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MODULAR FOR ARCHITECTS

HARRY WILLIAM PARKER
UNIVERSITY OF TEXAS AT AUSTIN
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MATTHEW FAJKUS, AIA, NCARB, LEED AP
SCHOOL OF ARCHITECTURE
SUPERVISING PROFESSOR

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ABSTRACT

Manufactured, modular architecture is at the forefront of modern design—with factory-built components, buildings are becoming more cost-efficient, transportable, and consistent. Often designed for profit or ease of construction, manufactured homes have historically compromised character to become more cost-effective, energy efficient, or fashionable. They are designed by spreadsheets and market research of developers, marketers, and engineers, not the sketchbooks or dreams of architects. Architects, taught to design with theory, passion and poetry, prefer to design traditional homes because historically it has proved difficult to implement a modular construction strategy while maintaining authorship of design. Each client and context are unique, and architects perceive modular construction as a betrayal of that truth, forcing homes into three or four product lines with no contextual adaptation. With new technology, proper planning, and business plan integration, however, modular architecture can now introduce far more variety with negligible impact on cost or production efficiency. This paper presents an overview of modular home construction and tools for the architect to exploit its efficiency without compromising on uniquely designed outcomes or profitability. It then shapes a design and business question of whether modular construction is the best solution for a test project of holiday rentals in Fredericksburg, Texas—explored through a business plan and preliminary design schematic.

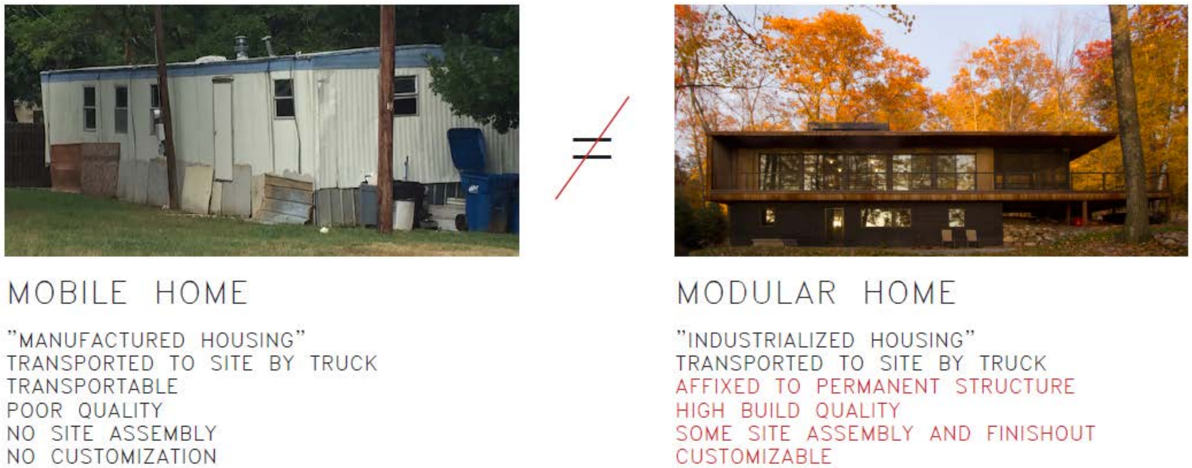
WHAT IS PREFABRICATED HOUSING?

> "What if you had to assemble a car after purchasing it? Imagine your new purchase strewn across the driveway in 10,000 pieces. Absurd, right? For most products, we take for granted that the product will be built offsite" (Court & Johnson, 2017).

With over a century of manufacturing excellence, why is it that building construction has not reaped the cost savings, efficiency, and quality control of manufacturing? Homes are vastly more expensive than cars, and yet they are less dependable. A home's construction costs are difficult to predict, and, even with an excellent architectural design, can yield a vastly different final product depending on the builder's delivery. Timelines and budgets can multiply from a storm, a missing component, a contractor's mistake, or a thousand other potential bottlenecks. And yet, after thousands of years of site-based construction, we still applaud it as the industry standard. But does construction have to be this way? Could homes achieve the same consistency in production time, quality, and cost that is standard to the automotive industry while not sacrificing a unique character?

Over the past four centuries, varying levels of factory-made building components have been implemented into residential construction. Building components constructed off-site, pre-fabricated or "Pre-Fab" for short, have enabled English mass-colonization, provided mass-housing for veterans after World War II, and more recently, for skyscrapers to be constructed in as few as 120 days (Smith, 2011) (Hawthorne, 2014) . Conventionally, a building's construction begins and ends on the same construction site. It is a linear process, and when one benchmark has been completed, the project moves to the next. This process is known as on-site, stick-built, conventional, site-built, or traditional construction, and can be incredibly inefficient—one delay along the line can push the project weeks or months behind schedule (Kamali & Hewage, 2016). Off-site construction can be categorized into several levels of factory production, in ascending order of completion: "Component subassembly": small scale elements are constructed in the factory (e.g. windows or doors); “Non-volumetric preassembly”, elements are assembled in a factory to create non-volumetric building components before installation at the construction site (think cladding and interior wall panels); “Volumetric Preassembly”, similar to the previous, but components actually create fully-furnished, spatial units (think bathroom pods) that are then shipped to the site and fit to site-built components; and Modular or “Complete Construction”, all building components, aside from foundation and sitework, are preassembled into modules which together, when assembled, make a building (Kamali & Hewage, 2016).

Modular housing is not to be confused with manufactured housing, however—which, formerly known as “mobile homes”, are built on non-removable steel frames and often put on wheels or temporary upstands. Modular homes are intended to be permanent residences, attached to structures and foundations (Tracey, 2016). This common misunderstanding has led consumers to associate “prefab” and “modular” with mobile homes and double-wide trailers—neither of which have the quality or permanence of modular homes (Tracey, 2016) .



Modular and panelized housing, given their ability to claim both legal and aesthetic parity with traditional construction, allow for the customization of site-based construction, while fully utilizing the efficiency of a manufacturing facility. Some see modular as a possible solution to the worldwide housing shortage, and an inevitable move of the industry given its numerous advantages: "A home that comes on a truck and is finished in 10 days could be the building method that will solve our housing crisis" (Spittles, 2016) "prefabrication's growth in construction may well be inevitable…if you're not willing to do things that will reduce schedule by 50%, reduce risk and improve safety, you'll be out of it [the construction industry]" (Parsons, 2017). If it is so revolutionary, however, why hasn't it been further implemented? The history of modular housing is one filled with many failures and a few successes, with each story providing a good lesson for architects hoping to implement it.

Figure 1 WeeHouse by Alchemy Architects

A BRIEF HISTORY OF MODULAR HOUSING

The first recorded example of prefabricated housing was in 1624 by Great Britain in a colonization mission of Cape Anne (now in Massachusetts) (Smith, 2011). As Great Britain was fast-expanding the British Empire, the English wanted to retain their architectural heritage in new colonies by developing traditional dwellings without depending on material availability in the new land (Panjehpour, Abdullah, & Ali, 2013). This led to the shipping of windows, doors, and other building components by boat that were then assembled on site. Two hundred years later, the Manning Portable Colonial Cottage was the first complete kit house that was designed and shipped by Great Britain in a colonization effort of Australia. Built by H. John Manning, the home was a system of timber frame and infill components. It was designed to be easily transported so that “a single person could carry each individual piece that made up the shelter” (Smith, 2011). The invention of the complete kit house served an important imperialist agenda—it enabled British colonies to be built virtually overnight.

In the early 20th century, the next big innovation in prefabricated housing occurred with the mass production of kit houses in the United States. From 1908-1940, Sears Roebuck popularized the mail-order house, selling over 100,000 units (Smith, 2011). Much of the company's success can be attributed to the variety of housing options and financing offered, which, paradoxically, also led to their failure. Sears suffered a catastrophic loss in the 1930s during the great depression from defaulting loan repayments (Smith, 2011). But Sears wasn't the only suffering company—all of America was in trouble, with rampant homelessness and poverty. Very few customers were capable of paying the premiums of custom-designed new residences. Thus, it was at this time that many architects, engineers, and real estate developers tried their hands at modular housing, promising an affordable price, good design, and high quality through manufacturing. This shift was by and large attributed to a new social need: quick, cheap housing for a broad audience. Additionally, with Henry Ford's "Flow" assembly line method of manufacturing that made the Model-T successful, a precedent was created to showcase the benefits of streamlined manufacturing (Smith, 2011).

In addition to public good, modular construction promised the dream of architects returning to the role of "Master Builder", like Brunelleschi and his dome, overseeing the entire project from concept to production (Smith, 2011). Little more than a dream, however, architects designed prefabricated dwelling units with little commercial success. After years of specialization, they possessed neither the financial acumen of developers, the pocketbooks of wealthy clients, nor the necessary experience or training to streamline modular manufacturing. Walter Gropius and Konrad Wachsmann's "Packaged House" proposal was a visionary design, but due to limited factory and business experience, it took them five years to start production after finishing the original designs (Smith, 2011). By this time, the government had pulled funding and the product died before it ever could start. Le Corbusier endeavored to create a modular housing concept for the masses as well, but like his predecessors, saw no commercial success in the enterprise. His most-known prototype, the "Citrohan House" was meant to be a “machine for living”, an affordable, quality house design for the masses (Smith, 2011). Though well-intentioned, Le Corbusier never actually built a single home from prefabricated building methods—his theories and designs were all (expensive) talk. Even his prototypes proved far too expensive for any hope of mass production. American architect Frank Lloyd Wright also shared the dream of modular, and in 1932 he spoke about the Usonian “assembled house”, a home made up of standard units and spatial building blocks that would define rooms (Smith, 2011). Wright designed and built 100 prefabricated dwelling units between 1936-1938, but without the discipline to quit designing and start building, his projects, too, proved far too customized and expensive for a broad audience (Panjehpour, Abdullah, & Ali, 2013). The 100 units were homes to wealthy clients, uniquely designed and finely crafted. While social factors encouraged the use of modular construction, the architects’ lack of business discipline and a timely design halt led project after project to fail, even with designs that were inspiring and beautiful.

After WWII, there was a tremendous shortage of housing for veterans and a glut of war-time manufacturing facilities. This prompted, yet again, an opportunity for modular housing to take the spotlight and serve as the solution. In 1946, the US federal government passed the Veteran Emergency Housing Act (VEHA) which mandated and provided funding for 850,000 prefabricated homes to be built in two years to solve the housing crisis (Smith, 2011). The film “The Spirit of ‘45” sums up the government’s idea: “we’ve been using factories to make weapons to kill Germans with, why can’t we use them to build housing and hospitals?”. VEHA brought new life into the industry, birthing startups that made use of the abandoned post-war manufacturing facilities and innovative materials. Lustron Corporation, one such manufacturer, produced homes in airplane factories that were constructed entirely of enamel steel, both interior finishes and exterior shell (Smith, 2011). Carl Strandlund, another manufacturer, used automobile manufacturing processes, materials, and factories to create homes (Smith, 2011). His designs, like Lustron Corp’s, were largely made of metal sheets and had little insulation, providing very poor interior comfort. While each of these enterprises promised affordability, and innovated with new materiality and methods, their impractical designs and costliness prevented any mainstream success. No U.S. modular home designs could rival the consistency, public appeal, or affordability of site-built or kit-built rivals. So, in modular's stead, the traditional suburban, site-built neighborhood emerged, built by a systemized planning of product delivery instead of the systemized manufacturing process of production.

In post-war England, the British implemented a program similar to VEHA mandating the construction of prefabricated dwellings. These homes were intended to be temporary and quickly built, not high-quality or aesthetically pleasing. The need for a quick solution was also more desperate, due to the volume of housing destroyed during the wars (Smith, 2011). Thus, over the next decade, hundreds of thousands were manufactured and delivered. While a great solution at the time, the homes were eventually replaced by permanent solutions in the 1980s-2000s. Today, the UK rarely makes use of modular construction and instead opts for traditional construction methods, ostensibly unable to view it in any context other than post-war housing: cheap, quick, and temporary. However, some of these original homes still remain in use, and stand as cultural artefacts to the needs of the time. Homes in the Excalibur Estate in Southeast London provide evidence of their long-term durability (Parker, 2017). With the pressing need for housing and the lack of implementation in the UK, it is clear that modular construction has been deterred by serious prejudice.

Figure 2 An Excalibur Estate Prefab. Photo from July 2017 by Hank Parker.

The U.S. and the U.K. were not the only countries to dabble with modular construction around this time. Russia wholeheartedly embraced prefab with nearly all housing after 1950 constructed with factory-made parts (Hatherly, 2015). Adopting the technology with great gusto, by 1991 prefab dwellings made up 75% of all Soviet stock (Hatherly, 2015). Many of these housing communities thrived and, though homogenous, created “desirable areas with schools, clinics and public transport better than anywhere in Britain” (Hatherly, 2015). Why was prefabricated construction so well-adopted in Russia but struggled to maintain a presence everywhere else? It is clear that the political environment was crucial: “Partly because of that totalitarian, forbidding, relentless appearance, no doubt, but also because of what made it possible—the nationalization of land, and factories committed to a central plan” (Hatherly, 2015). In the Soviet countries, the government’s control forced implementation, regardless of personal preference. Thus, the technology was accepted due to its pragmatic advantages, not hinging on social preference or prejudice. While a key to soviet adoption, perhaps Russia’s mandated implementation has been one of the greatest tools for solidifying Western prejudice: forever connecting images of communism and homogeneity with a technology that in no way requires it. After all, anyone who adopts modular construction must be a communist, right?

During this time, engineers also tried their hand at developing modular housing concepts. Of numerous engineers, Buckminster Fuller was the most visionary. Never trained as an architect, Fuller rose to notoriety through his ability to rationalize complex geometries and use them to create concept vehicles, housing, and structural systems (Smith, 2011). His Dymaxion House, completed in 1928, was a prefabricated unit inspired by airplane design which hung most of the structural weight through a central mast and rods in tension. His Wichita House, a more sophisticated adaptation developed in 1944, was made with airplane aluminum and fastened with rivets. Beyond its innovative use of aluminum in the structure, it weighed an astoundingly modest 6,000 lbs and when shipped could fit onto a single truck (Smith, 2011). While never gaining commercial success, his designs did influence architects, designers, and futurists for decades to come and remain innovative even today.

The next major wave of systemized or prefab architecture in home construction occurred in the 1950s with the mobile home industry. Built with a steel chassis and wheels permanently attached, these homes allowed for ease of construction and transportability that was popular at the time. By 1968, one in four of all single-family houses in the United States were mobile homes. What they lacked in beauty, quality, and permanence, they made up for in heavily discounted prices and flexible financing. Even today, mobile homes remain the cheapest per-square-foot option for home buyers (Smith, 2011). Because of mobile home's great success, however, it forever associated the words "manufactured" or "factory made housing" to with low-quality, cheap mobile homes—a stigma that has been hard to shake as modular, too, is created in the factory but a far better product.

Mobile homes filled the hunger for affordable housing at the time, but architects were not content with the poor quality and designs. From the 1950s to the 1990s, architect's interest in modular began to shift. In the early 20th century, prefabricated architecture was researched, designed, and built for a primarily social agenda—to create high design at an affordable price—whereas in the late 20th century, prefabrication was studied for its capability to realize unprecedented scale, quality, and form

(Smith, 2011). The eruption of new technology during this time changed the industry, leading to Computer Aided Design “CAD”, improved manufacturing methods, and fast-track production processes that pushed architects to the ever-more-specialized role of “designer” and not “builder”, and the ability of modular designs to be iterated quickly and efficiently.

In the late 20th century, modular construction began to be used at much larger scales. One example can still be experienced in San Antonio, Texas today. Because S.A. was hosting the 1968 World’s Fair, an enormous swell of visitors was expected for the 6-month-long event. So much was the anticipated demand, that new hotels were constructed specifically for the event. The Hilton Palacio del Rio Hotel on the San Antonio River Walk was one such hotel, planned as a 500-room behemoth that needed to open in time for the Fair. Over the course of 202 days, the hotel was built at a record-breaking speed thanks to efficient use of modular construction. While the steel and concrete structure for the hotel was cast, 496 rooms were constructed in a factory. Each of the units were built fully complete, with “color tv, am/fm radios, beds, carpeting, bottle openers, automatic coffee makers, ash trays” and measured 32’ 8” and 29’ 8” long, 13’ wide and 9’6” tall. (Zachry Construction Company, 2007). Eight hotel rooms were constructed each day, built by 100 men at sixteen jigs (Zachry Construction Company, 2007). After the structure of the hotel was completed and all hotel units constructed, each of the rooms were raised into place by crane over 46 days. While receiving notable press at the time for the accomplishment, the structure did not gain the historic significance due its achievement. This project showcased how powerful modular construction can be to construct buildings with tight deadlines, nearly halving the delivery date compared to an on-site alternative.

