MODULAR CONSTRUCTION

AN IMPORTANT ALTERNATIVE APPROACH FOR NEW HOTEL DEVELOPMENT PROJECTS

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Abstract: The construction industry, especially for new hotels, faces steadily increasing pressure to improve productivity and reduce environmental impacts. This paper explores these pressures and examines whether modular and prefabricated construction approaches and technologies can help achieve the desired goals. Modular construction is explained and its potential benefits and risks regarding new hotel construction are considered through references to relevant literature and anecdotal evidence. We conclude that modular construction has considerable promise, but it necessitates substantial rethinking and changes to the practices traditionally adopted in new hotel development. Moreover, in the author's view, while modular construction can be an important contributor but is not a complete solution to more quickly and efficiently building better hotels that are more sustainable. It must be complemented by other changes to traditional hotel development methods.

In Noordzy and Whitfield's previously published conception of the new hotel development life cycle, adopting modular construction methods mostly impacts the Delivery Stage, while leaving the Conception and Operations Stages largely untouched. Compared to the Delivery Stage for a traditionally built new hotel, adopting modular construction specifically necessitates considerably expanding "up-front" design efforts and substantially changing the contractual and working relationships between the developer, architect, interior designer, construction contractor, sub-contractors and specialist consultants. At the same time, it greatly reduces the hotel pre-opening team's traditional involvement (and workload) in the fit-out and final acceptance testing of the finished property.

Keywords: Project Management, New Hotel Development, Project Life Cycle, Hotel Openings, Hotel Management, Hospitality Management, Asset Management, Modular Construction, Sustainability.

1. INTRODUCTION

According Noordzy and Whitfield (2021), the overall life cycle of a hotel proceeds through three major stages. To begin the market and local situation is analyzed to conceptualize the kind of hotel that could most profitably satisfy the local demand and to decide whether building and operating it would be a worthwhile investment. If the project is deemed to be viable, the second stage is to actually develop the property and make it ready for business operations. The final (longest) stage is to operate and maintain the hotel for many years until it is finally disposed of.

Currently, hotels are mostly built using traditional construction methods whereby manpower, machinery and materials are assembled at the building site and the workforce uses the machinery and materials to construct the facilities in situ. On completion of the construction project the waste materials and machinery are removed from the site and the workforce is disbanded. Modular construction seems to be emerging as a new alternative construction approach for building new hotels. In modular construction (Jones & Laquidara-Carr, 2020) a building is made in sections in a factory while the foundations are prepared at the site where the building is to be located. The building sections are then transported to the site and assembled onto the foundations using cranes. The building sections may be flat wall, floor and/or ceiling panels that are assembled like making a house of cards. Alternatively, they may be volumetric boxes that can be arranged and stacked like shipping containers. Any particular building may be composed of a mixture of panels and volumes as needed.

Traditional construction is a large global industry facing many challenges, and hotel construction is an important sector within it. Hotel construction (and the broader industry) is plagued by poor labour safety and productivity, increasing labour scarcity, dysfunctional building regulation inconsistencies, a fragmented industry structure and conflicts of interest between architects, builders, asset owners and operators (Bertram et al., 2019). Many of these problems nearly always lead to large building project cost overruns and severe delays in building completion. Traditional hotel construction also generates a lot of site wastes that are increasingly frowned upon. Moreover, subsequent hotel operations are increasingly being criticized for excessive power and water consumption and waste generation, along with other sustainability issues.

Various experts believe that adopting modular construction concepts and techniques can resolve many of the above-identified problems with traditional construction. From the literature (Hardiman, 2008), (Lawson et al., 2012), it is clear that modular construction can greatly improve industry safety and productivity, help eliminate labour scarcity problems and improve project budget and timeline compliance. However, it does not fix conflicts of interest between project stakeholders (Hendrick-son, 1998) or building regulation disparities (Velamati, 2012). Similarly, by itself, modular construction does not rectify many of the environmental sustainability issues facing the industry.

According to a recent McKinsey study (Bertram et al., 2019) modular construction "can speed construction by as much as 50% and in the right environments and with the right trade-offs it can cut ("development") costs by 20%." The shorter project du-ration with modular construction lowers financing costs because the asset starts generating positive operational cashflows much sooner, so that even if there are no development cost savings it is still the better construction method.

It must be noted however that the methods and techniques of modular construction are focused entirely on how the proposed facilities are built, and the design of the facilities is taken as a "given", perhaps with some flexibility to simplify the manufacture of the building modules. For hotels, modular construction methods and techniques do not per se consider whether the property as designed is the best and potentially the most profitable for the local situation. Nor do they consider the ongoing electrical power and water consumption, waste generation and disposal and other sustainability issues related to the subsequent operations of the hotel.

The McKinsey study (Bertram et al., 2019) underlines that not all modularization is the same and that modular construction has its challenges (Modular Deluxe, 2019). In addition, this same report identifies seven factors that should be considered when determining whether modular construction should be considered in a given location, namely: regulatory conditions, access to materials, quality perception, supply chain and logistics conditions, local site constraints, labour availability and construction demand.

Given its undoubted promise, our goal with this paper is to see how modular construction considerations can be woven into the hotel asset lifecycle and the development of new hotels. We do this to judge whether the promises of modular construction can be realized for new hotel development projects and whether it provides a complete solution for the problems facing the industry.

2. CONSTRUCTION INDUSTRY CHALLENGES

The global construction industry, including new hotel development, is experiencing several widely recognized problems as follows. These are progressively getting acuter and leading to ever poorer industry performance.

2.1 Productivity. Construction accounts for 13+% of global output. It is highly cyclical and around 90% of infrastructure projects around the world are completed late and over budget (Whitfield, 2017-8-13). Furthermore, construction labour productivity growth has not kept pace with productivity growth in other industries. For example, in the USA construction productivity is now only half of what it was in the 1960s, and is only a quarter as productive as USA based manufacturing (Anon, 2017). These productivity problems are mostly attributed to industry fragmentation and social discounting of the value of construction trades, leading to an aging workforce and worker scarcity. The large numbers of small businesses in the construction industry adds to the administrative layers and greatly limits investment in equipment and training to improve productivity. In addition, the labour intensive nature of the industry leads to shedding workers during downturns and many leave the industry during such times, never to return.

2.2 Labour scarcity. Increasingly, the construction industry is challenged by a scarcity of skilled labour which is also unwilling to relocate. For example, from personal experience, the authors know that it is currently very difficult to find qualified masons, tilers, plumbers, electricians and carpenters outside of the islands of Java and Bali in Indonesia. At the same time, skilled laborers from these two islands are very reluctant to relocate and live in migrant labour compounds for extended periods for new hotel construction projects in other islands. Similarly, the authors know that in China it is challenging to find skilled construction labour willing to move to Ti-bet or Yunnan, despite the country's large mobile workforce. The main reason is unwillingness to work at higher altitudes, which causes Acute Mountain Sickness (AMS) or altitude sickness. Similarly, other countries are dealing with a reducing workforce or government restrictions on non-resident labour. In the Western world relevant stakeholders complain that general society and education systems encourage young people to enter white-collar employment, while trade training is often denigrated as a "second class" career.

2.3 Differing building standards. Another major construction industry problem is varying building standards. For example, in the USA there are 93,000 municipalities, each with their own somewhat different construction regulations and standards. In addition, the industry as a whole is very conservative so that various construction regulations limit new, innovative building design and construction methods. While adopting modular construction methods cannot eliminate building regulation inconsistencies by itself, it does open the door for broad scale review of construction regulatory frameworks, especially if industry sectors (like hospitality) can advocate for change.

2.4 Conflicts of interest. The objectives of key stakeholders across various phases of the project life cycle for new hotels are not aligned, leading to inherent conflicts of interest. The efforts of architectural and interior design firms mostly focus on the aesthetics of the design, and not necessarily on the ongoing operational efficiencies and costs. Main contractors focus on constructing buildings cost-effectively, using traditional methods, without too much consideration for property operations, maintenance and energy costs (POMEC). The hotel owner, asset manager and operator on the other hand are best served by high operating efficiencies.

