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COST-BENEFITS OF RELOCATABLE MODULAR BUILDINGS (RMB) FOR CONSTRUCTION SITE OFFICES: THE CASE OF SRI LANKA

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Abstract: Relocatable Modular Building (RMB) technology is widely utilised worldwide as a versatile solution for temporary shelter needs, including site offices. The substantial cost benefits associated with RMBs have been acknowledged globally. Nevertheless, the lack of empirical data hampers the ability to substantiate the cost advantages of utilising RMB technology. Therefore, the study aimed to find the cost benefits of RMB technology for temporary offices on construction sites in Sri Lanka through Life Cycle Cost Assessment (LCCA). From a methodological perspective, the research adopted a case study strategy. Data was mainly collected through semi-structured interviews, document reviews, and market surveys while following LCCA as the analysis method to derive findings. The findings disclosed that the initial cost of an RMB site office is 32% higher than a conventional site office, but the annual cost saving is 23%. Hence, it is worth investing in RMB because of its yearly cost saving due to its long life span and higher salvage value. Sensitivity analysis further established that employing an RMB is more cost-effective for contractors even at different discount rates, functional lifetimes, and project durations. This study enlightens construction industry practitioners about the cost-effective utilisation of RMBsin their projects.

Keywords. *Container-based Site Office, Cost Benefit, Life Cycle Cost (LCC), Relocatable Modular Building (RMB), Site Overhead*

1. Introduction

The construction industry comprises a tremendously competitive market primarily controlled by prices (Chan, 2012). Yang and Kim (2019) mentioned that preventing unforeseen cost upturns reduces the massive effect on the construction company's cost competitiveness. Even though trade work accounts for most project costs, project overheads are crucial since they relate to items directly delivered by the contractor, and any related risk is non-transferable (Chan, 2012). Thus, a deep understanding of how project overhead costs are incurred is vital for the overall success of project cost management (Chan, 2012). In addition, the cost of providing a construction site office is a site overhead that is unavoidable by any contractor (El-Sawalhi & El-Riyati, 2015). As cited by Fu et al. (2020), prefabricated buildings are extensively practised on construction sites due to the convenience and flexibility of prefabrication technology. In the modular building industry, Permanent Modular Construction (PMC) and Relocatable Modular Buildings (RMBs) are the two different industry segments (Smith, 2014). In comparison, PMC is the construction of permanent modular buildings affixing modular units to a permanent structure base (Schoenborn et al., 2012). Generally, their performance is comparable to conventional buildings, and their life span ranges from 30 to 60 years (Mapston & Westbrook, 2010). RMB is defined as a repetitively usable temporary structure of a volumetric unit or combination of several units that is movable from one location to another according to user requirements (Sandamini & Waidyasekara, 2022).

According to Schoenborn et al. (2012), cost reduction can be identified as a benefit when the contractor owns an RMB because the contractor can benefit from the Whole Life Cycle Cost (WLCC) reduction due to reusability. However, the body of knowledge lacks much empirical evidence to support the cost benefits of RMB technology. To address this knowledge gap, the current study aims to investigate the cost benefits of using RMB technology for temporary site office construction through comparative analysis. Given this, the following research question was developed to guide the study.

> **RQ:** "What are the cost-benefits of using RMB technology for site office construction over conventional construction technology?"

In order to address the above research question, this study adopted the following pathway. Firstly, a brief literature review has been presented to introduce the RMBs. Secondly, the adopted research methodology was presented as a case study design and unit of analysis, data collection and data analysi in section3 (methodology). Thirdly, research findings and discussions were presented in section 4. Lastly, section 5 presents the implications of theory and practice, followed by the conclusion. The findings of this study are expected to contribute to the theory by adding new

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insight into the cost aspect of RMB technology with empirical evidence through quantitative analysis. In terms of practical implications, the study's findings could raise awareness of construction industry practitioners about the cost-effective RMB technology in their projects to gain maximum profits by minimising unnecessary site overheads.

2. Relocatable Modular Buildings

RMBs are built to be readily disassembled, transported, and relocated. They are primarily intended for temporary or semi-permanent structures and have a relatively limited lifespan of 15 to 30 years owing to material selection more than artistry (Mapston & Westbrook, 2010). More attention has focused on establishing RMB because of its unique features such as a flexible approach, fast deployment, "relocatability", sustainability, and significant useful life (MBI, 2011). Jackson (2015) mentioned that the reasons for using RMB solutions over permanent construction are frequently linked to the belief that this structure can provide the necessary accommodations and facilities of a permanent building in a rapid, cheaper, and more flexible manner.

Construction-site trailers are used as standard site offices in the industry because they are readily available for instant delivery at construction sites and plants (MBI, 2019b). Moreover, RMBs can be used seven times on average within their lifespan. However, it will vary depending on the size, type, and market served of that RMB unit. RMBs are available as one or two-story relocatable units for construction site environments with soundproofing, and they can be typically moveable by a forklift. These units contained electrical and telecommunication wiring, heating, air conditioning, and even plumbing service lines. Therefore, RMB technology has been widely spread in the construction industry to serve different applications, including site office facilities. Though the RMB technology applies to site office construction, the literature findings revealed different arguments regarding cost as a benefit of RMB technology (Chen et al., 2010; Kyjaková et al., 2014; Lawson & Ogden, 2008; Lu & Liska, 2008; Mapston & Westbrook, 2010). Moreover, Silva and Vithana (2008) stated that high initial cost causes a lack of practice in modular building construction. Consequently, Sandamini and Waidyasekara (2022) emphasised that the mandatory requirement of an air conditioning system results in high energy costs, maintenance costs, and repair costs in small-scale modular construction. Accordingly, investigating the cost benefits of RMB technology becomes significant and appropriate since there are various arguments regarding the cost aspect of RMB technology. Hence, this study focused on identifying the cost benefits of using RMB technology for site office construction over conventional construction technology through Life Cycle Cost Assessment (LCCA). The research methodology used to bridge the knowledge gap is presented in the following section.

