RELOCATABLE MODULAR BUILDINGS FOR A SHORT-TERM INTERNATIONAL EVENT: THE PYEONG-CHANG WINTER OLYMPIC GAMES

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ABSTRACT

Modular methods based on the use of prefabricated structures are increasingly popular for construction projects as they contribute to sustainability by reducing waste and maintenance costs as well as improving time efficiency. For short-term international events, the use of relocatable modular buildings is a potential solution to the problem of "White Elephant" structures built specially for the events that serve no useful purpose once the event is over. This paper focuses on a representative relocatable modular project created for the 2018 Winter Olympic Games in South Korea using a single case study approach to develop an in-depth understanding of the advantages and disadvantages of relocatable modular construction from a practitioner's perspective and examine how this approach supports sustainability and the Olympic legacy. Important considerations are identified for each of the five main stages: 1) planning, 2) design and engineering, 3) manufacturing, 4) construction and 5) disassembly and reconstruction. These findings show how the use of relocatable modular facilities can be a useful approach for international events.

KEYWORDS

Relocatable Building, Modular Construction, Prefabrication, Sustainability, International Event, Case Study

1. INTRODUCTION

Modular prefabrication methods for building construction have become increasingly popular in many countries in recent years (Carriker & Langar, 2014; De La Torre, 1994) because these systems support the principals of sustainability by reducing waste and improving both energy cost and time efficiency (Aye, Ngo, Crawford, Gammampila & Mendis, 2012; Kamali, Hewage

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& Milani, 2018). The modular building is defined as a whole building consisting of room-sized volumetric units that are fully prefabricated at an off-site factory, and they are designed to be both the structure and fabric of the building. (Lawson, 2012; Gibb, 1999; Goodier & Gibb 2007). There are two main types of modular buildings, namely permanent and relocatable, based on the mobility of the building over the course of its life cycle. Since relocatable modular construction methods allow a structure to be utilized in one place and then recycled by moving it to another site once its original purpose has been accomplished (Lawson, Ogden Ray & Bergin, 2012), relocatable modular units are gradually becoming more common for construction projects that need a fast response for building supply and demand. According to the Modular Building Institute (MBI), the relocatable market value in North America alone amounts to about $6 billion each year (Basu, 2012). There are already over 550,000 code compliant relocatable buildings in use in North America, of which 300,000 are relocatable classrooms and 250,000 are relocatable buildings that are being utilized for various business occupancies (Basu, 2012). Other applications of relocatable modular buildings are being explored and this method has been proposed as a possible solution to the problem of "White Elephant" structures constructed for international events such as the Olympics and the World Cup that have no obvious subsequent function. Once the events are over, sustainable building targets can be achieved by disassembling the modular units and recycling them for alternative uses (Chen, 2015). Although there have been a number of studies proposing pre- and post-utilization plans for the facilities during the preparation stage of international events (Boukas, Ziakas & Boustras, 2013; Roult & Lefebvre, 2010; Searle, 2002), there are still fundamental problems in that the buildings are permanently in existence afterwards, requiring costly maintenance, unless they are dismantled. For example, research has shown that Olympic facilities can cost three times more than planned, in spite of careful planning for post-Olympic events (Roult & Lefebvre, 2010). For this reason, it is becoming clear that sustainable plans for the post-utilization of facilities are vital if the host cities are not to incur substantial long term economic losses due to the need to prevent the deterioration of neglected facilities and both small and large scale infra-structure elements (Chen, 2015; Panagiotopoulou, 2014; Searle, 2002). In this study, we therefore propose a relocatable modular construction method to solve the "White Elephant" problem, supported by a case study of the 2018 Winter Olympics, in order to develop an in-depth understanding of the advantages and drawbacks of this approach.

A relocatable modular hotel that was designed, manufactured and supplied for the 2018 Pyeong-Chang Olympic Games in South Korea was analyzed for this study as a representative relocatable modular project. The Pyeong-Chang modular Residence Hotel was constructed using a steel modular system to facilitate the system assembly and subsequent disassembly for the building relocation. The modular hotel was designed based on standard modularity and assembly principals with the objective being to retain the possibility of moving the structure to another site after its first temporary purpose was accomplished. The in-depth understanding achieved of the critical considerations involved in applying relocatable modular construction methods for this project enabled us to develop more effective strategies for supplying accommodation units for future international events. The purpose of this study was thus to explore the representative case carefully and use our findings to identify the factors that must be considered at each stage of the project, from planning to disassembly and recycling. The results of this study provide useful guidelines for the application of modular methods for future international events like the Olympic Games to reduce waste and unnecessary post-event expenditure and support sustainability.

2. LITERATURE REVIEW

2.1 Modular construction

The term "modular construction" is used to describe the process where a building is constructed of modules that are prefabricated off-site at a factory, delivered to the site, and then assembled usually with a crane (Goodier & Gibb 2007, Shaba 2014, Rahman 2014). The term "prefabrication" implies that the component parts of a building traditionally assembled at the building site are instead assembled in an off-site factory in modules as large as possible but small enough to be shipped to the site and lifted by a crane (Zhao & Riffat, 2007; Taylor, 2010). Unlike the term "prefabricated method," the term "modular method" applies only to the assembly of a building with modules fabricated off-site.

Modular methods are driving many of the improvements in construction productivity in the building industry due to the benefits gained in terms of reducing the duration of projects, saving costs and boosting assembly quality that are made possible by utilizing off-site construction in a remote factory (Gibb & Isack, 2003; Lu & Liska, 2008). Because most of the components for modular buildings are manufactured in the factory, this approach also supports sustainable production by saving resources and reducing waste (Lawson, Ogden, Pedreschi, Grubb & Popo-Ola, 2005). In the factory, the modular units and their individual components can be manufactured and semi-assembled before being transported to the site for the final construction phase (Gassel, Roders & Eindhoven, 2006). As modular units are effectively six-sided boxes, the main task on-site is to stack them up and join them together accurately, just like huge Lego blocks, to create a modular building (Ganiron & Almarwae, 2014).

It has been argued that modular construction based on off-site manufacturing is economically disadvantageous because of the high initial cost (Schoenborn, 2012), but others have shown that construction methods that utilize off-site construction can be competitive in terms of production speed and quality for buildings consisting of multiple rooms of the same type, such as hotels, temporary accommodation and school classrooms (Xu & Zhao, 2010). Other studies have examined technological innovations (Elnaas, 2014; Ozorhon, 2013), especially how this approach can support decision making based on project characteristics, objectives and stakeholder relations (Elnaas, 2014).

It is necessary to identify the factors that need to be considered in the decision-making process during the project planning stage because there are a number of different types of modular building methods that can be utilized. The first of these choices, which is between permanent modular, relocatable modular or traditional modular methods, will depend on the project's characteristics and the technology involved. The Modular Building Institute (MBI), which is the international non-profit trade association serving modular construction, defines Relocatable Modular Building (RB) and Permanent Modular Construction (PMC) as follows (MBI, 2017):

"Relocatable Modular Building (RB)s are designed to be reused or re-purposed multiple times and transported to different sites. Relocatable Building as defined in the 2015 International Existing Building Code is a partially or completely assembled building constructed and designed to be reused multiple times and transported to different building sites."

"Permanent Modular Construction (PMC) is an innovative, sustainable construction delivery method utilizing offsite, lean manufacturing techniques to prefabricate single or multi-story whole building solutions in deliverable module sections. PMC buildings are manufactured in

a safe, controlled setting and can be constructed of wood, steel, or concrete. PMC modules can be integrated into site built projects or stand alone as a turn-key solution, and can be delivered with MEP, fixtures, and interior finishes in less time, with less waste and higher quality control compared to projects utilizing only site-built construction."

2.2 Relocatable Buildings and Permanent Buildings

As noted above, modular buildings are classified as either Relocatable Buildings or Permanent Buildings (MBI, 2011) (Table 1). The modular units are generally prefabricated as individual cubes with their interior material, mechanical equipment, electric wiring, and so on installed in the controlled environment of a factory. They are typically used for schools, office, and residential facilities (Ahn & Kim, 2014; Gibb & Isack, 2003; Lawson, Ogden, Pedreschi, Grubb & Popo-Ola, 2005).

