Mass Customization in Architecture: Heterogeneity in the Making

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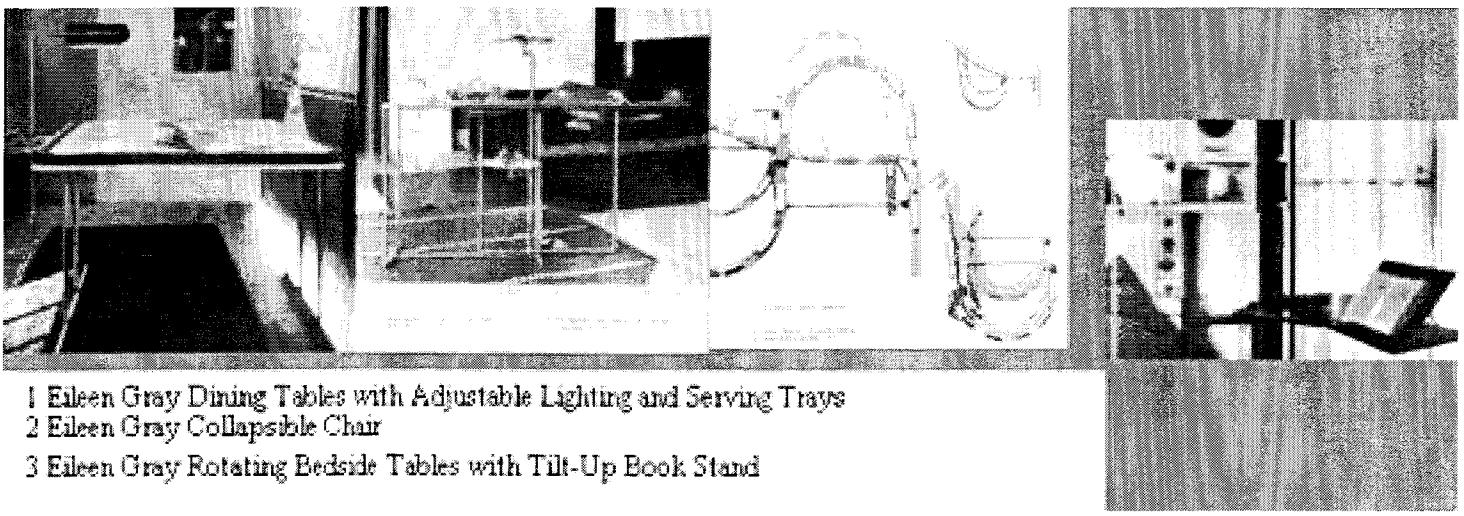
INTRODUCTION

> *"To bring the most of the best to the greatest number of people for the least."*[1]
>
> – Charles and Ray Eames

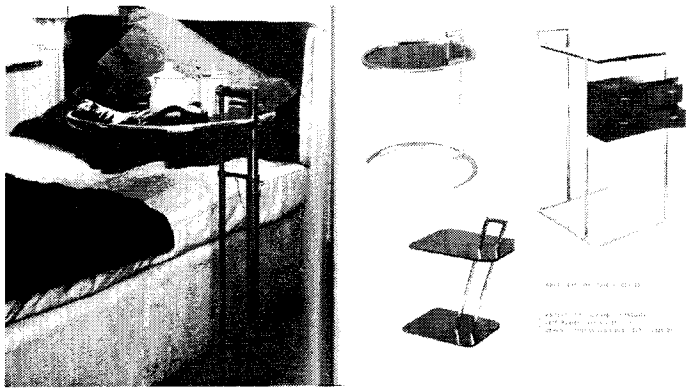
Although not actually realizing it at the time, my interest in concepts of Mass Customization began during my professional thesis in 1994. Even though I had never heard of the term Mass Customization, the concepts embedded in the research, design, and production of a series of flexible tables is uncannily similar to the concepts I am presently researching in Mass Customization. The thesis was research into two avant-garde movements, Constructivism and Deconstructivism; [in an effort to understand their agendas and values.] Becoming quite frustrated with both movements because of their embedded dogma, whether it was political, stylistic, cultural etc., there also seemed to be no linkage to the actual use, human interaction, and performance of their architecture; whether it was for individual users and/or the cities and masses at large; [something that I was extremely interested in providing for in design]. This is reiterated in a statement below from the thesis:

> "As we have moved from the first machine age within the principles of mechanical engineering into the second machine age within the principles of information theory; we have learned to recognize the second shift of the 'relativistic nature of our knowledge about the world' versus the first shift of the 'deterministic nature of our knowledge about the world.' Thus we begin to see the *effects* of designs *probabilistically* rather than *deterministically*. [...] Therefore, architecture that is formulaic and pre-determined [dogmatic] cannot possibly be *effective* for humanity that was and is becoming less and less under control. How can you concretize a formula for architecture that is for a heterogeneous humanity? We are in fact, individual human beings, not collective machines."[2]

Reflecting upon the thesis research I was drawn to some of the less dogmatic or what some have termed, reflexive modernists: architects like Jean Prouve, Charles and Ray Eames, and in particular, Eileen Gray. I felt that Gray's designs did not sacrifice style or beauty for adaptable individual uses. Her philosophies were not about overarching Utopist manifestos;



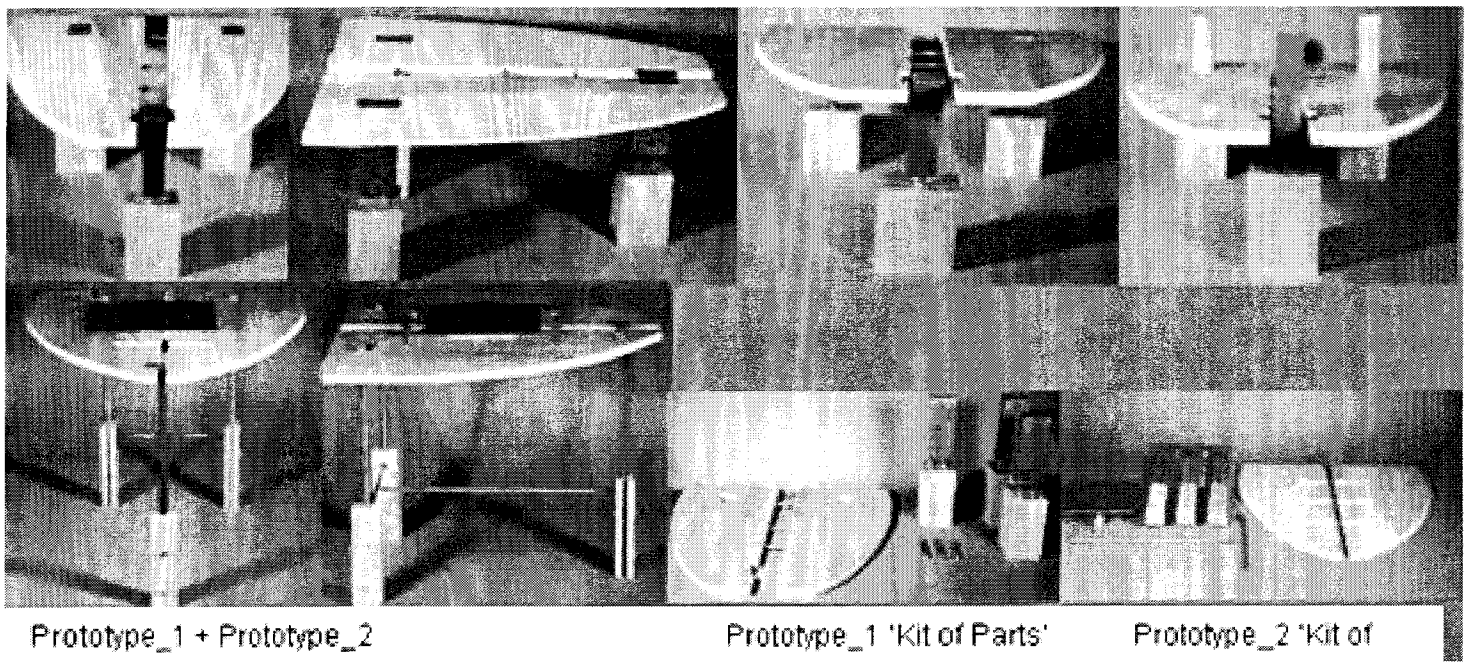
1 Eileen Gray Dining Tables with Adjustable Lighting and Serving Trays
2 Eileen Gray Collapsible Chair
3 Eileen Gray Rotating Bedside Tables with Tilt-Up Book Stand



but simply about producing beautiful, flexible designs that responded to the inhabitants needs *AND* desires. Caroline Constant has termed her work as "Non-Heroic Modernism."[3]

In response to this reflection and introspection I then produced as series of adaptable tables. In Prototype_1 the height of the table could adjust vertically in three positions. In Prototype_2 the height could adjust vertically and the square steel plate could adjust horizontally across the surface of table.

Caveat: I was only able to produce two tables [because I built them by hand]. Despite this, and not to mention the details and the weight of the materials were nowhere near refinement; I still felt they were noble failures and experiments in mass customization. Ideally, with more time and more prototypes produced, it would have become a repetitive and yet differentiated series of designs. Fortunately today with cad-cam, this differentiation and complexity can happen even more seamlessly and efficiently.



Eileen Gray Portable Table. Adjustable Bedside Table.