For example, building insulation somewhat adds to material and construction costs but greatly reduces later operational heating and cooling costs. If the building code is inadequate the contractor may short-cut to save construction cost, while the building owner will subsequently incur higher utility costs. Because they do not share in the operational benefits, architects, interior designers and construction companies have little incentive to include insulation in their buildings (Whitfield, 2017-8-27).

2.5 Carbon footprint. Buildings create massive environmental impact. The steel, concrete and glass from which they are mostly made, are responsible for over 14% of global carbon emissions. In addition, buildings consume around 40% of the electricity generated around the world. Many concerned parties are calling for major reductions in the carbon intensity embodied in buildings and their construction (Whit-field, 2019-1-23). Various studies have also shown that buildings are often extensively over-engineered and use much more steel and concrete than is actually necessary for their structural integrity (Debusmann, 2021). Finally, in addition to the substantial embodied costs, proper disposal of building construction wastes is becoming a major problem in many localities.

Hotels account for a substantial and growing part of all construction activity. At the time of publication, the global development pipeline stands at around 14,000 new hotel projects that incorporate over 2.31 million rooms (Lodging Econometrics, 2021).

2.6 Utilities. Hotels are relatively heavy consumers of energy and water. Based on benchmarking data for 2018 (Ricaurte & Jagarajan, 2019), **Table 1** shows the approximate median energy and water consumption per occupied hotel room per year in five different countries. Most interestingly, both the energy and water consumption in hotels vary markedly by location, where hotels in developed countries seem to operate much more efficiently on a per occupied room basis.

It should be noted that the worst-performing hotels often consume double the energy of the best-performing ones because of inadequate design and operating practices. Similarly, water consumption in less efficient hotels is equally high which is becoming more of a global problem as water shortages are becoming common in many parts of the world. Hotels significantly contribute to over-stressing the water supplies in many cities and islands (Kim et al., 2013).

2.7 Waste. Hotels generate a substantial amount of waste during construction, subsequent operations and during their eventual decommissioning and disposal. These include construction debris, sewerage, food and other material wastes, rainwater runoff, etc. Like utilities, waste processing infrastructure is often inadequate in various parts of the world, and new hotels can significantly overload existing facilities.

2.8 Lack of understanding combining all of the above issues, there are ever in-creasing building construction problems in many parts of the world. The litany of late, over-budget construction projects is also very well-known and widespread. Previous research has shown that new hotel construction delays and cost overruns are endemic (Noordzy & Whitfield, 2015), so hotel developments are experiencing a multitude of industry-wide problems.

The participants of the above-mentioned recent survey on modular construction identified a lack of understanding and information about modular construction among building owners and construction professionals as a key issue leading to indifference and resistance to its adoption (Jones & Laquidara-Carr, 2020). Furthermore, factories able to professionally make quality building modules are few and far between. The authors of this paper have also identified lack of knowledge and expertise to a.) adopting project management concepts and b.) including sustainability issues in hotel design and construction projects as major impediments (Jones & Laquidara-Carr, 2020).

According to Marriott International, "the construction process in North America has not changed significantly in the last 150 years and is ripe for innovation" (Brenner, 2019). Fortunately, many industry experts cite the growing industry adoption and experience with new modular and prefabricated construction methods as the way forward (Bertram et al., 2019).

In the rest of this paper the authors will explore this belief to understand what these new approaches to building construction are and their potential benefits and risks as they relate to the hotel industry.

3. EXPLAINING MODULAR AND PREFABRICATED CONSTRUCTION

Historically, each building is a unique design that is built entirely in situ, i.e., labour and equipment are brought to the site along with all the materials needed and this work team then constructs the finished property in place. Nonetheless, some of the furniture, fixtures, and equipment (FF&E) may be made elsewhere, then moved to the site and installed. By contrast, in modular construction (Jones & Laquidara-Carr, 2020) a building is made in pieces in a factory while the foundations are prepared at the site where the building is to be located. The building pieces are then transported to the site and assembled onto the foundations using cranes. The building pieces may be flat wall, floor and/or ceiling panels or volumetric boxes (that usually include fittings and furniture)

Table 01: Median Annual Energy and Water Consumption

Country	Energy kWh (median)		Water L (median)	
	POR	PSM	POR	PSM
United States	50.14	235.60	430.15	1,958.73
China	130.06	206.99	1,205.64	1,944.44
Indonesia	89.93	200.54	851.43	2,377.00
Germany	51.06	200.67	248.99	1,449.37
United Kindom	52.25	261.28	307.22	1,704.23

Source: Greenview LLC. (2020). Cornell Hospitality Sustainability Benchmark.

According to Buildoffsite's glossary of terms, (Gibb & Pendlebury, 2018) offsite is "a term used to describe the spectrum of applications where buildings, structures or parts are manufactured and assembled remote from the building site prior to installation in their final position." This means that construction processes and activities that are traditionally completed onsite are moved to a manufacturing environment. The spectrum of work that can now be done off-site is "extensive, and currently, the sector is diverse and fragmented," but it may be categorized, (Gibb, 1999) as outlined below.

- **Modular construction** (volumetric). A construction method where the building components are in a self-supporting structure that has a (part) finished room inside. This system is formally known as Prefabricated Prefinished Volumetric Construction (PPVC). The modular frames can be made from several materials, including:
  - Steel (e.g., citizenM and the extension of Crowne Plaza Changi Airport).
  - Reinforced concrete (to date, no hotel examples, only apartments).

- **Prefabricated construction** (panels). A construction method whereby (Building & Construction Authority, 2017) panels, columns or sections of partially completed buildings are pre-made and then erected onsite to form the volume of the structure. Examples include:
  - Precast Concrete Panels.
  - Structural Integrated Panels (SIPs).
  - Prefabricated Mass Engineered Timber (MET) Panels:
    - Cross Laminated Timber (CLT).
    - Glue Laminated Timber (GLULAM)

- **Combination**. It is possible to utilize different construction methodologies in parallel, for example:
  - Option 1: Prefabricated guest room (flatpack) + volumetric bathroom pod, (e.g., POP! Hotels), or
  - Option 2: Traditional or fabricated podium + modular or prefabricated guest rooms.

Non-structural prefabricated panels, for internal partition walls and building facades for example, have been used in construction for many years and their benefits are widely recognized. More recently, the use of non-structural and structural volumetric elements and frames has become more popular, especially for bathroom pods and shipping containers fitted out as rooms. The benefits of offsite manufacturing are more limited for non-structural panels and frames in multi-story buildings because the building skeleton must still be made in-situ from steel or reinforced concrete at the construction site. New technologies, especially MET, are starting to be seen for multi- and single-storey buildings whereby structural panels and PPVC frames are made in factories and assembled onsite to make the building skeleton and its entire internal and external structure. As noted later, in this respect MET is particularly important because wood is a beautiful, lightweight, renewable, carbon-neutral construction material. Furthermore, the glue-laminated nature of these wooden materials means that they are structurally safe and fire-resistant for large multi-story buildings. In 2019, the tallest MET building in the world was the 18 story, mixed-use Mjøstårnet building in Norway, (Block, 2019) which includes the Wood Hotel.

Among several other benefits (to be discussed in more detail later) pre-making building elements off-site in a factory means that work can continue irrespective of outdoor weather conditions. Economies of scale and other manufacturing efficiencies can be implemented to reduce wastes and improve labour productivity. Because its cost can be amortized over several building projects building module manufacturing factories can also invest in semi-automated production machinery to greatly raise labour productivity. Significantly, factories have stable, permanent and well-trained multi-skilled workforces, so that the administrative and quality control problems of the typical plethora of small, single trade subcontractors seen on traditional construction sites can be largely avoided. Moreover, and very importantly, work done off-site can proceed in parallel with onsite activities to significantly reduce the overall construction project duration.