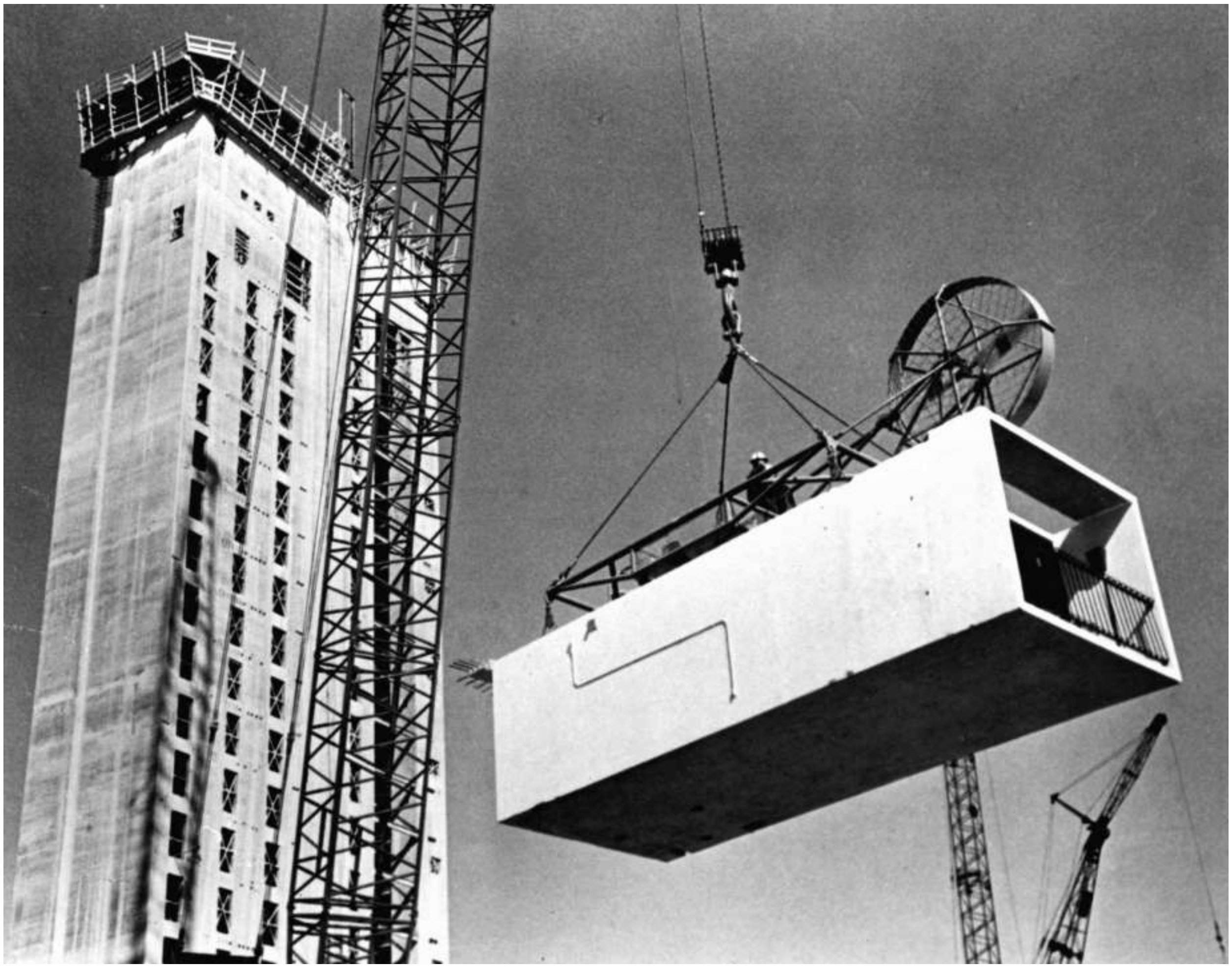


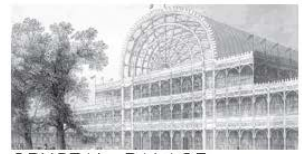
Figure 3 Hilton Palacio Del Rio, 1968 (Image from Zachary Construction)

While other large projects were built during this time, in the 1990s there began again a fascination with small, modular homes that were affordable, quick to build, and of a high design quality. Multinational giant Ikea introduced a prefab home concept in Sweden in 1996, offering a factory-built module for a reasonable price. These projects were designed with the assistance of CAD programs, streamlining processes and providing a simple way for designs to be transported and recorded. The key change was that, with innovations in manufacturing and technology, the focus could now become mass-customization rather than just mass-production (Spittles, 2016). Today, there are a dizzying number of modular housing designers and builders. San Antonio firm Lake Flato Architects, with their “Porch House” concept is an example of an architecture firm that both designs and builds modular homes with highly customized, site-specific adaptations. Each project is unique. This is in stark contrast to firms like "Modular Homes Austin" that take standardized floor plans and materials and replicate them everywhere, with no consideration to site or client. If it was not hard enough already for Modular to shed its industry prejudice, firms like Modular Homes Austin increase the difficulty, building nothing better than permanent mobile homes while using the same name.

Innovations in small scale units have also paralleled significant leaps at larger scales as well. Broad Sustainable Building, a Chinese development company led by Zhang Yue, is attempting to build the world's largest tower with modular components. In just four months, they will construct 4,450 apartments for 30,000 residents across 202 stories (Hawthorne, 2014). While BSB has made a name for themselves in constructing prefab towers in record-breaking times, other, more tenured companies are also implementing modular construction at large scales. For Example, Marriott Hotels has successfully implemented modular hotel rooms in their portfolio over the last decade. And in 2017, Marriott expects to begin 50 hotel deals that will incorporate modular guestrooms and bathrooms (Trejos, 2017). Marriott's interest in modular is not only for streamlined construction schedules, but also the increase in quality control that its manufacturing facilities can provide, with hotel rooms lasting longer and better insulated than previously possible (Trejos, 2017).

PEARSE–MAY HOUSE
GREAT BRITAIN, 1624

MANNING PORTABLE COT.
GREAT BRITAIN, 1833



CRYSTAL PALACE
SIR JOSEPH PAXTON, 1851

CLYDE HOUSE
SEARS, 1917–1918

PREFAB DUPLEX
FRANK LLOYD WRIGHT, 1917

CITROHAN HOUSE
LE CORBUSIER 1920

DYMAXION HOUSE
BUCKMINSTER FULLER, 1933

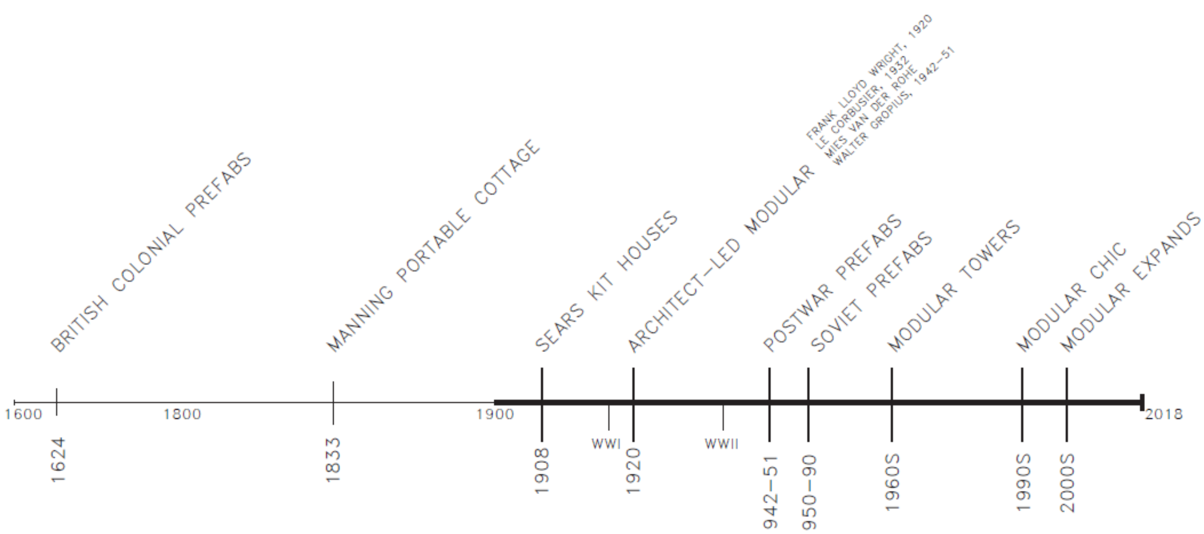
PACKAGED HOUSE
GROPIUS, WACHSMANN, 1942

POSTWAR PREFABS
LONDON, 1949

PALACIO DEL RIO
Hilton, 1968

AC HOTEL OKLAHOMA
MARRIOTT, 2017

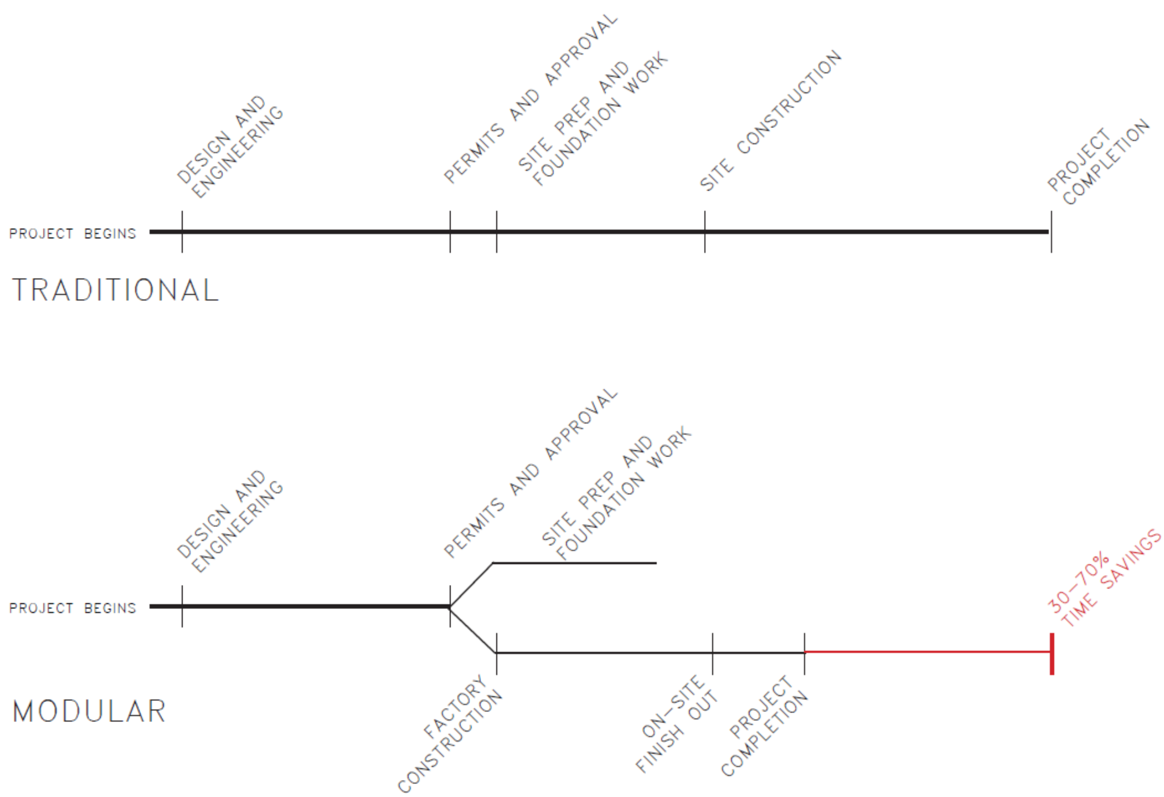
PORCH HOUSE
LAKE FLATO ARCHITECTS, 2015



ADVANTAGES OF MODULAR CONSTRUCTION

So what benefits, exactly, does offsite construction present that traditional does not? Cost, by far, is the most recognized benefit. It is generally assumed that anything produced in a factory, with predictable and easily repeated fabrication, will cost less than a custom-built rival. But is that the case with modular construction? In many cases, it is not. Professor Matthew Morris from the University of Colorado, Boulder states that, due to transportation costs of modules from factory to site, modular units are actually more expensive upfront, averaging 6% more than site built construction (Antillon & Morris, 2014). So how, then, was the new Saint Joseph hospital in Denver able to save $4.3 million by implementing modular construction methods? Williams, a multifamily real estate developer puts it simply: "Saving on construction costs isn't the reason for off-site construction…cost savings...[come from] the indirect costs of reduced supervision during framing, mechanical and finishing stages, as well as operating loan times being reduced from eight to four months" (Crowther, 2017). Due to the time savings, Saint Joseph Hospital was able to shave 72 working days off the construction schedule that led to a $4.3 million reduction in cost (Antillon & Morris, 2014). While time reduction is a benefit to any project, it is especially significant with cash-flow heavy businesses. For example, if a hotel chain takes out a loan to build a new hotel, it has to pay a high interest rate on a construction loan before it can refinance for a traditional, collateralized long-term loan. Additionally, the business is missing out on vital revenue from hotel guests with each day the hotel is not open for business. Each day that is cut in the production schedule saves twice—it is one less day for a high-interest payment and one more day of cash-flowing hotel revenue.

What makes offsite construction so much less time intensive? And just how much time can be saved? While there are general efficiencies that factories can produce through controlled manufacturing conditions, the greatest time savings comes from the dual timeline that it creates. In traditional construction, the path from preliminary design to turnkey inspection is largely linear. Before the actual construction of the house can begin, most of the sitework must first be completed and inspected. Delays due to weather are frequent, and each step in the process cannot begin until the previous has been completed. Not so with modular construction. The second the project begins, two timelines are given life: the construction of the house and the development of sitework. Both can work simultaneously, and, in theory, produce the building product in one half the time of traditional construction. Method Homes, a modular home manufacturer in Seattle, Washington, says that it can deliver a custom modular home up to 75% faster than a traditionally built home, meaning residents can move into their home after three to four months compared to nine plus months with a site-built competitor (Tracey, 2016).



On taller project types, time savings decreases to about 40% on average, due to the complicated nature of interfacing multiple building stories (Kamali & Hewage, 2016). These time savings come at a crucial time in the industry when building schedules are being squeezed to unreasonably short timelines. Jody

Willis, field operations manager at Mortenson Construction Co. in Denver, says that "this is the future of construction. It's starting to be necessary [to build modular] to meet schedules." (Moore, 2014)

The next important consideration is quality—how does modular quality compare to traditional construction? In the 1940s, modular homes in the UK were built to be temporary housing solutions for 1-3 years while more permanent solutions could be constructed. Some 70 years later, a few of these homes remain inhabited and continuously used, proving far greater quality than originally anticipated. But these are only a small sampling of modular homes that are still in use, and it is difficult to predict the lifecycle of this relatively new manufacturing method. In *Lifecycle Performance of Modular Buildings* Mohammad Kamali's research revealed numerous characteristics of modular architecture that give it a uniquely high quality. First, the repetition of construction tasks and use of automated machinery produces a higher level of consistency. Secondly, because the modules must be transported from the factory to the site, a higher level of structural strength is required for the journey that traditional construction doesn't need. Furthermore, the materials must be lightweight, durable, and resistant to weather (Kamali & Hewage, 2016). This is a crucial point—by the very nature of its transportation requirements, the housing product is ensured to be of a higher standard than its rivals. Marriott hotels have been implementing modular and the quality difference is readily apparent: "guests have indicated that they hear very little outside noise in their rooms. Because the modules have to be built sturdier to be transported, they end up having better sound insulation" (Trejos, 2017). Factory conditions also provide a controlled environment, preventing material exposure to weather conditions. Rain or shine, the product can continue to be produced without delay or damage. While still dependent on the builder's quality control, modular construction provides the opportunity for a far-superior building quality over traditional site-based construction.

While the decrease in site costs, construction time, and quality imperfections are among the most notable benefits to offsite construction, there are other benefits that should also be noted. On-site safety, environmental performance, and worker productivity are other benefits that are gained from off-site construction. Due to the snap-in-place nature of modular architecture, there is a significantly minimized number of staff that are required to be on-site at assembly. This prevents workforce congestion and decreases the workforce's exposure to weather conditions and thus, unexpected absences (Messner, Ramaji, & Memari, 2017). Additionally, because the entire building is constructed off-site, there is limited-to-no exposure of workers to elevated work (falling from a high point) and its risks (Messner, Ramaji, & Memari, 2017). Environmental impacts of offsite construction are also minimized. There is less material waste due to more precise construction and reuse strategies can be easily implemented. Additionally, as construction does not occur on-site, neighboring properties remain unaffected by noise and construction pollutants. With more consistent working hours and conditions in the factory and highly organized operations, worker efficiency is at its highest levels with a greater degree of specialization and clearer expectations.

DISADVANTAGES OF MODULAR CONSTRUCTION

There is no denying that modular architecture makes a compelling case for implementation with its numerous advantages. But there are also several key disadvantages to modular construction when compared with traditional methods. Among the most notable difficulties are project planning, scalability, transportation difficulties, prejudice, site constraints, difficulty in coordination, and upfront costs (Kamali & Hewage, 2016).

Among these difficulties, the greatest difficulty with modular construction is the far greater requirement for planning and coordination of all aspects of the project. If one component is not thoroughly vetted beforehand, when the project comes together at the end, it could undermine the cost and time savings with costly alterations. Therefore, the project staff, though more limited in numbers, have to be more skilled. The level of engineering required for the project is also greater than traditional construction. Engineers for traditional projects design structure for one location and purpose, whereas for modular projects, engineers need to plan for a project that performs well onsite and can withstand transportation stresses. Additionally, software design tools have not yet evolved to the new methodology. BIM software, such as Autodesk Revit, which has become an industry standard for project design, coordination, and construction, has yet to provide tools specific to modular construction. In order to best use modular, software itself needs to take a more modular approach to project management, focusing on individual components rather than the constructed whole and creating scheduling protocols that ease the coordination of each part (Lee & Kim, 2017), (Messner, Ramaji, & Memari, 2017). Thus, implementing modular carries some risk: modular construction requires a greater degree of skill, foresight, and innovation that can lead to great savings—or confusion.

