The Pleated Cape

From the Mass-Standardization of Levittown to Mass Customization Today

Richard Garber
GRO Architects, New Jersey Institute of Technology
Nicole Robertson
GRO Architects

Abstract

In the 1950’s, the Levitts put mass-production and the reverse assembly line into use in the building of thousands of single-family houses. However, the lack of variation that made their construction process so successful ultimately produced a mundane suburban landscape of sameness. While there were many attempts to differentiate these Levitt Cape Cods, none matched the ingenuity of their original construction process. The notion of mass-customization has been heavily theorized since the 1990’s, first appearing in the field of management and ultimately finding its way into the field of architecture. Greg Lynn used mass-customization in his design for the Embryological House in which thousands of unique houses could be generated using biological rules of differentiation (Lynn 1999). Other industries have embraced the premise that computer-numerically-controlled technologies allow for the production of variation, though it has not been thoroughly studied in architecture. While digital fabrication has been integral in the realization of several high-profile projects, the notion of large-scale mass-customization in the spec-housing market has yet to become a reality. Through the execution of an addition to a Cape Cod-style house, we examine the intersection between prefabricated standardized panels and digital fabrication to produce a mass-customized approach to housing design. Through illustrations and a detailed description of our design process, we will show how digital fabrication technologies allow for customization of mass produced products.

Introduction: Toward Heterogeneity

The use of CNC technologies to custom fabricate homes offers an alternative to the pre-fabricated modular homes which are increasing in popularity as evidenced by ‘Dwell’ magazine’s successful promotion of these products. These homes privilege a kit of standardized parts that can only be varied by recombination or through surface treatment, as seen in the mass-produced Levitt houses described below. ‘Automated Builder’, a trade publication for the engineered housing industry, discusses in their May 2006 issue the three pre-fabricated homes currently being offered in Dwell, noting that one is “conventional wood frame while the other two are post and beam. All feature 2x6 plywood-faced wall panels” (Sedan 2006). While the economy and novelty of these homes is made possible by their factory-crafted automated construction process, none of them engage the potentials offered by CNC technologies to introduce new kinds of geometry and space. Prefabrication should not necessitate a return to the ‘modernist’ box just because the modular components are factory-made. As demonstrated numerous times on
the component level, CNC production processes need not privilege orthogonal geometries over other forms. Digitally profiled Structural Insulated Panels (SIPs) allow for new geometries to emerge from the new material assembly of the panels themselves and the opportunity for the designer to provide a unique toolpath.

The new paradigm of mass customization that B.J. Pine first described in his book *Mass Customization: The New Frontier in Business Competition* (Pine 1993) used market turbulence characterized by unstable and unpredictable demand levels; heterogeneous desires; price, quality and style consciousness; high levels of buyer power; competitive intensity; product differentiation; and market saturation to identify the forces shifting the focus of manufacturing from mass production to the new paradigm of mass customization. Applied to the home building industry, the old paradigm is the philosophy of the inverted assembly line, such as in the houses of Levittown, New York. In this model, highly specialized workers moved from site to site repeating the same task, such as framing a wall or tiling a bathroom. The new paradigm, which involves the introduction of variation into a repetitive standard process to produce customization at a large scale, has not been tested in the home building industry. In the *Pleated Cape*, an addition to a Cape Cod style house in suburban New Jersey (Figure 1), we sought to investigate if such variation could occur by CNC profiling the structure/skin system of a Structural Insulated Panel system (SIPs). More specifically, by starting with a mass produced product (panel system) and uniquely cutting each panel we are able to produce an assembly of difference that can be more closely calibrated to program, lifestyle and environment.

To begin, this paper looks briefly at the history of mass-production in the Levittown houses and identifies how the need to differentiate these houses was not met with an equally innovative technique of production.

**Levittown: Construction Methodology and Standardization**

“We are not builders. We are manufacturers.”

Bill Levitt

The assembly-line method of building applied by Alfred and William Levitt allowed them to construct over 17,000 houses in Levittown, New York between July 1952 and December 1957. The speed and scale at which they accomplished this was made possible by a reversal of the assembly-line process developed by Henry Ford for the automobile industry. Instead of the product being moved along the assembly line, specialized workmen moved from lot to lot doing only the specific task for which they were
trained. This construction methodology stemmed from a close examination of home construction and the breakdown of the process into 27 individual steps for which the Levitts trained 27 separate teams, each team specializing in one highly specified operation. Building materials, from siding to nails, were delivered in perfectly calibrated house-sized amounts to each house site. Workers needed to do no measuring or cutting. Interchangeable, standardized parts also cut costs.