TABLE 1. Comparison of Permanent Modular Construction (PMC) and Relocatable Buildings (RB).

	Permanent Modular Construction (PMC)	Relocatable Building(RB)
Manufacturing Ratio/Rate of Recycling	60~70%/74%	80~90%/100%
Field Construction	Vertical installation piping, boilers, balcony ceilings, wall for evacuation, welding and bolt joints between modules, fireproofing, and exterior finish.	Electrical/equipment piping connections, bolt joints between modules
Exterior Finish	Installation of temporary scaffolding, exterior finish work	No external finishing work
Foundation	Non-recyclable	Recyclable
Elevator	Site construction	Elevator modularization
Junction between modules	Bolting, welding, wet work	Bolting, dry work
Waterproof	Breathable waterproofing paper on site	Units individually waterproofed
Usability	Permanent residence	Can be moved and reinstalled in another location
Representative images	 PMC Modular Construction	 RB Modular Construction

As PMC is utilized for buildings intended to be permanently installed in a single location and hence does not need to take into account future dismantling and reuse, wet construction can be done in the field and jointing methods such as welding can be applied to cope with any errors identified once the units arrive on-site. In general, between 60% to 70% of the production takes place in the factory (Shin & Ahn, 2016) and the exterior finish is often applied on the construction site. Although the construction period will still be shorter than with conventional construction methods, the need to carry out external construction reduces this advantage.

Relocatable Buildings (RB), on the other hand, are easy to install and dismantle and can be transferred to another location for reuse after they have fulfilled their original function. An RB is designed to be capable of being reinstalled multiple times on different sites after the initial site installation, and can be up to 100% recycled as the modular unit standard. In addition, since the modular unit has a high manufacturing ratio, with 80 to 90% of the construction being carried out in the factory, each unit generally achieves a high building performance. The work that must be performed on-site is minimized, thus shortening the site construction period considerably. These advantages make relocatable modular construction a useful method that can be used wherever the residential demand is likely to change after a certain period of time, which is typically the case for large-scale international event accommodation and dormitories intended for short-term use.

2.3 Applications of Relocatable Modular Construction

Recyclable buildings are widely used in school facilities in North America to enable local school districts to expand or reduce facilities quickly in response to population changes. Because of the fluctuating policy environment in the United States, additional educational facilities may also be required at short notice to cope with legislation mandating reductions in class size, for example. Since they are easy and fast to install and cheaper than general facilities, relocatable classes enable local school boards to respond quickly (Hodgson, Shendell, Fisk & Apte, 2004). Another potential use is for short-term accommodation, as was the case of the Olympic Legacy Housing constructed for the 2010 Winter Olympics in Vancouver, where the modular construction method was utilized for temporary housing facilities and subsequently recycled for other uses (BC Housing, 2014). Here, a modular construction company worked with the BC Housing and Vancouver Organizing Committee to build 320 temporary accommodation units in the Whistler Athletes Village to house approximately 600 of the Olympic officials responsible for running the games. After the Olympics, the units were repurposed to provide social housing for low-income seniors in several communities across British Columbia (Metric Modular, 2018).

The ease of recyclability means that relocatable modular construction is now rapidly gaining popularity in developed countries and has gained many adherents. In terms of the manufacturing industry, features of offsite-based and relocatable construction can provide a variety of benefits for many building processes (Goulding & Arif, 2013). However, as yet there is no established guidance or in-depth understanding of what is involved in utilizing relocatable modular production as a construction strategy for modular accommodation such as modular hotels and dormitories. Therefore, the purpose of this study is to analyze the development of a relocatable modular building project based on a qualitative analysis and a single case study in order to develop a set of guidelines for applying the relocatable modular method for future construction projects based on an in-depth understanding of the case study of a relocatable modular hotel constructed for the 2018 Winter Olympics in Pyeong-Chang, South Korea.

3. METHODOLOGY

3.1 Single Case Study Analysis

In this study, a single case study methodology was used to analyze the recyclability of the Pyeong-Chang modular hotel project. The single case study method is not a simple sampling method (Tellis, 1997), but is instead a research method that helps understand and explain the process and the results of a phenomenon through a complete observation and analysis of the case itself, extending beyond a simple quantitative statistical analysis (Tellis, 1997). The researcher can adopt a single case study method if there is no other case similar to the one to be analyzed and it has specificity (Zaidah & Zainal, 2007). The single case study approach has the advantage of identifying detailed information leading to a practical real-life problem. Instead of a generalized explanation of solving a problem, the single case study provides in-depth understanding of the complexities (i.e. data, problems, and solutions) inherent in real-life situations (Zaidah & Zainal, 2007). The single case study can be informative for both typical and unique cases (Yin, 2003).

In addition, a case study can be used as a research method if it offers useful support for the client 's decision making from a positivist point of view and can provide a way to judge the applicability of the modular construction method during the planning stage of future architectural projects (Riege, 2003).

The project selected for this study is a specific case of applying modular construction methods for a hotel to be used at an Olympic international event in South Korea. The case has a special characteristic in that it was successfully supplied for the Olympics and specifically designed and constructed for reuse after fulfilling its original purpose. This study therefore thoroughly analyzed this relocatable modular building project to develop an in-depth understanding, explanations and interpretations from practitioner's experiences based on the single case study research methodology (Stake, 1995).

3.2 Qualitative Analysis

A detailed analysis was conducted of the methods adopted to build an understanding of the various aspects of relocatable modular building practices over the entire life-cycle of a modular project from the early design phase to disassembly and reconstruction utilizing both a case study methodology and in-depth interviews. The case study was principally conducted using semi-participant observations involving in-depth interviews, direct observation, collective discussions, an analysis of the literature and personal documents related to the modular projects (Gillham, 2005) in order to identify the critical considerations required for the effective management of a relocatable modular building that contribute to a successful project.

For the in-depth interviews, industry experts with experience of modular projects who were directly involved with various aspects of the case project were invited to participate (Table 2). The interviewees were asked to identify the distinctive features of relocatable modular building projects that differentiate them from both traditional building projects and permanent modular building projects. Identifying the critical considerations that are vital for project success will help stakeholders seeking to implement similar projects avoid previously unexpected problems (Chan, Scott & Chan, 2004; Chua, Kog & Loh, 1999; Pinto & Slevin, 1987; Somers & Nelson, 2001). A detailed analysis was conducted to explore these semi-participant observations.

TABLE 2. Characteristics of the Study Participants.

Interviewee	Sector	Years Experience	Role and Responsibility
Participant A	Project Manager	Over 15 years	As a project manager, A has the authority to make decisions regarding the orderly implementation of the relocatable modular project.
Participant B	Construction Manager, Quality Manager	Over 10 years	B was responsible for managing the communication between the onsite and offsite construction. B also inspected the quality of the construction work performed onsite.
Participant C	Manufacturing Manager, Quality Manager	Over 5 Years	C was responsible for managing communications and conducting quality assurance checks for the modular units and organizing the schedule for the manufacturing process.
Participant D	Estimator	Over 10 years	As an estimator for the project, D performed role optimizing scenarios for supplying the relocatable modular buildings.
Participant E	Designer	Over 10 years	As a designer, E was responsible for drawing up documents defining the characteristics of the relocatable modular building in communication with each expert related with the project.

4. CASE STUDY OF A RELOCATABLE MODULAR BUILDING

4.1 Relocatable modular building in Pyeong-Chang: Outline and characteristics

In its original configuration, the modular hotel constructed for this project had three floors and a total of 300 rooms (Figure 1). The construction was scheduled to commence in June 2017 and be completed by December the same year, which included four months of factory production. The Pyeong-Chang modular hotel was designed to be recyclable and to minimize the on-site installation time by modularizing each part of the building, making the site construction period considerably shorter than the construction of a similar building using a conventional construction method. The modular units were designed to satisfy the excellent environmental performance required by the local building codes, and were expected to be suitable for reassembly anywhere in the country for subsequent reuse. Features such as these make it possible for modular units to be used in schools and dormitories where expansion or amalgamation is required due to fluctuations in local demand as well as for use in facilities that would no longer be required once the event for which they were constructed was over, such as the Olympic Games. The modular hotel was designed to be transferred to another site and reconstructed as a dormitory for university students afterwards. Because the modular building recycling rate can reach 100% when RB units are involved, this project is a good example of a relocatable modular project that combines the dual objectives of recycling and reuse with sustainability.