Transportation logistics are also a key consideration for modular construction. With the increased structural rigidity that is required for unit transportation, the structure can be costlier and stronger than needed for its primarily sedentary purpose. When evaluating the costs of transportation, they, too, can be overwhelming. In addition to contracting numerous trucks to carry the modules, State regulations levy licensing, certificate, and escort requirements. In the State of Texas, if the load of a truck exceeds 8’6” in width, 14’ in height, or 80,000 pounds gross, it requires a special permit for transportation (DMV, 2017). Additionally, if it exceeds 14’ in width, 17’ in height, and/or 110’ in length, the truck requires both a front and rear escort vehicle. If the width exceeds 20’, the height 18’11”, or length 125’, the transporter must file a surety bond of $10,000 and have a full route inspection completed by licensed inspectors before transportation. Permitting and inspection processes can be substantial and unpredictable for project timelines, lasting a week—or months. Then, if the modules are transported over long distances, more regulatory restrictions and even customs may be due, skyrocketing costs of an otherwise budget-conscious project. Not to mention, new risks of damage during transportation. Additionally, with strict regulations on height, width, length, and weight, designers are incentivized to keep each module to a certain size. This, in turn, can lead to design constraints that may ostensibly be deal breakers for clients or architects.

A few other disadvantages are also worth mentioning. First, modular construction often requires the majority or entirety of payment upfront. This restriction requires a less-conventional financing program, where, instead of the lender providing instalments of the loan upon incremental levels of completion, the borrower is given one lump sum (Panjehpour, Abdullah, & Ali, 2013). Scaling modular projects can also be difficult. Modular construction cannot be scaled up without new planning considerations at every height. For a single-family home with one to three stories in height, the structure required of stacking modules is limited. For buildings between three and 20 stories, more load bearing and lateral supports are required due to the increased weight from stacked units. And if the building has 50 or more stories, a brace frame is required, making the structural costs even more substantial (Hawthorne, 2014). Additionally, due to the many proprietary systems that exist within the modular home industry, future improvements and modifications can be costly. As the connection systems can be more complex than standardized construction, there is a higher level of skill and training required of the builders or modifiers. Like a BMW or an Audi, a modular home’s complex engineering and proprietary systems may require a specialized technician to work on the project.

TRADITIONAL

Buchanan Architecture : Casa Linder

BENEFITS

- UBIQUITOUS
- EASILY MODIFIED
- LOWER UPFRONT COSTS
- FEWER TOOL REQUIREMENTS
- EASY COORDINATION
- HIGHLY COMPETITIVE PRICING AND SKILLS
- LOWER CONSTRUCTION BUDGET

DRAWBACKS

- INCONSISTANT QUALITY
- UNPREDICTABLE TIMELINES
- SUBJECT TO WEATHER AND STAFFING SETBACKS
- DISTRIBUTED LIABILITY
- UNSAFE
- EMPLOYEE TURNOVER
- WASTEFUL
- VARIETY OF SITES

MODULAR

Lake Flato Architects : Porch House

BENEFITS

- POTENTIAL FOR LOWER COSTS
- FASTER DELIVERY
- CONSISTANT PRODUCT QUALITY
- ENVIRONMENTAL PERFORMANCE
- CONTROLLED WORKING CONDITIONS
- FACTORY EFFICIENCY
- SINGLE LIABILITY
- EMPLOYEE RETENTION

DRAWBACKS

- PROJECT PLANNING REQUIREMENTS
- HIGH INITIAL COST
- TRANSPORTATION CONSTRAINTS
- NEGATIVE PERCEPTION
- SITE CONSTRAINTS
- COORDINATION REQUIREMENTS

Hopeful as many architects are to deploy a modular construction strategy for a more cost-efficient, faster-built, higher-quality product, their efforts can, and have been, undermined by transportation difficulties, regulatory red-tape, and inadequate forethought. But if cost savings is paramount, a determined company could make it work and circumvent the aforementioned difficulties. It is clear, therefore, by its poor implementation, that there are still other reasons why developers have resisted implementing modular construction practices.

CULTURAL FACTORS PROHIBITING IMPLEMENTATION

Cultural factors are less-referenced, but perhaps the most imprisoning. The first, and most widespread problem is that, due to the ubiquity of lackluster designs and poor quality of manufactured homes in the past, there exists a widespread prejudice that modular homes are inferior to site-built projects. This, in turn, has led to some modular homes receiving lower residual real estate values than their competition, regardless of their typically superior quality (Panjehpour, Abdullah, & Ali, 2013).

The next roadblock comes not from the public but from the workers in the industry. Developers and contractors are unfamiliar with the process and fearful of the unknown: “There’s a bit of disarray within the industry”, says Ethan Cowles, a Denver-based senior consultant with construction consulting company FMI Corp, “We know what’s good for us, but nobody wants to go first!” (Moore, 2014). There simply aren’t enough examples of successful projects that can act as precedents. And, given how expensive buildings are to construct, no one wants to take a risk on trying something new. Additionally, for modular construction to work, a significant change needs to occur in the way firms conduct business. Value in a new technology is only obtained when it is commercialized through an appropriate business model, it cannot occur from just adapting a new tool or technology (Mao, Liu, Zhao, & Li, 2017, 2016). To implement modular construction methods in an established company, there needs to occur a cultural and strategic shift, changing the way employees are hired, the way they work, the skills that are necessary for the job, and the ways they get paid—a series of shifts that few companies can easily adapt. And just how capable are companies to accept these kinds of changes? Not very, according to the studies of Jim Parsons in his paper *Charting the Unfulfilled Expectations of Prefab.* Not only is it “staggering…how long it takes to get good at it [modular construction]”, says Steve Foote, Vice President for Greiner Electric in Denver, but “many contractors don’t fully understand how to measure and track prefab efforts” (Parsons, 2017). Even if companies wanted to implement more modular construction into their practice, they would have no idea how to implement, track, or manage it. Due to the many changes in scheduling and construction, new or very dexterous companies are required for successful implementation, “just dabbling in prefabrication is not the way” (Parsons, 2017). Business models and ideologies, less tangible social constructs, must change for successful implementation.

Another hurdle, and perhaps one of the most powerful and least noted, is that there is not just fear, but strong opposition on behalf of contractors and construction labor. While the benefits of prefab are clearly enumerated, contractors, for the most part, are not excited to adapt an entirely new business model (Parsons, 2017). This, in part, is because the traditional business model provides a greater profit to contractors, leading them to be some of the only losers in the growth of efficiency. Additionally, field staff are particularly concerned that, due to the great changes in project requirements, they might be out of a job: "Forcing prefabrication on field staff will be difficult and requires a stressing to field staff that it is designed to eliminate work they didn't want to do, not to eliminate their jobs" (Parsons, 2017). While drudgeries might be removed in partially prefabricated buildings, with modular construction, the field worker will be entirely replaced by a more highly skilled factory worker or robot (their fear is well-founded). Regardless of its benefits, there will undoubtedly be resistance by employees that have been engaged in, what has been up until recently, a very labor-intensive industry. And how can the industry change if many of the decision makers are adversely motivated?

One last social factor prohibiting its further implementation is the pushback from design-focused architects. Architects pride themselves on the creativity and originality of their designs, and, as history has shown, for modular housing to be successful, some loss of authorship is required for a product-focused approach. Modular homes, by no means, need to limited to set product lines, but some reasonable degree of consistency is required for affordability to be achieved. Instead of designing with a blank canvas, modular construction suggests that architects start with some constraints: 8'6" for the width of each module (per the truck transportation regulations within Texas, (DMV, 2017)), enhanced structures that can withstand transportation, designs that are based on permutations of pre-designed components (instead of creating everything afresh each time, designing some standardized pieces that can be rearranged for each new project), and a timely design halt—putting the pencil down when it is time to stop designing and start building, to name a few. Within these guidelines, there is no end to variation and originality, but it does require architects to think differently about the framework of their designs, which is unpopular.

CURRENT DEMAND

Prefabrication in US construction has steadily risen over the last two decades, leading to an average use of 35% in new construction in 2016 (Parsons, 2017). The percentage of fully modular new construction, however, is far less significant, limited to around 3% of single family houses and around 1% of multi-family residences between 2000 and 2014 (Kamali & Hewage, 2016). In Texas, there has been a considerable swell in the number of modular units produced in the last five years, though descending in the past two. The total number of modular units in 2016 in Texas was 4,387, of which 708 units were housing (TDLR, 2017). This, in comparison to the 165,853 total units of housing permitted in 2016, leads to a figure of roughly .4% of all new housing construction in Texas (Census, 2016). These numbers paint a striking picture of just how underused modular is in Texas housing. Modular projects hold a far greater market percentage in other regions, however, showing that Texas is a relatively underserved market.

Worldwide adoption of modular construction has shown far greater growth in other locations across the world. Sweden, by far the world's leader in its use, had as much as 85% of their new housing stock in 2016 constructed by prefabricated methods. Japan, noted as the second greatest adopter by percentage of total construction, had nearly 15% prefabricated homes in 2016 (Japanese Statsitics Bureau, 2017). While there are numerous explanations for why modular construction methods are less likely to be implemented in Texas compared to other regions and nations, climate is one of the most probable.

With no dependence on favorable weather conditions, the benefits of modular are most noticeably realized in less-favorable climates. In Figure 4, annual temperatures across the US are pictured--data that shows a possible correlation between favorable climates and modular use in Figure

6. Generally, Texas has a climate that is favorable to construction across the entire year. In Figure 5, average annual monthly temperature, days with precipitation, and hours of sunlight are compared between Austin, Texas and Boston, Massachusetts. The data reveals that Austin, with 50 days less of precipitation and significantly warmer average temperatures, is far more favorable to year-round construction and Boston, with over 1/3 of its days experiencing some form of precipitation. Boston, belonging to the North Eastern United States, has a 7 percent adoption whereas the South, with Texas as a member, has 2% adoption. Extrapolating these results to even less favorable climates for construction across the world like Sweden and Japan, it shows a correlation between the adoption of modular construction methods and relatively unfavorable annual building conditions.

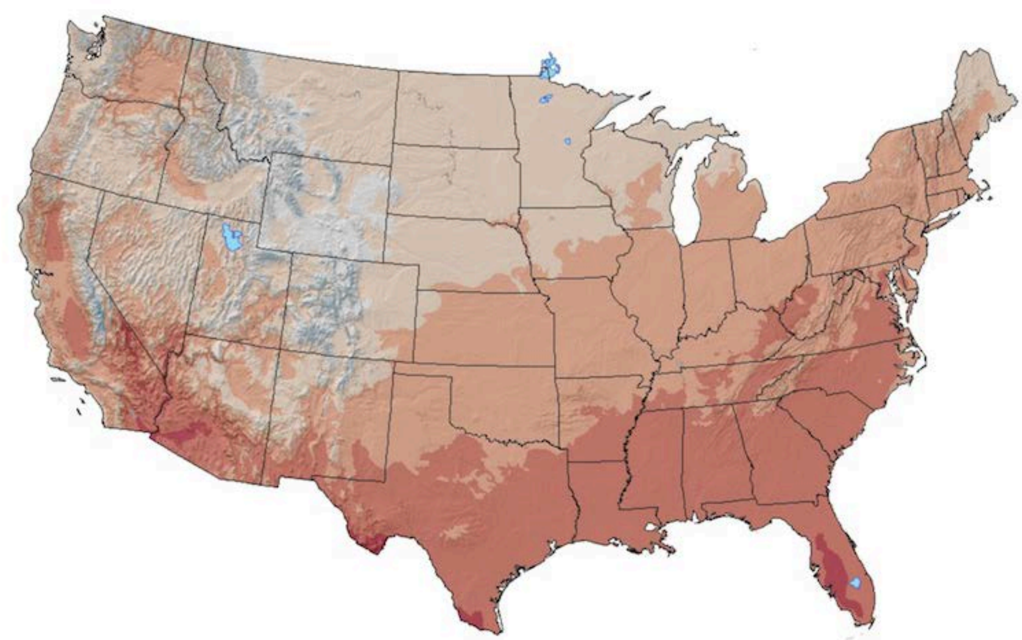


Figure 4 Source: National Oceanic and Atmospheric Administration (https://www.climate.gov/sites/default/files/ClimateAtlas.jpg)

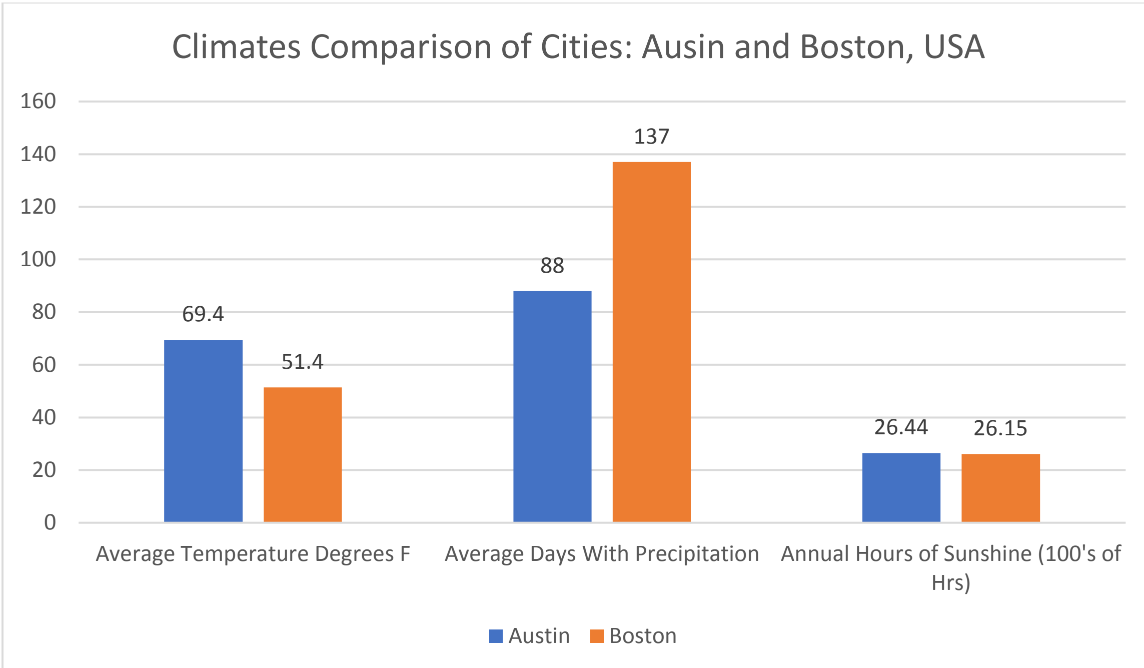


Figure 5 Data sourced from National Oceanic and Atmospheric Administration

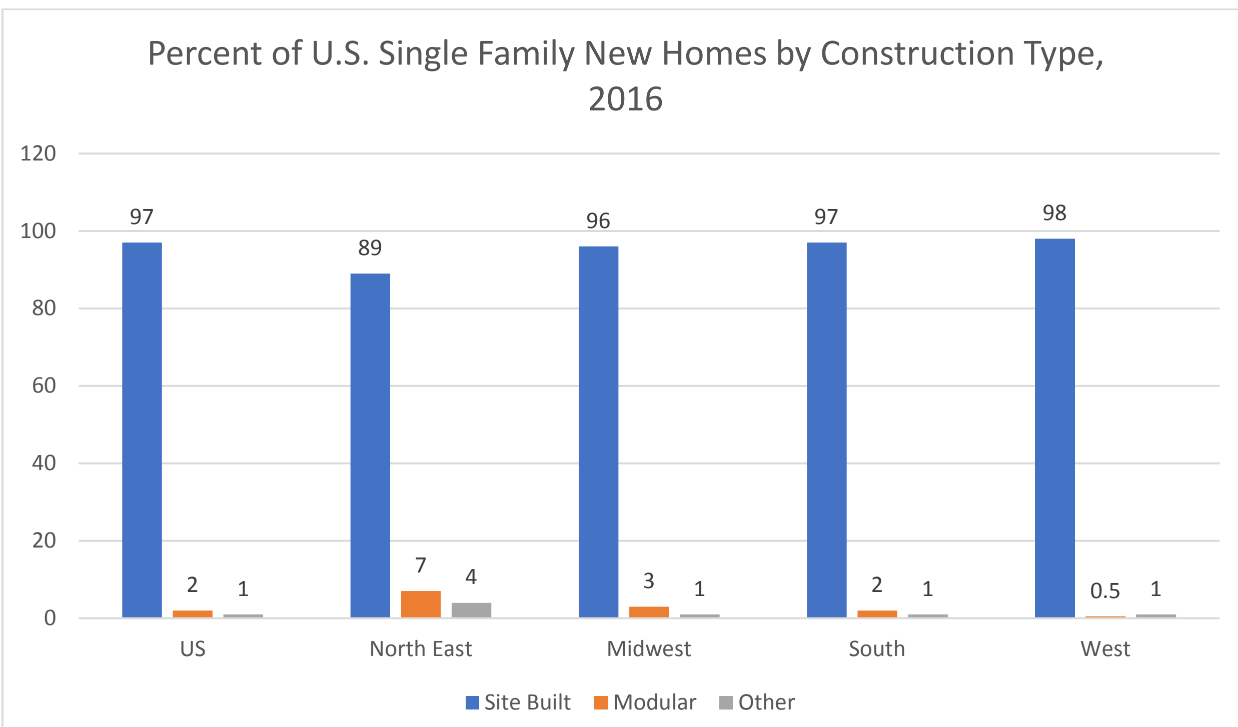


Figure 6 Data Sourced from US Census (https://www.census.gov/construction/chars/completed.html)