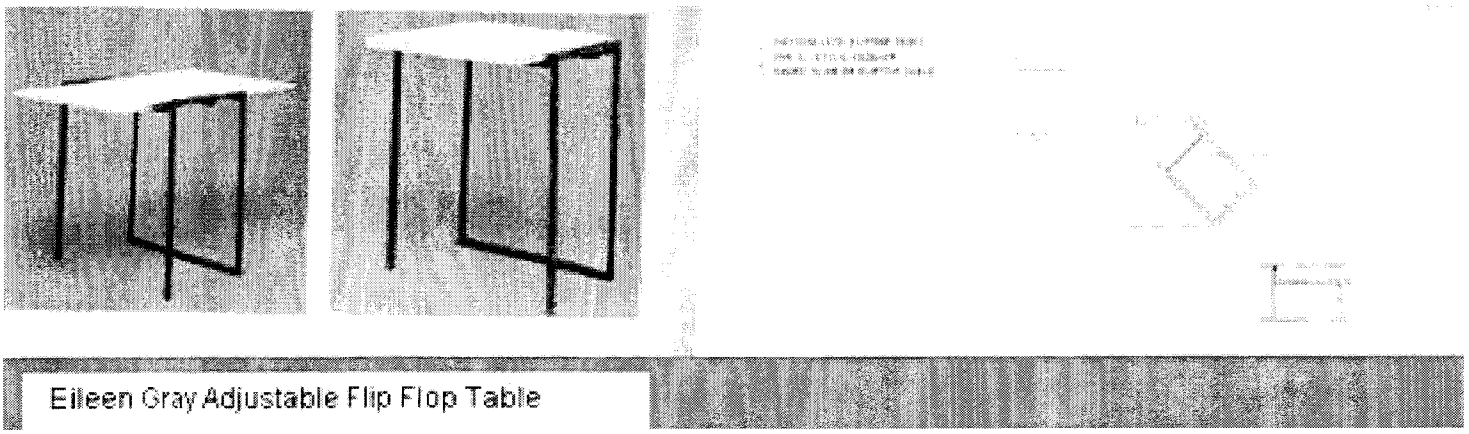
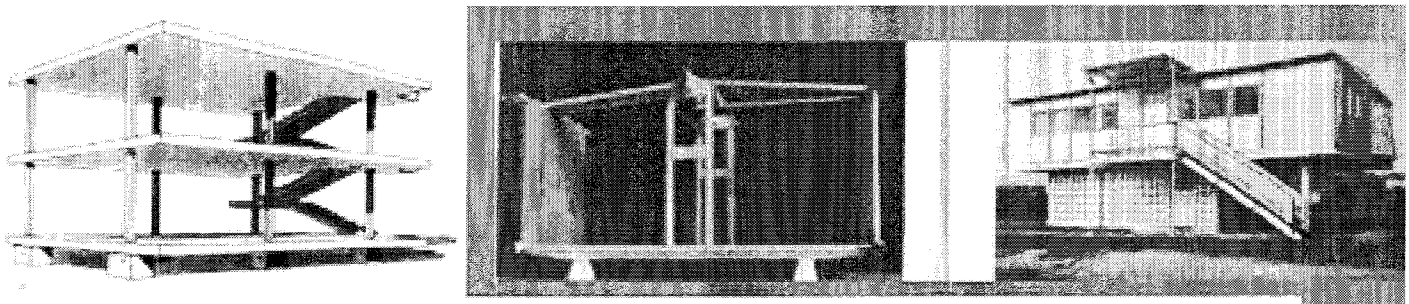


Table with Rotating Drawers.

Eichler Homes Inc. Eichler Townhomes Eames House



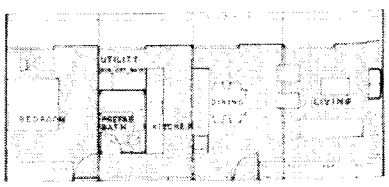
Le Corbusier's Dom-ino House Jean Prouve's Meudon House

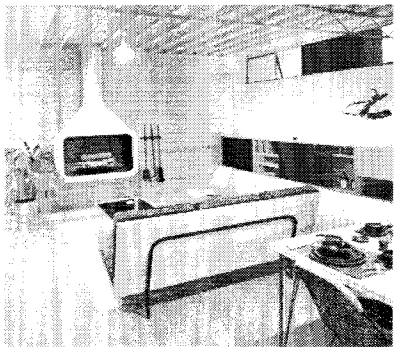
MASS PRODUCTION AND MASS CUSTOMIZATION: BRIEF HISTORIES IN BUSINESS AND ARCHITECTURE

"Things used to made to order and made to fit. But they were labor-intensive and expensive. Mass Production came along and made things more affordable, but at a cost – the cost of sameness, the cost of one-size-fits-all. Technology is beginning to let us have it both ways. Increasingly, we're getting more personalization at mass-production prices. We're moving toward mass customization."[4]
– Robert T. McTeer Jr

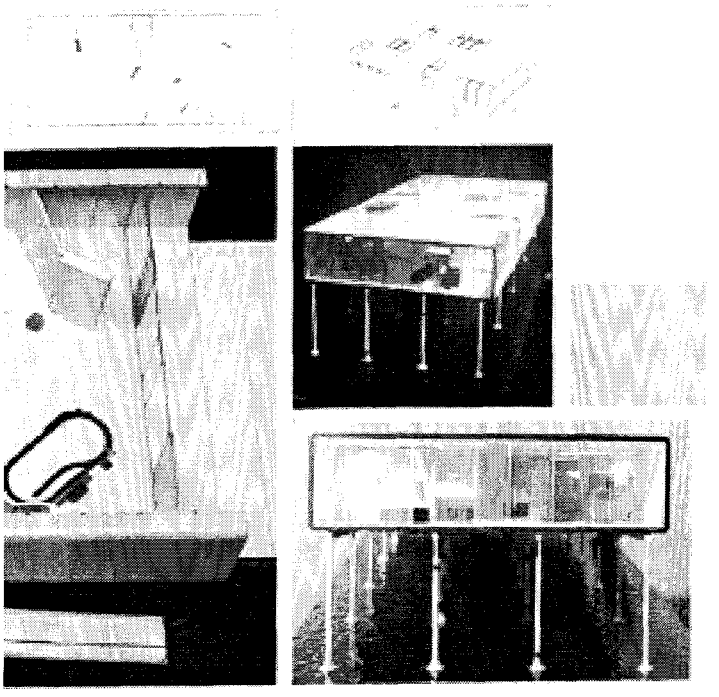
BUSINESS

"As a technological capability, Mass Customization was anticipated in 1970 by Alvin Toffler in *Future Shock* and delineated [as well as named] in 1987 by Stan Davis in *Future Perfect*. What has emerged is even more than Toffler envisioned [thirty-





STEEL LOCK PANEL ASSEMBLY



R. Rogers Zip Up Enclosures.

four] years ago and Davis described [almost twenty] years ago. Mass Customization is a new way of viewing business competition, one that makes the identification and fulfillment of the wants and needs of individual customers paramount without sacrificing efficiency, effectiveness, and low costs. It is a new mental model of how business success can be achieved, one that subsumes many of the 'silver bullets' of prevailing management advice such as time-based competition, lean production, and micromarketing. Further, the development of Mass Customization as a paradigm of management explains why product [and service] life cycles are decreasing, why development and production cycle times must follow, why businesses are re-engineering their processes, and why hierarchies are flattening and transforming into networked organizations. Mass Customization integrates all of these into one cogent system of management that describes what is going on today in industries whose markets – small or large, local or global – are characterized more by *turbulence* than *stability*."[5] [Emphasis and correct time frames in parenthesis added].

Defined below are the primary differences between mass production and mass customization as outlined in Joseph Pine's, Bart Victor's and Andrew Boynton's article: "Making Mass Customization Work." [In parentheses I have added definitions parallel to architecture].

Mass Production: "The traditional mass-production company is bureaucratic and hierarchical. Under close supervision, workers repeat narrowly defined, repetitious tasks. Result: low-cost, standard goods and services."[6]

[Typical results in architecture: processes, techniques, and designs that are homogenous, rigid, fixed, authoritarian, hierarchical, pre-determined, formulaic, etc.]

Mass Customization: 'Mass Customization calls for flexibility and quick responsiveness. In an ever-changing environment, people, processes, units, and technology reconfigure to give customers exactly what they want. Managers coordinate independent, capable individuals, and an efficient linkage system is crucial. Result: low-cost, high-quality, customized goods and services."[1]

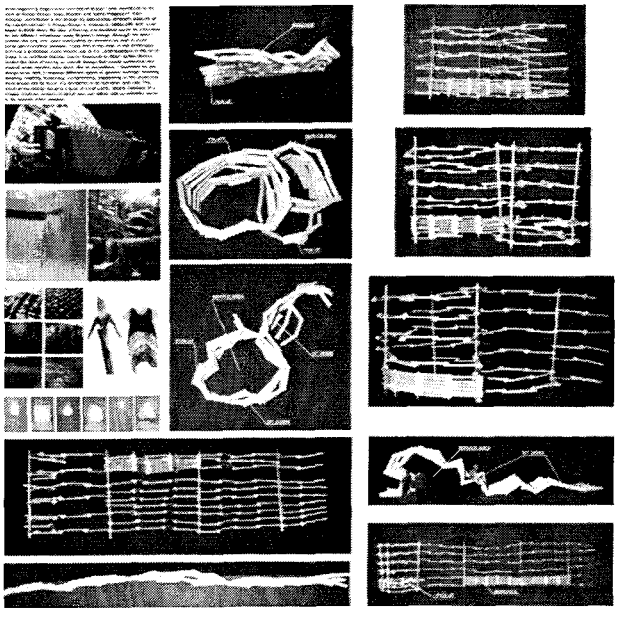


Fig. 1.