“Levitt and Sons used many of the building methods they had used over the years in previous developments, but reorganized these methods for even better efficiency and cost savings.” (Mataresse 2002) The shift to specializing workers or teams of workers to do the same specific task in every Levitt house allowed the company to better control inventories and cut training time for their construction crews.

Crucial to the assembly-line construction process, as it was to the automobile and defense industries, was a standardization of components. The original Levittown houses of 1947 were in the Cape Code style. Each house measured 750sf and included two bedrooms, living room, kitchen, dining, and one bathroom. The houses had no garage, no basement, and an unfinished second floor (Figure 2). While the floor plans were the same, variation was introduced through the choice of five exterior styles. By the fall of 1951, Levitt and Sons introduced new models, such as the ranch “Levittowner,” that were constructed in the same manner. Their houses also took advantage of emerging trends in the housing industry, such as radiant heating, a roofed carports, Bendix washers and General Electric stoves. Like their original Cape Code model, these models included no basement and no second story; however each attempted to better address the changing needs of American families (Figure 3).
The Illusion of Variation

In addition to creating a variety of new styles, Levitt used other techniques in the planning of the developments to create an illusion of variation. No two of the same style house were ever built side by side, and often main entrances varied from front yard to side yard. Levittown house slab angles were alternately rotated, shrubbery was variably planted, and different exterior colors were used to further create an illusion of individuality.

“In the struggle against monotony the same floor plan has been enclosed by four different types of exteriors, painted in seven varieties of color so that your shape of Levittown house occurs in the same color only once every twenty-eight times. Streets are curved gently for further esthetic effect, and to slow down auto traffic” (Kimball 1969). Owners typically developed their house’s identity through exterior surface treatments and decoration.

Despite these efforts to differentiate the Levittown houses, the privileging of low-cost efficiency over customization and individuality brought much criticism from architects, planners, and social theorists. Sensing this uniformity as well, homeowners sought to individuate themselves from their neighbors, most embarking on some kind of “improvement” project whether it was expansion into the yard, an additional story, exterior alterations, or interior decorating.

Additions to Standardized Houses

*Thousand Lanes,* (Figure 4) a magazine devoted to the decorating, expanding, and remodeling of Levitt homes, became essential to life in Levittown. LIFE magazine even sponsored a competition for the best interior design of a Levittown home, recognizing the need for homeowners to individuate themselves (Hales 1995). Anticipating the need for customization and expansion, the “The Homeowners Guide” provided to all new Levittown residents, permitted additions to the original structure as long as the following provisions were made:

“You can add another carport or garage or room – IF it is similar in architecture, color and material to the dwelling – IF it doesn’t project in front of the original house at all, or more than 15 feet in back of it – and IF at all times there still remain at least 20 feet of open yard in the rear and 7 feet on each side” (Levitt and Sons 1952). By stating the rules as such, the Levitts introduced their own de facto bulk and zoning regulations to their

Figure 4. *Thousand Lanes* magazine cover, fall 1955.
neighborhoods inadvertently making many of these additions similar. 

Most models featured an outdoor terrace that could be finished into a conditioned-living space and expandable attics were promoted as ideal recreational rooms for children. While there was the possibility of expansion designed into, and really necessitated by the layout of the home, there was no mechanism in place to customize the mass-produced additions in the manner in which they were originally built. An assembly-line method of customization of the Levittown house did not exist as the process of mass customization was not yet technologically, or conceptually, possible.

Critique of Mass-Produced Housing

Levittown, he [critic Lewis Mumford] implied, represented the worst vision of the American future: bland people in bland houses leading bland lives. The houses were physically similar, theorized Mumford, so the people inside must be equally similar; an entire community was being made from a cookie cutter. . . a multitude of uniform, unidentifiable houses, lined up inflexibly, at uniform distances on uniform roads, in a treeless command waste, inhabited by people of the same class, the same incomes, the same age group, witnessing the same television performances, eating the same tasteless prefabricated foods, from the same freezers (Halberstam 1994).