4. HISTORY

The first record of a modular building appeared in the South Australian Record in 1837, in an advertisement for the Manning Portable Cottage (Herbert, 1972). Henry Manning, a carpenter, designed and built the components for these cottages in London and shipped them to Australia. As well as small modular homes, Manning's company also built the 1,000-bed Renkoio Hospital in Turkey during the Crimean War, the biggest modular construction project of the 19th century (Aries Building Systems, 2017).

The first hotel ever to be constructed using this system was the Hilton Palacio del Rio Hotel in San Antonio, Texas, a modularly constructed 21-story building complet-ed in 1968.

Zachry Construction designed, constructed, and occupied this 500-room deluxe hotel in an unprecedented period of just 202 working days (Modular Building Institute, 2007). While the support facilities occupying the first four stories and the elevator and utility core were built of traditional reinforced concrete onsite, room and other steel-framed building modules were made in a nearby factory and hoisted into place using a large crane. The modules, each measuring approximately 10 meters long, 4 meters wide, and weighing 35 tons, were fully fitted-out and equipped before leaving the factory and all, including the 21st floor ballroom, were welded into place in just 46 days. Three years later, the Walt Disney World Resort launched its Magic Kingdom with two resorts, both modularly constructed (Disney Parks Blog, 2017).

More recently, the fully prefabricated 243 guest room extension of the Crowne Plaza Singapore Changi was built using Prefabricated Prefinished Volumetric Construction (Whitfield et al., 2021-01), (Dragages Singapore, 2017). The room modules were designed, manufactured using reinforced steel and fitted out in a factory in China, then shipped to Singapore and installed in just 17 months (from design development, prototype, modular manufacturing, logistics). Stacking of the 10 floors took 6 weeks, followed by 3 months to finish corridors, public areas and facade to ribbon cutting, with the bulk of the installation activities moved off-site to a factory-controlled environment (Dragages, 2021).

Currently, the world's tallest modular hotel is the 252-room ibis Styles East Perth, an 18-floor hotel, which opened in September 2019 (Lennon, 2019). Also, the AC Hotel New York NoMad on the corner of 30th Street and 6th Avenue in Manhattan was originally expected to open late 2020 (Marriott International, 2019), (Danny Forster & Architecture, 2020), (Murray Engineering, 2020). Once completed, it will be the world's tallest modular hotel at 26 storeys and will cost an estimated US$65 million. The hotel's basement and public areas are being constructed using traditional methods. At the same time the 168 prefabricated, fully outfitted, equipped and decorated guest rooms weighing 35 tonnes each, as well as the roof and rooftop bar modules have been manufactured in a factory in Poland. Upon completion, the individual guest rooms were shipped to New York and stored. They will be wheeled from the port to their final destination on flatbed trucks at night (to avoid traffic congestion) and stacked into place using a construction crane able to reach the full 110m building height. It is claimed that the final assembly process will only take three months onsite.

The pioneer of using modular construction for chain hotels is citizenM, a Nether-lands-based hotel chain, which opened its first hotel at Amsterdam Schiphol Airport in 2008 (Krzykowski, 2008), (Cheshire, 2012), (Lin, 2014). Several other international hotel companies have since become early adopters of modular construction for some of their lower-tier brands. These include Moxy Hotels (PrefabLogic, 2019), Holiday Inn Express (Schouten, 2017), Hampton by Hilton (Pedraza, 2017), Rama-da Inn (The Revelstoke Current, 2016), Travelodge (Alter, 2008), and Pod (Lubell, 2018).

It is important to understand that franchisors and third-party hotel operators typically do not invest in hospitality real estate. Usually, it is a local developer and franchisee that funds the design, construction and fit-out of each individual hotel asset. Thus, if modular construction is to be more widely adopted, many independent hotel developers will need to be educated and convinced of the benefits, as well as hotel management companies.

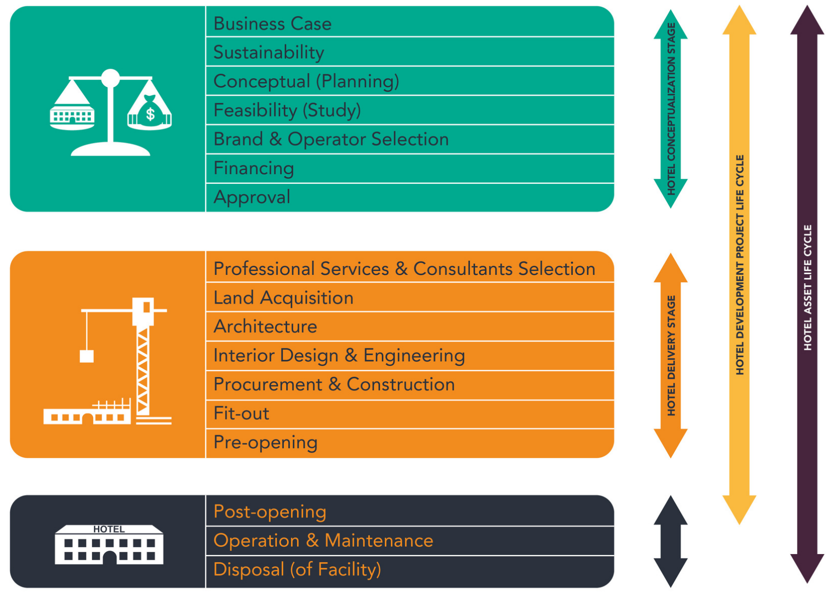
5. THE IMPACT OF MODULAR CONSTRUCTION ON THE HOTEL DEVELOPMENT PROJECT LIFE CYCLE

The complete hotel asset life cycle has been described in **Figure 1**. As can be seen, it is divided into three stages – conceptualization, delivery and operations. Hotel operation typically has the longest duration of all phases in the hotel asset life cycle and only finishes when the asset is eventually sold or otherwise disposed of (Noor-dzy & Whitfield, 2021) but is not part of the actual project to develop the property.

5.1 Conceptualization stage.

The first stage in the life of a hotel is where it is conceptualized. First, the business need for a new hotel in the proposed location is assessed to determine if the market environment will support an additional hotel. Then, the most suitable hotel concept with the highest probability of being financially and environmentally viable over its long working life is defined. Feasibility determines the viability of the investment, based on the anticipated budget for the total cost of development, projected cash-flows from operations and expected long-term returns on investment to determine the viability of the investment, as well as how it might compare to alternative uses of funds. Options for branding and operators are evaluated. This stage finishes when a decision is made to proceed with the project, based on economic viability, available funding for the totality of the project, and internal and external approvals.

Figure 1: Hotel Asset Life Cycle



Source: Adapted from Noordzy, G. and Whitfield, R. (2020).

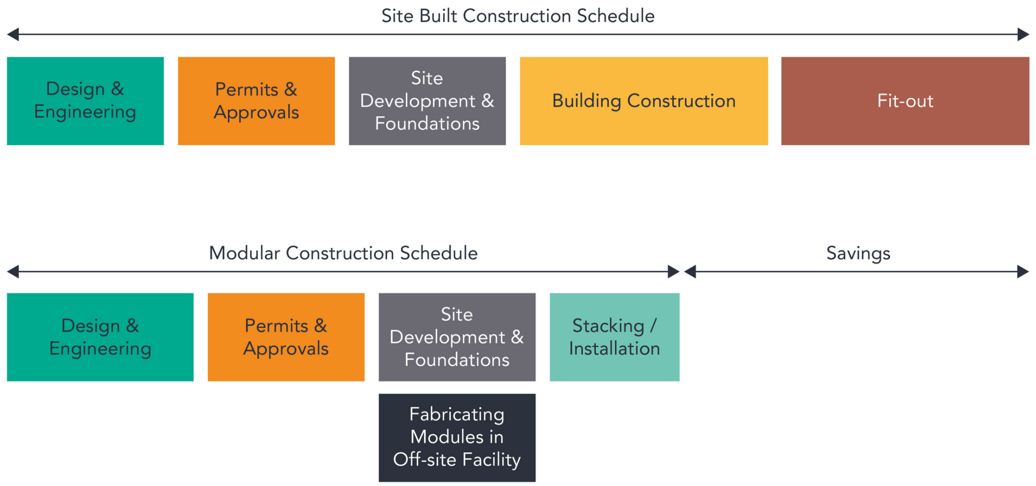
Several novel factors need to be added to this analysis if modular construction of the hotel is to be considered as an alternative method for delivering the property.