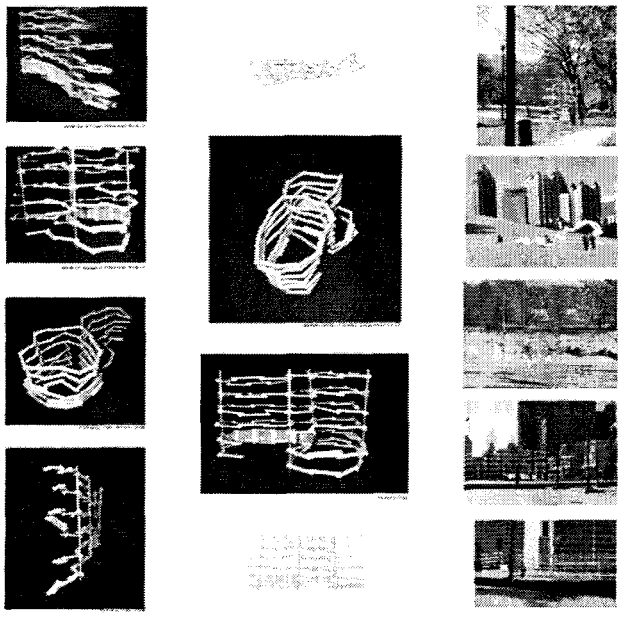


Fig. 2.

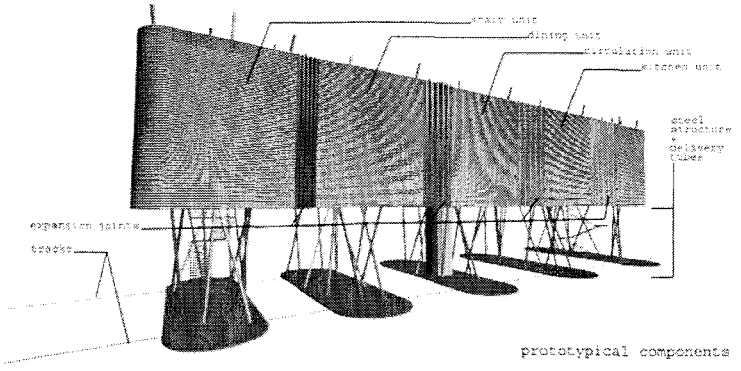


Fig. 3.

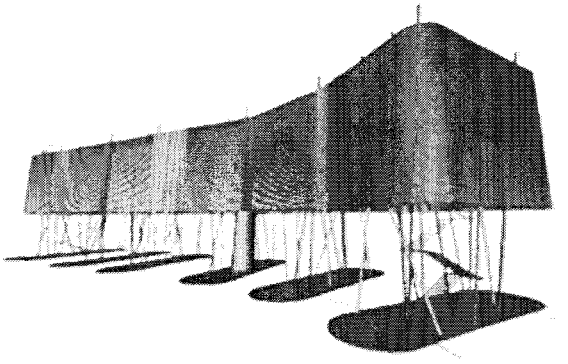
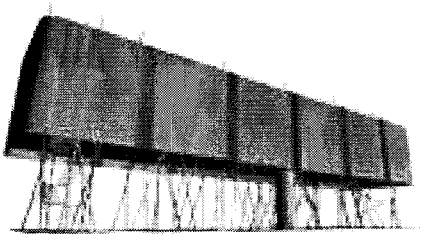


Fig. 4.

[Typical results in architecture: processes, techniques, and designs that are heterogeneous, flexible, adaptable, collaborative, non-hierarchical, parameter based, etc.]

ARCHITECTURE

> *"When we first started seriously to think about the prefabricated home, everybody jumped to the conclusion that it would lead to monotony. I say it offers us a way of building truly innovative and exciting homes."*[7]
> – Sir Richard Rogers



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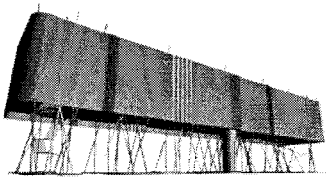

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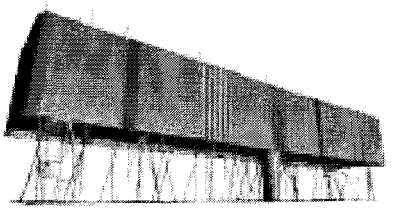
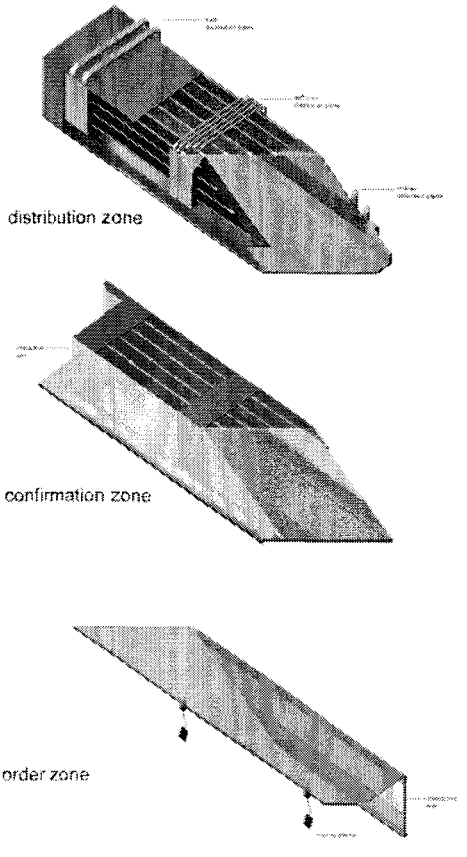


Fig. 7.

The successes of mass production in architecture have historically been fairly uneven. Not only because of the some of processes and techniques per se, but also because of the inability of a modern aesthetic appealing to the masses; not to mention the ability to weather the depression and turbulent war time economies: [a time in which most mass production in architecture was first introduced.] In addition, many of the mass produced architectures were relentlessly repetitive without options or variations. Some examples of this type of homoge-



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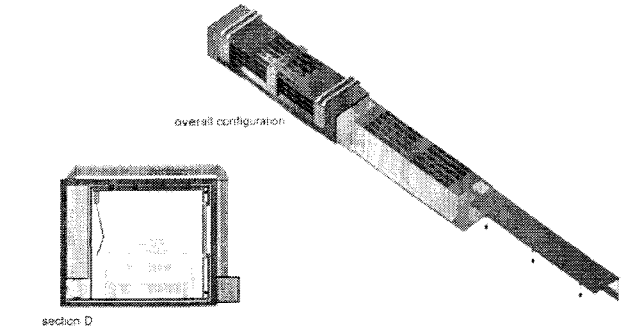


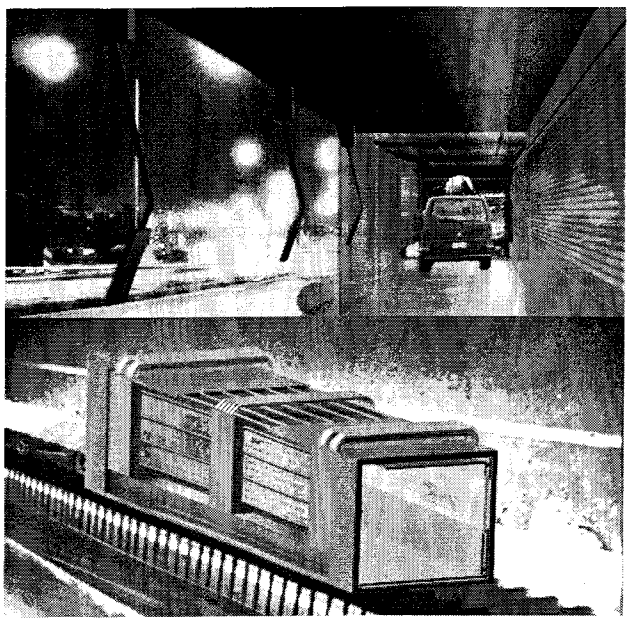
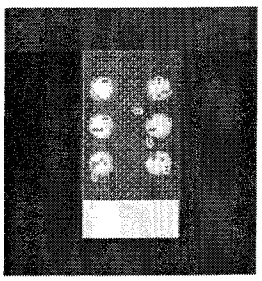


Fig. 9.



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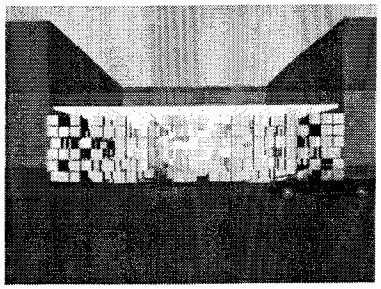

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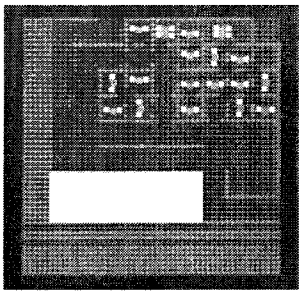


Fig. 12.

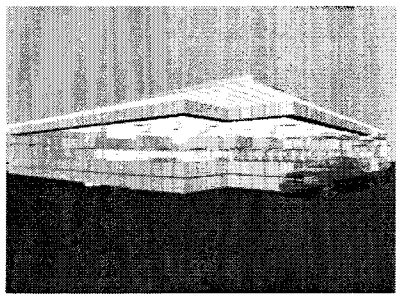


Fig. 13.

nous architecture were demonstrated in the Levitt Town Homes by William Levitt built in 1945. By 1948 he was putting up 150 homes a week; 6000 were finally completed. Another example was the Lustron homes; an all enameled steel dwelling founded by Carl Standlund in 1948. Although the idea of an enameled steel house seemed exciting and novel: its layout was still about sameness, and did not allow for flexibility. Not to mention the impracticality of the house being made of over 3000 parts and totaling over twelve tons of steel.

