EMERGING TECHNOLOGY- DILEMMA AND OPPORTUNITIES IN HOUSING

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Abstract. Digital Technology has transformed industrial manufacturing and production; and an array of Industrial Design products provide increasing comfort and benefit to millions of global citizens via ergonomic and mass production/customization strategies. Yet, housing needs of a rapidly growing global population are rarely affected by digital technology.

Shifts in societal demographics, from rural to urban city centres, and concurrently Global Warming and ecological changes are exacerbating the world housing situation. Millions are homeless, live in inadequate shelter, or as in the US Manufactured Housing (MH) market, live in nondurable poor quality “manufactured” houses that are detrimental to health, at best, or during extreme weather events, suffer catastrophic damages often resulting in death to occupants. Nevertheless, housing concepts and related living units have benefited very little when compared to architecture’s related manufacturing industries counter-parts (i.e. automotive, aerospace, marine industries, etc). While Technology has vividly expanded the shape language of architecture (i.e. Free-Form-Design), some may argue that Free-Form-Design buildings generally have beauty that is only “skin deep” and typically focus on providing signature statements for both the designer and elite clientele.

In this paper, we will briefly review the role of the architect in the US Manufactured Housing industry; additionally, we will identify the major problems that plaque the US Manufactured Housing Industry. Further, we will review how architects and Industrial Designers use technology in their respective fields and draw larger design-manufacture principals for issues of global housing. Our findings and analysis suggest that an Industrial Design approach, applied in architecture for mass housing, offers a means of improving the architect’s role and technology in manufactured housing for the masses.

1. Introduction

It is estimated that 56% of the world's population lived in areas affected by natural hazards between 1991 and 2005 (Source: United Nations International Strategy for Disaster Reduction - UNISDR). UN-Habitat estimates that nearly 200 million living in poorly designed and low quality housing are displaced annually due to natural disasters. The wide array of commodities surrounding us today of every shape, size and function attest that - with the advent of digital technologies - the only limitation binding the designer is literally one's own imagination; however, within costs and performance constraints. Generally, architects have recently realized the potential of digital tools, but are often perplexed as to the role that this technology could play in serving the masses as they have in Industrial Design (ID). Meanwhile, housing needs of a rapidly growing global population, coupled with an ever increasing number of annual environmental disasters prods architects for mass housing solutions. Thus, the question is raised as to how digital tools might assist in the increasing dilemma of mass housing.

In this paper we overview some of the many notable works of architects in the field of mass housing in the past century. We also summarize the manufacturing paradigm of the current US manufactured home industry, and further highlight major problems with current US MH products. We later focus on the role of digital tools in the design and fabrication processes of housing units in architecture; here we contrast it to that of designing and manufacturing commodities in industrial design. We conclude by proposing an approach towards the use of technology for the design and manufacturing of commodity housing that we think would improve the quality of mass housing units.

2. Architects and Mass Housing; A Century Long Struggle

Over the past century, architects' translated their preoccupation with industrialization and mass production principles through several mass housing projects and ideas.

Perhaps the initiator of this direction in modern architecture is Walter Gropius who expressed his philosophy in the 1920's:

> "For the national Economy it is important that home production costs should be lowered. We have tried to lower the costs of traditional building, but these efforts have shown very small results. The problem should be attacked at its roots. The real solution; houses should not be built at the site, but in specialized factories by serial manufacturing of mountable elements."

Gropius' work spanned nearly four decades; this included two mass housing ventures; the Copper and the Packaged House. Concurrently, Le Corbusier was exploring industrialized production of housing units in Pessac; this was described as a laboratory for Corbu's ideas and philosophies. Other works in this field include Buckminster Fuller's Dymaxion Dwelling

Machine, Jean Prouve's Tropical House, and Paul Rudolph's Oriental Gardens project. See Figure 1.

Figure 1: Modern architects' mass housing proposals: Left: Gropius' Copper House. Center: Le Corbusier's Le Pessac. Right: Fuller's Dymaxion Dwelling Machine.

The time and effort invested by architects in the field of mass housing is by no means restricted to that of the architects listed above. Others such as Frank Lloyd Wright, Mies Van Der Rhoe, Robert Venturi, Richard Neutra, Moshe Safdie, the Archigram group, and Kisho Kurakawa, among many more, are well-established figures in this field.

Sadly, these housing attempts have struggled with several obstacles. In many cases, it was the lack of funding and failure to establish a fruitful collaboration amongst architects, engineers, and businessmen; in others, it was unfavourable political circumstances and regulatory barriers. Other obstacles confronted were perhaps more related to architecture as a profession. These evolved around achieving a necessary balance between technical development of the housing units - to achieve an adequate level of performance, and lack of design for diverse and constantly varying residents' appeals while maintaining the economical advantage of mass production.