- Traditional construction. The availability of local construction expertise drives the decision to build a particular hotel in a specific location. Ergo, if suitable construction materials, equipment and adequate labour cannot be sourced locally at an economically viable cost, the new hotel simply cannot be built.
- Modular construction. The hotel modules may need to be transported considerable distances over land and/or sea. Large cranes may be needed to stack modules to make the hotel. For example, the modules for the AC Hotel New York NoMad were transported by land from a factory in Poland to a port in Germany, where they were loaded onto ships. Upon arrival in the Port of New York, the modules were unloaded and stored, after which they will be lifted onto flatbed trailers and transported by road through heavy traffic to Manhattan. Finally, cranes will be used to lift modules into place up to 110m in the air (Brenner, 2019). The equation therefore changes to considering:
  - **a.** whether economically viable hotel modules can be reliably and cost-effectively transported from the factory to the hotel location,
  - **b.** whether cranes are available locally, and can be transported, offloaded and raised, and
  - **c.** whether (a reduced quantity of) semi-skilled labour is available to assemble and finish the hotel.

These additional concerns must be folded into the analysis of what kind of hotel should be built and whether it can be built at a cost such that its subsequent operations will be profitable. Thus, considering modular construction expands the workload in the Conceptualization Stage. Nonetheless, this increased conceptualization cost is a relatively small part of the overall budget to develop a new hotel. Moreover, this additional "upfront" work will substantially reduce the risk of design changes, and time and cost overruns during the subsequent Delivery Stage. It may also significantly reduce the opportunity cost of the venture by opening the completed hotel much sooner.

5.2 Delivery stage. The second stage is where the hotel is actually designed, government approvals to build and operate it are obtained, and the structure is built and fitted out. In the last phase, the pre-opening team prepares the facilities for occupancy by paying guests (e.g., recruitment and training of the operating staff, etc.) and commencing operation of the property. **Figure 2** shows how applying the

Figure 2: Site Built vs. Modular Construction Schedule



Source: Adapted from Saliot, G. (2020).

concepts of modular construction affects the design, construction and fit-out process, and the time saving created for setting up the hotel to begin accepting paying guests.

5.2.1 Interior Design & Engineering. In traditional construction, detailed interior design work may start only after construction permits have been obtained and site development has commenced. Due to construction dependencies, fitting out rooms, front- and back-of-house areas cannot start until the shell and core have been completed. Unfortunately, this "slack" can lead to design changes during construction, and is often a major contributing factor to building cost overruns and construction delays.
However, in modular construction the detailed interior design work must be completed before construction (and fit-out) of the modules starts, in parallel with site preparation works. Finalizing the architectural and interior design phases is therefore a mandatory dependency for awarding the manufacturing and site preparation contracts. Two major advantages are that a.) the manufacturing scope and budget can be tuned and finalized before any major amounts of money have been spent, and b.) the work can proceed in a tightly controlled way with minimal changes and disruptions. Architectural and interior design work is relatively inexpensive and represents a small percentage of the total project budget.

5.2.2 Procurement & Construction. In traditional construction the main contractor is responsible for coordinating the work of various specialized subcontractors. These change as construction progresses. It is common practice to pay them based on completing milestones. This requires effort to verify satisfactory completion of work and process payments. Then, as the detailed design work progresses, problems are identified, and change orders are costed and negotiated. In addition, subcontractors often work on multiple buildings and may have schedule conflicts that lead to delays.

The chaotic nature of traditional construction makes the endemic schedule delays and budget overruns quite understandable. By contrast, the design work for modular construction is fully completed at the beginning of the project. At this point, qualified manufacturers are requested to submit detailed pricing, module delivery and installation schedules and payment milestones. From the developer's perspective there are no subcontractors and only a few larger payments. The developer can setup cameras and deploy quality controllers at the factory to monitor progress in terms of scope, schedule, and quality, and invoke contractual penalty clauses for deviations.

5.2.3 Fit-out. In traditional construction, the Fixtures, Furniture and Equipment (FF&E) can be ordered once the detailed designs and mock-up room have been approved. Delivery and installation can begin once the building has been topped off. Hotel Operating Equipment and Supplies (HOES) are ordered in parallel with the fit-out phase by the hotel pre-opening team or procurement agent.

Once installation has been completed and defects have been rectified, the building will be handed over from the contractor to the hotel pre-opening team. In the pre-opening phase, the latter will then clean the premises, setup all guest rooms, conduct in-situ training and simulation exercises to ensure the building is ready to welcome paying guests. By contrast, in modular construction, the vendors will deliver all guestroom FF&E and HOES to the factory for fit-out, cleaning and set-up by the manufacturer.

5.2.4 Pre-opening. In terms of pre-opening processes, there is fundamentally no difference between traditional and modular construction, except for the HOES delivery and defect rectifications; these mainly take place at the factory. One of the main advantages for the pre-opening team is increased certainty and predictability regarding the project completion date. This enables the pre-opening team to make informed decisions regarding staff recruitment and onboarding, start of sales & marketing activities, including pre-selling. Common financial consequences of construction delays pertain to furloughing staff, and repeating recruitment, training, and sales & marketing activities. These become very expensive and potentially cause pre-opening budget to overrun by approximately one-third (Noordzy, 2020).

5.3 Operations and disposal

Finally, whether a hotel has been modularly constructed or not has little direct impact on its ongoing operations. However, it can be significant when the hotel is eventually demolished, as building demolition normally results in large amounts of construction waste. With modular hotels, disassembly and removal can be much quicker and cleaner, by reversing the assembly process. Moreover, it is quite feasible to refurbish modules and re-use them in another location. This opens possibilities for "temporary" hotels that can be quickly erected for relatively short periods, then disassembled and moved to other locations. Accor's "Flying Nest" mobile hotel concept takes advantage of this idea (Martins, 2018).

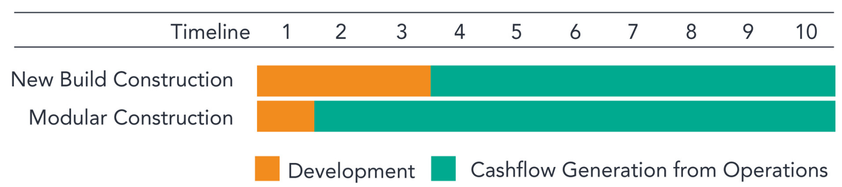
6. THE MEASURABLE ADVANTAGES OF ADOPTING MODULAR CONSTRUCTION FOR HOTELS

A recent online survey (Jones & Laquidara-Carr, 2020) of 608 experienced construction industry professionals (architects, construction engineers, general and trade contractors, and modular builders) found that over 80% of respondents agreed that modular construction:

- significantly improved construction safety, productivity and quality,
- led to more predictable and reliable project schedules,
- reduced construction waste (especially onsite), and
- increased client satisfaction.

Moreover, many respondents further agreed that modular construction reduced costs and project durations. It should be noted that reducing construction project du-rations may reduce direct labour costs in specific countries. More important, it reduces the potentially large opportunity costs associated with building an income producing asset like a hotel. Every added day of construction is a day when a hotel cannot serve paying guests, while still bearing financing, payroll & related and other operating costs. Please refer to **Figure 3**. This is especially important when hotels are built on fixed term, leasehold land, which is the normal practice in some countries, such as the People's Republic of China and Republic of Maldives.

Figure 3: Total Asset Life Cycle



Source: Adapted from Noordzy, G. (2017).