Although the examples outlined above are just a few of noble failures of mass production in architecture; some other architects were anomalies, and in my opinion, were already experimenting with ideas of mass customization within the systems of mass production: thus building in flexibility and variety from the beginning within their designs. Some of these architects include Le Corbusier, Harry Seidler, architects from the Case Study Houses Program, such as Richard Neutra, Charles and Ray Eames, Pierre Koenig, Craig Ellwood, developer Joseph Eichler, founder of Eichler Homes, Inc., Jean Prouve, and Richard Rogers to name a few.

In Le Corbusier's Dom-ino House, 1914, a post, slab, and stair system made of reinforced concrete afforded a differentiated 'Plan-Libre' or 'Free-Plan'. This repetitive system allowed for flexible and freedom on the interior, as well as on the periphery of the house. Free standing non-load bearing walls, glass curtain walls, and stucco skins could twist and turn without disrupting the overall structural integrity of the house. Jean Prouve as early as the 1930's began experimenting with prefabricated steel and aluminum structural systems that allowed for 25 customizable configurations of his Meudon House series.

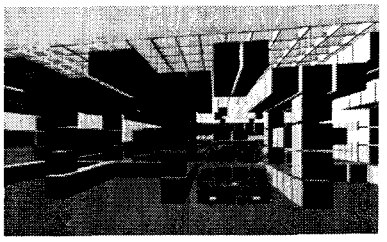


Fig. 14.

Fig. 15.

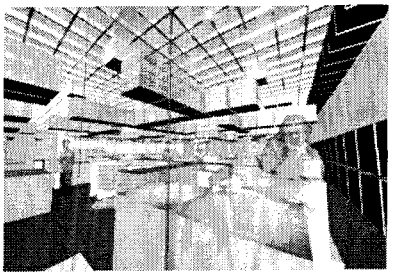


Fig. 16.

In the late 1940's Joseph Eichler, a developer in California, started a community called Eichler Homes Inc. These single family homes also used post and beam construction, but out of local laminated wood beams and cladding. The post and beam construction allowed for porous schemes through out each home; blurring the boundaries between inside and outside. His town homes were also innovative through customized facades skinned in various materials such as corrugated metal, wood shingles, painted stucco etc. Entenza's Case Study House Program, also in California established an experimental laboratory for innovative housing design and manufacturing. Charles and Ray Eames's House was built from standard off the shelf parts but were assembled in a way that accommodated their specific unique live/work environment.

In Australia, Harry Siedler's Exhibition House made of a repetitive steel and corrugated zinc panel system built in the 1950's also allowed for free plans and 'plug-in' prefabricated elements such as the bath room and suspended pre-cast fireplace.

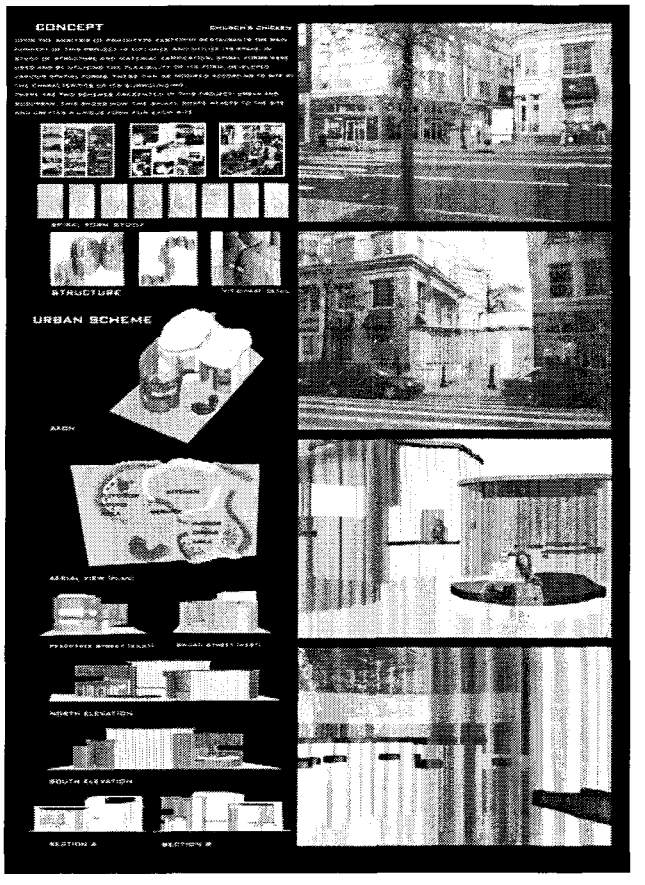
Richard Rogers in his Zip-Up Enclosures allows for a fixed, yet flexible system that could extend or be added on to both vertically and horizontally. The interiors were retrofitted with moveable walls allowing the inhabitants to configure and reconfigure their interiors as they wished.

RESURGENCE AND EMERGENCE IN TEACHING AND PRACTICE

Today there is a resurgence and emerging interest in mass production in architecture. But instead of mass production, mass customization is the system that is of particular interest, especially among young, innovative, emerging practices. Through the use and increasing affordability of cad-cam technologies, and information technologies such as the internet, this has enabled practices to maneuver the turbulent landscape of social, cultural, economic, desires, and needs of existing clients and potential clients. Mass customization deployed by these practices is in various forms and styles; but the common thread through-out, is the use of cad-cam technologies. Cad-cam affords complexity to occur within a repetitive process. Instead of the 'stamped' or the 'molded' homogenous designs; the milling machines, the 3-D printers, the stereo-lithographic machines, and the automatic 'file to factory' systems are allowing heterogeneity in the making of architecture.

In Stan Allen's article "Terminal Velocity: The Computer in Design Studio" he elaborates on these new digital design processes and techniques:

> "If for example, complex forms generated in the computer are translated into the standardized measuring systems of



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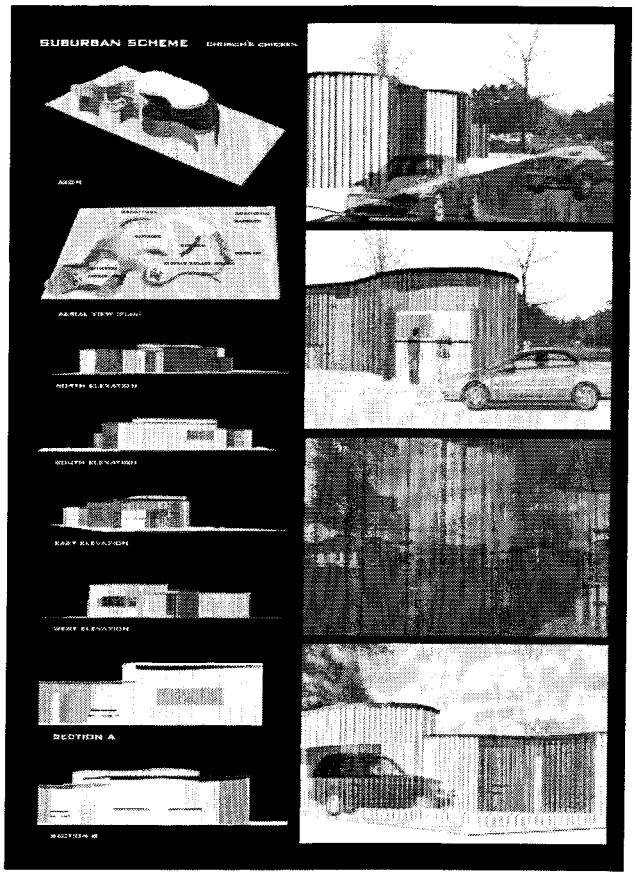
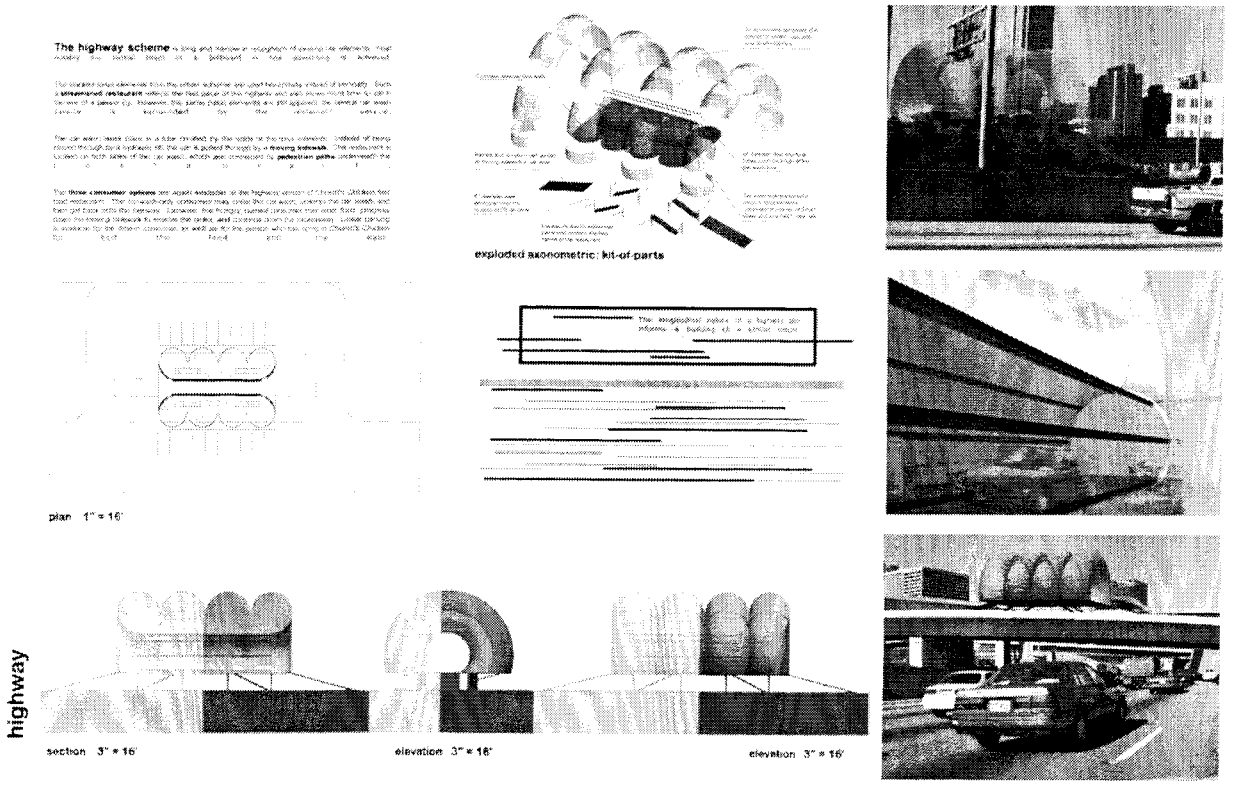


