Lessons learned from adopting modular construction in Brazil: A start-up journey

Jonas Silvestre MEDEIROS[1] and Reymard Savio Sampaio de MELO[2*]

[1] *CEO, Cubicon, Brazil*
[2] *Assistant Professor, Department of Construction and Structures, Federal University of Bahia, Brazil*
[*] *Corresponding author's e-mail: reymard.savio@ufba.br*

ABSTRACT

Although Modular Construction (MC) is already known in Brazil mainly to due the fast construction of health facilities during the Covid 19 pandemic, very few developers and building companies have adopted it as an ordinary strategy. Previous studies do not focus on analysing how start-up companies can contribute to MC establishment in the country. This study aims to describe the journey of a local start-up company in adopting MC following a descriptive case-study approach. The findings suggest that the following drivers are crucial for the survival and success of a start-up MC company (i) the development of a variety of products that fits market segments and ensuring a minimal sale revenue regularly to pay fixed costs until it manages to capture investment to scale its business; (ii) taking into consideration it takes time and practice first on a smaller scale before going to larger projects, and multi-story modular buildings; (iii) training of skilled professionals and education on design and detailing on MC building technologies; (iv) standardization of building components, product and design to certain levels is inevitable.

KEYWORDS

Modular construction; Off-site construction; Brazil.

INTRODUCTION

The construction industry is recognised and best described as a slow-to-change industry compared to other sectors. Despite this industry's attitude, the transition towards offsite construction (OSC) methods has begun. OSC is an alternative to the traditional on-site method. Previous studies focused on identifying the state of practice and offsite strategies adoption challenges in many developed countries and regions, such as Japan (Matsumara et al., 2019), the United States (Assaad et al., 2022), the United Kingdom (Iacovidou et al., 2021), Singapore (Hwang et al., 2018), South Korea (Shin et al., 2022), etc.

OSC methods can be divided into different levels, including modular construction (MC), planar construction, hybrid construction, cladding panels, and pods (Lawson et al., 2014). Although existing literature has many terms related to MC, such as industrialized building systems, modern methods of construction, modular integrated construction (MiC) (Pan & Hon, 2020) and prefabricated prefinished volumetric construction (Hwang et al., 2018), the authors followed the seminal definition proposed by Gibb & Pendlebury (2006), who defined MC as the production of 3D units in controlled factory conditions prior to transportation to the site.

Previous studies identified barriers, constraints, and challenges to MC adoption. Wuni & Shen (2020) identified 120 barriers to adopting MiC in 15 countries across Asia, Africa, North America, Europe, and Australia. The 120 constraints were clustered into knowledge, attitudinal, industry, financial, aesthetic, technical, process, and policy-related barriers.

Shin et al. (2022) developed and validated a technology acceptance model that can explain the mechanisms of MC adoption and identified the relationships between factors related to MC adoption in South Korea. Other studies focused on MC adoption on a given project (Rausch et al., 2020) or in an established organisation (Nam et al., 2020).

While previous studies have contributed to extending our understanding of MC adoption, each country faces particular and often unique challenges when adopting MC. Previous studies' findings overlook their geospatial sensitivity.

MC adoption has been slower in developing countries such as Brazil than in developed countries (e.g., United States, Japan, Sweden, and United Kingdom), where the technique is reasonably used. A few private large developers in Brazil have primarily driven the move towards MC. However, previous studies of MC in Brazil have not dealt with the particularities of start-ups adopting MC. This study aims to fill this gap by describing the journey of a Brazilian start-up in adopting MC. By doing so, this paper seeks to advance the current body of offsite construction knowledge from a practitioner's point of view since the first author is the CEO of a start-up.

RESEARCH METHOD

This study constitutes a longitudinal descriptive case study. The rationale for the single case designs is on the revelatory basis, i.e., a situation where the researcher can observe and analyse a case previously inaccessible to scientific investigation (Yin, 1994). The case selected was Brazilian start-up company CUBICON, of which the first author is also the founder and CEO. The unit of analysis was the organisation's business model. Table 1 shows the principles for interpretative field studies defined by Klein and Myers (1999) applied in this case.