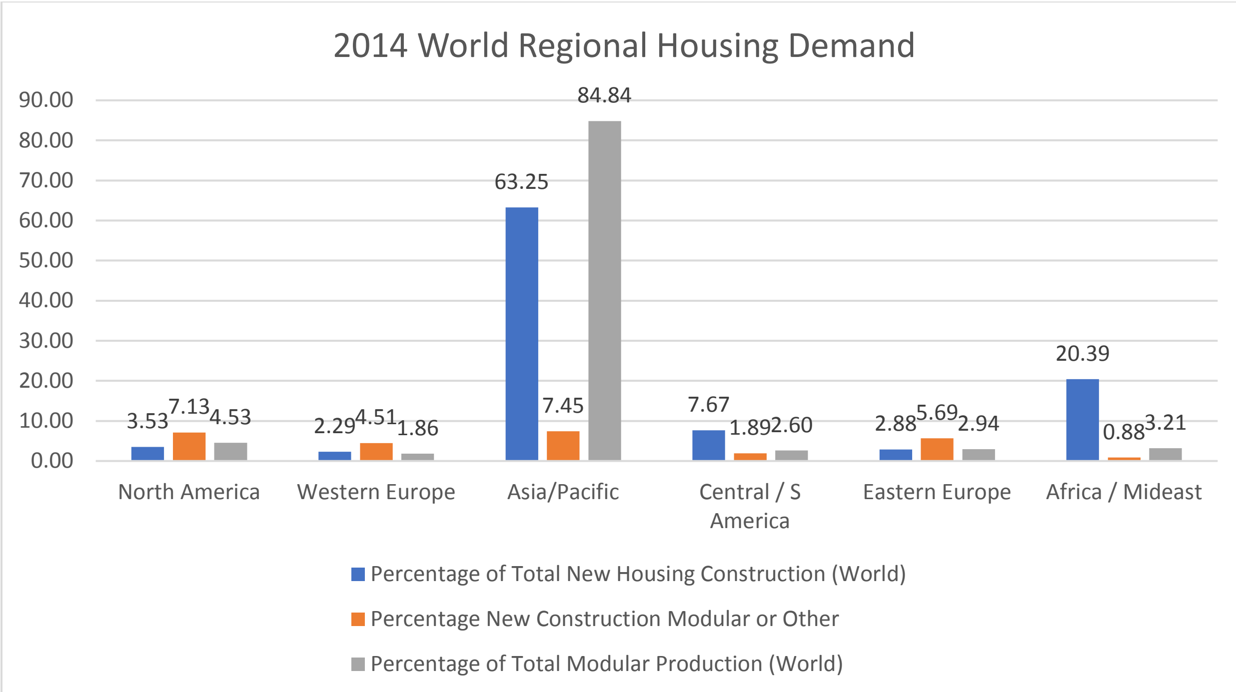


Figure 7 Data sourced from Freedonia Market Research Reports

DESIGNING A PROJECT FOR MODULAR CONSTRUCTION SUCCESS

Given the many advantages of modular construction, what alignment of factors can help produce a profitable, on-time, and successfully resolved project? The best way to piece together a recipe for futuresuccess is to analyze the success of past projects. James T. O'Connor in his paper *Recipes for Cost and Schedule Success* delivers just that analysis. Prefacing his research by the disclaimer that, due to the cost and permanence of modular construction, it is neither "empirically or economically possible" to create an ideal, laboratory-like experiment to test consistent success, the projects studied had consistent traits (O'Connor, Choi, & Kim, 2016). Every successful project had three factors in common: First, the owner furnished all specifications for equipment and long-lead time materials in the project. Waiting on the owner to specify these items later can lead to severe project delays. Second, there was a timely design freeze, meaning that all design related to the project was completed at an early date, allowing for a minimum of change orders and reductions in efficiency. Third, there was a combination of vender involvement and owner-delay avoidance. All parties had to commit to consistent communication, coordination, and efficiency. These factors were determined to be the most important from a range 21 predefined, critical success factors, and clearly show that if an owner does not, himself, endeavor to help streamline the construction of the project, benefits from modular will be difficult to reap.

What, then, are the key takeaways for architect-led design firms? Applying lessons learned from past failures, history can teach us five additional requirements for successful projects (Smith, 2011). First, that proprietary systems do not work for mass housing. What did the Fuller Dymaxion house, the Wright Usonian House, the Gropius and Wachsmann's "Prepacked House" and Lustron Corporation's Houses have in common? Each housing typology was designed with proprietary systems that did not lend themselves well to maintenance and modification over time (Smith, 2011). The best projects of today are prefabricated, modular construction that is virtually indistinguishable from site-built projects (Smith, 2011). The next important reminder is that offsite architecture requires design of not only the building, but the production and manufacturing to construct it. Architects love designing with a sketchbook, but to make a modular project successful, production also needs to be considered. Wright's Usonian Assembled House and Le Corbusier's Citrohan House are excellent examples of projects that focused too much on design and too little on production. Both architects modified and altered designs continually, even during construction, leading projects to be significantly over budget and behind schedule (Smith, 2011). This, perhaps, is the most difficult requirement of architects: to put the pencil down and just build. It conflicts with the architect's deepest love of a perfectly tailored project to both client and context. After all, what architect would want design to halt prematurely due to manufacturing constraints?

Additional to a production focused approach, it is clear that architects also need to have solid financial knowledge and business planning for successful implementation. Lustron Corp created a product that held widespread public interest and inquiry, but due to poor financial planning and a changing political and financial climate, debt skyrocketed and funding for the company was pulled before it had ever managed to deliver. Only 2,680 homes were ever constructed, despite the 234 dealers across the U.S. and hundreds of thousands of inquiries for purchase (Smith, 2011). Gropius and Wachsmann are another example of failure due to lack of business wisdom. They successfully created factories with a production capacity of 10,000 homes per year, but due to Wachsmann's continual refinement of the design, when production was ready to begin, demand had slowed to a halt in 1942. For an architect to successfully implement such a strategy, he or she needs to be willing to halt design in a timely manner and thoroughly understand the economics that will make the venture sustainable.

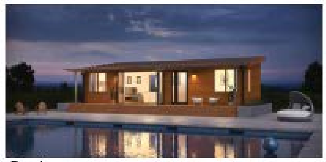
Another consideration is that perhaps modular isn't best suited to the project at hand. Is the stubborn, idealist architect willing to accept that and only choose modular for where it is best suited? Each project has a unique location, client, and labor availability that can make modular a great choice or a poor choice. And each project has a different sensitivity to timeline delays. If the project hinges completely on being delivered on time or even before deadline to make it successful for the project, modular may be best. If the project is less time-sensitive, and the client is willing to wait for longer project delivery for a vacation home or a second residence, perhaps traditional construction is the better way to go. Architects should critically evaluate, regardless of how much they would like modular to be used, whether it is best suited to the project. Further, the decision to use modular must be decided very early in the project and heavily integrated in the planning. As financial savings really are a result of intelligent planning and coordination, a project that is not well-organized or integrated can undermine the potential cost savings. Joel Turkel of Turkel Design summarizes these truths well:

"The future of prefab is an increasingly non-architectural problem. Traditionally, architects have tried to design things to be prefabricated using either existing or new means, as opposed to designing functional and integrated delivery methods…Real development for the industry will come from young professionals who are able to think in terms of complete front-to-back business models. They are aware of the needs and limits of manufacturing processes but also are versed in new technologies, entrepreneurial methods, how capital works, strategic partnerships, and the importance of marketing and branding. This group will not design buildings but rather solutions for distributed delivery methods…leading the way toward rationalized industry wide changes to benefit us all, rather than just promoting an individual vision or aesthetic."

CASE STUDY

In order to better understand the implications of cost, scheduling and design on a real project design and proforma, this thesis has undertaken a study and critical evaluation of eleven modular housing products and compared it to a site-built alternative for the purposes of application. Starting with a hypothetical business plan "The ParkerRaj Modern" from a fictional company "ParkerRaj Holdings, LLC", for the implementation of modular construction for holiday housing rentals in Fredericksburg, Texas, each of the 12 options was analyzed for their potential. Then, after evaluated by a range of qualitative and quantitative criteria, one of the 12 units was selected as the base "type a" holiday rental unit that would then be inserted into the business plan. Finally, from site and climactic analysis, a preliminary design was proposed for the implementation of 20 units on the property of 1345 Jenschke Lane, Fredericksburg, Texas, coupled with a business plan showing the profit-generating potential of the project.


WeeHouse
Alchemy Architects
532 SQ FT


Cabana
bluHomes
631 SQ FT


504
Brett Zamore Design
500 SQ FT


BrightBuilt Barn
Brightbuilt Homes
680 SQ FT


Connect 2
Connect–Homes
640 SQ FT


Northwest
Ideabox
560 SQ FT


Kasita
KASITA MODULAR
370 "470" SQ FT


Porch House
Lake Flato Architects
782 SQ FT


C6.3
LivingHomes
958 SQ FT


Casita
MaModular
850 SQ FT


M, SML Series
Method Homes
655 SQ FT


CONTROL – Site Built
Local Architect
650 SQ FT

December 9, 2017

THE PARKERRAJ MODERN

A BUSINESS PLAN FOR THE IMPLEMENTATION OF MODULAR

RENTAL HOUSING IN FREDERICKSBURG, TEXAS

THE PARKERRAJ MODERN SUMMARY

The PARKERRAJ Luxury Hotels group is proposing the development of a 20-unit, boutique hotel in the wine country of Fredericksburg, Texas, on land currently owned by the company. Given the town's historical character, the fast-growing wine industry, and breathtaking natural beauty, Fredericksburg is host to thriving holiday and event market with a shortage of hotel room stock. As a sum of detached hotel room units, The ParkerRaj Modern proposes a new product for the market—contemporary, boutique hotel units that provide unparalleled luxury and amenities, while maintaining the tranquility of secluded bed and breakfast cottages. Serving a target market of high-end customers, the ParkerRaj offers the most luxurious amenities, bespoke design, and world-class service expected by its elite clientele, but currently unavailable in the market.

Current demand for the luxury segment is currently being met by a few high-end B&B units in downtown Fredericksburg, and suites at conventional, mid-range hotels like The Fairfield, Holiday Inn, and Fredericksburg Inn & Suites. These hotels, however, are at least a 15-minute drive from the most popular vineyards, creating opportunity for a more convenient alternative. Additionally, without much space, these hotels sacrifice one of the greatest amenities of the area—stunning, hill-country views—in exchange for centrality. Thus, the market currently poses little competition for the luxury market. Future development poses a competitive risk, however, with a boutique hotel opening in 2019 catering to a similar target market and location.

The project development team currently consists of two fulltime personnel, the project administrator and marketing specialist, and several contract personnel, including a consulting accountant, lawyer, and architect. The project administrator is charged with the responsibilities of setting a consistent design vision, managing finances and funding, coordinating with all subcontractors and manufacturers, and overseeing project delivery from concept to turnkey completion. The marketing specialist is tasked with researching best ways to reach target markets, creating a market strategy for coherent brand identity across all promotional channels, and designing all aspects of the customer's experience—from booking to departure. After project completion, the project administrator will remain the hotel manager, overseeing maintenance, improvements, and quality control of the property while the marketing specialist will remain as the director of marketing, promoting and protecting brand identity while managing sales and interacting with customers.

There are three phases of project development, completing 6 months, 18 months, and 24 months after project commencement. Phase one includes completion of five one-bedroom, type "A" units at an estimated cost of $1,000,000 (total) sourced from private investment. After completed, these units will begin to generate cashflow and serve as collateral for institutional lending to fund Phase 2, the construction of 10 additional 1-bedroom units at an estimated cost of $2,000,000. After Phase 2 has been completed, Phase 3 begins with the construction of five 2-bedroom, type "B" units and the development of property amenities including a community gathering space, office facilities, and a rentable event venue at a total estimated cost of $2,500,000. After phase 3 is completed, investor loans become due. Equity will be taken out of the project by way of collateralized, long-term debt to payback private investors at a rate of $2.00 per $1 invested, and to fund promotional and marketing efforts to drive future sales. At no point will the property surpass a LTV of more than 70%. If payback requires a greater LTV on completion, the remaining balance of accounts payable will be withheld and accrue interest at an annually compounding rate of 6%. At the point that investors have been fully compensated, investors will forgo all claim to ownership in the property and it will be the sole responsibility and asset of ParkerRaj Property Holdings, LLC. The total estimated time for completion is 28 months, including a 4 month planning and negotiation period starting January 2018, and the total budget for the project is $5,500,000.

Modular construction, a strategy that lends itself well to the hotel industry, is being considered for this project. With two hotel unit typologies, a factory approach to construction will help to maintain consistency and quality while reaping time, material wastage and cost savings unavailable to on-site alternatives. Contracting with leading architectural designers is crucial, as the designs for hotel units need to embody the bespoke, international identity that ParkerRaj customers have come to expect while being deeply rooted in its context. No off-the-shelf products are acceptable. Off-site construction also provides phasing flexibility, as the development of additional units minimally disturbs hotel occupants. When modules are completed in factory, they can be assembled on-site in one week allowing for phase transition to occur seamlessly with minimal loss of revenue.

OPPORTUNITY

LOCATION, POPULATION, AND EMERGING TRENDS

LOCATION:

-Fredericksburg, Texas is 78.2 miles from Austin, (68 to Jenschke)

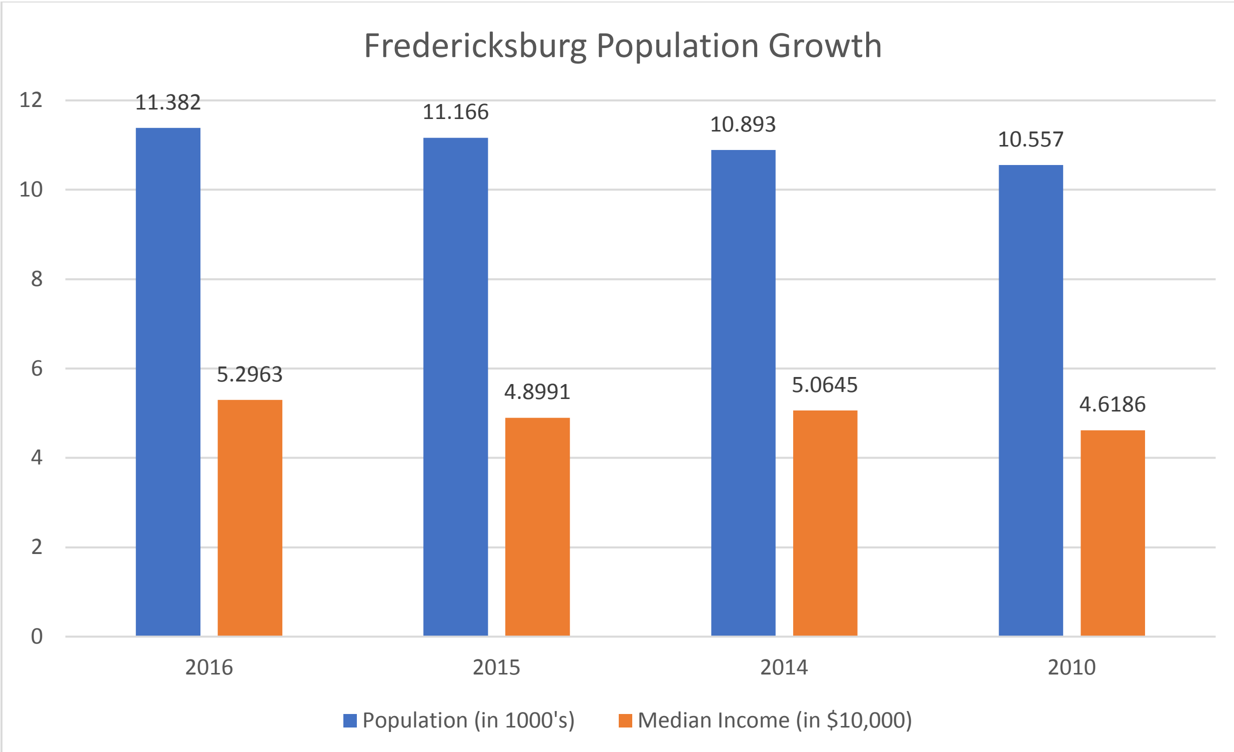
-Fredericksburg is 70.4 miles from San Antonio (70.8 to Jenschke)