However, Ron Rosenbaum speaks of a transformation to the Long Island community that gradually occurred over time: “But to drive through the place today is to experience a strange and unexpected transformation. None of the houses looks like any other house. Almost every single one of them has been added on to, extended, built out, remodeled to the max. The roofs have developed so many dormers it seems like they’ve grown dormers on dormers. Fronts have sprouted pergolas and porches, roof lines have been raised, pitched, expanded, corniced, and cupolaed. Sides have been carported, breezewayed, broken out, re-covered in redwood, sided in cedar shake, disguised in brick and fieldstone, transformed into ranches, splanches, colonials, and California ramblers. And those once-pathetic saplings have grown and flourished into fifty thousand shade trees spreading and merging, casting cozy covering of shadows and privacy over the rococo renovations.” (Rosenbaum 1983) More specifically, the changing of ownership, gradual shifting of social and economic trends, and maturing of natural systems ultimately brought variation to the community—but it still was not the kind of measured variation that Mumford spoke of, or that which mass customization promises.

Single-Family House Construction Today

Traditional wood construction and detailing is labor and cost intensive, must occur almost entirely on site, and leads to the use of fairly similar products based on spanning capabilities of wood. The writer and builder Ted Benson suggests that the traditional method of wood construction was developed “before all the paraphernalia of our modern lifestyle
was contemplated. At the time, walls didn’t even require insulation, let alone the masses of wires, pipes, ducts, and fixtures considered basic necessities today.” (Benson 006) Though approximately 94% of single-family houses are constructed with dimensional lumber—they are ‘stick built’—a series of companies have developed proprietary stress skin panel systems that speed construction and lessen the high labor costs typically found in the United States. These Structural Insulated Panel systems (SIPs) also boast greater insulation values and spanning capabilities than traditional wood construction. After initial consultations with our client, it became clear that there was an opportunity to utilize a pre-fabricated panel system to construct the house. However, doing so would mandate a clear understanding of panel production and capabilities, which would be considered at the initiation of the design process, as opposed to being applied to a formal “cerebral” solution devoid of material considerations.

The writer Manuel DeLanda contrasts such a cerebral methodology, one in which a form is generated as an immaterial thought process awaiting the application of a material with one that at its essence takes into account a philosophy of materials and methods (Delanda 001). Such a philosophy is also consistent with a shift away from the traditional format of architectural delivery: architects and designers can now interface their digital data with CNC hardware such as routers and laser and water-jet cutters—we no longer need to have sub-contractors interpret our intentions through shop drawings that ultimately need our approval.

Additions

It is not an uncommon request to propose an addition to an existing structure, particularly in dense suburban areas on the outskirts of metropolitan regions where real estate is increasingly costly for even modest homes. We feel this growing need to extend existing structures can generate new potentials for mass customization. Our client for the Pleated Cape initially approached us because of our interest in emerging digital fabrication techniques; coincidentally, she grew up in an original Levittown house and had an appreciation for the innovation in building process, materials, energy efficiencies, and integrated technologies in her childhood home. Discussions with her about a potential addition to her existing Cape Code style house, not unlike the one she had grown up in Levittown, raised for us the question of how innovative building technologies of the twenty-first century could interface with the standard practices of mid-20th century construction. We saw the utilization of pre-fabricated stress-skin panels as a way to engage a history of mass-production with an addition that would allow for the opportunity to explore the problems and potentials of mass-customization through the use of digital technologies.

Current Use of SIPs panels

The social and economic forces that drove the mass-production of housing at Levittown are quite different from those that drive the housing market now. Whereas the mass-production methods employed at Levittown satisfied a housing demand created by the Great Depression
and World War II, the construction methodologies and principals developed then form the basis for the current construction of ‘cookie-cutter’ speculative housing developments. The speed with which many of these contemporary developments are completed is dependent upon many of the same rules that governed construction of Levittown, especially the use of one typical floor plan with variation either produced primarily through exterior paint colors and material change or created by the homeowners with the creation of dormers, carports, or additional rooms, as a way of individualizing the floor plan ‘common’ to the entire community. Many homebuilders introduce these primarily cosmetic variations into their products as a way of minimizing design fees and special construction, while still allowing them to market their products as ‘custom homes’.

The use of new pre-fabrication technologies, specifically the use of SIPs makes the production of identical speculative homes even more economical. Interestingly, further research into the technology behind the design and fabrication of SIPs revealed a reliance on CNC cutting technologies for window and door openings within the panels. Many manufacturers have already incorporated such technologies into their production processes; however, they are not using the digital tools to produce variation.