TABLE 3. Pyeong-Chang Residence Modular Hotel Architectural Overview.

Location	Gangwon-do Pyeongchang, South Korea
Building area	2,749.16 m^2
Gross area	10,305.5 m^2
Floor-area ratio	27.53%
Floor space index	103.19%
Building plan	4 Floors, 3 Buildings, 300 Rooms
Construction period	June 2017 to December 2017 (7 months)
Architecture/Manufacturer/ Builder	POSCO A&C

This study identifies key issues from each phase of the project, from the planning to the post-production stages, through semi-participant observation. Our findings provide useful guidelines for the successful and effective management of future projects of this type by identifying the aspects that should be considered when carrying out a relocatable modular construction project.

4.2 Important Considerations for Relocatable Modular Construction

The success of any construction project requires rational decision-making from the planning stage to the implementation stage (Williams & Samset, 2010). From the owner's perspective, the first step in the project planning phase is to establish the ordering method (Ahn & Kim,

FIGURE 1. Pyeong-Chang Modular Hotel.

2014); the project delivery method has a significant impact on the project's success because it defines the objective, characteristics and environment of the project, all of which work together to achieve the best result for the project as a whole (Hosseini, Lædre, Andersen, Torp, Olsson & Lohne, 2016). Although all construction projects are grouped into the same categories, each project has its own independent characteristics depending on the specific requirements of the various stakeholders, all of whom have different interests, and the project's site and the surrounding environment (Elnaas, 2014).

In the local environment where an international event is to be held, the first goal is to provide appropriate infrastructure and accommodation facilities within the limited time frame available to meet the sudden increase in demand. Because "schedule delay" and "quality performance" are considered to be the most important considerations in decision making for procurement, schedule management and quality assurance are critical factors; further consideration of potential post-event utilization of the facilities supplied for short-term international events is also recognized as an important factor (Hosseini, Lædre, Andersen, Torp, Olsson & Lohne, 2016).

This case study focuses on a project to build suitable accommodation for the broadcasters and journalists covering the 2018 Winter Olympics, taking into account the construction period and quality, as well as the post-utilization plan for the facilities after the Olympic Games ended. The accommodation provided was based on the use of relocatable modular construction methods, as outlined in the initial technical proposal. The study identifies the important factors associated with the successful completion of a modular project at all phases in the construction process, including: 1) Planning, 2) Design and engineering, 3) Manufacturing, 4) Construction, and 5) Disassembly and Reconstruction.

4.2.1 The Planning Stage

As the planning process required for the relocatable modular method is more complex than that for either conventional construction or permanent modular building, the primary focus for the initial planning should be on decision making and a careful consideration of the requirements for disassembly and reassembly (De La Torre, 1994). As mentioned earlier, there are a number of important issues to consider during the planning stage when carrying out a relocatable modular project for a particular environment. The issues listed below were identified during the expert interviews conducted for this study, all of whom were active participants in the project, along with a thorough examination of documents containing information related to the project, and information gathered through direct observation on site.

Initial decision making process driving the selection of strategies that coincide with project objectives

A wide range of construction methods and systems have been developed to provide an appropriate infrastructure for big international sports events such as the Olympics or the World Cup. Decisions need to be made at a very early stage regarding how the necessary buildings and infrastructure can be constructed in the limited time available; time overruns are simply not acceptable. When it comes to modular projects, participants must start by determining the optimum construction strategy that achieves the best balance between onsite and off-site construction (Eastman, Teicholz, Sacks & Liston, 2011; Zhai, Reed & Mills, 2014). This will depend on the local environment, the proposed requirements and the characteristics of the owner including specifying the level of construction quality required, the funding available and the time limits.

Project delivery methods for the relocatable modular project

In modular projects, it is important to bring the modular contractor/manufacturer into the planning stage as early as possible as a member of the task force team. Adopting a Design-Build approach or Integrated Project Delivery (IPD) will allow the modular company to take full advantage of the benefits provided by a modular building approach. Relocatable modular building projects have a number of unique considerations that are not shared by permanent modular building methods. As the earlier comparison between permanent and relocatable modular buildings shows (Table 1), a permanent building is very similar to traditional buildings in many ways, but a relocatable building is specifically designed to be moved to another site for reuse and must be designed and constructed with this is mind (MBI, 2011). It is therefore vital to specify the responsibilities of each stakeholder so that the owner can organize the project to reflect these characteristics when selecting the optimum project delivery method (Kent & Becerik-Gerber, 2010).

Different stakeholders are responsible for different aspects of the project. For example, a designer will create an appropriate modular unit at the design stage, while a manufacturer can create prototypes in their factory during the manufacturing stage, and a construction company would need to develop an appropriate modular construction capability. It is important to establish the precise role and responsibility of the project participants at every stage. Creating a bridge between all the various stakeholders to facilitate communication is thus a critical factor for the success of the project. It is also important to consider the subsequent reuse of the modular unit when it moves on to another site and another purpose, so the stakeholder who will receive the relocated modular building needs to participate in the initial decision making process to provide direction for the planning and design of the project.

Assemble task teams for the relocatable modular building project

Having a task team for each specific objective for the project allows managers, designers, fabricators, erectors, and transporters to participate in the development of the relocatable modular units (De La Torre, 1994; Tatum, 1986). Information from the interviews supports the contention that appropriate task teams should be assigned to achieve effective outcomes for the project. For example, in this project the company manufacturing the modules indicated that the organization of a module design task team was a necessary step that proved highly beneficial for the organization and planning of the project (De La Torre, 1994; Tatum, 1986). Participants also suggested involving a modular consultant could accelerate the project and strengthen the task team, as he or she would provide valuable relocatable modular design and manufacturing expertise. For example, in order to design a prototype modular unit at the design stage and demonstrate the modular unit's performance and space concept, some trial and error is inevitable. As part of this process, it is very important for the design team to suggest several alternatives for the design concept and collaborate with the manufacturer to verify the viability of each alternative. As shown in Figure 2, once the initial design is made during the shop drawing step, the prototype can be made at the factory and then revised and adjusted until all the participants are happy.

Plan for recycling the modular construction units

Unlike conventional buildings or permanent modular buildings, relocatable modular building projects must take into account post-recyclability during the initial planning stage. Careful planning is critical, because modular construction methods do not adapt to changes flexibly. It

FIGURE 2. Shop Drawing and Manufacturing Phase.

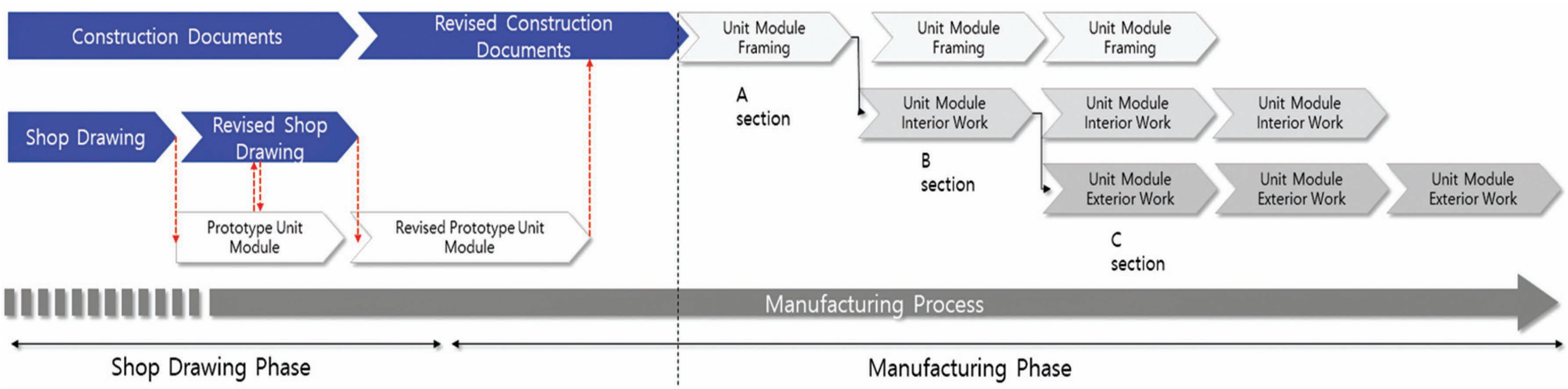


TABLE 4. Critical Considerations for Relocatable Modular Buildings in the Early Design Stage.