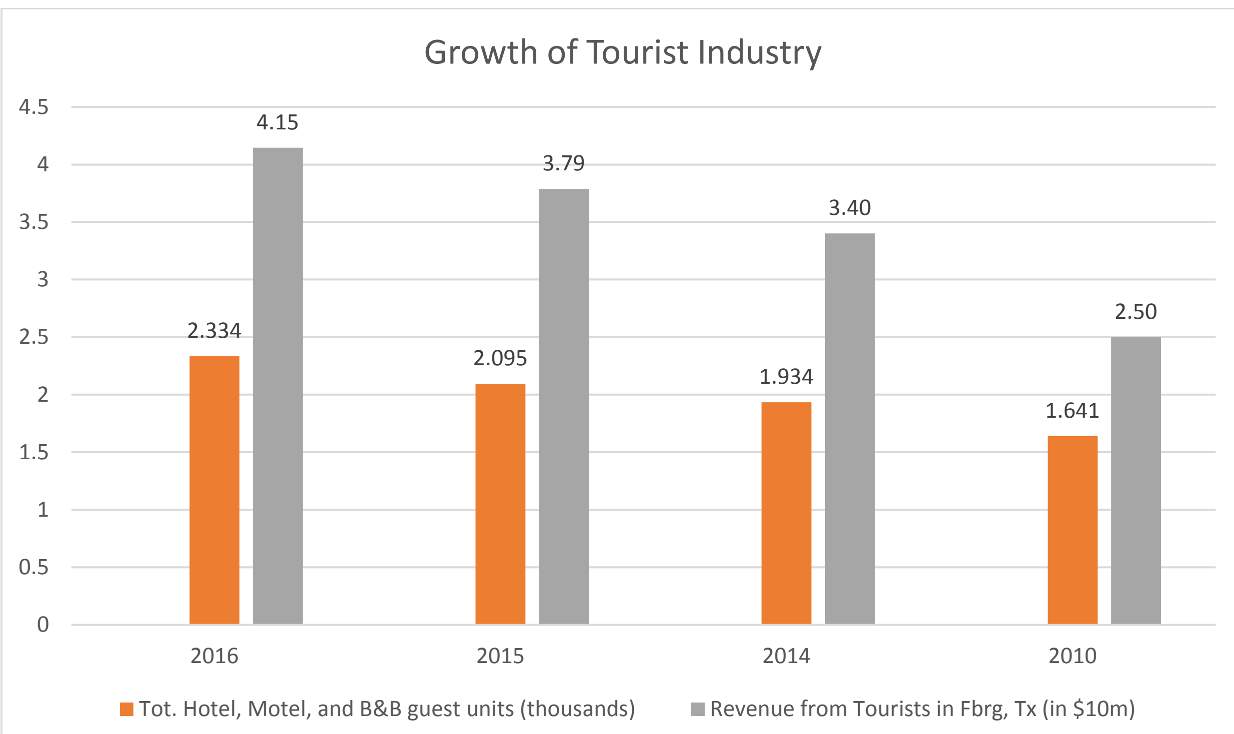
-Fredericksburg is 261 miles from Dallas (251 to Jenschke)

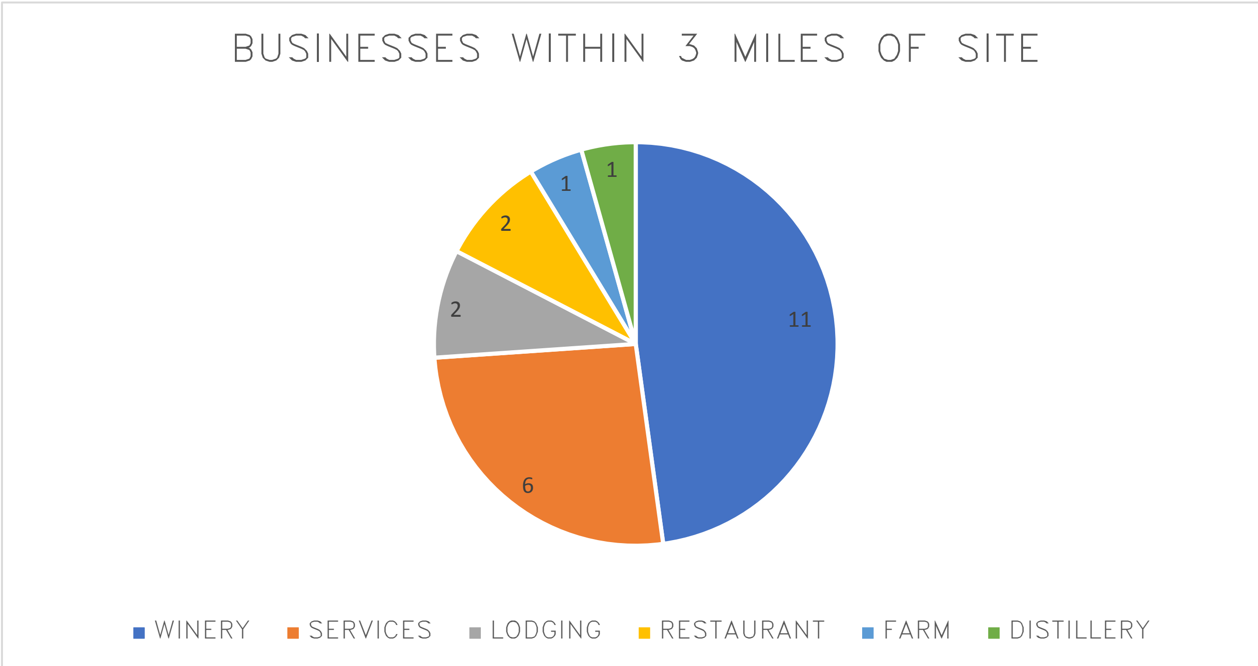
-Fredericksburg is 238 Miles from Houston (227 to Jenschke)

-Fredericksburg is 498 miles from El Paso (512 to Jenschke)

-Fredericksburg is 69.1 miles from San Marcos (60.6 to Jenschke)

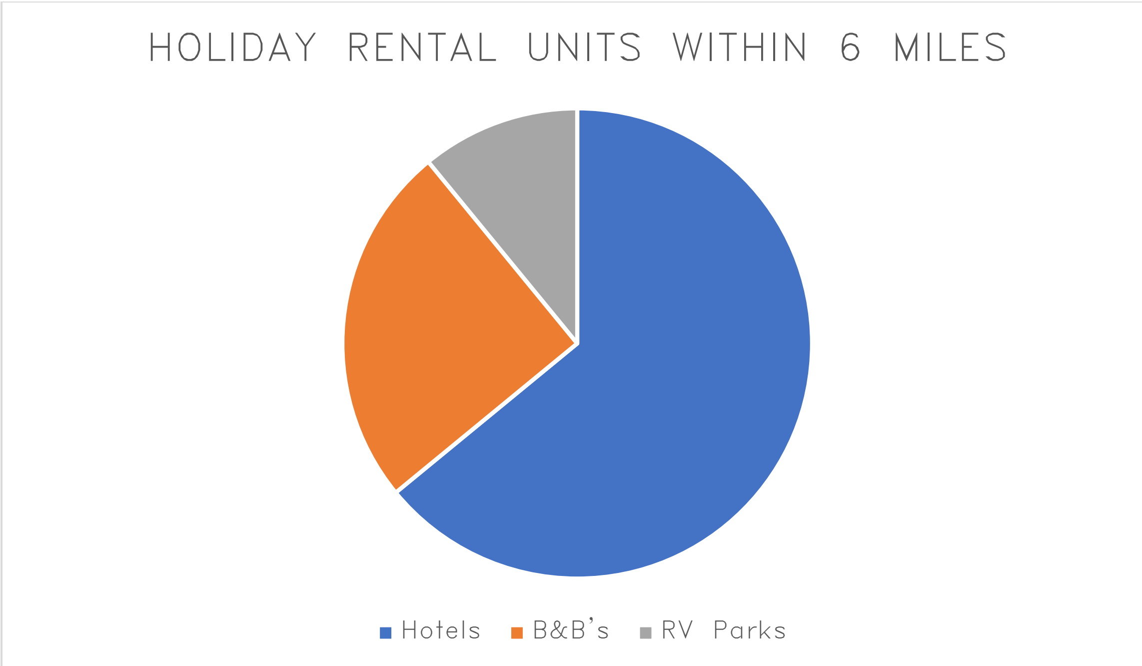

Fredericksburg Population Growth
12
10
8
6
4
2
0
11.382
5.2963
11.166
4.8991
10.893
5.0645
10.557
4.6186
2016
2015
2014
2010
Population (in 1000's)
Median Income (in $10,000)


Growth of Tourist Industry
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2.334
4.15
2.095
3.79
1.934
3.40
1.641
2.50
2016
2015
2014
2010
Tot. Hotel, Motel, and B&B guest units (thousands)
Revenue from Tourists in Fbrg, Tx (in $10m)



Becker Vineyards	Winery
South Grape Creek School	Winery
Torre Di Pietra Vineyards	Winery
Hilmy Cellars	Winery
Mendelbaum Winery	Winery
Woodrose Winery	Winery
Inwood Estates Vineyards	Winery
Fredericksburg Sunday Houses	Lodging
Stonewall Smokehouse	Restaurant
Spirited Oak Distillery	Distillery
Grape Creek Vineyards	Winery
Messina Hof Hill Country	Winery
Vogel Orchard	Farm
Vogel Tractors	Retail
Four Points Cellars	Winery
Fat Ass Ranch & Winery	Winery
Grape Creek Construction	Services
Dvine Wine Tours	Services
Nielsen Automotive	Services
Ottmers Electric	Services
Stout's Trattoria at Grape Creek	Restaurant
Rose Hill Manor	Lodging
Pedernales Cellars	Winery
Eckert & Son Wrecking, Inc	Services
Lance's Body & Paint	Services

Businesses		
	Winery	11
	Lodging	2
	Distillery	1
	Retail	1
	Services	6
	Restaurant	2
	Farm	1
Total Businesses		24



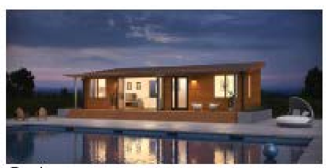
Stars	Name	Property Type	Std Room Rate	Pools	Units	Hot Tub
1	Texas Wine Country Park	Campground	$170	2	8	0
2	Mendelbaum Winery Loft West	B&B	$149	0	2	0
2	Mendelbaum Winery Guest Cabins	B&B	$219+	0	6	2
2	Vineyard Trail Cottages	B&B	$189	0	13	0
3	Messina Hof Hill Country	B&B	$138	0	4	0
2	Rose Hill Manor	B&B	$150	0	14	0
NA	Blumenthal Farms	B&B	NA	0	NA	na
2	The Italian Place Bed and Breakfast	B&B	$110-199	0	3	0
1	Peach Country RV Park	RV Park	$125	0	1	0
NA	Stonewall Motel	Motel	na	na	na	na
2	Rapunzel Cottage	B&B	$155	0	2	0
3	Der Fels	B&B	$129-199	0	3	1 each
2	Jenschke Orchards B&B	B&B	$139	0	1	0
2	Full Moon Inn B&B	B&B	$185	0	6	0
3	Monarc Ranch: Among the Pecans	B&B	$299	0	2	1
3	Among the Crepe Myrtles	B&B	$215	0	1	1
3	Among the Texas Stars	B&B	$155	0	1	1
1	Armadillo Farm	RV Park	$60	0	4	0
	Booking.com Average Price		$195			

EXECUTION

After investigating the competition in the area, and the units that are most rented on AirB&B and other booking services, it is clear that certain product features differentiate from common stock, and allow for the highest per-night rates and occupancy. For luxury rental customers who require new and novel experiences and high-end amenities, the Parker Raj offers a contemporary design, high-end finishes and furnishings, and a private heated and cooled pool per unit. Through its unparalleled location, privacy, excellent views of the countryside, and luxurious amenities, customers enjoy a five-star experience unlike any currently available on the market.

Instead of designing a modular housing unit from scratch, this plan compares products currently available on the market. Out of many hundreds available, these eleven were selected because of their factory location (within the continental United States), their architect-led design, and their relatively

WeeHouse
Alchemy Architects
532 SQ FT



Cabana
bluHomes
631 SQ FT

504
Brett Zamore Design
500 SQ FT

BrightBuilt Barn
Brightbuilt Homes
680 SQ FT

Connect 2
Connect–Homes
640 SQ FT

Northwest
Ideabox
560 SQ FT

Kasita
KASITA MODULAR
370 "470" SQ FT

Porch House
Lake Flato Architects
782 SQ FT

C6.3
LivingHomes
958 SQ FT

Casita
MaModular
850 SQ FT

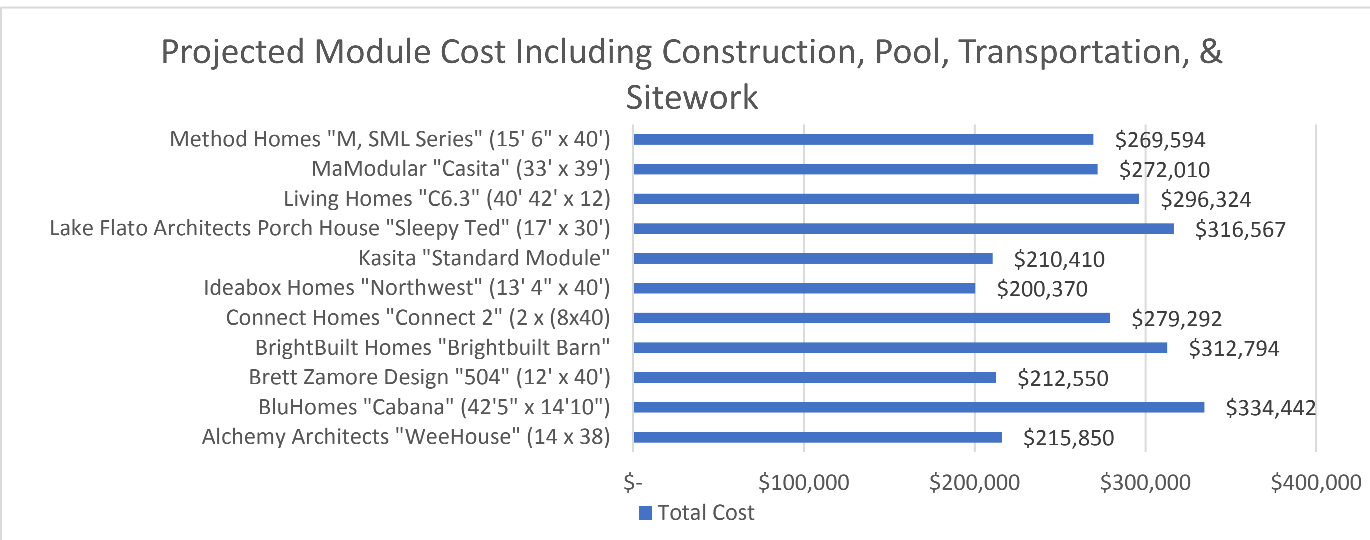
M, SML Series
Method Homes
655 SQ FT

CONTROL – Site Built
Local Architect
650 SQ FT

reasonable cost. Then, qualitative and quantitative criteria were needed to adequately compare the designs for their appropriateness to the project and their long-term profitability.

UPFRONT COSTS OF CONSTRUCTION

While many modular manufacturers present costs in a cost per square foot estimate, few adequately provide complete turn-key-costs that include additional sitework, transportation costs, and landscaping per unit. The following data represents total projected costs of each product compared. To clarify, cost per square foot is the total projected cost for the unit divided by unit square footage, not just the cost per square foot of construction.



Firm	Product	Size	Cost / SqF	Mod Cost	Site Cost	Miles from Factory	Est. Cost to Transport	Total Upfront
							$8	
Alchemy Architects "WeeHous	WeeHouse (14 x 38)	532	405.7331	135,000	50000	1250	$10,850	$215,850
BluHomes "Cabana" (42'5" x 14	Cabana (42'5" x 14'10	631	530.019	190,000	110000	1699	$14,442	$334,442
Brett Zamore Design "504" (12'	504	500	425.1	139900	50000	225	$2,650	$212,550
BrightBuilt Homes "Brightbuilt	Brightbuilt Barn	680	459.9912	225,000	50000	2118	$17,794	$312,794
Connect Homes "Connect 2" (2	Connect 2 (16x40)	640	436.3938	221480	25600	1314	$12,212	$279,292
Ideabox Homes "Northwest" (1	Northwest	560	357.8036	113000	50000	2065	$17,370	$200,370
Kasita "Standard Module"	Kasita Concept	370	568.6757	139,000	50000	70	$1,410	$210,410
Lake Flato Architects Porch Hou	Porch House	782	404.8171	245157	50000	70	$1,410	$316,567
Living Homes "C6.3" (40' 42' x 1	C6	958	309.3152	168000	96000	1328	$12,324	$296,324
MaModular "Casita" (33' x 39')	Grand-Ma	850	320.0118	199750	50000	70	$2,260	$272,010
Method Homes "M, SML Series	M, SML Series	655	411.5939	132,000	100000	2093	$17,594	$269,594

Additional Costs

Rezoning to Commercial		$0	$5,000.00
Loan Initiation Fees			$3,500.00
Furnishing	Per unit	$5,000	$5,000
Pool	Per Unit	$20,000	$20,000

FIXED AND VARIABLE OPERATING COSTS

After determining the hard and soft costs of construction, it is necessary to understand the regular costs of doing business. To determine these values, the following variables were used for calculation:

Recurring Fixed Costs	*Quantity Explained*	*Total*
Land Rent Costs	Per Year Land Rent	$0
Maintenance Costs	Monthly Cost / Unit	$125
Annual Property Taxes	Rate	2.20%
Insurance	.004(value of home)	0.004
Recurring Variable Costs		
Pool Maintenance	Per Month / Pool	$100
Management Annual	Percent Of Total Rent	10%
Cleaning Fee Base	$40 / Trip (cleaned daily)	$40
Cleaning Fees Variable	$0.10/SqFt (over 500) per trip	$0.10
Utility Cost Base	$45/ Month	$45
Utility Costs	$0.10/SqFt per Month	$0.10