Table 1. Application of Klein and Myers's seven principles of interpretive field research.

Principles (from Klein and Myers, 1999, p. 72)	How the principles were applied in the case study
1. The Principle of the Hermeneutic Circle	The data collection is supported by the first author's observations and literature review.
2. The Principle of Contextualization	The case study is conducted from two viewpoints – the current start-up maturity and how this start-up has emerged over time.
3. The Principle of Interaction Between the Researchers and the Subjects	Japanese market data is based on semi-structured interviews.
4. The Principle of Abstraction and Generalization	The contribution of rich insight is the generalisation type of this study.
5. The Principle of Dialogical Reasoning	The theory applied to the case was not used to plan and guide the data collection.
6. The Principle of Multiple Interpretations	This principle is followed by collecting data from two sources of evidence.
7. The Principle of Suspicion	The data have been analysed by the second author, who is external to the organisation and has no legal interests or agenda.

The longitudinal data, based on the investigation, was collected over six years and originated from two sources of evidence: participant observation in the factory and on-site and document analysis—figure 1 shows of CUBICON modular start-up company. Walsham (1995) argues that there are four types of generalisations from interpretive case studies: the development of concepts, the generation of theory, the drawing of specific implications, and the contribution of rich insight. This case study contributes rich insight into MC organisations operating in Brazil.