Phase	Considerations
Planning	• Initial decision making process driving the selection of strategies that coincide with project objectives • Project delivery methods for the relocatable modular project • Assemble task teams for the relocatable modular building project • Plan for recycling the modular construction units • Overall costs, including recycling and the cost of leasing and/or selling the modular units

is therefore important to engage in clear decision making by the project manager or the owner, since this will affect the direction of the future design stage and the scalability of the application.

Overall costs, including recycling, and the cost of leasing and/or selling the modular units
Although modular building costs are sometimes greater than those of conventional buildings, in the long term, when the total modular project cost is spread over the building's entire prospective life-cycle these may be reduced considerably. A detailed cost analysis comparing traditional and modular building methods revealed that it is important to monitor the cost variances continuously while developing the design and specifications.

The economic validity of a modular project that is to be relocated must be established during the early design stage. Such a modular building must be designed differently from one that is to remain in place for its life. It is also necessary to know at the early design stage the objective of the relocation and the distance that the modules must be shipped.

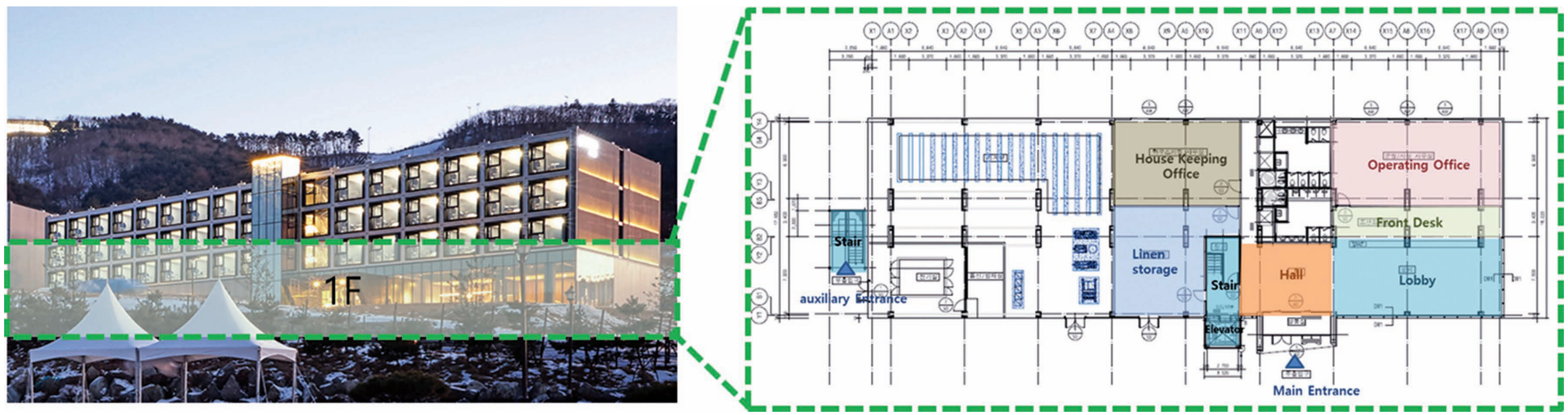
4.2.2 The Design and Engineering Stage

The design for the prefabrication is developed during the design and engineering stage. For a relocatable modular project, the participants are required to engage in rapid decision making during this stage.

Design for prefabrication of relocatable buildings
Modular architecture determines the type of prefabrication, which will depend on the type and characteristics of the building. Drawings are made based on the capacity of the fabrication plant and the specific site conditions. In this case, the modular building was designed according to the technical suggestions made during the conceptual design stage, where the decision was made to minimize wet construction and design the structure in such a way as to facilitate removal and reattachment in the field in order to achieve the project's recycling and sustainability goals. Although, modular construction applies mainly to buildings that have repetitive units (e.g. hotel rooms), every building also has non-modular spaces such as reception, lobby and other service areas. Figure 3 shows such a case where the first floor does not consist of large box-like modular units. Instead it is built of a recyclable steel structure with large external panels that can also be recycled.

Cooperation during the design development stage for relocatable modular building units
During the design development phase, the relocatable building (RB) system that would meet the project's requirements was created in cooperation with the design, manufacturing and

FIGURE 3. The first floor plan of a modular hotel shows the non-modular service area of the building.



construction experts who had already participated in the initial design stage. Since the RB system was designed to be easily separated for recycling after its initial use, it consisted of multiple sub-assemblies that would be easy to detach and reattach as often as needed.

Unit standardization for productivity and recyclability

Standardization of the modular unit not only improves the productivity of the production but also improves the field construction speed (Schoenborn, 2012). Relocatable modular units also have the advantage of being easily recycled for various purposes and arrangements in the future. In the case project analyzed in this study, the identical room modules were designed to boost the efficiency of the factory production and ensure speedy field construction. Better factory production ratios were also achieved for the 3 boiler rooms, 11 step modules, 11 hall modules, 90 roof modules, and 66 roof modules required for the project due to the improved productivity gained through segmentation and standardization. Figure 4 indicates the second-floor plan which is a standard modular unit floor plan.

Environmental performance of each modular unit

It was important to design the modular units to provide a good environmental performance for each individual unit to support future recyclability. Because it is not always possible to predict where relocatable modular buildings will be located throughout their life cycle, they must comply with building codes in all areas to meet building performance requirements. This design approach has many advantages, as even if the several individual room units are subsequently split up and sent to several different areas, they will still deliver a satisfactory performance. Moreover, this method takes advantage of avoiding many of the defects that conventional construction projects are vulnerable to that are generated from the external environment, such as rain damage during on-site construction and the transportation of the modular units.

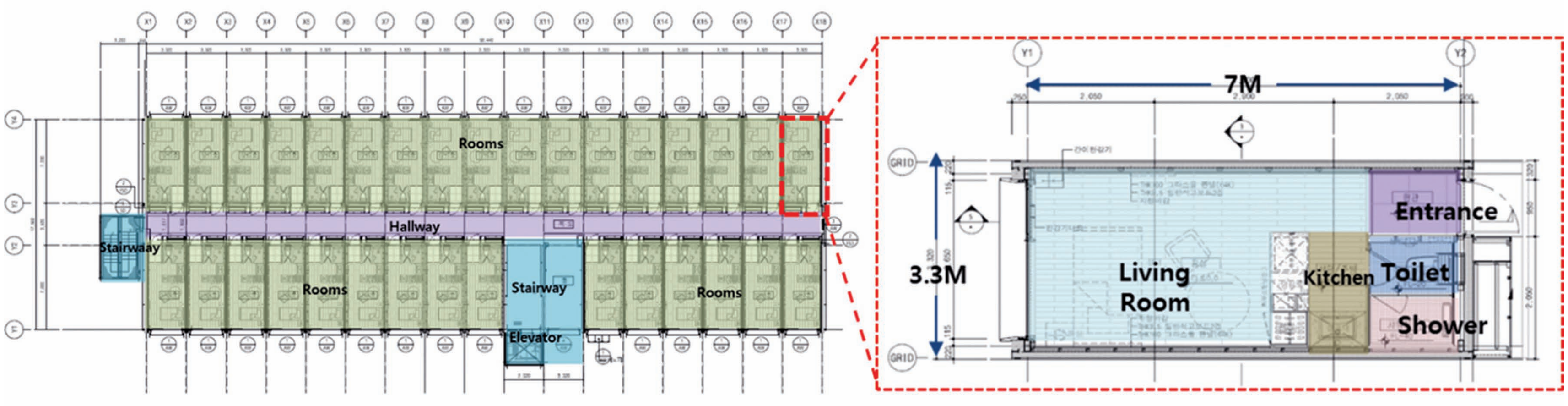
Structural and regional regulations

When design units for future recycling, the structural performance for both the initial use and after it has been recycled must be considered. Generally, when determining the structural performance of a building, the structural requirements are calculated based on the number of floors and the characteristics of the region where it is installed. However, since a relocatable modular building may be moved between multiple locations during its lifetime, it is not possible to define the precise characteristics of the area where it may be sited, the structural performance must therefore meet the characteristics appropriate for every application where they may be used by planning in advance for recyclable uses.