REVENUE AND INCOME PROJECTIONS

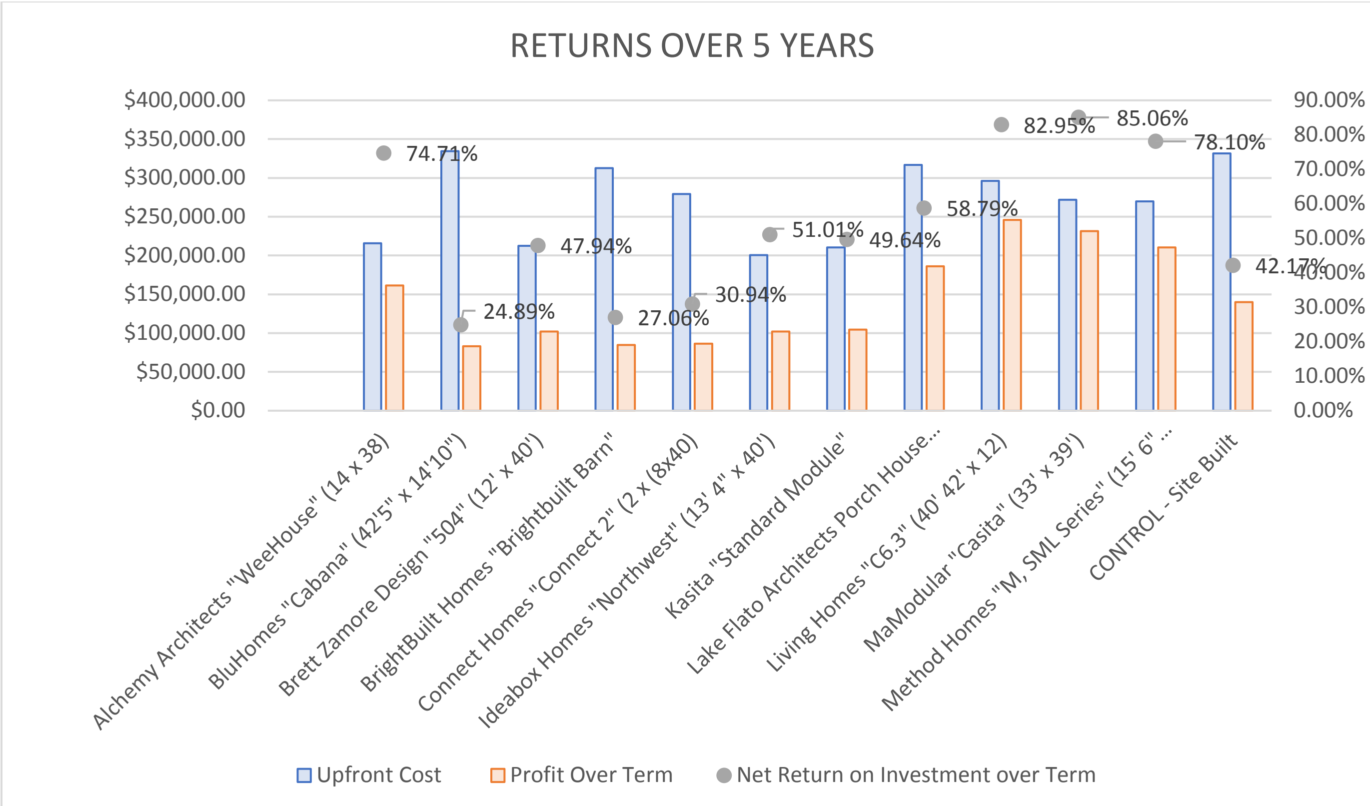
Based on market research of surrounding competition, the following variables were used to produce conservative estimates on revenue and return on investment. For nightly revenue, $200 was an assumed base nightly rate, for which incremental increases were achieved for extra square footage or exceptional design (a design score totaling over 10). Resulting projected nightly rates totaled from $200 to $437 as a result.

<u>Assumed Variables</u>

35%	Occupancy for Year 1
50%	Occupancy for Year 2
70%	Occupancy for Years 3-5
90%	Occupancy for Years 5-10
$200	Per Night Base
$0.50	Per Square Foot over 500
$0.10	Per Square Foot with Top Total Design Score (Aesthetics + Site Specificity)

FINANCIAL RESULTS

After taking into account all of the financial variables, resulting returns were able to be collected and compared. The overall highest return on investment started with the Ma Modular "Casita" closely followed by the Living Homes C6.3 and the Method Homes "M, SML Series".



RESULTS APPLIED

A Thorough, Scored Analysis of Site-Built Verses Factory-Built Alternatives

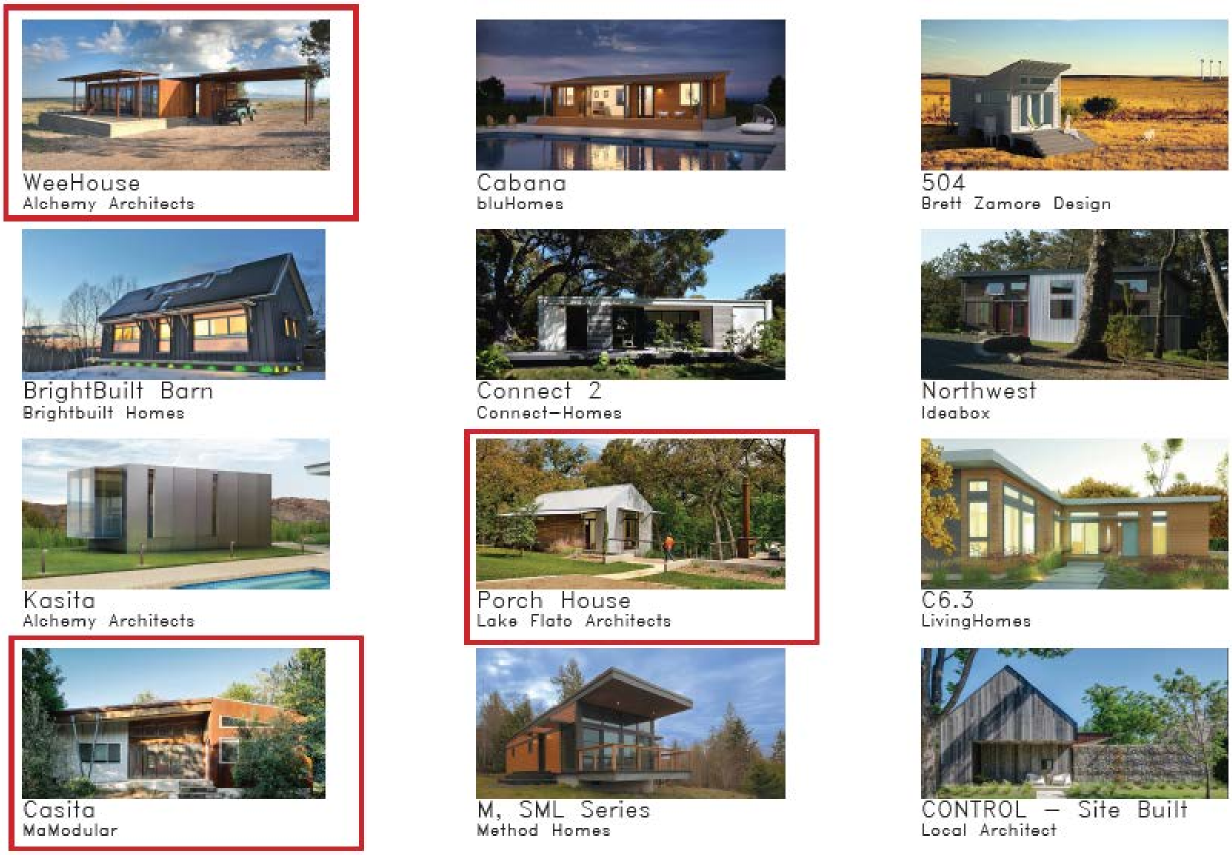
While these three projects might be the best designs for a 5-year timeline, additional criteria are necessary when considering the entire lifecycle of the project. Therefore, in a thorough project analysis, qualitative and quantitative characteristics were given a certain weighted score value. Summed at the end, three winning products were determined.

Among the qualitative criteria were Site Specificity, Aesthetics, and Use of Proprietary Systems. Among the quantitative criteria were Location of Factory (distance to the site), Potential Energy Use, Practicality of Design, Total Turnkey Costs, Total Turnkey Time, and Net Operating Income Over Term. Site Specificity is, for the purposes of this study, defined as the ability for the project to adapt to site-specific requirements by way of exterior finishes, modification of modules, and the ability to incorporate, site-specific designs like outdoor “rooms”. Each product could gain a score ranging from 1 to 10 points. Aesthetics, out of a possible five points, was the most subjective criteria used to score the sample set. It was based entirely on the writer’s opinion on how well-designed were the products. The Use of Proprietary Systems, out of a potential five points for no use of proprietary systems, rewarded projects that did not seek to implement proprietary connections or configurations that would make future modification more difficult or costly.

Quantitative criteria enjoyed a far-higher weight in overall score, but were, in part, determined by qualitative characteristics. The first quantitative quality was Practicality of Design, which was determined by the overall product dimensions, and was split into four subcategories—weight, height, length, and width. As a width that surpasses 8’6” per module would require more expensive transportation, and a module surpassing 14’ would be even more expensive and cumbersome, each product received a score that ranged from 1 to 5 based on the designed width. If any product was longer than 68’, taller than 14’ or weighed more than 80,000 lbs, it would not receive a score of ‘5’ in each criterion, stepping lower for any significant violations. Most modular projects received more than 17 points overall, as the builders were conscious to transportation limitations in their designs. The next quantitative characteristic was the distance between the product’s point of manufacturing and the site. If the manufacturing facility was less than 500 miles away, it was determined to be “close” and received a perfect 10. If the manufacturing facility was more than 500 but less than 750 miles, it had a “medium distance” (6 points), and if it was between 750 and 1250 miles, it was considered “far” (4 points). If the manufacturing facility was more than 1,250 miles from the site, it received a “very far” ranking, receiving only 1 point. As distance significantly complicates the product delivery process, travel distance needed to be an influential scoring criterion.

The next important quantitative criterion was energy savings. If the project was able to employ energy saving strategies, or even included photovoltaic and or other energy saving technologies, the product was entitled to a high “energy savings” score of up to 5 points. Total turnkey cost was determined by an in-depth financial analysis of each of the products, including the price of construction, design costs, transportation costs, site costs, and the construction of a small pool (as required by market research for differentiation). As turnkey costs have a significant effect on the projects viability, turnkey costs received a score from 1 to 30 points. To receive 30 points, however, the project needed to have a total cost of $150,000 or less, a goal that none of the products were able to achieve. With a cost of $175,000, a product would receive 25 points, $200,000, 20; $225,000, 15; $250,000, 10; $300,000, 7; $400,000, 5; and anything more than that, 0. The lowest total cost that any project was able achieve was a scoring of 15 points. Total Turnkey Time, out of 10 points, was determined by how many projected months the product would require before the was ready to be inhabited by holiday guests. If the project required 3 months or less, it would receive 10 points; 4 months, 9; 5 months, 8; 6 months, 7; 8 months 6; 10 months, 5; 12 months, 4; and more than 12 months, 0. While showing the timeliness of the products deployment, product delivery time also affects return on investment significantly, as the faster the product is delivered, the faster it can cash flow. Net operating income over term was determined by including all initial construction costs, all projected annual fixed and variable costs, operating revenue (based on market research of nightly rates, occupancy, and occupancy increases over time), and costs of improvements over a five-year term. The projected net operating income, the total revenue minus all costs, taxes and fees, received a score of “20” if the product produced more than $150,000 over 5 years, “16” if over $100,000; over $60,000, 12; over $40,000, 8; over $20,000, 4; over $10,000, 2; zero or negative income, 0.

After the scores of each of the quantitative and qualitative criteria were summed, the winning product was determined, the Casita by Ma Modular (an Austin-based firm). It was closely followed by Alchemy Architect's WeeHouse and Lake Flato Architects Porch House Concept.



The key reasons for these three product's high scores are enumerated below and a snapshot of the scoring results can be found on the following page.

1ST PLACE

MA MODULAR : CASITA

BENEFITS

- SITE ADAPTABLE AND GOOD OVERALL DESIGN
- FACTORY LOCATED NEAR SITE
- LOW COST/SQFT
- QUICK CONSTRUCTION TIME
- EXCELLENT INCOME POTENTIAL

DRAWBACKS

- LARGE UPFRONT COSTS
- NOT AS CUSTOMIZABLE AS SOME ALTERNATIVES

2ND PLACE

ALCHEMY ARCHITECTS : WEEHOUSE

BENEFITS

- GREAT OVERALL DESIGN AND GOOD SITE SPECIFICITY
- EXCELLENT ENERGY SAVING SCHEMES
- LOW UPFRONT COSTS
- GOOD INCOME POTENTIAL

DRAWBACKS

- SLOWER TO COMPLETION THAN COMPETITION
- FACTORY IS FAR FROM SITE

3RD PLACE

Lake Flato Architects : Porch House

BENEFITS

- BEST OVERALL DESIGN WITH EXCELLENT SITE SPECIFICITY
- EXTREMELY CUSTOMIZABLE
- FACTORY LOCATED NEAR SITE
- EXCELLENT INCOME POTENTIAL

DRAWBACKS

- HIGH CONSTRUCTION COSTS AND DESIGN FEES
- SLOW CONSTRUCTION TIMELINE COMPARED TO ALTERNATIVES

Qualitiative	Model	Site Specificity (1 to 10)	Aesthetics (1 to 5)	Practicality of Design (1 to 10)	Location of Factory (1 to 10)	Proprietary Systems (1 to 5)	Energy Savings	Total Turnkey Cost (1 to 30)	Total Turnkey Time (1 to 10)	NOI Total 1st Term (1 to 20)	Total Score
Alchemy Architects "WeeHous	WeeHouse (14 x 38)	8	4	18	4	4	4	15	4	16	77
BluHomes "Cabana" (42'5" x 1	Cabana (42'5" x 14'10")	6	3	17	1	4	4	5	7	2	49
Brett Zamore Design "504" (12	504	2	1	18	10	3	3	15	9	8	69
BrightBuilt Homes "Brightbui	Brightbuilt Barn	3	3	18	1	3	5	5	7	2	47
Connect Homes "Connect 2" (2	Connect 2 (16x40)	7	3	20	1	2	4	7	6	4	54
Ideabox Homes "Northwest" (	Northwest	6	3	18	1	3	3	15	9	8	66
Kasita "Standard Module"	Kasita Concept	1	1	18	10	1	4	15	10	8	68
Lake Flato Architects Porch Hc	Porch House	10	5	17	10	5	4	5	4	16	76
Living Homes "C6.3" (40' 42' x 1	C6.3	8	4	18	1	3	4	7	7	20	72
MaModular "Casita" (33' x 39'	Grand-Ma	7	4	17	10	3	3	7	7	20	78
Method Homes "M, SML Serie	M, SML Series	7	4	17	1	3	4	7	9	20	72
CONTROL - Site Built		10	5	20	10	5	3	5	0	12	70

<u>Location Scoring</u>

Close	10	<500	Miles
Medium	6	500<x<750	miles
Far	4	750<x<125	miles
Very Far	1	1250<x	miles

<u>Cost Scoring</u>

<150,000	Miles	30
150-175	Miles	25
175-200	Miles	20
200-225	Miles	15
225-250	Miles	10
250-300	Miles	7
300-350	Miles	5
400+	Miles	0

<u>Turnkey Time Scoring (Represents Lost Revenue)</u>

3 Months	10
4 Months	9
5 Months	8
6 Months	7
8 Months	6
10 Month	5
12 Month	4
More thai	0

<u>Net Operating Income (Over First Term) Scoring</u>

$150,000	20
$100,000	16
60,000	12
40,000	8
20,000	4
10000	2
<0	0

FINANCIAL CONCLUSIONS

Through this preliminary financial analysis of the viability of modular construction for holiday rentals in Fredericksburg Texas, it is clear that Modular Construction, though costlier upfront, shows significantly better returns than a site-built alternative. Additionally, when compared against other quantitative and qualitative criteria, it still takes no medals compared to a modular alternative.

While this financial summary presents a thorough comparative analysis of modular verses on-site construction, it stops short of producing a thorough business plan ready for production. Some unanswered questions for further research include:

- Is the proposed funding proposal realistic? Are there institutional funding options that might provide greater returns on investment?
- What volume discounts would be available if all 20 units were the same? How much greater would the returns become?
- What booking service would customers use? A pre-established service like AirB&B, or would a new system need to be developed?
- Would providing a more hotel-like experience, complete with chauffer's, reception, and community amenities provide a greater return, all costs considered, than the Bed and Breakfast model?
- What is the ideal collection of units on the property? At what number of units do profits marginally decline?
- Given the quick growth of the holiday rental industry in Fredericksburg, would it be better to consider a slightly larger unit design in order to allow for the property to convert itself to single-family residences, should market preferences shift?

December 9, 2017

THE PARKERRAJ MODERN DESIGN

PRELIMINARY DESIGN SCHEMATIC

Parker 52

After concluding that the Ma Modular Casita was the best unit, overall, for application in this project qualitatively and quantitatively, there still remained the question of how the project could be implemented on a particular site. Therefore, a site analysis and preliminary project design were created to test the viability of a factory-made product at 1347 Jenschke Lane, Fredericksburg, Texas. The 80-acre site is ideally situated in the heart of Fredericksburg wine country, and across the road from Becker Vineyards, the most established Hill Country Winery. The results of the study are pictured in the following pages, starting with an overall context study to the design schematic.

