Industry Review

Timber Based Prefabricated Single Modular Housing: A Brief Comparison to the Auto Industry

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The present article gathers examples of modular dwelling concepts, where Cross Laminated Timber (CLT) and other timber-based products are the primary elected material, and makes comparisons between the 'prefabrication construction process and marketing strategies' for modular dwellings with the 'automotive industry'. The article is divided in three parts. First section of the article provides an analysis of the environmental impacts of transportation and building sector, then identifies reaction trends between electric vehicles and prefab modular homes. The second section deals with work flow, emphasizing the prefabrication process of house modules, the constraints given by transportation and storage, and arguing for the personalization of a mass production product demonstrated through six case studies. The third section debates possible marketing strategies, evoking business models based on collectible concepts, cataloging, mass customisation principles and image/brand for tourist/urbanistic developments.

Keywords: *Manufacturing, Prefabrication, Cross laminated Timber, Single Modular Buildings, Eco Resorts*

Today, the transportation sector represents close to 30% of the world's final energy consumption (IPCC 2014; EIA, 2019) and is responsible for more than a fifth of greenhouse gas emissions, which is impacting upon our urban air pollution and having an adverse impact on the landscape, affecting fauna and flora (European Commission, 2018). Measures to mitigate these harmful effects include the creation of specific pedestrian or public transport exclusive zones, limiting the large influx of private vehicles that are congesting many urban centres, and through improvements in taxiways, roadways and infrastructure. By opting for low emission vehicles and developing alternatives to fossil fuels, from say electric vehicles, the future holds great promise.

It is estimated that one billion people live in informal settlements often without reliable electricity, water, sanitation or even food (GrayOrganschi Architecture, 2018). The residential construction sector consumes 40% of the world's total resources and subsidises more than a third of global greenhouse gas emissions. The promotion of 'efficient houses' as response to these threats seems plausible. The solution might include sustainable materials, selecting the correct form and orientation of a house optimized to reduce unwanted solar heat gain, endorsing passive stack effect ventilation, allowing for ample natural light and applying next generation's green technology by means of reuse and filtration of wastewater, micro-agriculture, generation and management of energy and waste. The sophistication of these houses through prefabrication implies that efficiencies can also be gained in terms of timeframe of manufacturing, transportation and assembly.

Electrical locomotion stands today as the cutting-edge ecological technology in the auto industry, as Cross Laminated Timber (CLT) modular prefabrication positions itself in civil construction. In drawing a comparison between the two we have on the one hand arguably the most effective vehicle to reach a certain destination; on the other, possibly the most comfortable and sustainable shelter to live in. Both exist within the realm of what is considered renewable technology. The automotive industry and the construction of prefabricated houses, despite the comparative delay (Congresso Nacional da Indústria de Pré-fabricação em Betão , 2000) of the latter, share several points in common in both the manufacturing process and associated marketing strategies.

The Manufacturing Process

The first serially produced automobiles emerged in 1908 with Ford's Model T, the first car to be called 'sustainable' (Price, 2004). The organization of an assembly line and the capacity to mass produce (Tolliday & Zeitlin, 1987) reduced both production and sale prices as well as higher wages allowed the workers themselves to acquire a car. Fordism's manufacturing process introduced a cluster of terms that have since become fashionable: assembly line, synchronization, precision and specialization (i.e. within the same factory (Hounshell, 1984)), standardization, serial and mass production. Albert Farwell Bemis in 1930, compared the work flow steps in the assembly of a car - "chassis, engine, wheels, body and accessories" - with the construction of a house - "foundations, frame, cladding, finishes, accessories" (Oliveira, 2009).

Looking at the prefabrication process of module houses, apart from foundations and general grid connection, most of the tasks that take place on the construction site are transferable to a manufacturing unit - structure assembly, infrastructures, finishes,

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equipment, functional tests - to which two more significant stages are added: the packaging for transportation and storage. These last two tasks, transportation and storage, are identified as the main constraints for product sizing thus resulting in viability of house designs.

If one enquiries as to the ground transport capacities, looking for alternatives to the standardized dimensions of sea containers, according to the German reference (Proholz, 2017), it is possible to carry a maximum width of 5.50 meters, a length from 13.60 to 30 meters and a height of 4.20 meters. All dimensions are directly related to the permissible transporting of loads on the roadways. However, several levels define the conditioning of transportation.