Anecdotally, traditional construction sites are clearly very often dirty and chaotic, and are exposed to the elements. At the same time, they can be littered with waste offcuts from standard materials delivered to site. Moving a substantial part of this work off-site increases safety and reduces waste by pre-cutting materials in a factory. In addition, production lines and other manufacturing techniques can be used to improve labour productivity, while considerable work can be done by machinery which cannot feasibly be set up at an open-air construction site. Factories can also take advantage of economies of scale, especially if they expand to concurrently make modules for several buildings.

Another major advantage of modular construction is that site preparation work and factory production of building modules can proceed in parallel. By contrast, traditional construction is subject to mandatory dependencies: site preparation precedes (room) constructions, which precedes (room) fit-out. The inherent parallelism in modular construction significantly reduces the overall construction project duration. Subsequently, because the building is made from pre-fabricated modules that are simply placed into position by crane onsite, the work onsite can be completed faster and with less manpower, thereby contributing to reducing project duration.

The above mentioned recent survey also found that modular construction approaches are most applicable (in descending order) to healthcare facilities, hotels and motels, apartment buildings, college and school buildings, student dormitories and low rise offices. It is self-evident that buildings with repeated similar room types and other facilities can benefit most from offsite module manufacturing and economies of scale.

In parallel, global climate change, spiraling construction costs and dwindling resources (The Guardian, 2008) have prompted governments in Singapore and China to issue new legislation to promote prefabricated construction to improve productivity (Building & Construction Authority, 2014), (The State Council, 2016). Similarly, regional housing crises in the United Kingdom (Gardiner, 2017), Sweden (The Lo-cal, 2015) and Australia (Hutchinson, 2015) are forcing local governments to think and act "outside of the box" and (re)consider modular housing. Thus, many experts clearly believe modular construction holds considerable promise for the construction industry (Gibb, 1999).

These are just some of the purported benefits of adopting modular construction concepts and techniques. Here, the authors analyze the potential benefits of modu-lar construction by systematically considering their impact on each of the well-known project management knowledge areas. As defined by the Project Management Institute, a knowledge area is an identified aspect of project management defined by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools and techniques. It is the knowledge within the profession of project management that is generally recognized as good practice, and applied to most projects in most countries most of the time (Project Management Institute, 2017). In addition to the general project management knowledge areas, there are construction-specific knowledge areas (Project Management Institute, 2016). **Table 2** and **Table 3** examine each of these knowledge areas to highlight specific benefits that may be realized by adopting modular construction concepts, especially for new hotel projects.

7. ENVIRONMENTAL IMPACT OF MODULAR CONSTRUCTION

Logically, environmental impacts occur at three distinct times during the life of a building, i.e., during its (1) construction, (2) ongoing operations and (3) end of working life demolition. Generally, the literature on modular construction focuses almost exclusively on the initial construction of a building, but it in the authors' view, should also consider its eventual demolition. The available literature generally assumes that environmental impacts related to building operations are handled during the design of the building, which is a "given" when deciding how to modularly implement the specified design.

Thus, the choice to use traditional or modular construction methods and techniques does not per se affect the operational environmental impact of the resulting building and is not assumed in this paper. The implication is that if a new hotel is not designed to minimize its operational energy and water consumption, and the wastes it produces, adopting modular construction methods would just help the developer make an inefficient hotel asset faster and possibly at a lower cost.

This section is an exploratory analysis on the effect of the use of modular construction pertaining to environmental impact of new hospitality real estate coming online, including carbon footprint implications.

As mentioned, at the time of publication the global development pipeline stands at around 14,000 new hotel projects comprising 2.31 million rooms (Lodging Econo-metrics, 2021). Previous studies have indicated the large industry-wide aggregate opportunity to conserve resources if future hotels are developed to operate more efficiently (Noordzy et al., 2016), (Ricaurte & Jagarajan, 2019).

Table 02: Modular Construction - Impact on Project Management Knowledge Areas

Knowledge Area	Predictability / Advantages
Project Integration Management	The current status quo for new hotel developments is one of interdependent, but non-integrated phases, whereby owner-ap-pointed, but separate entities design, build, open, and operate each new hotel. In the case of modular construction, the module manufacturer could assume the role of Project Management Office, to "identify, define, combine, unify and coordinate the various processes and project management activities within the Project Management Process Groups" (Project Management Institute, 2017).
Project Scope Management	One major issues in traditional hotel construction is upward and downward scope creep. Causes include: • Inadequate financing at the get-go. • Disjointed change control processes. • Personal preferences of the developer. • Influence and interference by family members and friends of the developer. Modular construction will greatly reduce financially and emotionally driven scope changes by ensuring adherence to the signed-off designs and mock-up rooms.
Project Time Management	Modular built hotels are completed faster by up to 70% (depending on country) compared to in-situ construction. The main differentiator is that manufacturing of modular units can occur simultaneously with site and foundation works. In addition, mod-ularly built hotels are less prone to delays caused by inclement weather. A 100-room modular build hotel can be manufactured and opened in less than 12 months, versus 2-3 years for a conventionally constructed hotel. Based on past work experience, this reduces time to market and opportunity costs greatly, as outlined in Figure 3.
Project Cost Management	Modular buildings are built to the same building codes and standards as site built structures, but cost can be up to 10-15% lower (depending on country) than comparative in-situ buildings. The main reason is that factory production line processes eliminate time wastage on task duplication, increase worker efficiency and reduce labour costs. Professional fees are reduced due to simplified design and repetition. A study by KPMG on offsite manufacturing indicates that "there are financial benefits of applying offsite manufacturing at the project level: additional revenue and savings from inflation and interest on borrowings were found as a consequence of the shorter build programme, equating to a 7% cost saving against traditional construction" (KPMG, 2016).
Project Quality Management	According to the PMBOK® Guide, the Cost of Quality (COQ) (Project Management Institute, 2017) includes "all costs incurred over the life of the product by investment in preventing non-conformance to requirements, appraising the product or service for conformance to requirements, and failing to meet requirements (rework). Failure costs are often categorized into internal (found by the project) and external (found by the customer)". Modules are built under cover in a controlled environment, improving quality control over materials, products and workmanship. Consistency in deliverables is ensured by performing Quality Assurance and approving each module before it leaves the fac-tory (Manley, 2015). The client could have (independent) "eyes" in the factory as well, and sign off after final testing. A 2005 re-search study found that "77% of all contractor respondents recognized the increased quality of offsite products. This improved quality lowers the failure rate of the assets, thereby improving predictability and reducing the quantum of asset maintenance costs" (Goodier & Gibb, 2005), (Goodier & Gibb, 2007). When modules are locked together and sealed, the modules become one integrated wall, floor and roof assembly which are generally stronger structurally than traditional in-situ construction. Modular buildings are engineered to withstand any extreme weather conditions including earthquakes. Greater control over compliance of the building also increases overall safety. There have been a number of documented cases of poorly manufactured modular hotels (in terms of process). These include two hotel examples from Great Britain (Bernstein, 2008), where one modular hotel had "bouncy" floors, and the other had to be demolished after 3 years because of poor build quality (Noordzy, 2017). There have been other instances of manufacturers changing building module designs to reduce costs, but at the expense of build quality (Midler, 2009).
Project Human Resources Management	Modular construction reduces the dependency on contractors and migrant workers by moving much construction work into factory environments. This allows for the development of a more reliable, permanent workforce, with relevant experience and training. Factory-based modular construction teams enable hotel development in areas that experience a shortage of skilled labour and craftsmen. At the same time, it should recognized that factories making building modules must invest in production equipment to improve productivity and quality.
Project Communications Management	The dispersed off-site manufacturing of building modules and accelerated onsite building assembly work requires: • More and better coordinated, up-front design efforts than traditional construction. • More coordination and requires detailed design information to be available to all stakeholders much earlier in the project. These communication and coordination requirements between different project stakeholders make the use of sophisticated Project Management Information Systems (PMIS) and Building Information Management (BIM) software mandatory. Their use greatly improves and systematizes project communications. The participants to the above-mentioned survey concluded that if the whole project team and all relevant stakeholders do not use dedicated shared software it is very difficult to achieve the touted benefits of modular construction.
Project Risk Management	Besides risks of schedule delays, cost overruns and scope creep, traditional hotel construction projects usually suffer from various other negative risks. These include risks of accidents, theft, damage and weather. Manufacturing off site in a facto-ry-controlled environment allows for improved safety, and better control of inventory (waste / leakage). It also protects building materials from the elements, reducing moisture damage. Modules arrive on site locked-up, thereby reducing the possibility of theft and damage. At a corporate level, it allows project developers and hotel companies to improve hotel opening forecasting.
Project Procurement Management	In modular construction the manufacturer assumes the role of Centralized Procurement Agent, thereby reducing the number of supply lines and vendor relationships. This approach equally results in less delivery traffic and on-site storage space for con-struction materials, Fixtures, Furniture & Equipment (FF&E), and Hotel Operating Equipment & Supplies (HOES). Preselected vendors can streamline the process and reduce the overall timeframe of the procurement process.
Project Stakeholder Management	Modular construction reduces on-site traffic from workers, equipment and suppliers, reduces the negative impact on surround-ing residents, businesses and traffic, in terms of noise, dust, debris and congestion. The neighbourhood will only experience activity for a period of maximum 4 months during civil works and complexing. To illustrate, a 100-room modular hotel could be stacked and completed in 7 days.