3. The Manufactured Home

Parallel to architects' attempts in the 20th century, the building industry in the United States played an important role in the mass housing scene; the early MH building industry adapted materials and methods from the automotive industry (circa 1930). However, the US MH industry later adapted site-built tactics in the 1970's. Thus, the US manufactured home industry developed with little, if any, contribution from architects. Instead, it was guided by the consumers' inclinations and needs as perceived by manufacturers for "cheap" products.

3.1. PRODUCTION PROCESS

Though having the advantage of the factory setting, production of US manufactured homes typically follows a process identical to that of stick built construction, using the same techniques and equipment, thus it depends chiefly on manual labour rather than automation. A survey conducted across several US manufactured housing producers looked at the level of computerization involved in the process (Barrow & Pan, 2003), revealed that the use of technology, even at its most modest levels, was limited to a very small percentage of companies, and even then it was restricted to administrative and managerial tasks not affecting MH production.

3.2. PROBLEMS

US manufactured homes suffer several performance deficiencies and problems as a result of focusing on cost reduction. They are as follows:

1- The production of the entire housing unit in the factory to minimize onsite assembly expenses.
2- Use of cheap low Quality Material.
3- Minimum use of technology and the dependency on low-skilled manual labour.

These problems could be summarized in the following seven major points:

1. Excessive flammability: As declared by US administration National Fire Data Centre October 2004 report, MH units have the highest death rate per thousand fires among all residential and non residential structures, killing 271 people and costing $120 million in losses in 2001.
2. Vulnerability to extreme weather: Based on obtained from the National Oceanic and Atmospheric Administration, Manufactured homes suffer more wind damage in comparison to conventional housing during hurricanes and tornadoes. Furthermore, based on statistics obtained from the manufactured housing institute, the majority of MH housing units are poorly fixed to their foundation. This increases their risk of being damaged as they are pushed off these foundations by high winds, flood waters and storm surges.
3. Low Indoor air quality: According to the American Journal of Public health, manufactured housing structures excessively emit noxious fumes that have adverse health effects.
4. Financing and Insurance complications arise due to the limited collateral associated with manufactured homes in light of their deficient performance. Such complications include higher financing and insurance interest rates which are not tax deductible, shorter loan periods and the units' depreciation in value. Such financial drawbacks are important and ironic issues posed by this “affordable” housing solution.
5. Lack of Durability: MH units have limited durability with simultaneous problems relating to construction emerging within the first year of ownership (NFO Research Inc., 1999).
6. Transportation of the manufactured home unit imposes several dimensional, weight and aesthetical restrictions. Such limitations contribute to the unit's problematic performance and lack of appeal. That in addition to dangers and expenses of the process.
7. Prejudiced perception established by the deficient performance, financial complications and the lacking aesthetic of manufactured homes, leads to the creation of local government laws that mandate zoning manufactured homes out of single family housing communities to edges of cities away from jobs and services.

4. Architecture and Industrial Design; Divergent Approaches

4.1 ARCHITECTURE, TECHNOLOGY & MASS HOUSING

Contrasting to Manufactured Home production, both architecture and industrial design use digital design and manufacturing tools extensively. However, the focus and approach of their use varies tremendously.

Architects today are perhaps cautious, drawing lessons from previous works in the MH field as to how to tackle the issue of differentiation and customization, a pitfall shared by many pioneering mass housing architects. However, the capacity of digital tools to support extreme differentiation (i.e. Free-Form-Design), within a traditional linear architectural design process, has led to a fervent chase for unique original undulating forms; this being done with little regard to technology's potential role in perfecting performance aspects and high volume production requirements found in Industrial Design. Further, due to the high costs associated with the use of digital technologies, houses as a project typology do not benefit from CADCAM applications. With this in mind, it is worth mentioning that there are a number of high end highly customized residential projects that engage the use of these newfound tools; however, typically they are of high cost or intended as original one-offs. Additionally, many of these projects remain unbuilt as they are unfeasible even for highly affluent clientele. Examples are the Lewis Residence, designed by Frank Gehry and Philip Johnson, and the Embryo House designed by Greg Lynn. A rare example of a completed residential project that employed digital technologies in design and fabrication is the Turbulence House designed by architect Steven Holl, see Figure 2.

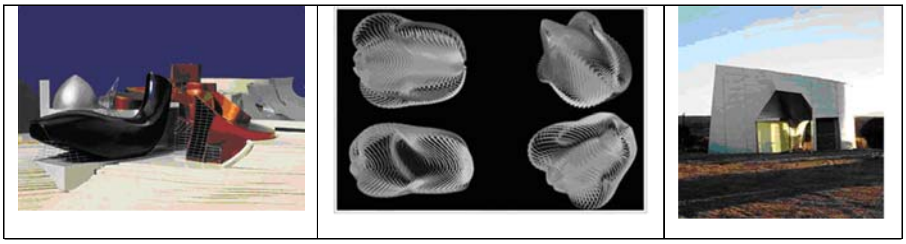

Figure2: Right to left: Ghery's Lewis Residence, Lynn's Embryo House, and Holl's Turbulence House

4.2 ID, TECHNOLOGY & MASS PRODUCTION

Similarly, reaping the advantages of a global digital setting, industrial designers are today liberated from the "Fordist" mass production dictum: "you can have it in any colour you want as long as its black", and are free to explore ways beyond that of solely satisfying mass demand, to satisfying the consumer's demand to be differentiated from the masses (Wind & Rangaswamy, 2000). The following highlights a number of aspects through which Industrial Design (ID) approaches the integration of technological advances.