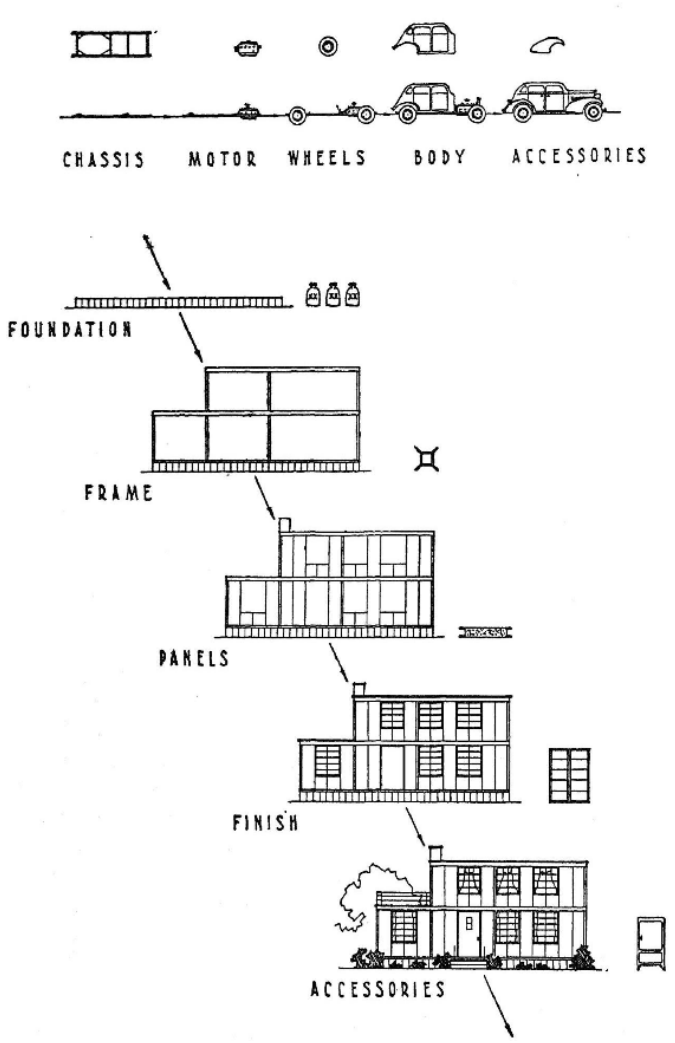


Figure 1. Illustration 1 – Workflow Comparison. (Bemis, 1936)

Special Authorizations of Transport are required from a width of 3 meters onwards; a 3.50 meters wide cargo requires a support escort; Traffic Brigade escorts are mandatory for 4 meters wide and 3.10 meters high loads. If the product is 4.50 meters wide and / or 4.20 meters high, the transport requires a low semi-trailer platform; From a width of around 5.50 meters onwards, thorough itinerary studies must be carried out. Subsequently the larger the modules, the more constraints there are and the higher transportation charges will be. Hence, multiplying parts or using components with large volumes of voids, increases the number of trips or quantity of vehicles to be used, every choice weighing-in on the scale of environmental impact.

Conceivable strategies for transport and storage correspond to volumetric geometry planning work, such as the concept of mini shelters or boxes equivalent to standard containers, pliable volumes, a box inside a box system or houses made up of smaller prefab components, some of which are exemplified later within the article. However, such transportation configured geometry still impacts the manufacturing process, specifically from a Design for Manufacture (logistics) and Assembly perspective. Indeed, the concept of automated manufacturing impacts more than just the production process.

Where once houses were individually and uniquely constructed by skilled craftsmen to the exacting needs of the owner, mass manufacturing conjures ideals of standardisation and commonality in design/product. Satirized in 1936 Modern Times by Charles Chaplin, highlights the many problems generated by the Fordist economic model including the alienation of labour. Such an issue is echoed in the exclusivity function of each worker who, being unaware of his/her purpose and through continuous repetitive movements, can contract psychological and physical disorders. Transposing the idea of dehumanization to the prefabrication of single modular houses the critical point lies in the depersonalization of the product, the lack of individuality in the standardized product and an almost contempt for the greater foundation of Architecture, the genius locci – the ubication.