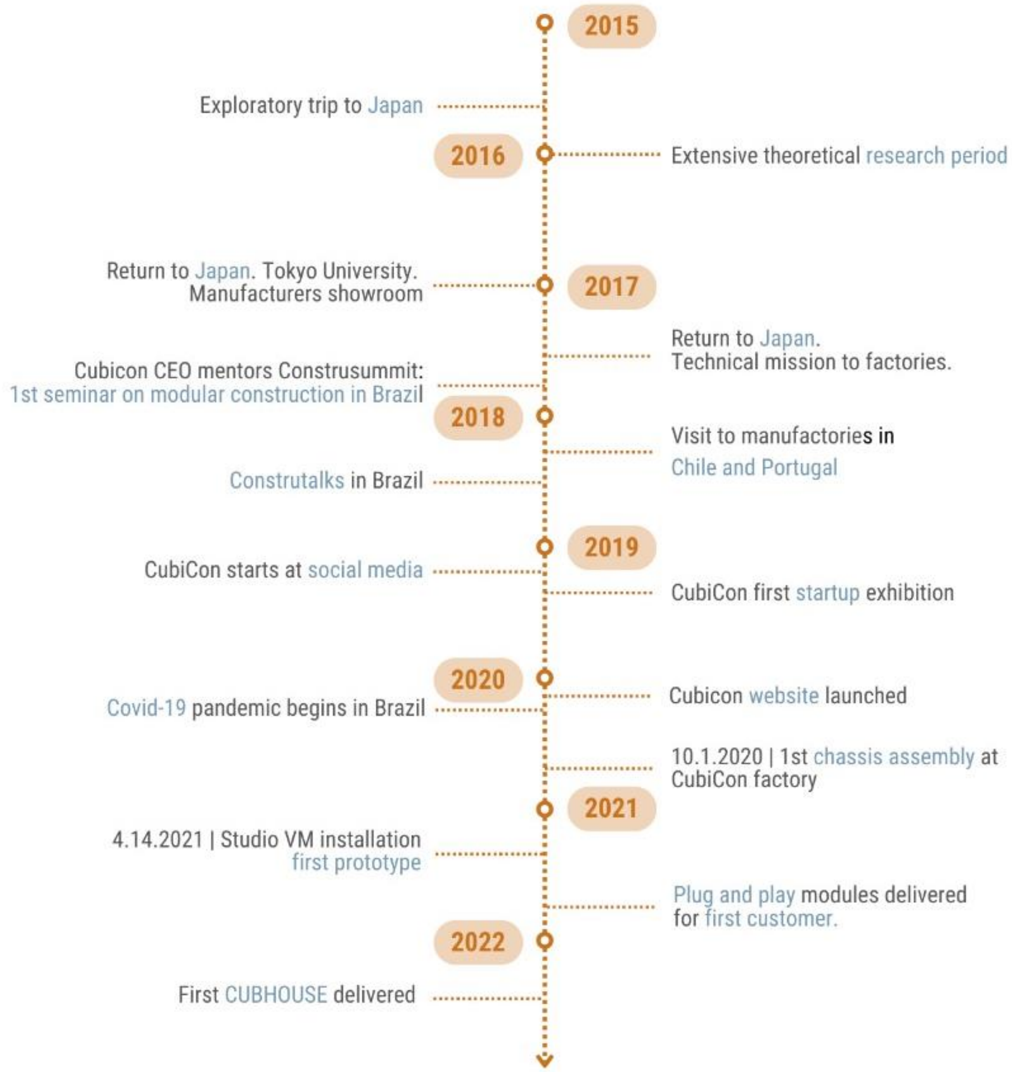

Figure 1. Timeline of CUBICON modular start-up company

RESULTS AND DISCUSSION

Lessons from Japan

A more careful historical search on modular construction will lead the reader to publications citing or exploring the Japanese modular construction. To the best of the authors' knowledge, no other country has advanced so much and for so long in the use of modular construction, particularly in single-family houses. The Japanese modular construction has evolved since the "Mizet House" was developed in 1959 by Daiwa House Industry (Noguchi, 2003). The major Japanese prefabricated housing manufacturers created their early housing products using a small team in a short-term timeframe while obtaining collaboration from architects, academics, and other prefabricated housing manufacturers (Matsumara et al., 2019). The technical visits carried out by first the author to Japan in 2015 and two times in 2017, plus extensive field and literature research overturned the three most significant paradigms of prefabricated construction: (standardisation versus customization, (ii) low quality versus high quality; (iii) low price versus high price as following:

Standardisation versus customization. The products, materials, and means of production for large-scale modular construction must be standardised to be viable. On the contrary, Japanese housing manufacturers generally work with customized projects. Customization meets customer preferences and involves project geometry, equipment, and finishes. In addition, the so-called invisible items such as structural elements, internal floor, wall, ceiling components, and mechanical, electrical, and plumbing (MEP) systems are standardized.

Low quality versus high quality. The Japanese modular houses have become a consumer's dream. They are much more comfortable regarding thermoacoustic performance and have several types of equipment that ordinary homes do not have. Companies such as PanaHome Corporation, Sekisui Hime, Hebel House, and Toyota Home Company equip homes with photovoltaic cell phones, air purification systems, electronic doors, and other devices that leverage product upgrades. These manufacturers are present throughout the country. Their products are showcased at model house exhibition parks. They offer premium products and are responsible for 20% of the single-family house market.

Low price versus higher price. Houses manufactured by companies in the segment known locally as “model houses” have a higher average price of 15 to 20% higher than traditional wooden houses in Japan built by small carpentry companies using the solution known as “post and beam”.

Business model development

The fundamental question asked before CubiCon® foundation was those basic ones for a small business: what to sell, to whom, and at what price? The business partners' lack of initial capital led to initially defining a market segment that would facilitate the practice of designing, manufacturing, marketing, and delivering modules.

Thus, it was decided to operate in the segment of country cottages and compact housing for rural land and multi-module residences. This stage of business model development was called Phase 1. However, to attract investors, it was necessary to think of a segment that would allow rapid growth and higher profit margins. Thus, in Phase 2, the organisation would explore the urban market with a strategy of undertaking small multifamily buildings with the participation of landowners. The quick delivery of the finished work allowed by a modular design would be the business driver. In Phase 3, the business would gain scale by multiplying these projects, first regionally, then across Brazil through a decentralized assembly manufacturing strategy and CubiCon® model supply chain. This system would become “the secret” to CubiCon®’s successful large-scale operation.

Materials and building system

CubiCon modules are built using steel and drywall materials and components such as gypsum and cement boards and Rockwool insulation. Both building structure ASTM type and light steel galvanized frame are used. Almost all types of finishing and covering materials can be used, including PCV and aluminium window frames and several kinds of floor and wall cladding as wood, ceramic, and painting. Figure 2 shows ten steps for assembling a steel structure chassis of a typical module. All connections are bolted to allow quick assembling in the factory. In Figure 3, the main parts of a typical CubiCon® module are shown.