Fig. 18.

contract documents, interpreted by a builder and realized by conventional means, the impact of the computer remains exclusively formal. If, however, the specific capacities for computer fabrication are integrated into the process of design itself, new possibilities are opened up. The properties of the material become part of the design process. A complex surface can be proposed, and material constraints – the maximum size of the individual panels, for example, or their capacity to bend or twist – can be entered as working variables. The same system that lays out the grid of the surface in the design process can in turn drive the machine that cuts those panels. [...]...computer fabrication is indifferent to the forms of repetition enforced by conventional production. For a computer milling machine to calculate and cut every member of a curtain wall system to a different length, for example is no more time consuming than to cut every member the same. The potential here is that variation can be introduced into the system not as an exception from the outside, fragmenting or braking down the unity of the whole, but as incremental variation of the parts themselves. By introducing local difference that accumulates to create variation without destroying the overall coherence, a more complex and fluid notion of the whole can in turn be produced."

From here, I would like to describe some case studies implementing mass customization through digital processes and techniques. These will be drawn from my design teaching and



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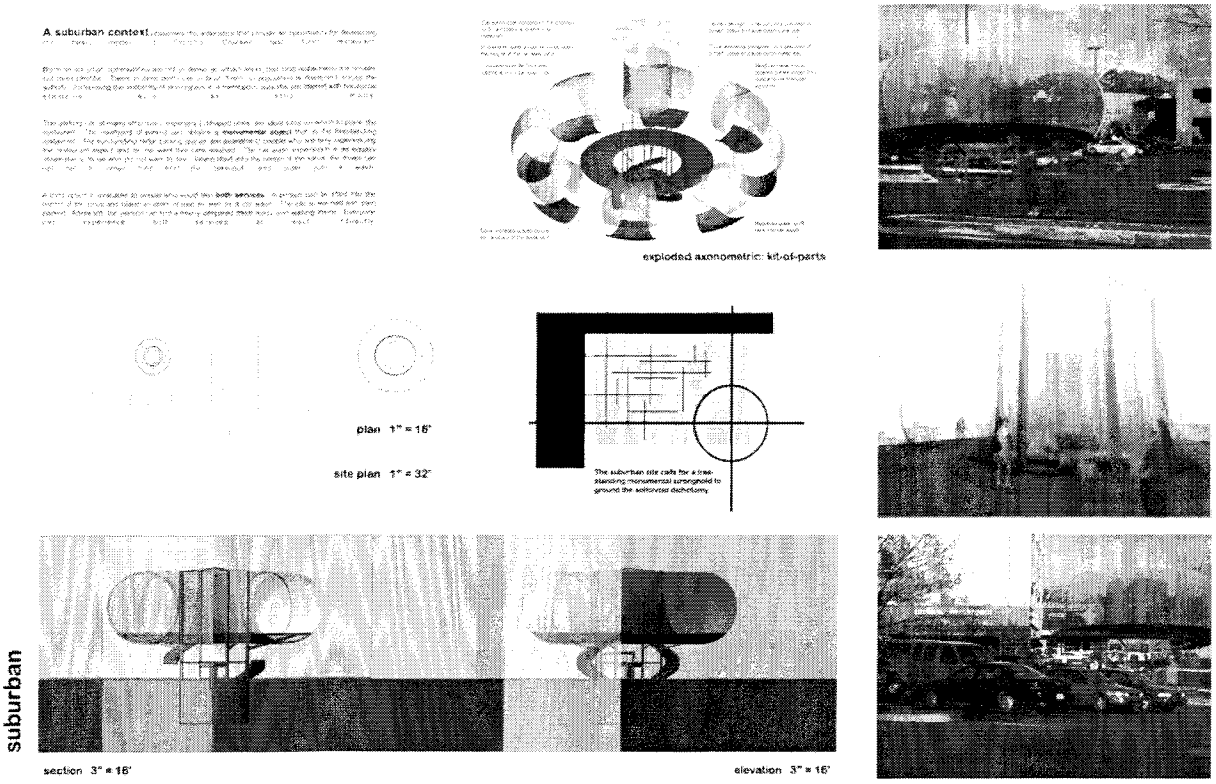


Fig. 21.

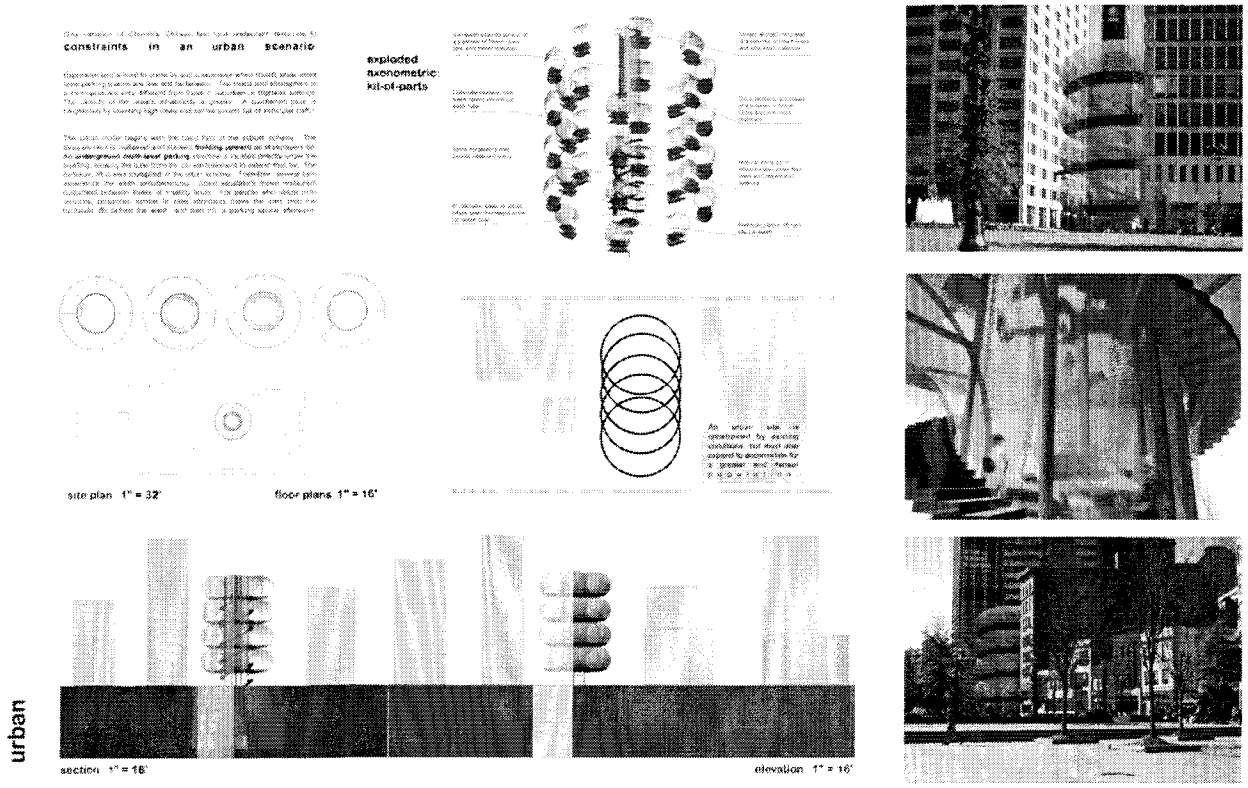
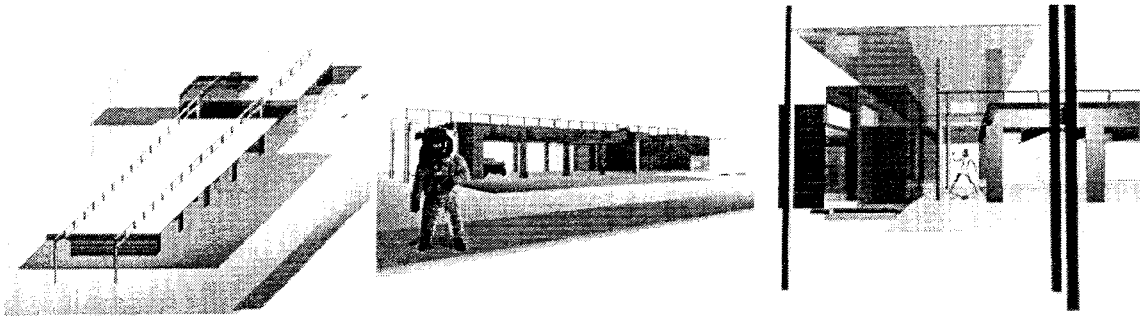
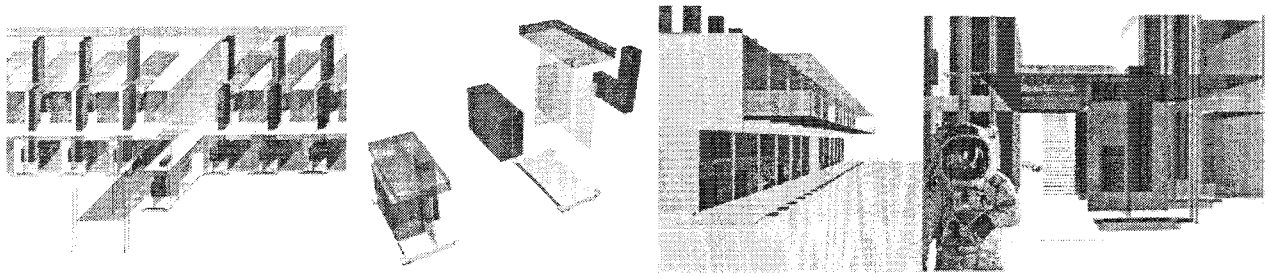