The production and assembly of a product - be it automobile or a modular home –distinguishes between the essential, the “base model”, and the “customizable”, variable features adjustable to the needs of the context and consumer’s desires and pocket. The architects´ inventiveness rests within their ability to use standardization without interrupting creativity and taking advantage of benefits afforded by normalized production in Architecture (Fernandes, 2009).

William J. Mitchell (2002) proffers the concept of “Mass Customization” on the basis that “Every new house could soon be built on its owner’s unique design” . Combining product customization with automated production is possible through the simplification and unification of the design process, concealing technical aspects from the user / client, and communicating the possible options that can be customized by the user in an intuitive and expeditious manner.

In Beechwood West, former Craylands Estate, in Essex, United Kingdom, Pollard Thomas Edwards together with Nu build modules factory is proposing to construct 251 prefabricated houses using CLT for the structure (New London Architecture, 2018) covering an area of 68.900m2 by the year 2022. Buyers use an online configurator to choose their plot, select a plan type (open or cellular, adding additional rooms), external materials (brick colours, tile cladding), specify appliances, sanitaryware, cupboards and floor finishes. These parameter choices ascend to more than a million different combinations, giving customers the chance to design a home relevant to them, and contribute positively to the suburban phenomenon of individualisation at the same time maintaining an urban volumetric cohesion.

Nevertheless the “variable” factor in the prefab houses will reside not only in optional extras (in terms of equipment, appliances and finishes, the system hence defining thresholds or product ranges) but also in its adaptation to the context, namely the amount and type of offsite tasks – placement, foundations etc. Non-customisable elements of the building process include: pre-ground preparation, earthmoving, appropriate foundations and grid connections, depending on geology, water level, exposure to climatic factors and natural hazards, which are required to attach

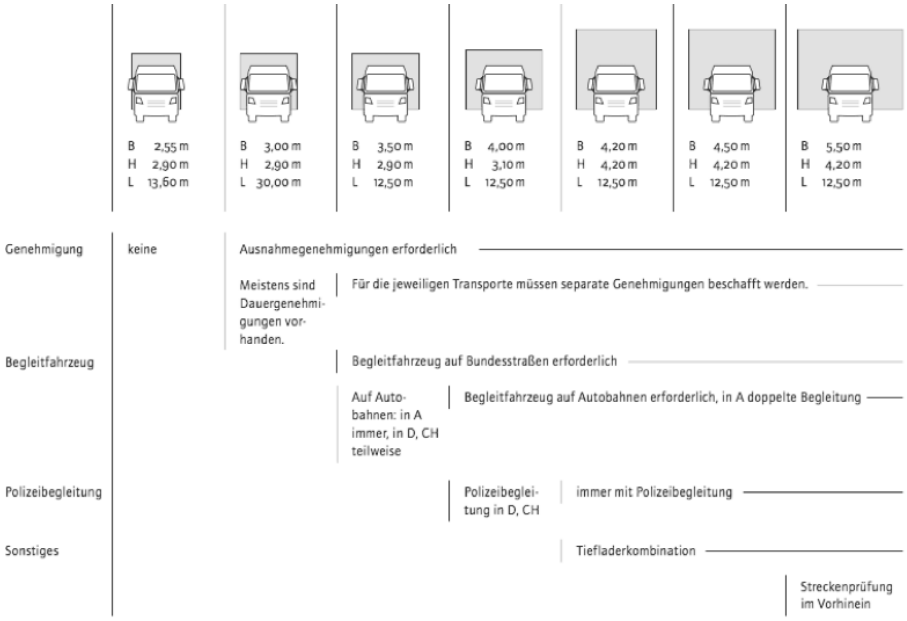


Figure 2. General conditions for the transport of modules.(These specifications apply to Germany, Switzerland and Austria)

the module to the ground. However, the cladding composition, as a variable, is a “customizable” parameter allowing for some adjustment to the climate in which the house may be implanted.