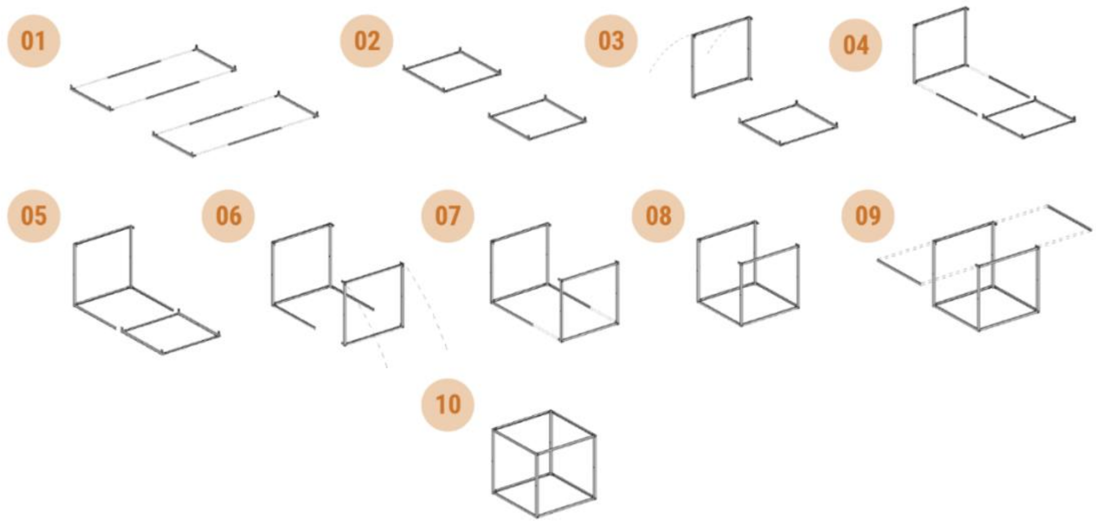

Figure 2. Structural chassis (framework) assemble process of a CubHouse®

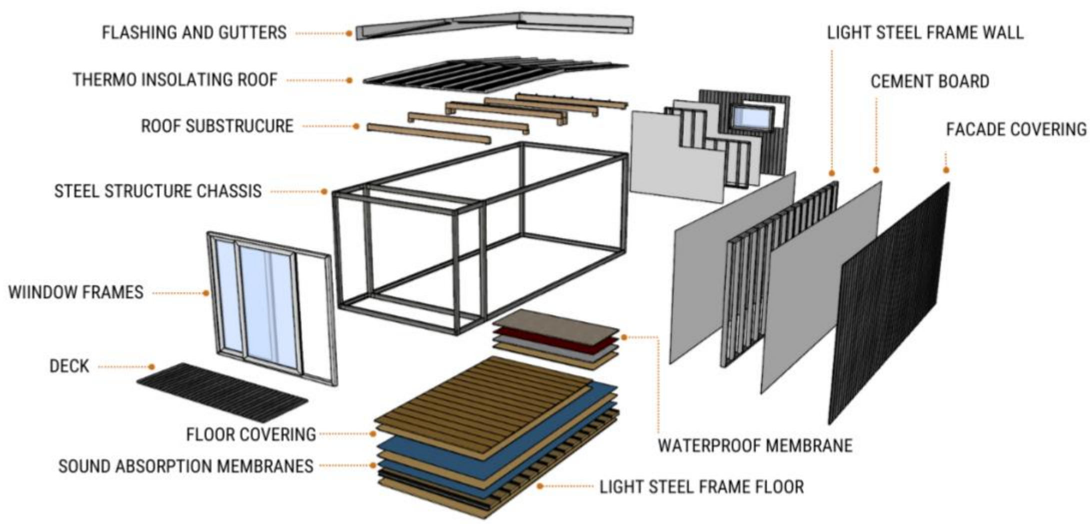

Figure 3. Parts of a CubiCon® residential module.