Design for disassembly (DfD) modular units

Design for disassembly (DfD) is the design approach used to facilitate future change and eventual dismantlement for recycling of structures, their components and materials (Crowther, 2018). Relocatable modular buildings should be designed with future recyclability in mind, including easy assembly and dismantling in the field. During the design stage, it is advantageous to design the same type considering the recyclability of the modular unit. This is because there is a high likelihood that the modular unit will be reused multiple times. Experts agree that minimizing the number of different types of modular units will be beneficial for the relocatable modular building concept in terms of efficiency. The Pyeong-Chang modular project was therefore designed to be installed using dry/bolting methods without the need for wet methods or welding operations during the field assembly, while at the same time ensuring that the required structural performance would be achieved. In addition, the use of a single type of

FIGURE 4. The second floor plan of the modular hotel and an enlargement of the floor plan of a typical module are shown.



module supported efficient production and installation during the production and construction stage. This represents the biggest difference from the permanent modular method and conventional construction approaches.

Selection of material to facilitate recycling

Design for disassembly is intended to reduce the use of new materials and minimize waste, thus supporting the sustainability throughout the construction, renovation and demolition process. The materials selected in design phase should thus be considered in terms of their durability and performance quality as well as their suitability for recycling. These considerations ensure the modular building will retain its value and be a more feasible candidate for reuse (Sev, 2008).

For a modular building that will be relocated, it is important not only to design for efficient prefabrication but also to make it easy and efficient to disassemble the modules. Productivity in the factory and minimization of waste in the disassembly process are also important design considerations. Codes and regulations must be considered not only for the initial location, but also for potential future locations.

4.2.3 The Manufacturing Stage

The manufacturing stage is important as it is the phase where the offsite methods that are a crucial part of modular construction take place. Here, the components are assembled based on the documents that were drawn up during the design stage. The documents upon which the factory manufacturing rely, known as shop drawings, connect the designer and manufacturer, so ensuring the shop drawings are accurate will support the delivery of high modular unit quality and the reuse of materials. Preventing task conflicts in the factory requires early coordination and constant communication between all the participants throughout the design development process, which is when the detailed shop drawings are produced (Schoenborn, 2012). In this section, we consider the operations that are important for manufacturing relocatable modular units.

Produce high quality shop drawings for relocatable modular units in coordination with stakeholders

Stakeholder participation in the design phase improves the quality of the project (Ahn & Kim, 2014). Cooperation between stakeholders during the design stage is crucial as it enhances the design completeness of construction drawings and shop drawings and ensures that the

TABLE 5. Critical Considerations for Relocatable Modular Buildings in the Design Stage.

Phase	Considerations
Design	• Design for prefabrication of relocatable buildings • Cooperation during the design development stage for relocatable modular building units • Unit standardization for productivity and recyclability • Environmental performance of each modular unit • Structural and regional regulations • Design for disassembly (DfD) modular units • Selection of material to facilitate recycling

documents that guide the manufacturing process are accurate and complete, thus reducing the need for expensive and time consuming changes once production is underway. Involving the participants in the manufacturing phase raises the quality of the modular units because there is always some element of trial and error in developing the final drawings (Varma, 2008). Just as in other construction projects, shop drawings are important in modular construction, but as at least 60% of the building work in modular construction projects is performed in the factory it is not easy to change the specifications "on the fly" and it is thus important to minimize errors in construction documents such as the shop drawings through good collaboration beforehand (Murtaza, Fisher & Skibniewski, 1993).

Pilot production to verify the performance of the prototype module

Since the performance of the individual relocatable modular units is an important factor, a critical activity is the production and verification of prototype modular units prior to commencing full-scale mass production. In this project, a great deal of effort was devoted to producing high-level modular units by conducting a careful review of prototype units produced according to the shop drawings. For example, in the shop drawings, details such as the joints between modules, the joints between equipment, and the waterproofing method were examined and the results confirmed through prototype inspection.

Repetitive activity for modular unit manufacturing

If the modular units for a project are designed with a minimum number of different types, during the production phase the worker's repetitive activity can lead to a rise in the work-learning curve (Mályusz & Varga, 2016). This boosts modular production productivity and is regarded as an advantage for both securing construction workability in the field installation and in the later dismantling and recycling stages when units are moved to another location.

Managing the scheduling for repetitive jobs

A scheduling method for the production of modular units that progresses uniformly through the same series of processes is a form of linear method scheduling that is often used for projects requiring continuous production (Harmelink, 1995). In the Pyeong-Chang Residence Hotel project, many of identical modular accommodation units were manufactured. To facilitate this process, schedule management was implemented to plan the procedure to ensure a smooth flow and equalize the workload. This process plan has the advantage of preventing bottlenecks and reducing wait times between different stages in the factory production line, and has the merit that the entire process can be monitored simultaneously. This type of graphical process management method is particularly suitable for modular manufacturing plant process planning because it supports workflow optimization, flexible work productivity and continuous resource allocation (Harmelink, 1995).

Selecting a production factory to secure mass production and modular quality

To benefit from the efficiencies of mass production, a large factory space is required in order to construct multiple large-scale modular units at the same time. In this case study, the factory site would need to have sufficient space to produce and store 3 boiler rooms, 11 step modules, 11 hall modules, 90 roof modules, 66 roof modules and 300 room modules, a total of 481 units. Appropriate factory sites were selected and set up to meet these requirements. The plant, which had built ships in the past, had the great advantage of being able to produce 200 modules at the same time. This manufacturing process minimized material wastage and made it possible to run the same processes uniformly, thus supporting a very efficient manufacturing process.

Durable material for relocatable modular units

In order to recycle modular units, it is necessary to ensure that the materials in the buildings are very durable and capable of being transported to a new site without sustaining damage. When wet construction methods are utilized for the interior of the modular unit, the building may develop defects such as moisture or mold due to the external environment. If the modular unit is intended to be retained and recycled, it is therefore important that it is built using products with excellent durability and corrosion resistance, especially for the products used as interior materials (Sev, 2008). In the case of the modular hotel, a product made of steel sheet was developed and applied to ensure the durability of the interior material. This product has a corrosion resistance 5 to 10 times higher than that of hot dip galvanized steel and is recognized as a product that is suitable for long-term use in products and buildings (Choi, Cho & Oh, 2016).

Satisfactory modular unit manufacturing performance

Relocatable modular buildings may at some time in the future be utilized individually in stand-alone form in unspecified areas, so each modular unit needs to be manufactured to a level that can meet the desired performance level. It must therefore be able to satisfy the legal requirements in the area (e.g. seismic performance standards, insulation performance standards, sound environmental standards, airtight performance standards, etc.). In this case, the hotel modules were designed and manufactured to meet the structural and environmental performance standards in any region in South Korea. The design specifications are indicated in Table 6.

Easy renovation of modular units

Modular buildings that are recyclable should take into account the need to be able to repair any defects that may occur during disassembly. Even if the factory production rate is high and the modular unit performance is satisfactory, there is a possibility that an unexpected incident may occur when the used building is dismantled. In order to minimize the impact of such events, it is important to prioritize the design of units so they are easy to repair and provide documentation that shows how the repairs should be performed as part of the plan produced during the production stage. In the case analyzed in this study, pipelines were placed on the wall of each modular unit to be easily repaired.

Inspection system for modular manufacturing

Unlike traditional construction, more than 60% of the total construction work involved in building a modular unit takes place in a factory environment (Shin & Ahn, 2016). For the hotel in this case study, inspecting the modular units before they leave the factory is very important because more than 90% of the work on constructing the units is performed in the factory. In order to manage the product quality, the inspection of the modular units was carried out in a way that was deemed appropriate for each, as there is no standardized method for inspecting modular units. Consequently, it is not only important to define the subject of the quality inspection, but also to establish clear criteria for quality control. For this reason, appropriate relocatable modular building unit quality inspection standards must be established that take into account the unit's recyclability.