In what follows are six examples presented below that stand out due to their conceptual approach in responding to the dimensional limitations of transport and degree of personalization

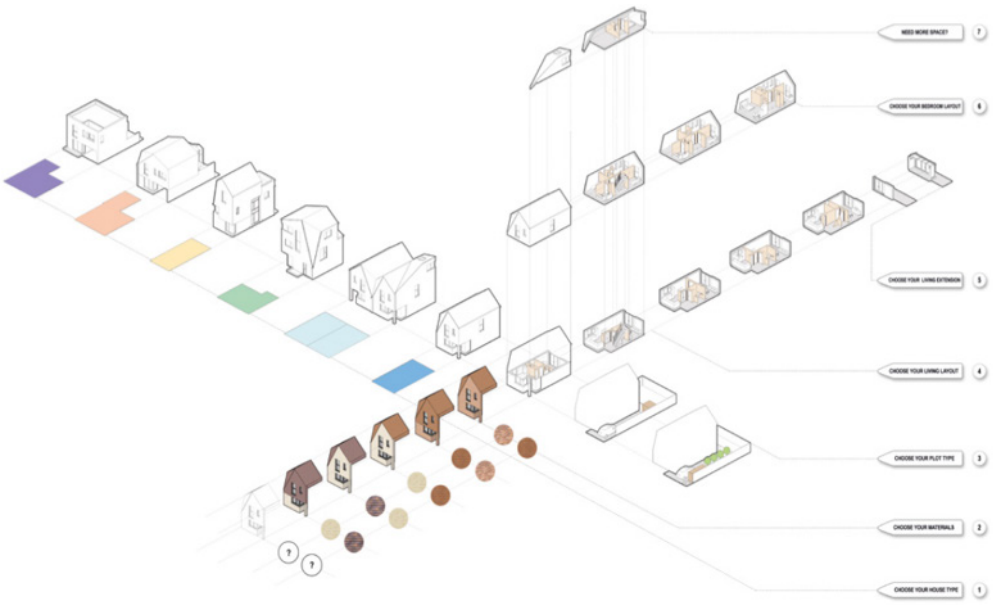


Figure 3. Diagram of customer design choices for Beechwood West, Basildon, Essex.

M.A.D.i.

M.A.D.i. (Italy | 2017 | Renato Vidal) is a foldable house transported in a pleated form and then 'mountable in only 6 hours'. It is analogous to a folding cardboard box. It presents 5 different models with additional variable features and different finishing materials. The range includes: Single, a 27m2 one-bed; Double Young, a 56m2 two-bed; Double Luxury, a 46m2 one-bed, with premium materials and features; Triple Family, an 84m2 three-bed; Triple Cottage, a 70m2 two-bed with a balcony.

Ecological Living Module - Tiny House

The Ecological Living Module (ELM) - Tiny House (New York | 2018 Gray Organschi Architecture and Yale Center for Ecosystems in Architecture) is a 22m2 prototype home, presented within the framework of the United Nations High-Level Political Forum on Sustainable Development and constructed from locally sourced bio based materials, fully powered by renewable energy (specifically solar power generation), collection and filtration of waste water, air purification through plants and passive 'stack effect' ventilation. Manufactured offsite, the ELM is transported as a compact 2,5 x 2,5 x 6,7m container and once set onto its lightweight foundations the roof assembly pivots on a steel hinge to create a 4,8meter double-height interior space with a built-in sleeping loft. Prefabricated wall panels are then set in place by hand.

Heijmans One Student Mobile Housing

Heijmans One Student Mobile Housing (Netherlands | 2015 Daan Roosegarde & Heijmans) is a prefab house for students, or young professionals for provisional-use (recommended for up to 5 years use). In the Netherlands, this concept does not require planning permission due to its "removability". The mobile houses are composed of two overlapping modules each being transported as a 3.5 x 6 m container and when fitted the total area is 39 m2.

Wikkelhouse

The Wikkelhouse (Amsterdam, Netherlands | 2016 | Fiction Factory) is a weekend house system, comprising tubular segments (4,5m x 1.2m x 3.5 m) in a steel framed structure cladded with 24 layers of bonded corrugated cardboard and covered by a waterproofing layer and a timber finishing inwards. Each segment has 5m2, weighing 500kg and is fully recyclable.

MIMA Light

MIMA Light (Viana do Castelo, Portugal | 2015 | MIMA Architects) is composed by combining 3 meter-wide modular cells where only the colours of the materials can be customized. The optional typologies differ in length by modular increments of 1.2 meters.