The design took into account solar and wind conditions of the site, ideally situating each of the modules in a North-South orientation, with pools sited to the South of each unit. This allowed for each unit to enjoy optimal sighting for light, privacy, and views. The units, in accordance with the business plan, were clustered into three phases—the first 5 units at the Northwest corner, the second five units near the existing buildings, and the final 10 units in the wooded region at the Northeast corner of the site. Each clustering is intended for a different subgenre of customer—the first 5 units are closest to the road and allow for easy access to the wineries. The Southeast 5 are closest to the future amenities that include a pond, the clubhouse, and event space, providing ample activities for active couples and families. The final 10 units in the Northeast corner provide the most privacy and seclusion, away from the road and ideal for a retreat.

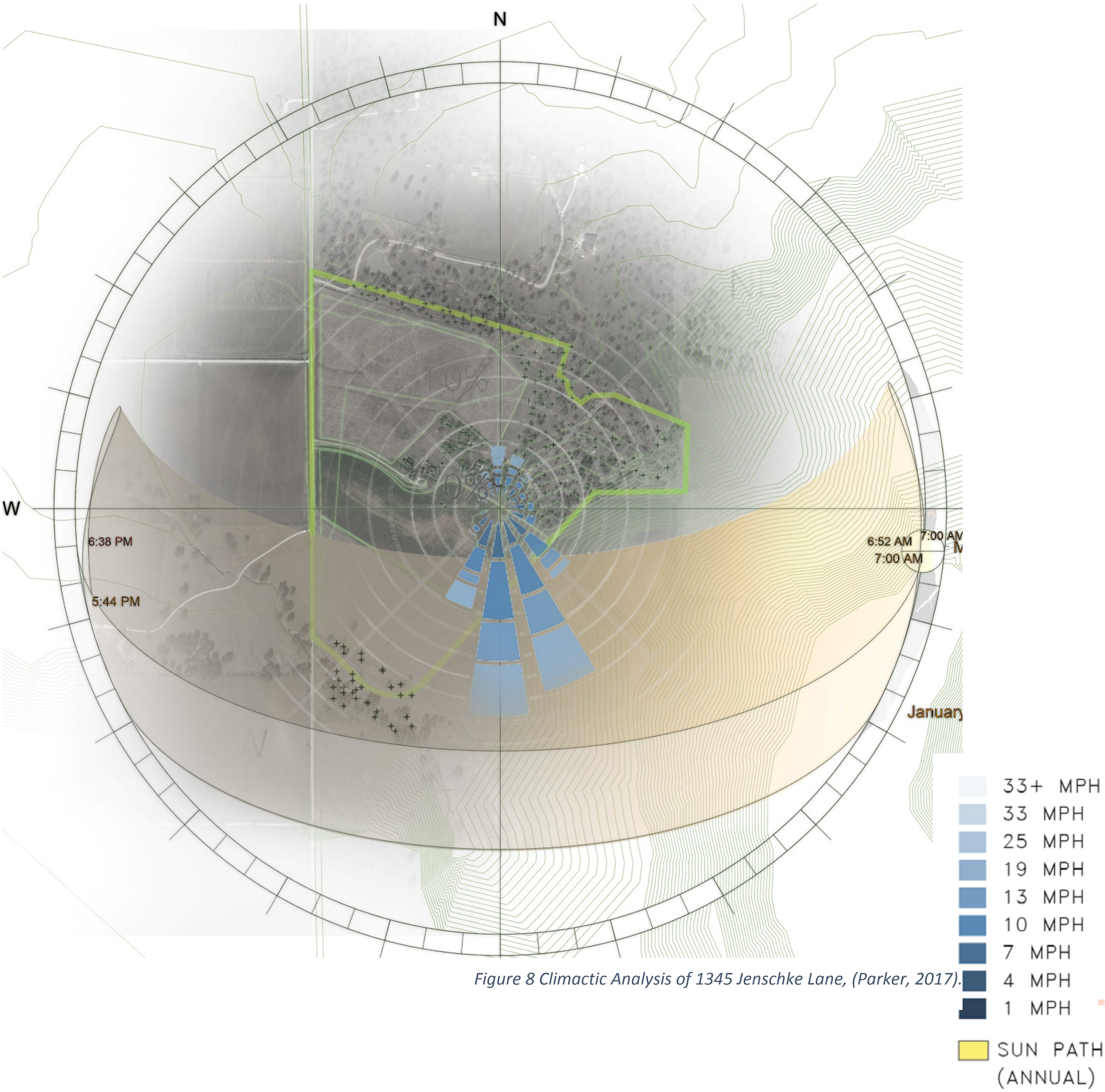


Figure 8 Climactic Analysis of 1345 Jenschke Lane, (Parker, 2017).

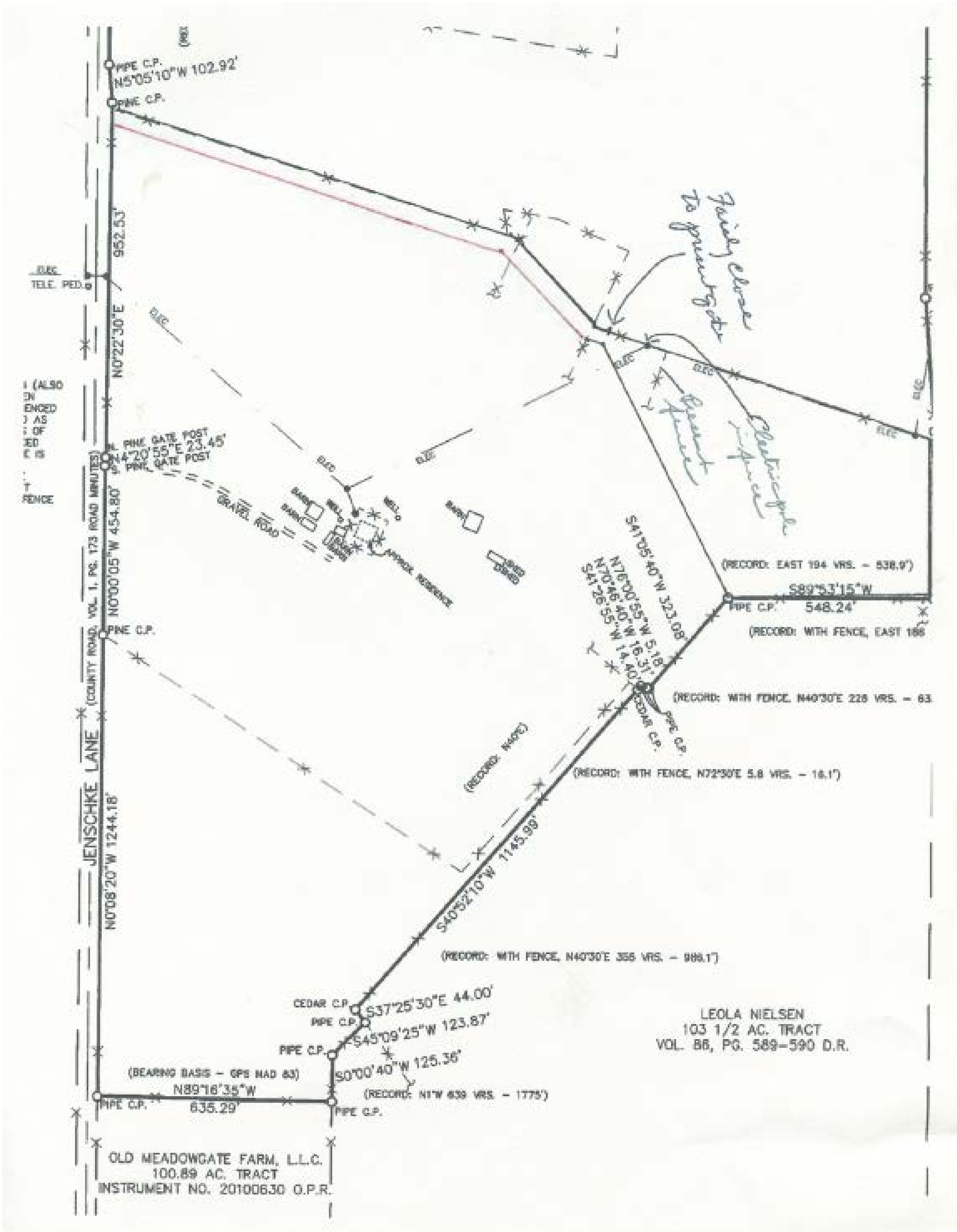


Figure 9 Official Plot of 1345 Jenschke Lane, Fredericksburg, Texas.

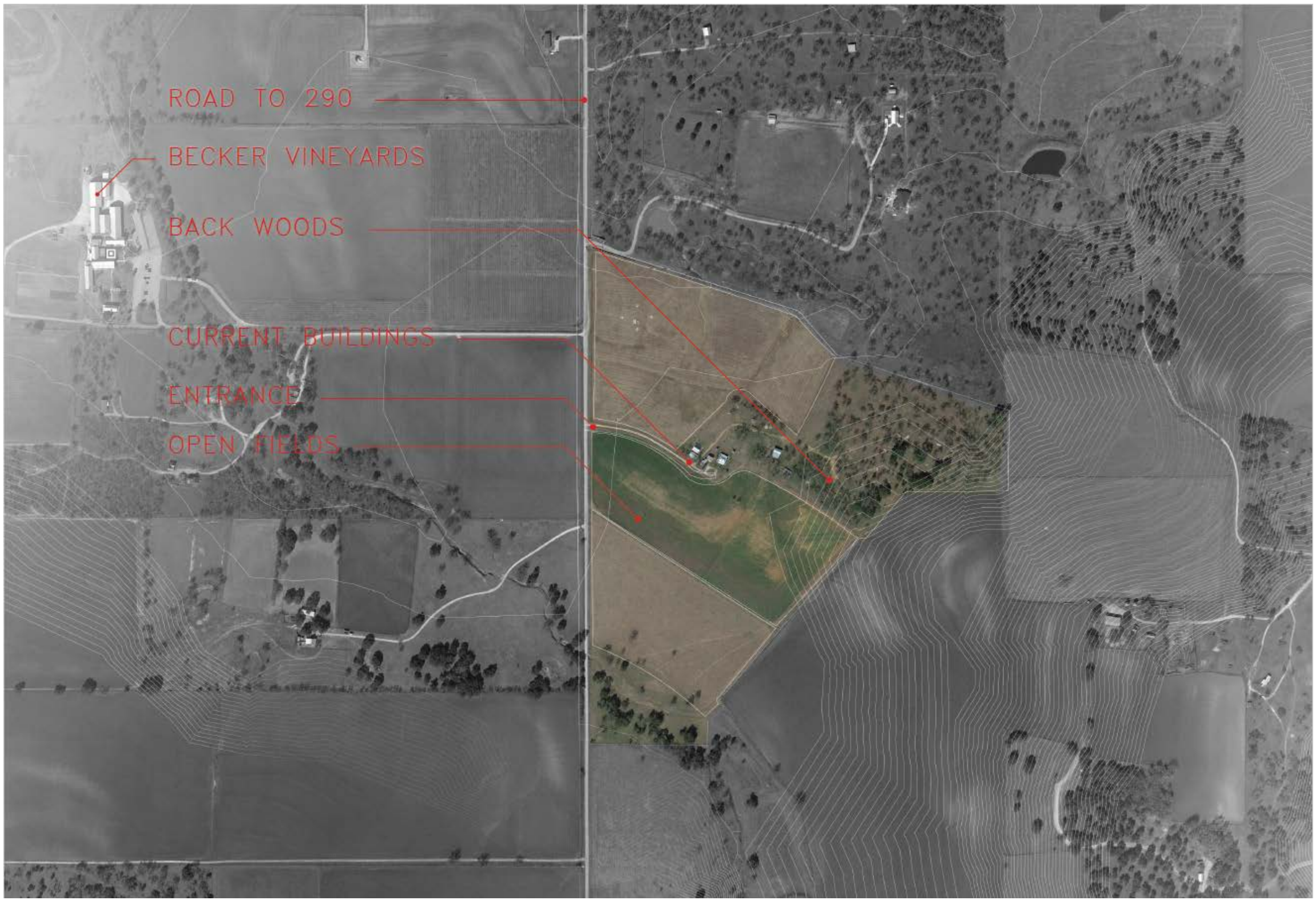


Figure 10 Current Site Conditions. Source Image from Google Earth Pro

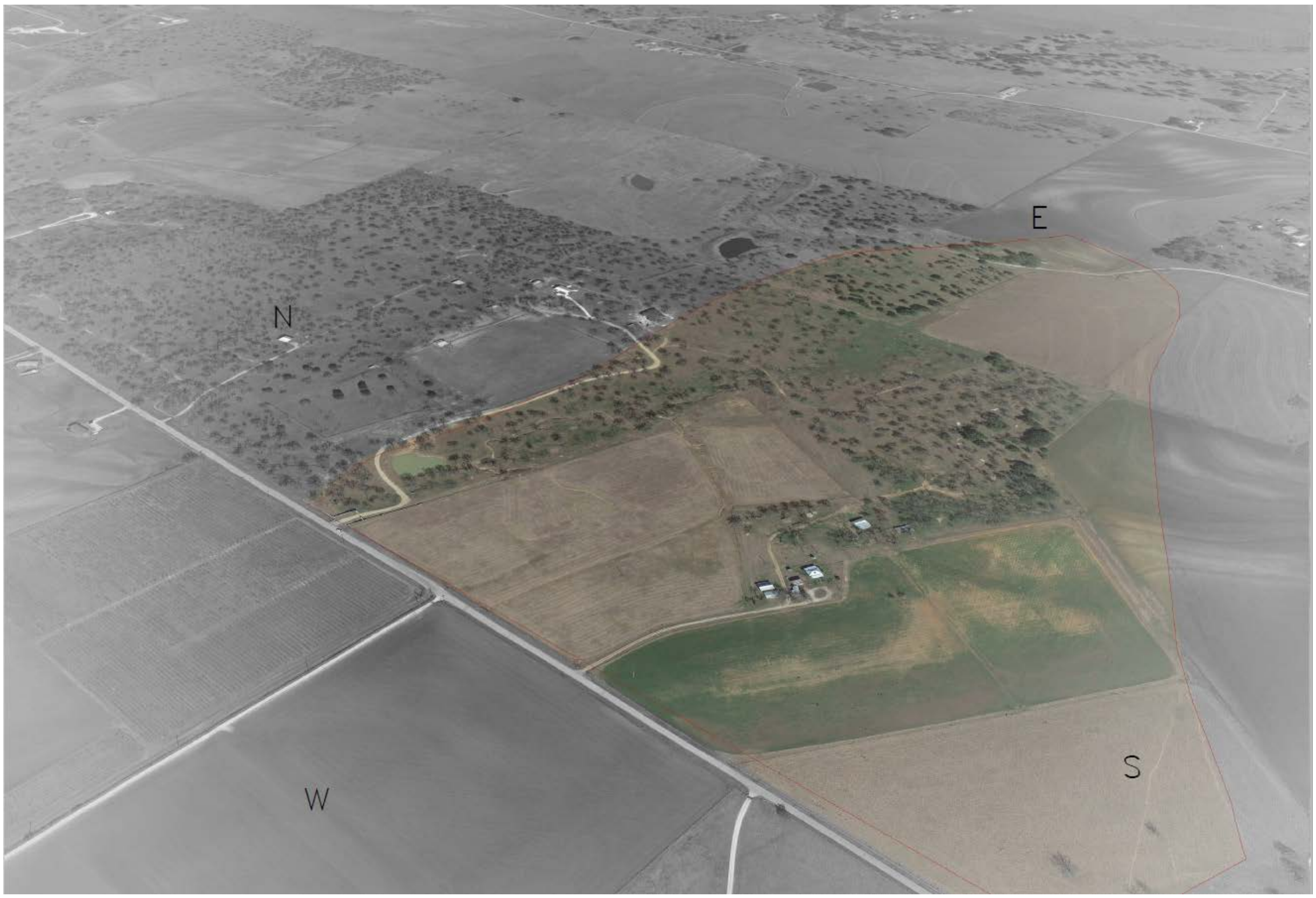


Figure 11 Current Site Conditions, Source Image from Google Earth Pro

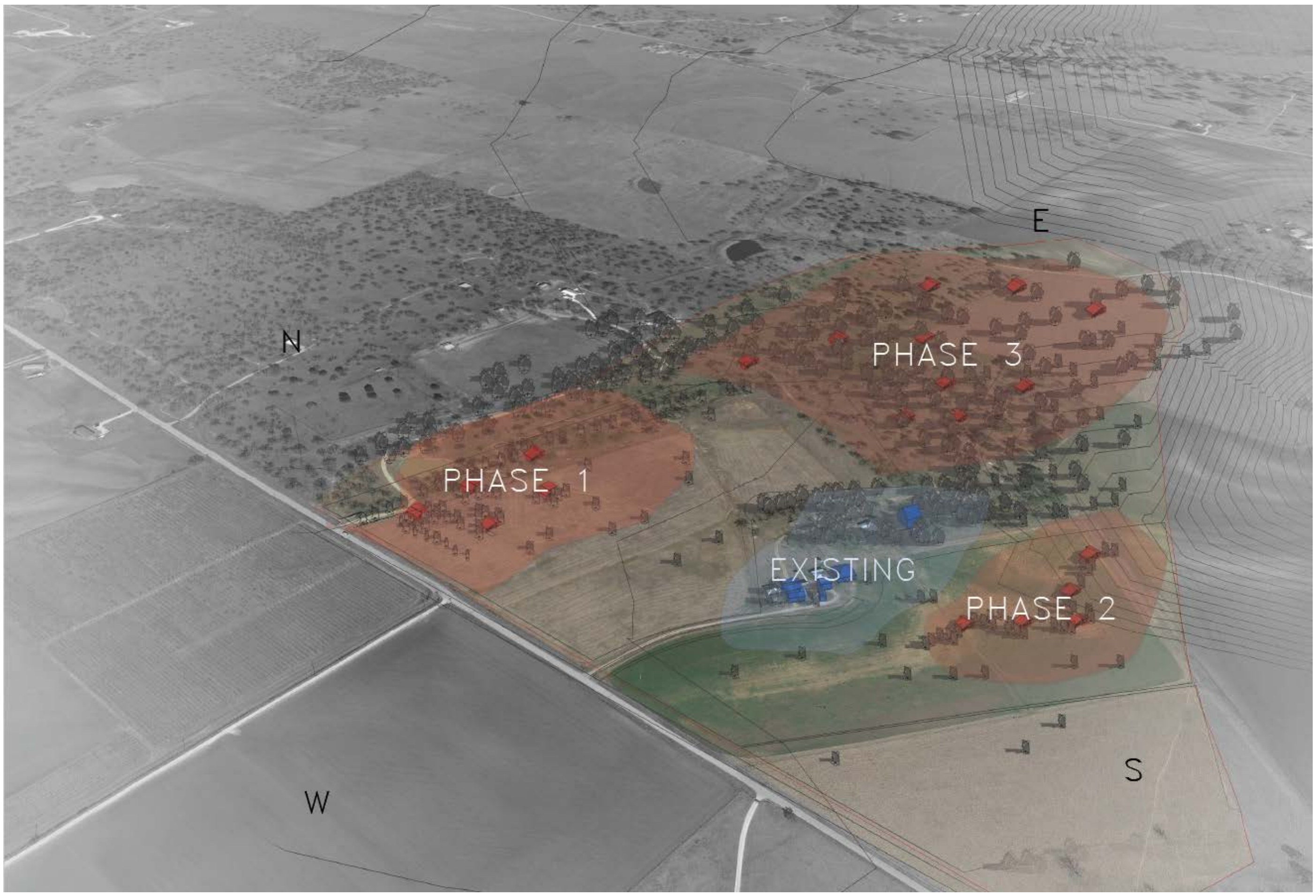


Figure 12 Phasing of Development, The ParkerRaj Modern, (Parker, 2017).