Source: Adapted from Project Management Body of Knowledge, 6th edition. (2017).

Modular construction may be an approach to lessen impacts and improve efficiency, with further study and data.

Traditionally, the most significant environmental impacts studies of hotels have been on their operational impact, namely energy and water usage, waste generation and disposal, and carbon emissions. Few studies have been conducted – and even fewer hotel companies have disclosed quantitative data – regarding the impacts associated with design and construction of new hotels. The effect of modular hotel construction on hotel environmental impacts requires analysis across the hotel as-set life cycle. Life Cycle Assessment (LCA) studies of hotels have identified the impacts of the operational or “use phase” of a hotel, as compared to the upstream phases of building it, and the downstream phases of demolishing or repurposing it. In terms of energy usage and carbon emissions, the estimated percentage of a hotel's environmental footprint in the operational phase varies by study, with a general range of 40% to 85% (Ylmén et al., 2019) (Earth Guest Research, 2011), (UNEP, 2016) of the LCA footprint of carbon emissions. This suggests that 15% to 60% of the footprint is not quantified, pointing toward a larger footprint that the hospitality industry will need to address.

If the lens of environmental impacts for modular construction is expanded, the authors decided that the following 4 key areas should be analyzed:

7.1 Impacts from the amount and type of materials used for core and shell. LCA studies show that the majority of the carbon footprint in construction is attributed to steel and concrete, which constitute approximately 32% and 20% respectively (Ylmén et al., 2019). Modular construction has seen examples of reduction in steel and concrete used by approximately 35% and 36% respectively (Junnila, 2004). In addition, as mentioned earlier, the ability to use sustainable wood as a structural element in modular construction further enables the potential for reducing environmental impacts.

7.2 Land use change and associated impacts during construction. Particularly for sensitive sites situated in remote areas or smaller island destinations, modular construction can reduce the amount of space needed to construct the hotel (Whit-field et al., 2021-02), (Whitfield et al., 2021-03), (Whitfield et al., 2021-04). This includes materials storage, preparation and staging areas, housing for workers, and other logistical structures that could be reduced. The impacts are not only important to evaluate from the amount of land that may be needed, but also three important downstream effects:

- Waste management,
- Acidification, and
- Eutrophication.

Table 03: Modular Construction - Impact on Construction Management Knowledge Areas

Knowledge Area	Predictability / Advantages
Project Health, Safety, Security, and Environmental (HSSE) Management	Reduced on-site activity affords a cleaner worksite with fewer disruptions, resulting in increased worker safety. Additionally, the site will see less debris and stored materials, less construction traffic, and safer installation practices. At the same time, moving components of the construction off-site improves safety for various stakeholders, including the contractors' employees, supply chain partners, and the general public (Jackson, 2014).
Project Environmental Management	Modular is a lean construction method engineered to cut out any construction waste. When building offsite in a factory environ-ment, waste is eliminated by recycling materials and controlling inventory. Because of reduced on-site activity, a much smaller staging area is needed, thereby reducing the environmental impact on the areas surrounding the building site. Modular buildings have higher thermal ratings due to the wall design and products used in insulating each module. Acoustic ratings are also greater due to use of air gaps in walls and design and the materials used in floors and ceilings. Another great advantage of modular buildings is locational flexibility. At the end of the land lease agreement, a modular hotel can be simply disconnected and disassembled, and the modules stored or relocated or refurbished for new use. This reduces the demand for raw materials and minimizes the amount of energy expended to create a building to meet the new need. The aforementioned Mass Engineering Timber can be produced from replanted forests, for example pine and other fast-grow-ing varieties. One species used is Spruce Douglas (grade strength > C24 or 90% by EN 338) (Ridley-Ellis, 2016). Overall, modular hotel construction supports the United Nations sustainable development goals (2017) in terms of innovation and sustainable cities.
Project Financial Management	One common problem is for new hotel projects to run out of funding before completion. Causes include project approval without securing full financing, inaccurate total budgeting, diversion of project funding and corruption. Once financial institutions understand the easier and more transparent cost control with modular construction, funding of mod-ular hotel projects should be preferred to more traditional in-situ hotel construction. For example, placing funding in escrow accounts enhances control. At the same time, funding costs are reduced as the end-product is brought to market quicker, thereby reducing the investment payback period, as outlined in Figure 3. Research and analysis by KPMG on offsite manufacturing indicates that “there are financial benefits of applying offsite manu-facturing at the project level; additional revenue and savings from inflation and interest on borrowing were found as a conse-quence of the shorter building program, equating to a 7% project cost saving against traditional construction.”(KPMG, 2016).
Project Claims Management	In modular construction, design work is completed much earlier and module manufacturing does not begin until the whole building design is settled. Thus, there are far fewer design changes during the project which greatly reduces the quantity and value of change orders thus improving project budget compliance and predictability.

Source: Adapted from Construction Extension to the PMBOK ® Guide. (2005).

Adopting modular construction can reduce onsite construction waste by up to 60% for steel and 56% for concrete (Jiang et al., 2019).This reduces both impacts from sourcing materials, and the need to haul them off site and the use of landfill or incineration for disposal by up to 70% (Navaratnam et al., 2019). One case study suggests a 90% reduction in waste generation (Brooks, 2021).

A building’s contribution to ocean acidification from its piping and HVAC equipment, as well as decay of concrete can also be reduced with less and more environmentally friendly materials. One study suggests that modular construction can mitigate the impact of acidification and eutrophication of the oceans (Ylmén et al., 20219).

7.3 Impacts from transportation of materials. Even though modular construction involves the manufacture of the building further away from the site and subsequent transportation of materials, studies have shown that modular construction can reduce the total number of deliveries to site by 90% (Wilson, 2019). LCA studies have shown construction materials transport to only account for 2% of the total carbon footprint of a building (Ylmén et al., 2019) . Yet with a potential 90% reduction, this is the area that collectively could have a large benefit from increased use of modular construction. A trade-off may occur between the opportunity to source materials locally, which have a lower footprint of transportation. However, this may be counter-balanced with the scalability and efficiency of sourcing materials centrally for several buildings, and also avoiding the risk of traceability for ensuring materials and products have been properly sourced.

7.4 Impacts from decommissioning, demolition, and reuse. Demolition of a building has been shown to be less than 1% of the total carbon emissions (Ylmén et al., 2019). However, this area presents perhaps the biggest opportunity for reducing environmental impact. Modular construction enables more repurposing of building materials for subsequent reuse in new buildings. As mentioned earlier, this represents one of the biggest impacts, particularly the use of concrete and steel.