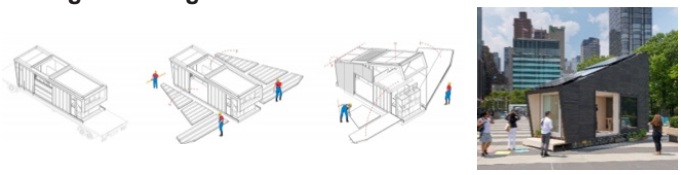
Timber Modules

The Timber Modules (Latvia | -) are monoliths composed of a single module of 40m2 (12m x 4m x 3.8m) using a CLT structure. Despite the space compaction, the alignment of windows and the corner windows provide a sense of wider space. The entrance is confronting with a cabinet of recessed sliding doors splitting the interior into common and more intimate zones.

The restricted viability of these six mass produced concepts is due to the definition of a base model that is robust yet flexible enough to create several scenarios and extra functions for customers, all of which are catalogable.

M.A.D.i.

Ecological Living Module



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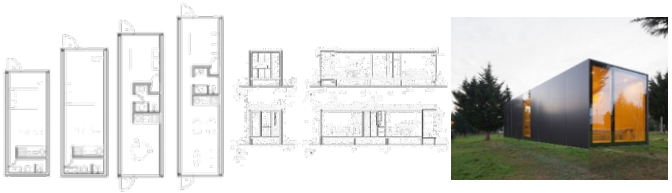

Timber Modules

Figure 4. Six Case Studies

Marketing Strategies

In the same year that Ford's Model T came out, Sears and Roebuck and Co. published its first catalogue, and along with Gordon van Tine and Montgomery Ward, pioneered a catalogue -selling method of pre-fabricated houses delivered by postal services (Domingos, 2013). In the 1920s, Le Corbusier, a pioneer himself - of what is now called modern architecture - used his

"L'Esprit Nouveau" magazine to propagate his controversial ideals, not only showing their application in his projects, but also displaying alongside his texts images of planes or attaching industrial catalogues or factory advertising leaflets. His purpose was the insertion of the Modern Architecture within the industrial productivity process. His 'Citrohan' house (with its phonetic affinity with the Citroën car brand), designed in 1921 to be a 72m2 mass built with a concrete skeleton is the emblematic example of the 'machine à habiter', a phrase that not only proclaimed an aesthetic principle however also recognized through his admiration for engineering and the crucial integration of systems in modern construction (Tostões, 2009).

The ecological, social and economic advantages of pre-fabricated systems are obvious: a reduction in execution time, a better finishing quality control, a reduced environmental impact, less annoyances to the surrounding and less occupational hazards on site. The global expansion of prefab systems can be seen as a disruption. The cataloguing and selling of houses through major distributors within the residential housing sector (Serrats et al., 2014) is akin to products created by IKEA (www.boklok.com) and MUJI (www.muji.net/ie). Essentially, flat-pack houses. The multiplication of the same concept in use for touristic purposes (such as youth camps, resorts, hiking shelters, public space facilities, sale stands) is yet another business model that promotes pre-production of modular housing units. The 60s and 70s, particularly, gave birth to architectural icons (Kronenburg et al. 2013), ironically collectible (Cividino, 2018), for their form and materiality, similar to what happens to classic vintage cars.

Bule Six Coques (Gripp, Pyrénées | 1964 Jean Benjamin Maneval & Pétrole Aquitaine | Bâtiplastique), presents a 36m2 star shape with 6 wells, each conforming the envelope - floor, walls and ceiling – in a moulded polyurethane glass sandwich, and a hexagonal dome above. All the joints have a screwable plastic sealing gasket. The base of the original model was a hexagonal concrete foundation. In a set of 20, the individual units comprised a 1964 holiday village. Later Prisunic stores adopted the model, replacing the concrete footing with a 4-wheel metal base, and redesigning the interiors (by designers Gérard Ifert and Rudy Meyer).

Algèco 2002 (Munich | 1968 Lantz Clément Cividino) was a transformable and expandable pavilion, used as information points, exhibition stands, or even weekend houses. In the Olympic village of Munich, various units housed locker rooms, toilets, anti-doping control rooms, conference rooms, etc. They are made of white polyester bent panels in transparent plexiglas with 4 combinable faces and can be installed individually or grouped together.