**SIPs Production Process**

There are numerous producers of SIPs panels, and each company has developed its own production methods and composite materials to produce different structural, energy, and assembly performance. ‘Automated Builder’ discusses various configurations in each monthly issue: T-Clear’s panels combine steel, foam, and cement board, while Winter Panel’s product consists of a urethane expandable foam sandwiched between particle board panels. While the composition of the panels varies between companies, there is a consistency in how the panel shapes are fabricated that opens up new possibilities for mass-customization in the housing industry. The possibility of profile cutting SIPs prior to assembly allows for variation with little to no additional cost, as a CNC router has no preference for cutting the same shape many times or a series of unique shapes. The only variable is in programming time for each new tool path the machine cuts.

Interestingly, many of the houses found in Automulated Builder that are constructed with stress skin panels replicate the appearance of traditional stick-built homes. Panel seams are concealed under fiberglass shingle roofing materials or vinyl siding. The architectural features prevalent in spec houses such as orthogonal layouts, dormers, and bay windows appear not to have been impacted by this new mode of semi-prefabricated construction. This may be because of the negative connotations associated with mass-produced housing, which emerged from a critique of suburban towns like Levittown. If this new mode of production were embraced, new criteria for the design and construction of suburban houses could emerge.
Pleated Cape 1

Our proposal, Pleated Cape 1, is a mass-customized addition to a Cape Cod style house in Livingston, New Jersey (Figure 5). The existing structure was constructed in 1941, 11 years before the Levitts brought mass-production to Long Island. This initial study has been approached from the standpoint of research and invention, and the techniques employed will be subjected to a process of refinement and optimization so as to achieve a mass-customized product of unlimited production.

Design Opportunities

The primary challenge of creating an addition to an existing Cape Code style house is the very complete nature of the original plan. It is a self-contained, highly compact unit composed of three bedrooms and one and half baths, made possible by expansion into the attic space. The possibility for expansion through the side or rear of the structure, as seen in Levittown, is difficult to accomplish in an integrated way. Alternatively, an entire story can be added making the former attic spaces habitable.

The changing needs of our client’s growing family called for a 500 square foot addition that would triple the size of the existing cape structure. The specific request by the client not to create a ‘McMansion’ was in turn met with a proposal to make the addition disappear into the context. The bulk of the new addition was set 15’ from the rear of the existing house and was connected by a new kitchen space (Figure 6). From the street only five folded roof peaks of the

Figure 5. Schematic perspective, Pleated Cape 1.
new addition, which are at the same pitch as the house’s existing roof, protrude above the existing roofline.

The relationship between existing structure and addition was based on quality of space, consistency of geometry, and construction method, as opposed to superficial appearance. Through this relationship, design goals of the project became:

- The preservation of existing roof angles and geometries
- The articulation, where possible, of ceilings as is characteristic of capes
- The use folds as a way to reinforce varied articulation of ceilings, roofline, and exterior walls
- The minimal presence of the addition to the street

A study of the geometry of the existing gables and roofline was extended to propose a new geometry for the addition roofline, which would emerge from the interplay of gables and dormers to create the pleated roof (Figure 7). This multiplication of the original ‘gable motif’ in the new roof was then translated to exterior walls to meet a specific client request for window seats (for viewing
the expansive wooded rear yard. The cantilever, which has become so pervasive in conventional wood construction in order to achieve bay windows and ‘breakfast nooks’, is repeatedly employed to create this series of alcoves that link to the geometry of the gabled roof, ultimately creating a pleated rear exterior wall over an insulated concrete formed orthogonal foundation wall.

In addition to linking the vertical and horizontal house geometries, the pleats allow for:

- A drainage strategy for directing water from the roof to specific garden areas
- The increase of interior space without increasing the size of the foundation
- Window seating with storage below
- Increased surface area for glazing
- Lateral structural stability

The structural characteristic of the pleat allows the shell of the house to be largely self-supporting and provides additional lateral stability. The form of the roof is reinforced on the interior through the use of CNC cut plywood trusses, which follow the roof form and are exposed in the double height living space on the first floor of the addition (Figures 8, 13).

Figure 8. Exploded Pleated Cape component drawing.
Design Methodology

The design process for the house addition evolved like many in our office, where a fully developed virtual model is constructed and serves as the basis for all 2D drawings, which are cut from it. While we have had the opportunity to transfer digital data directly to manufacturers for isolated parts of structural members of projects (ACADIA FABRICATION 2004), it became clear following a tour of the Winter Panel plant in Brattleboro, Vermont that there was opportunity to use the virtual model to accurately size and profile the panels for CNC cutting. It was possible with even a crude model to accurately develop a cost estimate of the SIPs panels. The Winter Panel engineers also rationalized the house geometry in terms of panel production and were not deterred because the house might be seen as ‘looking different’.