In the case considered for this study, a major goal was to ensure the satisfactory performance of the modular unit itself, including its recyclability. Even if the individual modular unit is exposed to the outside air, it is necessary to be able to install it without any problems due to leaking, so the quality inspection standard was modified by strengthening the criteria for leakage and airtightness. In addition, given that the building may be recycled several times during its lifetime, the standard includes a consideration of its resistance to the type of vibration

TABLE 6. Relocatable Modular Unit Design Specifications.

Performance Type		Code Requirements	Design Specifications	Performance Validation
Structure	Live Load	2.0 kN/m^2	3.0 kN/m^2	Joint Seismic Performance Design: M 6.3 Test: M 7.1
	Snow Load	6.0 kN/m^2	7.0 kN/m^2	
	Wind Load	26m./s	44m./s	
	Earthquake Load	S = 0.22g	S = 0.22g	
	Transportation	—	Transportation Structure Safety	
Air Tightness	Air Tightness	N/A	2.59 times	OK (2.2times)
Fire Proof	Beam & Column	1 hr	1 hr (Refractory Paint)	—
	Wall	1 hr	1 hr (Fire-rated Board)	Fire proof certification
Thermal	Insulation Performance (Heat Condensation Rate, W/m^{2}K)	Exterior(0.31), Ceiling(0.15), Floor(0.26), Window(1.2) Exterior/ ceiling/floor(0.15), window(0.8)	Exterior(0.13), Ceiling(0.12), Floor(0.23), Window(1.03)	OK
	Condensation (TDR)	N/A	Below 0.23	OK (Thermal camera)
Sound Control	Sound Insulation (Each Room)	Level 3 48 dB above	Level 3	OK (Level 1)
	Floor Impact Sound	Floor Impact Sound	Light Weight Impact sound 58dB below Heavy Impact Sound 50dB below	OK (Level 4) OK (Level 1)
Water Proof	Wall, Floor	N/A	Roof → TPO Waterproof Exterior wall → Expansion Tape PC slab floor → Rubber gasket	Sample House Mock and Check

typically generated during movement and the unit's durability against the load transferred to the modular unit frame during lifting.

In order to generate and maintain the high-quality work necessary to construct tight modules that can be relocated several times, it is necessary to have a quality management system. For example, shop drawings should be examined several times during the creation of prototype

TABLE 7. Critical Considerations for Relocatable Modular Buildings During the Manufacturing Stage.

Phase	Considerations
Manufacturing	• Produce high quality shop drawings for relocatable modular units in coordination with stakeholders. • Pilot production to verify the performance of the prototype module • Repetitive activity for modular unit manufacturing • Managing the scheduling for repetitive jobs • Selecting a production factory to secure mass production and modular quality • Durable material for relocatable modular units • Satisfactory modular unit manufacturing performance • Easy renovation of modular units • Inspection system for modular manufacturing

modules to assure both quality and production efficiency. Also, the modules must be carefully inspected before shipment to the construction site.

4.2.4 The Construction Stage

The first step in the modular construction stage is to prepare the site where the relocatable modular units will be installed when they arrive from the factory. It is necessary to prepare adequate access for the trucks bringing these large volume loads onto the field. In order to plan for just-in time delivery for the modular units arriving on site to fit the construction schedule, constant communication with the manufacturer is essential.

Plan for just-in time delivery

Just in time delivery is a lean manufacturing logistics strategy in which materials are kept off-site and delivered to the construction site precisely when needed according to a pre-determined schedule (Aziz & Hafez, 2013). When establishing the transportation plan, it is necessary to take care of any legal requirements such as a request for permission to occupy roads and to report large cargo transportation events to the appropriate authorities. Local conditions such as the route to be taken, the transportation time, and the number of modules to be transported per day must also be kept under constant review (Shin & Ahn, 2016).

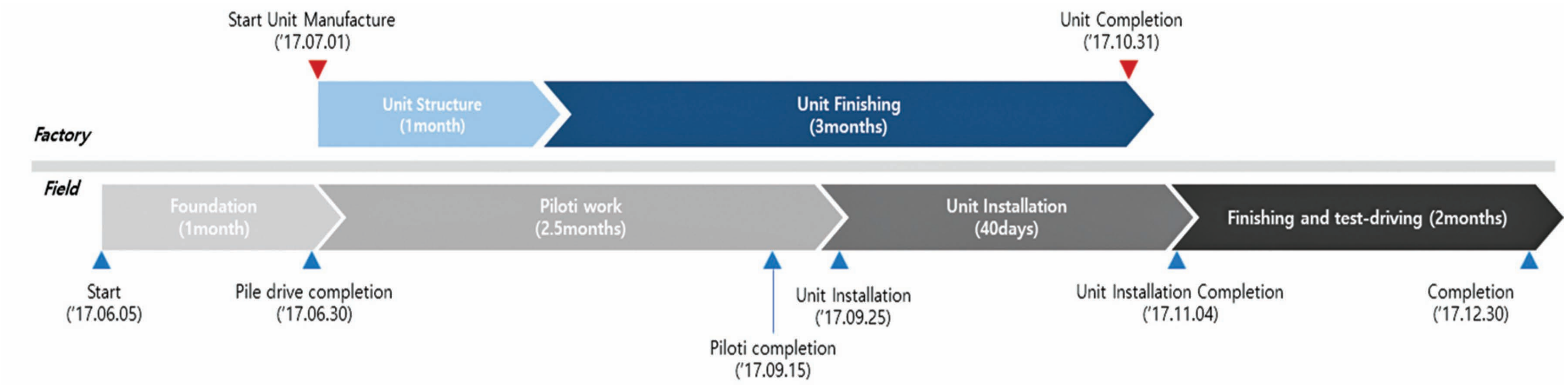
For the modular hotel, the modular units were transported from the plant to the site, a distance of 327 km. The room modules were transported and assembled over a period of about 40 days, with 8 deliveries each day arriving at the site (Figure 6.). This speedy installation was made possible because the factory production rate was so high that the work required on site was very small and the construction was done faster than planned. However, because the factory schedule was planned based on 8 shipments per day, this actually imposed a restriction on the construction period.

Secure bonding using post tension

If the modular unit are linked together only with bolted joints, consideration should be given to the structural integrity of the final structure and the way the modular units interlock with one another (Sharafi, Mortazavi, Samali & Ronagh, 2018). Unlike permanent modular buildings,

FIGURE 5. Modular Manufacturing Process.

FIGURE 6. Construction Schedule for Relocatable Modular Projects.



relocatable modular buildings are bonded only using dry methods to facilitate dismantlement, and a careful structural examination of the dry joints at the design stage is necessary. The results of this review will determine an appropriate joining strategy that will also support convenient dismantling later. In this project, the post tension method was used. According to the structural expert interviewed for this study, the post tension method improves the integrity of the joins between the modules and was thus deemed suitable as a dry method for this modular construction project.

Minimize wet construction for ease of disassembly

Because the modular hotel was constructed on site and was always intended to be recycled after the event, it was preferable to perform dry construction work instead of wet construction to facilitate the future demolition and redeployment. Because the modular building consisted of almost 100% indoor production based on the modular units and the final building assembly was done mainly using dry methods, the effect of the weather was minimal even during the on-site final construction stage. Nevertheless, it was important to establish a strategy to fill any gaps between the joints that might be vulnerable to water damage and expansion tape was used to prevent water leaking into the joints.

Site construction management for modular buildings

The advantage of modular construction is that the work time on site is significantly shorter than that required for a traditional building. Since most of the work is completed in the factory, a relatively small amount of work is done in the field. However, it is important to assemble the modular units correctly in the field even if the work on the individual units is mostly done in the factory and this can be an issue for modular construction because this is the point at which construction errors are most likely to creep in. One way to reduce the number of construction errors is to use guide pins, which are often used on-site as a way to increase the assembly speed and reduce the construction error rate by improving the assembly accuracy. This has a major advantage of preventing construction delays caused by the need to reassemble the modular units if a mistake is made. In general, it is important to determine the optimum sequence for assembling the modular units because the types of modules will differ according to the planned arrangement of the modules on site (Diez, Abderrahim & Padron, 2007). However, the modular unit types were largely standardized in this case, thus improving the installation efficiency as it reduced the need to consider different module types when planning the assembly order.