Product design for the Brazilian market

It is challenging to know whether the product created will sell at the price that will bring the minimum viable profit to establish the business. Therefore, the market segments for modular construction in Brazil were subjectively evaluated, and the following assumptions were reached:

- The organization was born with the know-how of its business partners for housing and accommodation market share.
- Existence of other companies operating in the segment of commercial and retailing.
- Ease of deployment first in small projects.
- Ease of implementation and project approval in more extensive and rural land.

In addition to not being served by the existing companies, the off-site residential segment was poorly done regarding product quality by container companies or other construction systems. So then, CubiCon® decided to create three types of products to test in the market: (i) The “plug and play” modules for lodging and country cottages, (ii) Multimodule houses (iii)Small urban buildings.

Business feasibility, production capacity, fixed cost, and sales price
In the first few months, the main challenge faced by CubiCon® was finding a balance between the selling price and fixed production capacity costs. That is, finding a safe answer to the following questions: 1. What is the minimum sales and production volume to pay all costs, fixed and variable, to bring profit to the organization? 2. Can the organization sell this minimum volume of products offered at this price to bring a minimum viable profit?
The organization's operation showed in practice that these are the most significant difficulties from a commercial and managerial point of view so far:

- Customer service and filtering to select the most potential customers.
- High fixed cost to maintain the project team, customer service, proposals and budgets, supplies, planning, production, logistics, implementation, and technical assistance.
- The relatively high selling price of the construction system involves greater steel consumption (structure, walls, floors, ceiling, and roof), use of floor and wall unique cement boards and membranes, transportation cost and lifting operations.
- Opening step values, materials specifications, and manufacturers' names for customers to enable direct billing without double taxation.
- Difficulty in entering into a commercial agreement to finance sales institutions.
- Need for minimal sales volume to sustain fixed costs and generate minimum acceptable profit – the current need is to produce at least 20 units of 41m^2 CubHouse® per year.
- Sales arguments based on comparative prices, quality, and performance offered against conventional construction products and other companies in the modules and dry construction segment.
- Process of purchasing materials and contracting services suitable for small unit volumes and production planning in the various specialities to maintain the sequence, deadlines, and quality of execution, notably from the assembly of the chassis with the frames of light steel profiles floor wall.
- Accounting framework for issuing invoices without encumbering charges and taxes.
- Elaboration of contracts, mainly regarding the warranty of materials used.

Table 2 shows the current challenges faced by Cubicon.

Table 2. Current challenges.

Design	Need to quickly and quality design all parts of the module and its constructive details on a BIM platform without impacting the expectations of deadlines for delivery, especially for projects that are outside the standard CUBHOUSE chassis structure.
	Availability of BIM designers.
	Dedicated time to checking the drawings and quantities for each project to be prepared to avoid errors.
	Construction detailing of the modules, notably concerning geometric precision in installing frames, coatings, and installations.

Table 2. Current challenges (continued)

Supply chain	Difficulty in implementing internal purchasing processes, contracting, and sequencing factory execution operations.
	Difficulty in hiring specialist labour to work with dry construction solutions and other parts of the execution on drywalls and floors.
	Lack of national supplies and fast delivery for items such as cement sheets, finishing materials, reinforcements for cement sheets, finishing siding-type facades, waterproofing sheets, and special adhesives.
Management	Direct involvement in practically all stages of execution and lack of focus on production management and control activities
Production	Complementation of the insulation and closing services of the lower part of the modules' floors at the construction site.
Logistics	Hiring and managing a provider of cargo transport and lifting services that offer safety at a competitive price.
	Difficulty in defining a safer and more economical scheme for the modules transport handling due to the lack of experience of the organization and service providers such as carriers and cranes.
	Difficulty preventing damage to flashings and facade cladding during lifting and transport.
	Difficulty in aligning the foundation anchors and module levelling.