4.2.1 Integrative Collaboration:

Unlike architecture, Industrial design departs from the traditional linear design process found in the construction industry, where decisions made in earlier stages predetermine decisions taken in subsequent phases, to a more collaborative approach that brings together all those concerned in design and manufacturing at the outset of the project (Jarvinen & Koshinen, 2001). This ensures that an optimum holistic design and manufacturing methodology is pursued for production that is based on thorough research which takes into account the capability of digital tools to support the design and manufacturing of fluid ergonomic forms. Other issues are considered as well regarding performance, consumer demand, and possible changes of a fickle consumer taste requiring mass-customization. Further, factors of the manufacturing facilities, material availability, and global resources, even business and marketing tactics are taken into account in the early design phases.

4.2.1 Performance Studies and Form Development:

Within the collaborative ID paradigm, form is not a pure manifestation of the designers creativity and digital capabilities; rather, it is a by product of several factors, most prominent of which are *manufacturing* and *performance* requirements.

4.2.3. Simplification and Standardization:

Manufacturing requirements dictate simplification and standardization of fabricated components instead of relying on technology's ability to support complexity.

4.2.4. Modularity:

Intricately built product ideas are not abandoned in favour of streamlining manufacturing, but are achieved through the amalgamation of simpler modular components. In fact, modularity is perceived as a prime factor for feasible mass production in the current global manufacturing setting.

4.2.5 Mass Customization Strategies:

Modularity is further highlighted as an asset to survive in a world of "customerization" (Wind & Rangaswamy, 2000). This is carried out through mass customization strategies.

4.2.6 Flexible manufacturing processes:

Modularity also extends to encompass machinery and equipment used in production. Interchangeable machinery parts accommodate the production of different models and products eliminating the necessity to change entire machines and pieces of equipment. This also includes the use of software that is easily reconfigured to carry out different sets of operations whenever changes are necessary.

4.2.7 Cradle to Cradle design:

Industrial Design is expanding its design process beyond the realms of design, manufacturing, marketing, and costumer use phases of the product's life to further incorporate the following phases of reuse or dismantling and recycling (McDonough & Braungart, 2002).

From these brief highlights it is evident that the achievements in ID do not come as a result of arbitrary incorporation of technological advances; rather, they are the result of a broader strategy to govern the role of Technology in the design and manufacturing process. The potential of such a holistic strategy was recognised with the emergence of the phrase “little “d” and BIG “D” design” (Barrow, 2004), here it was stressed that conceptual design ideation in architecture must encompass both product and manufacturing process in order to fully leverage technology in mass architecture. This suggests that the traditional linear project delivery model is eroding as we move toward an integrated inclusive design-manufacture-operate-recycle paradigm in architecture.

5. Conclusion

Our previous analysis illustrates that Industrial Design’s approach to incorporating technology in design and production processes varies from that followed in architectural practice. Table 1 lists aspects as extracted from the proceeding overview; further, we rate how technology is utilized for mass production in the compared industries and scenarios.

TABLE1: Comparison of the different approaches for use of technology in mass housing production

Phase	Action	Industry	Architecture	Modern Movement	MH
Conceptual Ideation	Integrative Collaboration	●	◑	◑	○
Design Development	Performance Studies & Form Development	●	◑	○	○
	Simplification & Standardization	●	○	●	●
	Modularity	●	○	◕	●
	Customization Strategies	●	○	◑	◑
Manufacturing	Flexible Manufacturing Strategies	●	◑	○	○
End of Product life	Reuse, Recycling, and dismantling	●	○	○	○

100 % considered ●
75 % considered ◕
50 % considered ◑
0 % considered ○

Though this proceeding breakdown is a crude simplification of the actual process, it does indicate that mass housing attempts, whether those by architects of the early modern era or contemporary architects nor the manufactured home industry, fail to mimic the more holistic approach to incorporating technology as utilized in Industrial Design.

As such, the success of mass production for commodity items found in Industrial Design. is attributed to its holistic approach to technology. Thus, we conclude that following a holistic design strategy for the integration of technology could improve the quality of mass housing fabricated units. We further claim that a performance based integrated design-fabricate-operate-recycle approach provides the framework to achieve a holistic process and product that may result in a performance based mass manufactured housing that achieves, for both designer-makers and mass-owners, Beauty.

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