The SIPs panels come in wall thicknesses consistent with those framed traditionally with 2x4s or 2x6s. For the Pleated Cape, we used 4 ½” wall and 6 ½” roof panels. The panels we chose are filled with expanded polystyrene (EPS) and are sheathed with a 7/16” wafer-board. Company literature promotes the panels as twice as strong as a x wall (www.winterpanel.com) with R-values up to 25. The panels are formed in one area of their warehouse then transferred to another for CNC cutting on a router.

We transmitted two types of digital data to WinterPanel, both a 3-dimensional virtual model constructed with Rhinoceros 3D and a series of 2-dimensional profile drawings that delineate the shape of each of the wall and roof panels. First, the 3D virtual model was sent so that preliminary sizing of wall and roof panels and the angles between them could be determined. Wall panels are typically joined with a routed tongue-and-groove joint. The pleated wall and roof forms in our proposal required a slightly different joint, which is similar to one suggested in WinterPanel literature for joining a dormer without a ridge beam. The pleat angles in our addition’s walls and roof were maintained at 140° for the walls and 100° for the roofs, the latter being consistent with the roof pitch of the existing cape. Ultimately, joints and angles were verified digitally with the creation of new 3 dimensional details to be verified by the SIPs manufacturer (Figure 9).

Interestingly, typical joints are accomplished with 3” x 5/8” pieces of plywood called splines. A spline is most simply defined as a projection on a shaft that fits into a slot on a corresponding shaft, in effect locking the two together. Delanda suggests, in geometry, that splines can be more virtually instrumental. Spline refers to “special points that define a curve, such as at the inflection points at which a curved line changes direction.” (Delanda 2001) The splines are slid into two wall panels that are butted together on a framed sub-floor and then titled up into place. A foam bead is then applied to a center channel that is routed into the end of each panel. For heavier loading
considerations, or when the SIPs change direction, dimensional lumber such as a 2x4 or 2x6, can be used as the joining splines. Because of the heights, spans, and change in direction of our pleated walls and roof, our panels utilize a 4x block that is factory cut to the specified angle for joining panels together.

The 2-dimensional profile drawings were sent to verify tool paths created so that specific panel profiles could be cut with the CNC router (Figure 10). The path codes are generated with a plug-in for Rhinoceros called RhinoCAM (Figure 11). The router is a 3-axis machine with an 8 foot wide by approximately 30 feet long bed and can accommodate panels up to a maximum length of 28 feet (Figure 12). As the panels can be cut to any 2D shape within the sizes of the router's bed, the ultimate production of the panels shift from one of mass-standardization in the panel-forming process to mass-customization in the panel-profiling and assembly process.

Figure 10. Flattened profiles of each planar pleated surface, each will be further subdivided based on a maximum panel width of 8 feet and height of 28 feet.

Figure 11. 2 1/2D profile cut from a 6 foot x 28 foot SIPs in RhinoCAM with toolpath code shown at upper right.

Figure 12. WinterPanel router profile-cutting SIPs panel.
Conclusion

The technologies necessary for mass-customization of the mass-produced single-family suburban house already exist; however, they are not in wide use. Many companies that produce Structural Insulated Panel systems have computer aided manufacturing (CAM) capabilities, but the demand for using CNC hardware in the production of variation in these panels is limited. In Pleated Cape 1, we sought to combine our interest in and use of digital fabrication technologies with the manufacturing capabilities of a stress-skin panel producer with mass-customized results. The costs associated with stick-building such an addition would not have been sustainable, nor would the building form be easily achievable with traditional wood frame construction. This ability to customize mass-produced wall panels provides an opportunity to make the construction process of single family houses more efficient, while still providing the variation that was not available in the reverse assembly line process pioneered by Levitt and Sons. Current detailing provided by SIPs manufacturers can also be augmented, as in our pleated wall joint detail being a modified dormer ridge detail. We will continue to study this opportunity so as to more fully integrate a notion of mass-customization within these panels. In conclusion, the project gives us the opportunity to understand more fully the history of mass-standardization and how new CNC technologies promise variation.
which responds to structure, mode of assembly, material, and program. Ultimately the goal of mass-customization on a mass-produced scale might be achieved through these technologies.

References

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