Fig. 22.

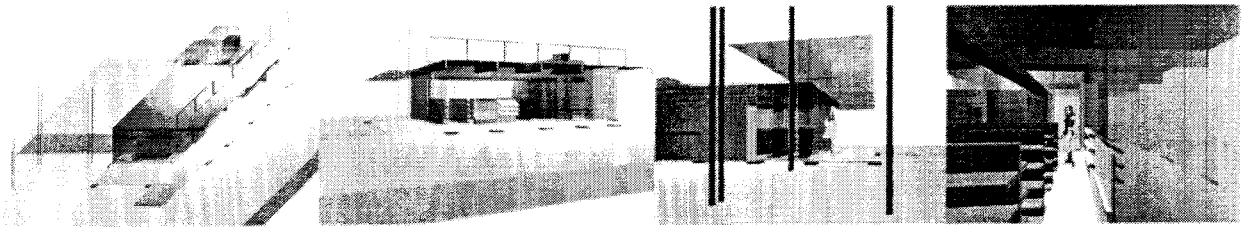
contemporary architectural practices, as well as design work from my own students.



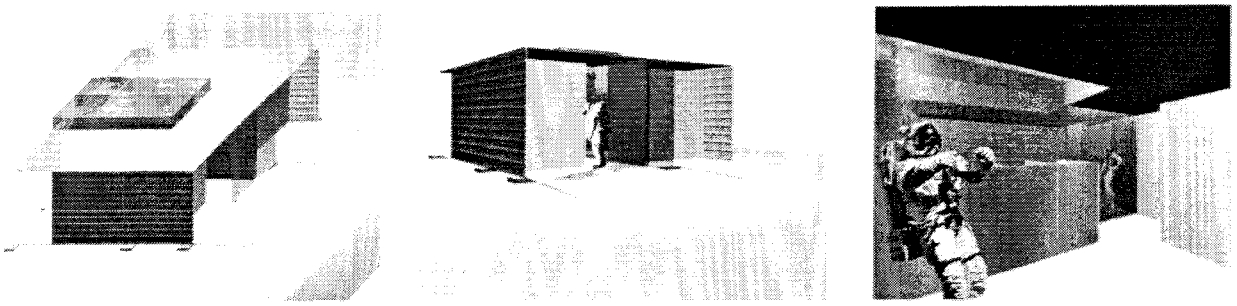
Nathan Koskovich's Auto Repair: Axonometric, Exterior and Interior Perspectives.



Nathan Koskovich's Motel: Axonometrics of Module's and Kit of Parts, Interior and Exterior Perspectives.

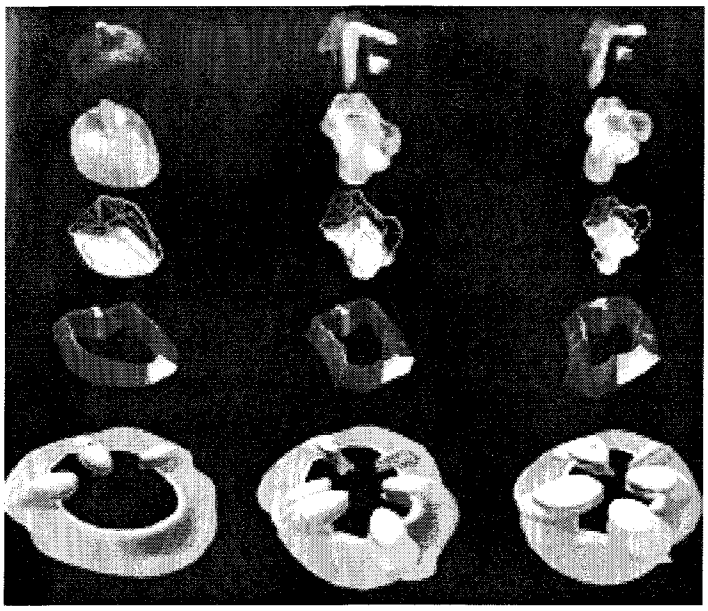


Nathan Koskovich's Quick Mart: Axonometric, Exterior, and Interior Perspectives.



Nathan Koskovich's Restrooms: Axonometric, Exterior, and Interior Perspectives.

In teaching I coordinated an undergraduate design studio in which we experimented with concepts of mass customization. The project was to create flexible prototypes for fast food corporation, Church's Fried Chicken. It was an actual collaborative think tank with their in-house architects. It was an opportunity to rethink drive-thru architecture through critical inquiry and experimentation with the most ubiquitous typology, [fast food restaurants] in our global everyday landscape, [especially in the United States]. Unlike the typical universal and 'one size fits all' fast food prototypes currently deployed across the landscape, the studio was charged with designing more flexible prototypes, prototypes that were responsive and adaptive to different outside forces, forces such as site, program, budget, climate, culture, movement, time, speed, homogeneity, etc. Diagrammatic and operative techniques, as well as obtaining difference through repetition, through mass customization were some of the tactical strategies explored in the studio; as



Greg Lynn's Embryologic Houses.

well as rethinking the relationship between the car and the drive-thru through hybridization and integration.

How can the prototype be repetitive, yet differentiate as per all of the outside forces of site, homogeneity, globalization, cultural diversity, economics, climate etc.? How can we use other media, materials, and new fabricating technologies to re-think building standardization and conventions in an effort to produce something new and different, versus 'cookie cutter' methods?

How can we produce an architecture of "maximum performative effects with minimal architectural means"?[8] [This does not suggest a simplistic architecture, but a lean 'diagrammatic' architecture toned by the desires and complexities of contemporary urban/suburban life.]

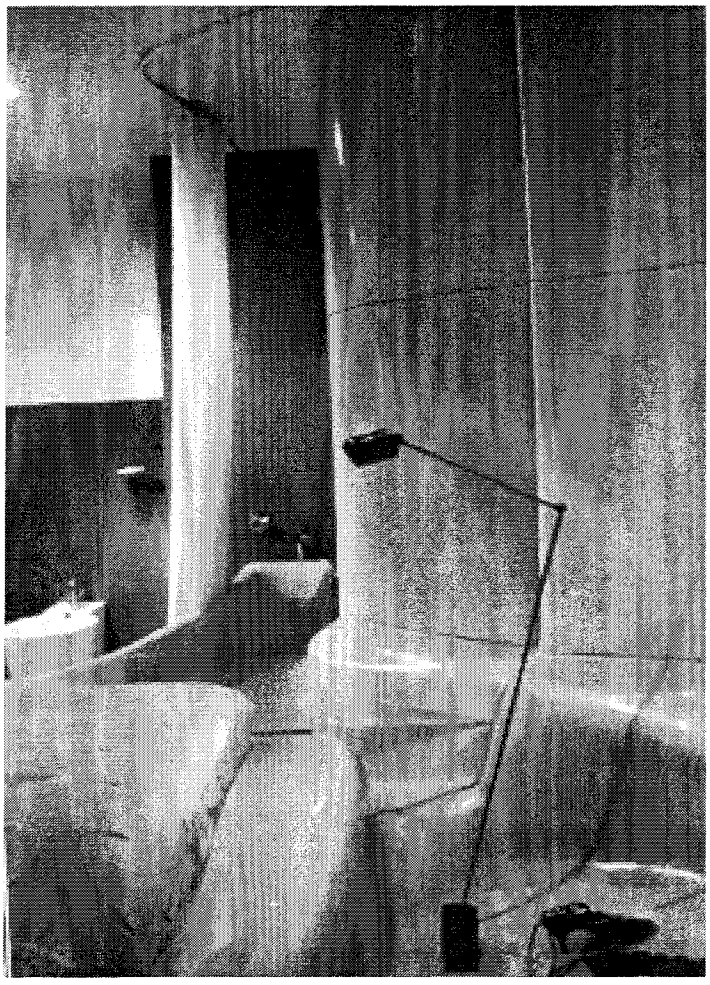
How can we produce an architecture that "organizes, integrates, and coordinates"[9] qualities and quantities through tapping into the complexities and temporalities of the urban/suburban landscape, and its spaces of distributions?