Site foundation construction plan that takes into account moving and recycling

It is important to set up a construction plan that ensures that the site condition can be fully restored after the construction of the building for recycling purposes. For example, when a concrete mat foundation of a type that is widely used in foundation work is utilized, the foundation for the concrete mat must be permanently preserved, normally by being buried. To prevent this outcome, planners should aim to design a foundation whose material can be recycled and minimize waste, while at the same time preserving the original site conditions during the site foundation work.

In the case of this project, the H-BEAM pile construction utilized made the foundation easy to recycle by reflecting the above considerations and minimizing the wet construction required. Figures 7 and 8 show the foundation before any of the modules were installed and during the construction, where H-BEAMs embedded in the ground were directly connected to the modular units on the first floor of the hotel.

FIGURE 7. Piloti construction.

For the efficiency of the project, production of the modules in the factory and the site work must be carefully coordinated. For example, the site concrete work must be completed by the time the first modules are ready to be delivered. Furthermore, the site erection of modules must keep pace with the rate that the modules are produced in the factory. Also, the design of the foundation must consider the fact that the modules will be relocated at some later date.

4.2.5 The Disassembly and Reconstruction Stage

As relocatable modular buildings are designed to be reused and reconstructed in different locations, a comprehensive disassembly and reconstruction plan must be considered from the outset. Indeed, since the deconstruction and construction work will likely be taking place simultaneously, an appropriate dismantling process for the modular building is required.

FIGURE 8. Piles directly connected to the modular units.

TABLE 8. Critical Consideration for Relocatable Modular Building at Construction Stage.

Phase	Considerations
Construction	• Plan for just-in time delivery • Secure bonding using post tension • Minimize wet construction for ease of disassembly • Site construction management for modular buildings • Site foundation construction plan that takes into account moving and recycling

Modular construction disassembly process

Disassembly process planning is vital to reduce the amount of resources that must be invested in the disassembly process and maximize both the recycling rate of the modular building materials and the quality of the parts recovered. In order to relocate the modular hotel, the dismantling work should be carried out in the reverse order to that used for the installation of the existing modular unit (Figure 9) When the modular hotel was dismantled, it was disassembled back into its original modules, including the roof, exterior panels, and corridors. The disassembled materials, including the modular units, were then carried to their next destination and reinstalled to create the new building.

Document materials and methods for deconstruction

The as-built drawings and deconstruction plans included careful labeling of the materials and details of whether they were bolted, screwed or nailed connections in the specifications to facilitate an efficient disassembly and reconstruction process. A detailed inventory of the building components used in the project was also provided, along with a description of the entire lifecycle of the product and a semi-assembly to help identify best options for reuse, reclamation and recycling and any remaining materials for each of the building elements.

Provide instructions on how to deconstruct individual elements

Providing a comprehensive deconstruction plan with information on how to disassemble the modular units is a significant consideration for deconstruction. It is necessary to provide adequate information on appropriate deconstruction methods that can be used in conjunction with the "as built" set of drawings to demonstrate the optimum technique for removing specific elements. This plan should include strategies and list the equipment required to disassemble the modular building, as well as discussing the implications for health and safety as part of the management requirements. The future demolition contractor should be consulted regarding the best practices for categorizing, recording and storing the disassembled elements (Klang, Vikman & Brattebø, 2003).

Provide a transportation and reassembly plan

Relocatable modular buildings must be transported and reassembled at the same time once the dismantling work has begun, since the dismantling process involves a process of disassembly, followed by transporting the modules to their new location, and finally reassembly. This plan should be developed in consultation with the dismantling contractor, the shipping contractor, and the reassembly contractor, and a close collaboration among these parties is indispensable. In addition, documentation for the dismantlement plan should be kept with the contract so that it is legally valid. The contents of the plan should include environmental concerns, safety,

FIGURE 9. Modular building dismantling process.

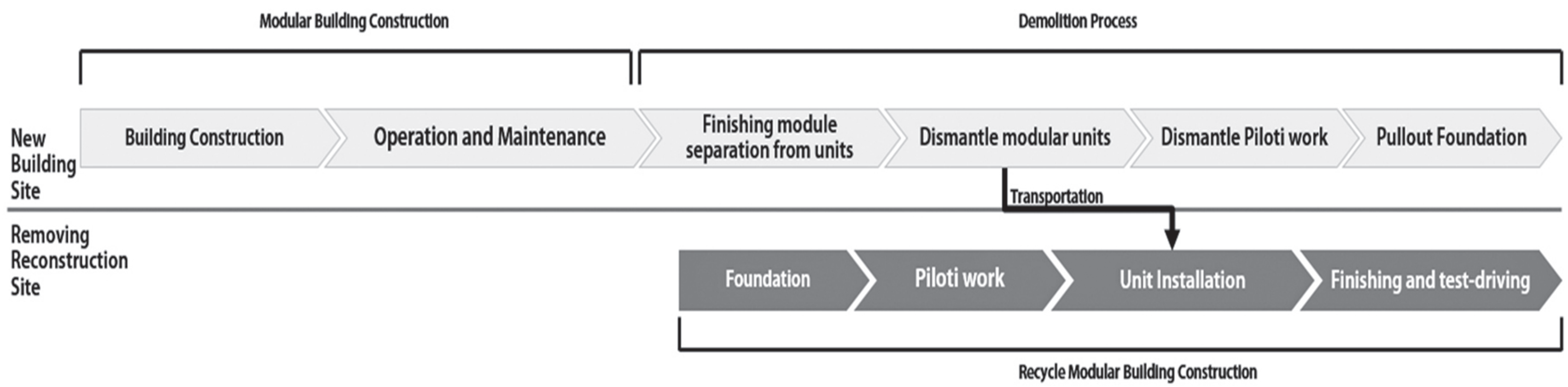


FIGURE 10. Plans for modular hotel (Alt 1).

a list of recycled materials, disassembly instructions, transportation options, assembly methods, a treatment plan for any hazardous materials, a schedule for the planned work, disposal method for any unwanted parts after dismantling (Couto & Couto, 2010).

Quality assurance and safety

It is important that the modular units can be separated into recyclable units. No matter how much they are used, it is important to preserve their quality in order to enhance their utility and increase the recycling rate. When separation/disassembly, transportation, or reassembly work is ordered, it must be accompanied by a guarantee of freedom from damage or defects (Huang, Lin, Chang & Lin, 2002).

Preserved as Olympic heritage structures

The modular hotel was built as a set of units that can be recycled, with the planned reuse being for student dormitories and hotels (Figures 10 and 11), among other possibilities, after the

FIGURE 11. University dormitory double room (Alt 2).

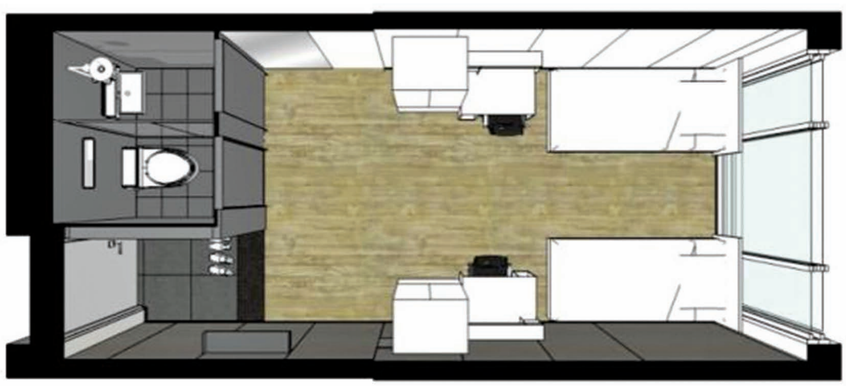


TABLE 9. Critical Consideration for Relocatable Modular Building at the Disassembly and Reconstruction Stage.

Phase	Considerations
Disassembly & Reconstruction	• Modular construction disassembly process • Document materials and methods for deconstruction • Provide instructions on how to deconstruct individual elements • Provide a transportation and reassembly plan • Quality assurance and safety • Preserved as Olympic heritage structures

Pyeong-Chang Winter Olympics were over. This plan is an improvement on previous practice in terms of maintaining the value and sustainability of the Olympic heritage rather than simply dismantling and destroying the building when it was no longer needed.

