engineering Graduate Program at USC

7 For more information on this see http://www.solidworks.com/pages/onlinetour/popup.cfm

8 Architecture in the Digital Age: Design and Manufacturing by Branko Kolarevic

9 See also Wim Delvoye☐Madison Square Park, Manhattan☐Doris C. Freedman Plaza, Manhattan☐June 2003 to October 2003

10 Particularly the house in Greenville, DE, (1980) or the House in Stony Creek, CT (1984).