One study estimated that 81% of the embodied energy of a building can be reduced through material reutilization (Aye et al., 2012). Modular construction could play a large role, as the real estate, lodging, travel, and construction industries of also need to seek circular economy solutions.

A previous study by Noordzy et al. estimates the aggregate potential reductions in carbon emissions from more efficient operations in China’s new hotel pipeline. One can add in some of the LCA considerations to a similar analysis with these assumptions of an average modular construction project compared to a typical project:

1. 400 room, 300,000 square foot hotel with average annual GHG emissions of 9 kgCO2e per square foot, assuming a 20 year service life with the operational footprint of the building over 20 years constituting 70% of the total LCA carbon footprint.
2. Reduction in design and construction from less use of concrete and steel in core and shell: 25% less than a conventionally built hotel.
3. Transportation of materials: 50% less than a conventionally built hotel.
4. Assembly of the hotel: 20% less than a conventionally built hotel.
5. The financial benefits of modular construction are used to make choices for increased efficiency of major capital equipment of chillers, boilers, and air handling, for a 20% more efficient building.
6. Ongoing waste generation from the hotel unaffected, but eventual renovation, refurbishment, or conversion, or decommissioning of the hotel affords a 10% reduction in other buildings as materials can be repurposed.

The results in **Table 4** and **Table 5** show the scenario for a modular construction scenario to reduce total LCA emissions of the building by 20%.

The authors intend to prepare an initial study/exploration of this subject in a subsequent study.

8. HURDLES FOR IMPLEMENTATION

City hotels and leisure resorts require different construction solutions. City hotels meet the challenge of building vertically, as these assets must go up, due to the cost of land. Leisure resorts meet the challenge of building in remote locations. In other words, modular construction is not a one-size-fits-all solution, and the authors acknowledge that there are social and other challenges to making modular construction mainstream as outlined below in alphabetical order. This list is based on interviews with modular construction manufacturers in China, Indonesia, Singapore and Australia.

Table 04 - Percentage Reduction Potential for Modular Construction

Building Properties		Conventional Construction Method GHG Emission Percentage Breakdown		Percentage Reduction Potential for Modular Construction	
		Life Cycle Stage	Percentage	Life Cycle Stage	Percentage
Service Life of Building	20	Production	41.0%	Production	25.0%
Square Footage	300,000	Operation	50.0%	Efficiency	15.0%
Annual GHG Emissions Per SqFt	9	Waste Management	5.5%	Waste Management	0.0%
Total Annual GHG Emissions	2,700,000	Transportation	2.2%	Transportation	50.0%
Number of Rooms	400	Assembly	0.8%	Assembly	20.0%
Total Operational Footprint (kgCO2e)	54,000,000	Demolition	0.5%	Demolition	10.0%

Source: Adapted from cited sources above.

Table 05 - GHG Emissions Calculator

GHG Emissions Calculator (kgCO2e)			
Life Cycle Stage	Conventional Construction	Modular Construction	% GHG Reduction
Production	44,280,000	33,210,000	25.0%
Operation	54,000,000	45,900,000	20.0%
Waste Management	5,940,000	5,940,000	0.0%
Transportation	2,376,000	2,197,800	7.5%
Assembly	864,000	691,200	20.0%
Demolition	540,000	486,000	10.0%
Total	108,000,000	88,425,000	18%

Source: Adapted from cited sources above.

- **Fear of change**. The development of modular and prefabricated construction requires significant changes in the habits of the various stakeholders involved in design and construction. The construction industry, like the hospitality industry, is very conservative, and as a result gets defensive of the status quo when new ideas are introduced (Hardiman, 2014). People generally do not like change. In addition, modular construction raises conflicts of interest between stakeholders, including the architects and interior designers, builders, financial institutions and hotel chains. It tends to reduce the level of control and involvement of, and dependence on these stakeholders, and diminishing the importance of their contribution. Modular construction also disallows/reduces the opportunity for "creaming off" project and construction budgets so that the current beneficiaries of such corrupt practices will resist industry changes. All this may explain why until now the use of modular construction has been limited to mostly independent development companies. These were established based on a business case rooted in the use of modular construction and the development of a new hotel brand around it (e.g., citizenM).

- **Job displacement**. Modular construction moves the process into a factory, thereby increasing (local) factory employment and materials supply chain opportunities, but displacing (local) construction jobs where the hotels are actually to be located. In addition, it puts interior designers and contractors located near to the hotel (mostly) out of work. However, one can now argue, post COVID-19, that a high reliance onsite resident workers, often living in close proximity is not acceptable, thus generating a further shift towards the offsite paradigm.

- **Lack of module manufacturing capacity and capability**. Expertise and production facilities for modular hotel construction are few and far between. This means that new hotel developers are sometimes unable to use these ideas even when they want to. This is very much a "chicken and egg" problem. Therefore, a concerted effort is needed by large hotel groups to increase the capacity and capabilities of the industry so that they can take advantage of the considerable benefits of modular hotel construction going forward.

- **Lack of module transportation capacity and capability**. Factories manufacturing modules will need to be close to transport links. Sea and land transportation can be costly and complex:
  - **Sea transportation**. Modular manufacturing and full assembly in a factory far from the hotel site may require significant and complex pro-fessional logistics to cover regional and intercontinental distances. For example, the authors earlier noted that the modules of a New York ho-tel were manufactured in a factory in Poland and transported by cargo ship to New York. The cost of sea freight is subject to highly variable oil and shipping costs. In addition, modules diverging from international shipping container dimensions may incur additional charges. Finally, there are import duties to consider.
  - **Land transportation**. The cost of logistics to transport modules from port to site may only make economic sense if the site is within a specific, viable radius. In addition, modules exceeding specific measurements and weights may require a police escort and circuitous routing to avoid obstacles (overhead powerlines, railway crossings, low underpasses, power sharp corners, heavy traffic, etc.,) during transportation, incurring further costs.

This explains why it is important to manufacture building modules nearer to hotel sites for effective and efficient production and transportation. To reduce dependency on, and costs and complexities related to logistics, and to facilitate development of modular hotels on industrial scale, it is essential to establish modular manufacturing units in proximity to regions with substantial new hotel development pipelines.

- **Misunderstandings and misconceptions**. Modular construction is relatively unknown in the industry, especially among hoteliers and the other stakeholders involved in developing hotels. Moreover, when the term is known it is often misunderstood (Hudson, 2019). As a consequence, these important and useful ideas are too often dismissed. A strong awareness building campaign is needed for the whole industry, especially when it comes to developing new hotels.
- **Permitting**. While modular construction is faster, there is uncertainty in terms of the complexity and duration of the construction permit application process in different local jurisdictions. Local building authorities may lack experience in processing modular construction applications. In addition, in certain jurisdictions, the application for modular buildings may not fall under the municipal building code and the process for regional permitting may be lengthy and immature.

- **Price Volatility**. Scarcity and the high cost of skilled labour in Western Australia in the early 2010s encouraged local developers to use modular solutions to build hotels. Leading Chinese modular construction companies established representative offices in Perth in order to import modular hotel rooms by sea from China to Perth.
  - The cost of Chinese labour increased significantly from 2015/2016, thereby substantially increasing the production cost of Chinese modular hotel units.
  - Simultaneously, relatively sudden oil price increases also resulted in a very significant increase in the cost of maritime transportation from China to Perth.

These two events abruptly stopped the use in Western Australia. This is a global problem and concern.

- **Size and scope constraints**. In the experience of one author (Saliot, 2020), modular construction is an especially effective, proven method for Economy, Midscale and Upper Midscale hotels with smaller guest rooms (less than 40 m2). Larger modules run into especially difficult logistical and installation challenges, sometimes making them cost prohibitive.