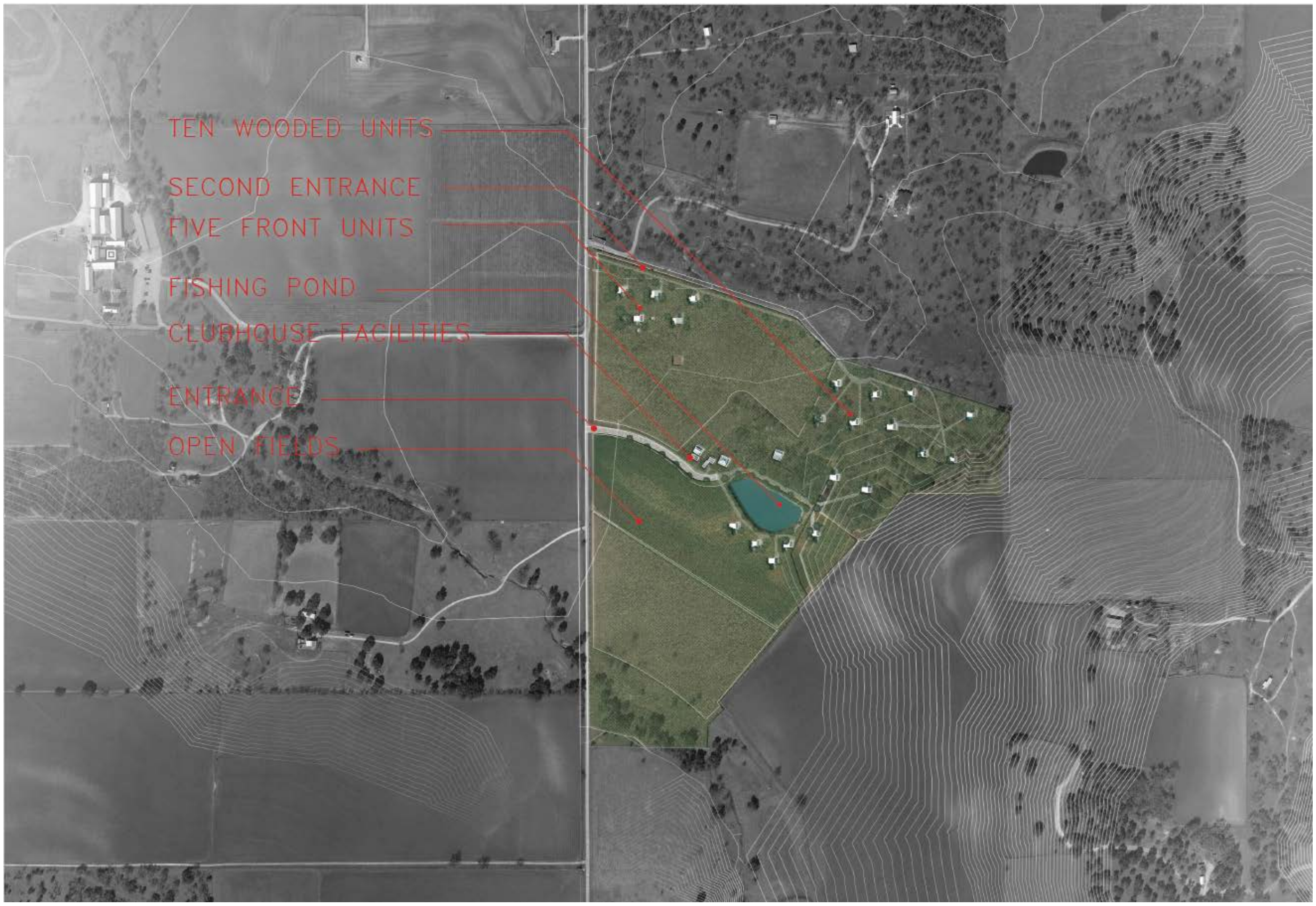


Figure 13 Site Plan of Design Schematic for The ParkerRaj Modern, (Parker, 2017).

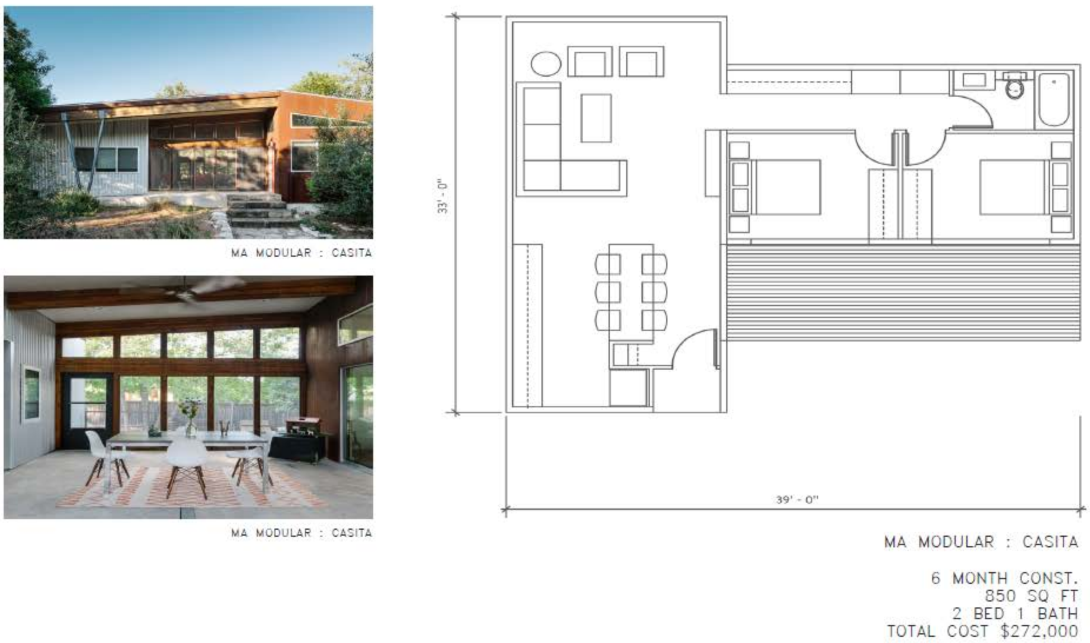


Figure 14 Above Product Photos and Plan taken from website of MaModular

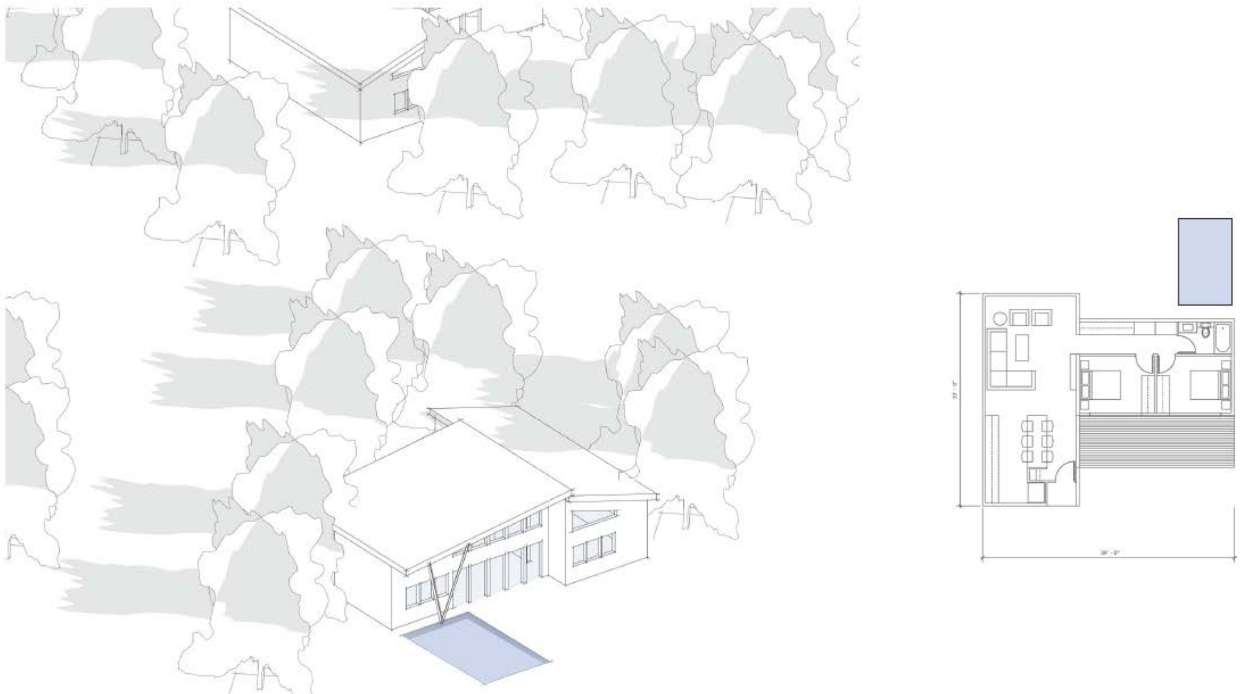


Figure 15 Slightly Modified Casita for The ParkerRaj Modern, (Parker, 2017).

Figure 16 Close-up Perspective of Casita Unit for The ParkerRaj Modern, (Parker, 2017).

DESIGN CONCLUSIONS

While this design schematic demonstrates one solution for site planning in accordance with the business plan, it also shows just how many alternatives are also possible. Some design questions still remain: would the consistency of a single modular unit be a detriment to the overall site? While this clustering is one good solution, what alternate strategies are available, and would they provide better for future expansion? What implications would this level of density have for the infrastructure of the project?

CONCLUSIONS

After thorough research into the history, advantages, disadvantages and applications of modular architecture, the research was applied to a case study that included financial analysis and a design schematic for real-world application. Seeking to answer the question of why Modular construction techniques are not further implemented in the construction industry, the research revealed that there are a series of barriers—both practical and cultural—that are holding it back from widespread acceptance. To overcome these barriers, comprehensive planning, coordination, and design are required to reap the benefits of factory construction. If, for instance, any of the modular projects were significantly delayed in their project delivery due to unforeseen circumstances, a site-built alternative could prove a more promising solution. But if it is not significantly delayed, the efficiencies and improvements in construction quality make Modular an easy sell for highly time-sensitive projects.

While this thesis provides a comprehensive overview of Modular Construction from the viewpoint of an Architect and Investor for a particular application, it still leaves numerous questions to be investigated in future research. As a designer, important questions about density and clustering remain—what is the best way for individual units to work together to form a full project? How best can Modular be used for other types of locations with greater zoning requirements and restrictions? What is the right balance between reaping efficiencies of a product-focused design, and client-specific modifications? And then there are questions from the view of the investor—It all looks well and good in financial projections, but what are the actual returns one could expect to receive? How would an investor best obtain financing for a project that requires lump-sum-upfront financing? And finally, from a cultural perspective, how can society be best educated and convinced to shift to a new way of constructing buildings, when it has been done the same way for millennia?

These questions, and many others, are yet to be answered. But the conclusion still remains: Modular architecture provides significant advantages over traditional construction, and should be implemented far more than it is currently. In the 20th century, Modular's potential was realized and failed to gain a foothold—what will you do to help make it a success in the 21st?

WORKS CITED

Antillon, E., & Morris, M. (2014). Use of Prefab at New Saint Joseph Hospital Saved $4.3 Million. *ENR: Engineering News-Record*, 1.

Census, U. (2016). *Building Permits Survey.* Retrieved from United States Census: https://www.census.gov/construction/bps/txt/tb2u2016.txt

Court, G., & Johnson, M. (2017). Is this Modular Construction's Breakout Moment? *Commercial Real Estate, Construction & Landing Guide*, 32-33.

Crowther, S. (2017, April 15). Home Builders Embrace Prefab; Massive Disruption in Alberta's Housing Sector Has Convinced Many Developers of the Benefits of Off-site Construction. *Globe & Mail*, p. S4.

DMV, T. (2017, August). *Industrialized Housing and Buildings*. Retrieved from Texas Department of Motor Vehicles.

Hatherly, O. (2015). If the Soviet Bloc Prefab Craze Sounds Absurd, It Did Solve a Housing Crisis. *Architectural Review*, 6-8.

Hawthorne, C. (2014). Prefab Grows Up. *Architect 103.2*, 64-69.

Japanese Statsitics Bureau. (2017, January 31st). *Official Statsistics of Construction Method of Total Construction of Japan.* Retrieved from Portal Site of Official Statsitics of Japan: http://www.e-stat.go.jp/SG1/estat/ListE.do?lid=000001171643

Kamali, M., & Hewage, K. (2016). Life Cycle Performance of Modular Buildings: A Critical Review. *Renewable and Sustainable Energy Reviews 62*, 1171-1183.

Lee, J., & Kim, J. (2017). BIM-Based 4d Simulation to Improve module Manufacturing Productivity for Sustainable Building Projects. *Sustainability 9.3*, 426.

Mao, C., Liu, G., Zhao, D., & Li, K. (2017, 2016). Business Model Innovation and Its Drivers in the Chinese Construction Industry during the Shift to Modular Prefabrication. *Journal of Management in Engineering 33.3*, 04016051,1-10.

Messner, J. I., Ramaji, I. J., & Memari, A. M. (2017). Product-Oriented information Delivery Framework for Multistory Modular Building Projects. *Journal of Computing in Civil Engineering 31.4*, 1-23.

Moore, P. (2014). Putting the Key Pieces Together, Ahead of Time. *ENR: Engineering News-Record 273.7*, 17.

O'Connor, J. T., Choi, J. O., & Kim, T. W. (2016). Recipes for Cost and Schedule Successes in Industrial Modular Projects: Qualitative Comparative Analysis. *Journal of Construction Engineering and Management 142.10*, 4016055, 1-9.

Panjehpour, M., Abdullah, A., & Ali, A. (2013). A Review of Prefab Home and Relevant Issues. *Constructii 14.1*, 53-60.

Parker, H. (2017). Post War Prefabs of Excalibur Estate.

Parsons, J. (2017). Charting the Unfulfilled Expectations of Prefab. *ENR: Engineering News-Record*, 14-15.

Smith, R. E. (2011). *Prefab Architecture: A Guide to Modular Design and Construction.* John Wiley & Sons, Incorporated.

Spittles, D. (2016, October 5). Modular Goes Mainstream. *Evening Standard*, pp. 6-7.

TDLR. (2017). *Industrialized Housing and Buildings.* Retrieved from Industrialized Housing & Buildings Certification Inspections: https://www.tdlr.texas.gov/ihb/agendas/staffReports062317.pdf

Tracey, M. D. (2016, November). Shunning Prefab Preconceptions. *REALATORMag*.

Trejos, N. (2017, May 8). Marriott Adopts Modular Construction: Rooms Built Off-site Can Avoid Problems with Labor, Weather. *Dayton Daily News*, p. Z6.

Zachry Construction Company. (2007). *21-Story Modular Hotel Raised The Roof for Texas World Fair in 1968*. Retrieved from Modular.org.