Figure 1 and 2 Catalina Victoria's project used the accordion, Isamu Noguchi's lanterns, and Issey Miyake's dresses as diagrams for the prototype. Through operations of articulating, folding, and extending the outdoor prototype responded and adapted to different appropriations, programs, and sites.

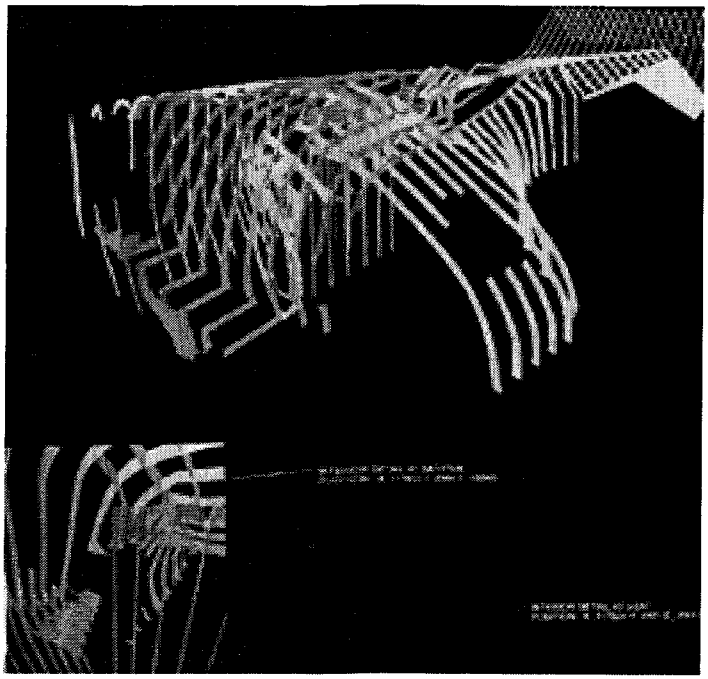
Figures 3 – 7 James Fullton's project used the articulated bus and toll plaza as diagrams for the prototype. Through operations of repetition, bending, stretching, and extending the prototype responded and adapted to different highway and infrastructural sites. The prototype also integrated the car using ideas of interstate toll plazas and bank drive thru's pneumatic tube delivery systems. The concept of obtaining difference

through repetition was also explored through the flexibility of the prototype's components.

Figure 8 and 9 Dara Douragi's project used the shipping container and vending machine as diagrams for the prototype. Through of operations of nesting, extending, and sliding the prototype responded and adapted to different numbers of customers, condensation of programs, and attenuated sites of the highway. The prototype also rethought its relationship with the car by driving through the prototype versus around it.



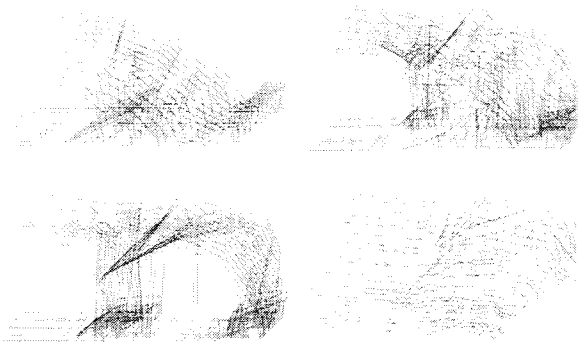
O/K Apartment Final Installation.



Raybould House Structural Templates.

Ryan Godfrey's project used the Japanese checker game of 'GO' and two way grid system as diagrams for the prototype. Through operations of stacking, sliding, extending, and repeating the prototype provided differentiation in suburban and urban conditions, as well as responded to users' movements and desires of creating individual landscapes. The prototype also rethought its relationship with the car by driving through the prototype versus around it. The concept of obtaining difference through repetition was also explored through the flexibility and mobility of the prototype's components.

Figure 17 and 19 Christina Ow's project used the topological amoeba as a diagram for the prototype. Through operations of repeating and bending the prototype responded and adapted to different urban and suburban site conditions, as well as created indoor and outdoor eating areas. The concept of obtaining difference through repetition was also explored through the flexibility of the prototype's components.



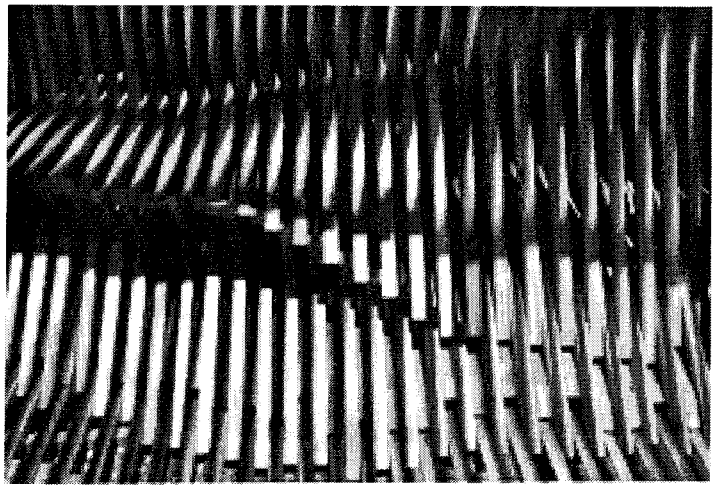
PS 1 MOMA 'Urban Beach' Wire Fame Tamplates.

Figures 20 – 22 Christina Luu's project used the topologic torus and the car wash as diagrams for the prototype. Through the operations of repeating, stacking, and articulating the prototype responded and adapted to different site conditions and numbers of customers. Hybridization and integration were also explored through combining the program of the car wash with fast food. The concept of obtaining difference through repetition was also explored through the flexibility and interchangeability of the prototype's components.

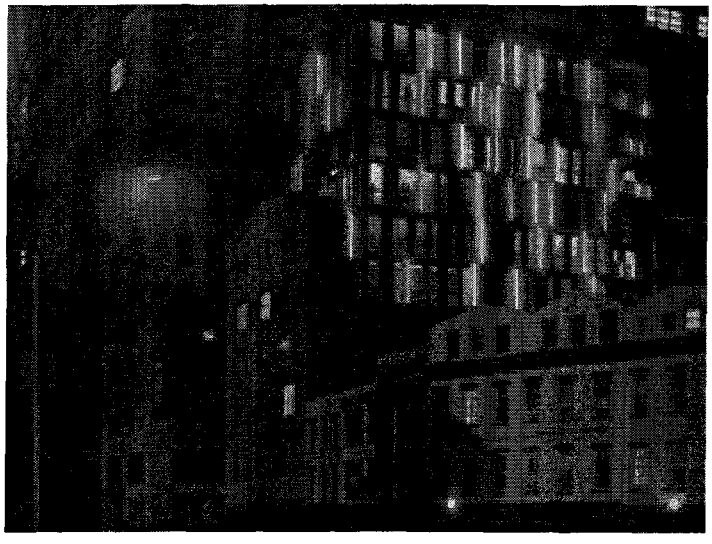
In another graduate studio I coordinated, I asked the students to design mass customizable prototypes for a Travel Plaza located along the interstate. The students were asked to integrate other programs such as motels, recreational spaces, retail and even housing in some cases. The prototypical site was a median located in-between a six-lane interstate highway. The highway connected Atlanta to the east coast, as well as served as a high traffic route to Florida; [so there was a tremendous cultural and socio-economic cross section.] Below is one of the proposals utilizing pre-fabricated components that came in various colors and materials. The concept was about 'fixed' elements that would serve as infrastructure, such as structure, bathrooms, HVAC, electrical, data etc.; and 'fluid' elements such as program, skin enclosures, signage, furnishings, etc. The units were modular so that they could grow or shrink and/or reconfigure as programs, demographics, sites, budgets etc. changed.

Greg Lynn, one of the first architects and teachers to bring animation software and cad-cam into the academic design studio. His Embryologic Houses proposal utilizes animation software and laser cutting technologies to construct multiple aluminum shelled envelopes.

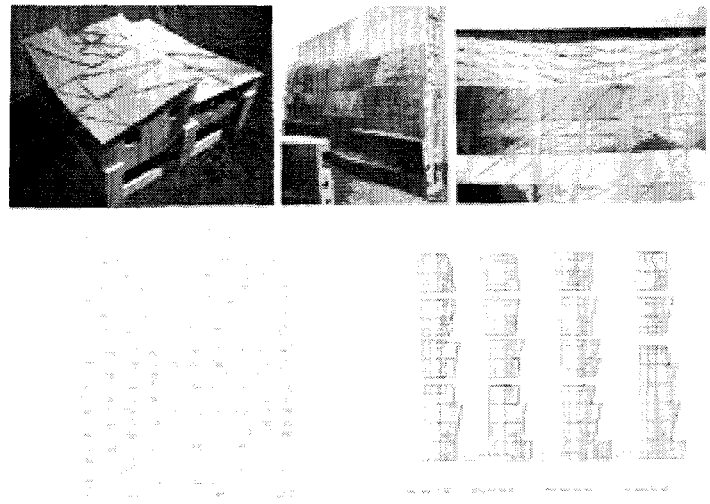
Kol/Mac Studio are probably one of the first practices, who began experimenting with digital technologies, generative processes, and customizable fabricating techniques. Several of there projects such as the 'Angelica Film Center' [1995], 'O/K



Final Installationof Repetive yet Differentiated Teak Members.