9. CONCLUSIONS

Clearly, the construction industry in general, and new hotel construction in particular is facing many challenges. Low productivity, weak project cost and schedule control, inadequate consideration of life cycle costs and fundamental conflicts of interest between property owners, and the architects and construction companies that design and build their properties. All these challenges lead to the development of suboptimal properties that are wasteful and unsustainable. The sooner that the hospitality industry fundamentally rethinks and changes the ways in which new hotels are developed, and subsequently operated and maintained the better for the future of the hospitality industry. Greater use of the concepts of modular hotel construction shows great promise in improving new hotel development, but it is only one piece of the puzzle, albeit an important one. The authors strongly believe that practitioners also need to consider the entire hotel asset life cycle in an integrated way so that all stakeholders can have a coherent shared 360 degree view of each hotel venture in its entirety from inception to final disposal. This holistic view of the venture must ensure asset life cycle efficiency and sustainability is thoroughly considered.

It is only once the hospitality industry has a complete and coherent idea of the entire venture with strong and clear lines of communication between all stakeholders that it can effectively apply modular construction concepts to predictably and efficiently design, construct and open a new hotel in minimum time and at minimum life cycle cost. This is not normally considered to be within the purview of established modular construction concepts and methods.

Modular construction is an important piece of the puzzle for improving new hotel development. It has been practiced to a limited extent for many years, so why is it not used more widely? There seem to be several issues that explain the limited adoption of modular construction for new hotels thus far, as the authors have outlined in this report. These must be overcome if new hotel development is to significantly improve, as it must.

APPENDIX A: TERMINOLOGY

Construction, and modular construction in particular, uses important terminology that is quite unfamiliar to most hoteliers. Therefore, the authors include a dictionary of important terms here. The following definitions are mainly promulgated by Web-finance, Dictionary of Construction (WebFinance, 2017).

Full modular. Entire guestrooms are assembled off-site and installed on-site. Every element of the room can be pre-fabricated and replicated including the walls, windows, carpet, fixtures, accessories and even the artwork on the walls. This is particularly helpful for hotels looking to emulate their portfolio properties and adhere to brand standards.

In situ. Descriptive of work accomplished on the site rather than in prefabrication elsewhere, as in cast-in-place concrete.

Modular buildings. Sectional prefabricated buildings or houses that consist of multiple sections called modules. “Modular” is a method of construction differing from other methods of building. The module sections are constructed at an off-site (sometimes, remote) facility, then delivered to the intended site of use. Complete construction of the prefabricated sections are completed on site. The prefabricated sections are set onto the building’s foundation and joined together to make a single building. The modules can be placed side-by-side, end-to-end, or stacked, allowing a wide variety of configurations and styles in the building layout.

Modular construction. Construction in which similar units or subcomponents are combined repeatedly to create a total system or a construction system in which large prefabricated units are combined to create a finished structure.

Partial modular. Portions of a guest room, like a bathroom, are assembled as a pod. The pod is then placed into the traditionally constructed building guestrooms with all electrical, plumbing and mechanical connections.

Precast concrete. Concrete structural components, such as piles, wall panels, beams, etc., fabricated at a location other than in-place. Precast concrete is a construction product produced by casting concrete in a reusable mold or “form” which is then cured in a controlled environment, transported to the construction site and lifted into place. In contrast, standard concrete is poured into site-specific forms and cured on site.

Prefabricated construction. The practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.

Prefabricated Prefinished Volumetric Construction (PPVC). A construction method whereby free-standing volumetric modules (complete with finishes for walls, floors and ceilings) are either constructed and assembled; or manufactured and assembled, in an accredited fabrication facility, in accordance with any accredited fabrication method, and then installed in a building under building works (Building & Construction Authority, 2021).

Slip forming. An on-site process that involves moving the formwork as the concrete is poured, simultaneously consolidating and finishing it in a continuous or near-continuous operation.

System kits. Electrical, plumbing and mechanical systems are manufactured off-site and kitted. For example, a guest room electrical panel system is made with the required electrical panel and wiring runs to make all connections. Each kit is labeled for a specific guestroom, so it meets all requirements.

Unitized building. The UB System is a building structural system that breaks up high-rise residential and hotel construction projects into transportable units, which are manufactured in a quality-controlled factory environment, then craned into position onsite (Arney, Fender, Katsilidis, 2017).

Unitized construction. Construction through pre-assembled rectangular panels (Ochshorn, 2015).

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Gert Noordzy, The Chinese University of Hong Kong

Gert Noordzy is an international hotelier, acknowledged hotel opening process maven and Organizational Project Management expert for the hospitality industry. He graduated from Hanze College Hotel Management School in Zwolle, the Netherlands, and holds an MBA from the University of Saint Joseph in Macau, China, with majors in strategic management and marketing, as well as financial and business analysis.

He has over 25 years of professional experience in Greater China and South East Asia and has been involved in opening over 30 new hotels and 3 integrated resorts. For 15 years, he worked for 3 of the 10 largest global hotel companies and has held corporate roles specializing in hotel openings and project management since 2006.

Gert first started researching hotel opening processes in 2008 and is the author of Project Management of Hotel Opening Processes, which has been translated into 11 languages. He has been working on his follow-up book as part of his studies for a doctorate in business administration.

His personal objective is to help the hotel industry transform itself and embrace project management as a strategic competence. He is a lecturer and an avid blogger on the subject for HOTELSMag.com. Gert is Managing Director of Northside Consulting, a boutique firm specializing in the tactical and strategic aspects of hotel opening processes.

Richard Whitfield is president of the East-West Institute for Advanced Studies. He has been a professor at several universities in South East Asia and Macau. Richard's undergraduate and doctoral degrees are in manufacturing from the University of Melbourne, Australia. One of the MBA classes he teaches is Process and Technology Management.

Whitfield has 10 years IT consulting and computer software development; 14 years university teaching at post-graduate level; 8 years academic management and business management consulting; 8 years experience running substantial companies in China, Hong Kong and Macau.

Gérard Saliot has more than 35 years of experience in international trade business and project development management in the tourism, hospitality and leisure industry.

Gérard is the founder (1996) and CEO of Euro Asia Management Group, which offers project development services for tourism, hospitality and leisure estate projects.

In 2014, Gérard established HMD (Hotel Modular Development) to design, engineer and fabrication of modular solution for the hospitality industry. He has been involved in the development of various modular and prefabricated resort projects in Asia Pacific, including the Meridian Adventure Dive Resort in Raja Ampat (West Papua, Indonesia), which opened in 2018.

in 2017, Gerard signed a business development agreement with Venturer Pte Ltd, a Singapore based firm founded by Kevin Hill, specialised in Prefabricated Mass Engineering Timber (MET) construction, the term used for timber panels, colons or sections of partially completed buildings off-site which are erected on-site to form the volume of the structure – Cross Laminated Timber (CLT) and Glue Laminated Timber (Glulam).

Gérard and Gert Noordzy a breakout session on modular construction at HICAP Hong Kong in 2017. He is based in Singapore.

Eric Ricaurte, Greenview founder

Eric founded Greenview in 2008, an international consultancy catalyzing innovation and best practice in sustainability and ESG, providing services for strategy, programs, data management, benchmarking, and reporting. Greenview's clients include most of the largest hotel companies as well as hotel owners and developers, event organizers, cruise lines, NGOs, DMOs, OTAs and industry organizations including the WTTC and UNWTO.

With 20 years of hands-on experience, Eric is a frequent speaker, convener, and researcher on the topic of sustainability. His notable industry work includes launching the Cornell Hotel Sustainability Benchmarking Index, Green Lodging Trends Re-port, Destination Water Risk Index, Hotel Global Decarbonisation Report, and Hotel Owners for Tomorrow Coalition. Eric is a member of the UFI Committee on Sustainable Development and the International Standards Working Group of the Global Sustainable Tourism Council. Prior to founding Greenview, Eric specialized in the operations and development of nature-based lodges, theme parks and attractions in Costa Rica, Mexico, and Brazil.

Eric earned a Bachelor of Science degree from the Cornell University School of Hotel Administration and a Master of Science degree in Tourism & Travel Management from New York University. He has held a research fellowship at the Cornell University Center for Hospitality Research and been an adjunct instructor at New York Uni-versity.

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