Of similar function, the Hexacube (Various locations | 1972 | Georges Candilis and Anja Blomsted | Dubigeon Plastiques, Cifam) presents as a 7m2 hexagonal cell, covered by two layers of reinforced fiberglass laminated polyester with large window spans that are connectable conforming habitats of varying sizes and combinations.

Finally, the CasaNova 2400 (Munich | 1972 | Frank Huster & Peter Hübner) was a set of 110 space capsules, ordered as temporary elements for the Olympic Games of 1972. They are combinable orthogonal polyhedral forms, 3.6 meters wide, whose walls are in corrugated cardboard coated with a fibre glass reinforced plastic layer. Later, further CasaNovas were implemented as private property individual elements. "The houses arrive in the morning and you move in the evening" assured the creators.

Bulle Six Coques

HexaCube

Algéco

CasaNova 2400

Figure 5. Four Architectural Icons

Learning from these architectural marvels, tourist lodges or mountain shelters spread all over the world, are adopting and developing prefabricated house systems. Recently Krakani Lumi (Archdaily, 2018) was premiered at Mount William National Park, Australia (2017 | Taylor and Hinds Architects | Cutek), a place of shelter for 10 visitors and two guides, for two or four-day long trails through the Natural Park. Designed for the Aboriginal Land Council, it comprises a series of pavilions clad in charred timber from Tasmania. When open, the display features vaulted voids representing typical Australian Aboriginal meeting spaces and serves as a shelter for birds and endemic marsupial animals. The pavilions were prefabricated in modules and transported and laid on the ground by helicopter.

Figure 6. Krakani Lumi

With the tourism increase in Portugal from north to south, several examples have emerged in recent years. Zmar (Zambujeira do Mar | 2009 | José Costa Pina Arquitectura Lda, Aida Correia, 3H | Julár) comprises 95 timber frame dwellings, called 'treehouses', composed of modules of 22 m2 each forming various typologies from a simple 20m2 one bed to 90m2 three -beds. In Pedras Salgadas (2011 | Luís Rebelo de Andrade / Diogo Aguiar / Modular System), the modularity of the 60m2 Ecohouses is quite astonishing with each unit comprising an entrance, bath, living and bedrooms, allowing different configurations so no trees were removed from their surrounding area in their installation. The Cocoon Eco Design Lodges at Comporta (2011 | Arquiporto, Modular System) bring together a set of 30 'mobile homes', 3.50x 12m in cross laminated timber, to a 28ha site. One-and two-bed typologies, from 29,40m2 to 42m2. Whilst the Bukubaki Peniche Eco Surf resort (2017 | Sofia Loss) has eight houses in CLT, at a four to five meters high level, again alluding to tree houses.

These business model examples provide evidence for a mass prefabrication of repetitive autonomous monoliths, above all, providing a brand image — an ecological one — respecting the place where dwellings are implanted.

Zmar

Cocoon Eco Design

Pedras Salgadas Spa

Bukubaki Peniche Eco

Figure 7. Four Eco Tourism Resorts in Portugal

The present article and exemplar case studies have shown that the usage of timber products is common in self-contained prefabricated dwellings. It also demonstrates that timber, and timber fibre associated products, are a low impact alternative to more conventional materials with a much inferior embodied carbon footprint. With the exceptions of the cardboard Wikkelhouse, with a tactile interior finish in wood and the timber frame Zmar treehouses, all examples resort to Cross Laminated Timber Panels as a structural and finishing material.

CLT provides a quicker construction time over traditional methods due to its prefabricated construction methodology - some claiming it is up to six times faster - and ease of subsequent fixing and remediation. Timber also offers a much lighter, cleaner, with much less waste when produced in a controlled manufacturing environment, whilst handling is vastly reduced so it is much better in terms of health and safety. Combining the maturity and efficiencies from the manufacturing industry with construction, an integrated design process where all the specialties must be onboard upfront, and overlaying clever marketing, the quality achieved is exponentialized and made affordable. Such efficiencies are gained despite claims of CLT's costs being relatively high when compared to more traditional materials. It appears that industry is slowly observing the recovery of the sustainable sense of Ford's model T car and coming nearer to J. Mitchell's premise: Every new house could soon be built on its owner's unique design.

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