CONCLUSION

The findings of this study have several implications for the future practice of start-up companies in the MC market. First, the study suggests that unlike traditional construction, which has fixed costs associated with a given project, a module factory must continue operating even between one project and another. Second, it takes time and practice on a smaller scale to be ready for multi-storey modular buildings or delivery of large projects, which are much more complex in technical and logistical terms. Third, lack of skilled professionals trained in modern building techniques applied to MC, especially in design detailing and manufacturing. Finally, although facades and finishes can be customized, standardization at certain levels is inevitable. Floor plans must also be the same to optimize costs for vertical buildings.

This study contributes to the further development of knowledge in MC and provides a basis for further research in Brazil and other Latin American countries. This research could also give some business leads for MC adoption. However, the generalisability of these results is subject to certain limitations. The application of the current study is limited to organizations operating in Brazil that have a similar size and maturity to the one studied. Future research can improve the generalization of this study by collecting additional data on MC organizations from Brazil and other Latin American countries.

REFERENCES

Assaad, R.H., El-adaway, I.H, Hastak, M. & Needy, K.L. (2022) Quantification of the State of Practice of Offsite Construction and Related Technologies: Current Trends and Future Prospects, *Journal of Construction Engineering and Management*, 148, 7, https://doi.org/10.1061/(ASCE)CO.1943-7862.0002302

Gibb, A., & Pendlebury, M. (2006). *Build offsite glossary of terms*. Report. London: Construction Industry Research & Information Association (CIRIA).

Hwang, B., Shan, M. & Looi, K. (2018). Key constraints and mitigation strategies for prefabricated prefinished volumetric construction, *Journal of Cleaner Production*, 183, 183-193, https://doi.org/10.1016/j.jclepro.2018.02.136

Iacovidou, E., Purnell, P., Tsavdaridis, K.D. & Poologanathan, K. (2021). Digitally enabled modular construction for promoting modular components reuse: A UK view, *Journal of Building Engineering*, 42, https://doi.org/10.1016/j.jobe.2021.102820

Klein, H. K., & Myers, M. D. (1999). A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. *MIS Quarterly*, 23(1), 67-93, https://doi.org/10.2307/249410

Lawson, M., Ogden, R. & Goodier, C. (2014). *Design in Modular Construction*. CRC Press.

Matsumura, S.; Gondo, T.; Sato, K.; Morita, Y. & Eguchi, T. (2019) Technological developments of Japanese prefabricated housing in an early stage. *Japan Architectural Review*, 2(1), 52-61. https://doi.org/10.1002/2475-8876.12064

Nam, S., Yoon, J., Kim, K., & Choi, B. (2020). Optimization of Prefabricated Components in Housing Modular Construction. *Sustainability*, 12(24), 10269. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su122410269

Noguchi, M. (2003). The effect of the quality-oriented production approach on the delivery of prefabricated homes in Japan. *Journal of Housing and the Built Environment*, 18, 353–364. https://doi.org/10.1023/B:JOHO.0000005759.07212.00

Pan, W. & Hon, C.K. (2020). Modular integrated construction for high-rise buildings. *Proceedings of the Institution of Civil Engineers - Municipal Engineer*, 173, 2, 64-68. https://doi.org/10.1680/jmuen.18.00028

Rausch, C., Edwards, C., & Haas, C. (2020). Benchmarking and Improving Dimensional Quality on Modular Construction Projects – A Case Study. *International Journal of Industrialized Construction*, 1(1), 2–21. https://doi.org/10.29173/ijic212

Shin, J, Moon, S., Cho, B., Hwang, S. & Choi, B. (2022). Extended technology acceptance model to explain the mechanism of modular construction adoption, *Journal of Cleaner Production*, 342, https://doi.org/10.1016/j.jclepro.2022.130963

Walsham, G. (1995). Interpretive Case Studies in Is Research: Nature and Method, *European Journal of Information Systems*, 4(2), 74-81, https://doi.org/10.1057/ejis.1995.9

Wuni, I.Y & Shen, G.Q. (2020). Barriers to the adoption of modular integrated construction: Systematic review and meta-analysis, integrated conceptual framework, and strategies, *Journal of Cleaner Production*, 249, https://doi.org/10.1016/j.jclepro.2019.119347

Yin, R. K. (1994). *Case study research*: Design and methods. Thousand Oaks, CA: Sage.