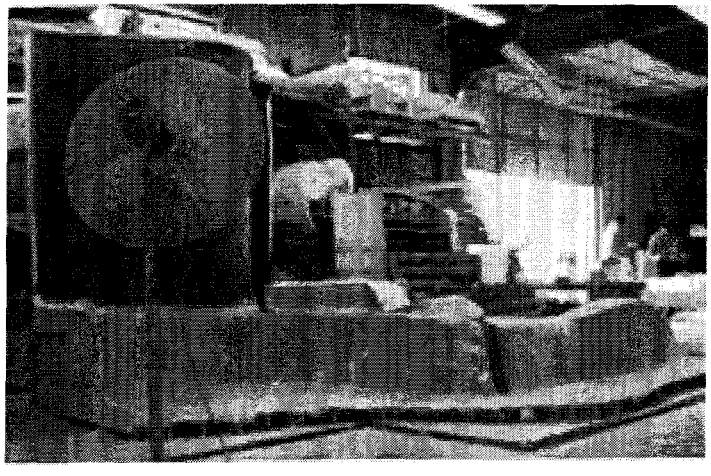


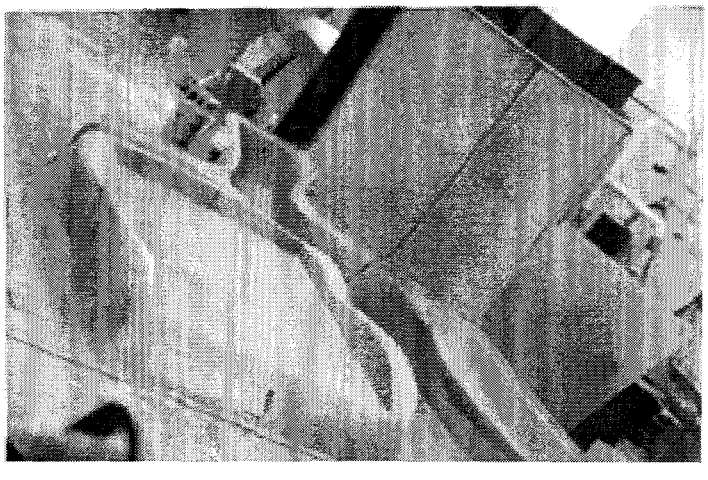
Housing Project and Display Wall.



Shop Drawing Templates for Fabrication and Final Assemblies of the Skins.

Apartment' [1996], 'Vehicles' [1997], 'Housings' [1999], and 'Raybould House' [1999] are just a few of their evolving experiments. Following are images from the O/K Apartment fabrication process and finished installation; as well as a computer generated model for the structural framing templates in the Raybould house. Kol/Mac not only utilized the computer to generate the space and forms of these topological hybrids, or what they like to term 'chimerical' landscapes; but also went outside the boundaries of typical construction and material through hiring boat builders to fabricate their fiberglass composite structures.





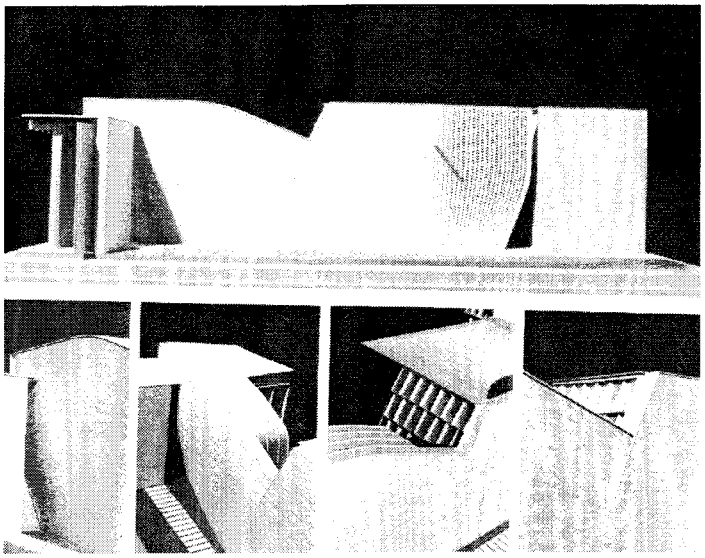
O/K Apartment Fabrication.

SHoP Architects have also seen the physical results from Mass Customization. Practically every project in their office utilizes cad-cam, file to factory technology. Their 'shop' drawings are like beautiful assembly instructions for model airplanes. The precision of the laser cut parts and the tolerance in assembly is uncanny. Following are images of the wire frame drawings that served as a template for the laser cut teak repetitive yet differentiated system. In a housing project a laser cut zinc panelized skin was mass customized through cad-cam. In addition, titanium panels produced for a display wall were constructed out of triangulated topological geometries because of the tremendous computational capabilities of these emerging digital technologies. As a result, both skins were beautifully precise and yet unbelievably complex.

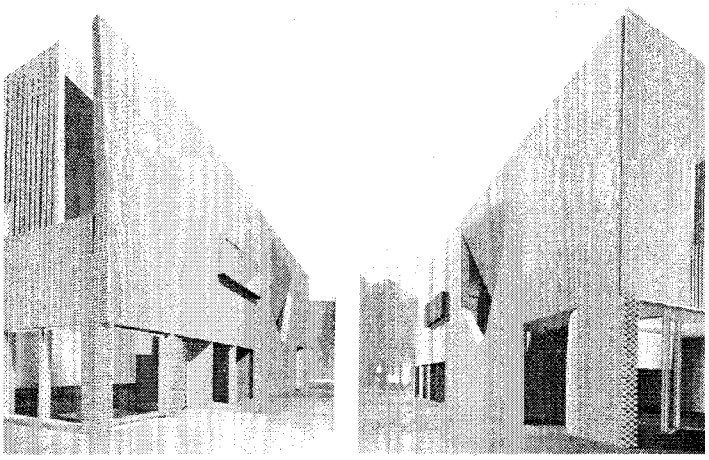
Bill Massie of Massie Architecture is producing of series of single family dwelling units in a variety of forms, materials, and colors to choose from thanks to prefabrication and cad-cam technologies.

FOA, in their Yokahoma Port Terminal Design utilized the computer's computational processes to plot the complex geometries needed to build their enormous roller coaster constructed infrastructural complex.

Office Da, has also experimented with mixing new cad-cam customizing technologies with traditional building crafts such as masonry construction.



Office DA's Tongxian Arts Centre.



The Witte Arts Building.

CONCLUSION

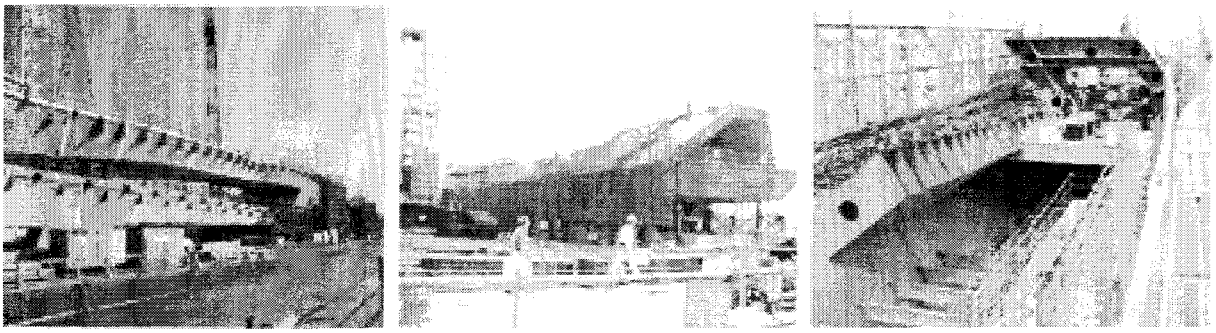
> "*At its limit, it is the mass* production of individually *customized* goods and services. At its best, it provides strategic advantage and economic value."[10]
> – Joseph Pine

In conclusion, Mass Customization has tremendous potentials and possibilities in critically transforming architectural practices, pedagogies, and production. But, it still has its constraints. The new hardware and software still have learning curves, and as stated below, are still not as affordable as one would hope. But, this should *not* discourage curiosity and experimentation. For it is becoming more affordable as we speak, technology has always been that way and will continue to evolve more quickly than ever. Another constraint is scale. Most of the practices outlined in the paper are dealing with relatively small scaled structures. Issues with scale are also being addressed. Modularity is a key component of Mass Customization. Perhaps more research into modularity will alleviate some of these constraints at the moment and in the future. Another possible constraint is too much variety and choice. If we allow the client total free rein, or if the system is only fluid without a framework or robustness, well, all hell could break loose. Too much variety *can* be a bad thing; so strategize tactfully, choose your variables carefully.

CAVEAT

Some of you may wonder why I have not included Frank Gehry's practice as an example of Mass Customization. Well, to be honest, I did not think it was fair because he is in a league of

Bill Massie's Prototypical Single Family Dwelling Units.



FOA's Yokohama Port Terminal.

his own. His technological infrastructure is beyond most experimental practices dreams; [although technology and fabricating machines are quickly becoming more and more affordable.] In addition, his budgets are much more luxurious than these more emerging practices: unfortunately, or, fortunately, he does not have to consider economy or efficiency as much as they do. I am sure there are a lot you who would not agree with me on this matter. This is where I have perhaps suppressed objectivity. Therefore from a critical *and* subjective standpoint, I would like to stick with the true values of Mass Customization: and one of those most important values, in my mind, is *economy* and *efficiency*, without giving up *variety* and *complexity*.

NOTES

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