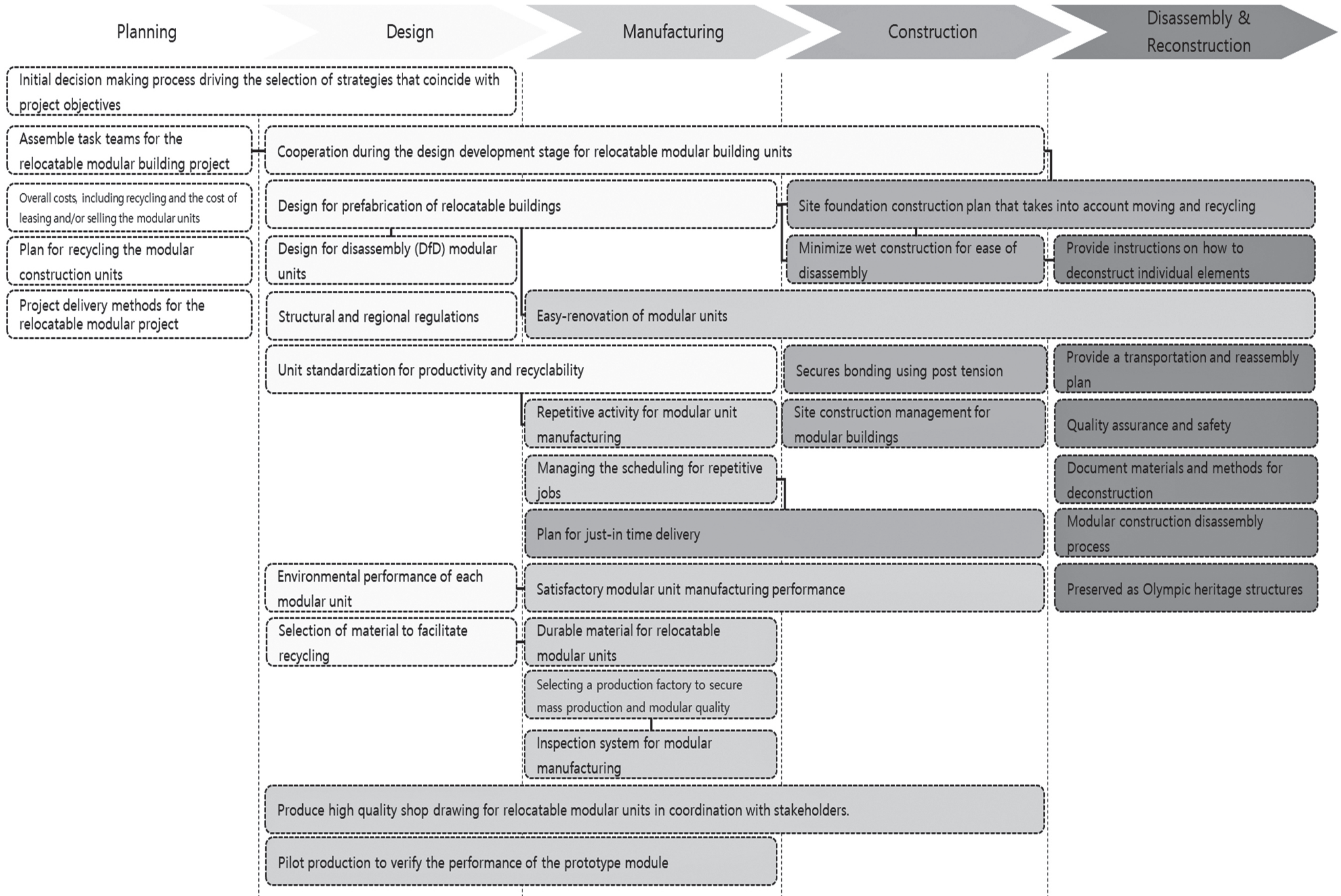
The design of the modules must include guidelines for disassembly and for moving them to another site. In the planning and design of a new building using modules from a previous building, the following challenges must be considered: time and effort to disassemble the old building, moving modules to the new site, and the site preparations to receive the modules.

5. FRAMEWORK FOR THE CONSTRUCTION OF RELOCATABLE MODULAR BUILDINGS

All construction projects are based on demand. To meet this demand, the relocatable modular approach can provide an architectural technical solution that is capable of responding to rapidly changing environments. The study reported here recognizes that the RB modular units that are already widely utilized as school classrooms and offices and residential facilities in the construction industry could also be used to provide temporary services at international events. The research reported in this paper indicates that an in-depth understanding of the special characteristics of relocatable modular performance is required to deliver cost-efficient, effective and sustainable options. This requires careful consideration during each stage of the complex process involved if this type of project is to be managed efficiently and effectively.

This study utilized a single case study approach in conjunction with semi-participant observations to identify the critical factors associated with each stage of a relocatable modular building project. In particular, modular construction can facilitate recycling of the construction materials, either by reusing material during the factory production that would otherwise be discarded during on-site construction or by reusing the entire module once its initial purpose had been accomplished (Mora, 2007). In terms of sustainability, innovative building technologies such as modular construction facilitate the partial replacement of waste materials during maintenance, thus enhancing the sustainability of the final construction. Based on this analysis, we propose a new framework to guide relocatable modular building projects that incorporates the critical considerations identified in this research from the planning stage right the way through to the disassembly and reconstruction stages (Figure 12).

FIGURE 12. Framework for application of relocatable modular building with critical considerations.



6. IMPLICATIONS AND CONCLUSIONS

In this study, we investigated a project that applied the modular method to a hotel that was built for a short-term international sports event that could then be dismantled and reused for other purposes in one or more new locations.

As mentioned earlier, the single case study has advantages and disadvantages. Although much was learned, it does not guarantee that this study explains all the problems of a specific real project, and some of the assumptions made for this project are not common. Since this project was designed for South Korea, many changes would have to be made for modular construction in other countries and regions of the world. Nevertheless, much was learned that can be used for an actual modular construction project.

The present study is based not only on critical considerations and examples derived from interviews with project staff engaged in the project, but also on a single case study conducted in conjunction with previous research in the area and semi-participant observation. Our findings indicate that it is feasible to utilize a relocatable modular construction method in a region where sudden demand fluctuations are expected. In addition, unlike permanent building types, the modular nature of Relocatable Buildings is advantageous as it increases the factory production rate. Our findings also highlight the need to design in recyclability right from the initial design stage.

The following implications can be drawn:

- This was the first hotel to utilize a modular construction method for an Olympic venue.
- The provision of high-quality modular housing facilities satisfied the performance required by South Korea's Building Law.
- The resulting eco-friendly building can be recycled to other areas after the Olympics.
- It is possible to provide modular accommodation in areas where it is necessary to host large numbers of people for a short period of time, such as an international sports event.
- Appropriate design and engineering technology for the intended purpose is required from the beginning of the project in order to fully benefit from the unique advantages of the modular construction method.

Particularly for short-term events such as the Olympics, the demand for temporary housing space will only increase. The modular construction method can be applied to solve the demand for sudden rapid increases in residential space at the Olympic Games, the World Cup and World Championships, all of which are attended by large delegations of athletes, officials and fans from around the world. Moreover, this method could be applied to deliver post-disaster housing for refugees and others made homeless by natural disasters. In Korea, it could become a major construction supply alternative to support the nation's housing supply policy in preparation for unification.

This study examined the construction of a modular hotel project, focusing on details such as the recycling during the modular construction process and the critical considerations that came into play as the Olympic residential space was recycled. The modular construction method shortened the initial construction period considerably compared to traditional construction methods; more than 90% of the modular unit construction was performed in the factory, thus greatly reducing the work done on-site. In addition, the environmental performance and structural performance required for apartment complexes in South Korea mean that even if a modular unit is moved to another area, it will continue to satisfy all the building codes in its new location. There is an added benefit in that each modular unit is an independent object, so all of the accommodation units constructed for the modular hotel can be independently isolated for reuse and supplied for various types of individual residential spaces. As this analysis of a representative modular hotel indicates, modular housing facilities can be provided for accommodation at international events and then repurposed once the event is over, thus maximizing the benefits of the relocatable modular approach.

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