3. Methodology

A comprehensive literature review was conducted first to establish theory-based knowledge on RMBs. As Simons (2009) defined, a case study is "an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, program or system in a real-life." Similarly, this study investigated the cost benefits of having RMB site offices in the Sri Lankan construction industry, and the case study strategy has been adopted to explore the real cost benefits of RMBs independently.

3.1 CASE STUDY DESIGN AND UNIT OF ANALYSIS

The case study was conducted to achieve the aim of the study, which is to comparatively analyse the cost aspect of the RMB site office and conventional site office. Hence, the researcher used two cases: an RMB site office (C1) and a hypothetical conventional site office (C2). RMB (C1) was limited to container-based RMB due to the less availability of different RMB types in Sri Lanka. C2 was a hypothetical case due to difficulties finding a conventional site office with similar features to C1. Further, time and accessibility constraints were the reasons the research was limited to two cases. Selected case profiles are descriptively presented in Table 1.

Table.1 Summary of case profiles

Characteristics/ Properties	RMB site office (C1)	Conventional site office (C2)
Floor area	160 sq. Ft.	160 sq. Ft.
Size	20 x 8 x 8.5 Ft	20 x 8 x 8.5 Ft
Foundation	4 numbers of 12x12x6 inch sized four concrete blocks firmly kept on perfectly levelled ground	4 numbers of 500x500x225mm sized RCC column footing foundation on 75mm thick cement concrete screed
Floor	PVC embossed floor carpet	75 mm thick grade C20 concrete 1:2:4 (20mm) floor
Exterior wall	Exterior and interior metal surfaces de-corroded & spray-painted with appropriate primer coats and the exterior spray-painted with Auto paint	150mm thick solid block masonry wall, Cement washing to both sides of walls

Interior panelling	Walls finished with aluminium striking and panelled with 3mm PVC decorative plyboard	No interior panelling
Interior wall	No interior walls	No interior walls
Insulation	Fully insulated interior with McFail	No insulation
Doors	1 number of lockable Aluminium half glass paneled swing door (lock size 3'x6'6" "")	1 number of lockable Aluminium half glass panelled swing door (lock size 3'x6'6"")
Windows	2 numbers of aluminium casement windows, including all windows gear (size '2' x '3')	2 numbers of aluminium casement windows, including all windows gear (size '2' x '3')
Roof	The top of the container box is used as the roof. The roof height is 8.5""	23^{o} pitch shed roof covered with asbestos corrugated roofing sheets
Ceiling	3mm white plyboard and aluminium striking	Super Flex (Plain) suspended ceiling system using 2400x1200x4.5 mm ceiling boards
Air conditioning unit	Wall-mounted split-type air conditioners having a minimum cooling capacity of 12000 BTU	Wall-mounted split-type air conditioners having a minimum cooling capacity of 12000 BTU
Lighting accessories	3 number of 12W ceiling-mounted LED lights	3 number of 12W ceiling-mounted LED lights

3.2 DATA COLLECTION TECHNIQUES
Yin (2018) stated that documents, archival data, interviews, direct observation, participant observation, and tangible artefacts are all possible data collection techniques for case studies. Saunders et al. (2019) suggested that semi-structured interviews might be utilised in exploratory research, while Hancock and Algozzine (2006) claimed that semi-structured interviews are ideal for case study research. Therefore, semi-structured interviews with the project manager and the project quantity survey document review, government publications, and a market survey were used to collect cost data within the scope of the selected case study. With regard to cost data, this study utilised current market prices (2022) and referenced the Building Schedule of Rate 2021 (BSR) for accurate estimations. Due to the unavailability of real-time examples for the same featured conventional site office, a hypothetical case was formulated to address the research objectives effectively. To maintain the credibility and transparency of the process, researchers prepare design (drawings) for the particular conventional site office according to an available large-sized site office and prepared a separate Bill of Quantities (BoQ) along with rate breakdowns. With this, the credibility and transparency of the research process have been achieved through rigorous adherence to ethical standards, including obtaining informed consent, ensuring data confidentiality, and following established research protocols. Additionally, transparency in reporting collected data further bolsters the research's credibility.

3.3 DATA ANALYSIS TECHNIQUES
This study followed the LCCA technique to analyse cost data. Further, a sensitivity analysis was conducted to validate the outputs of LCCA. With this, sensitivity analysis plays a crucial role in ensuring data validity within research by scrutinising the effects of variations in key variables on the study's outcomes. This methodological approach allows researchers to evaluate the robustness and reliability of their findings by systematically exploring diverse scenarios and assessing the consistency of results.

3.3.1 Life Cycle Cost Assessment
The Royal Institute of Chartered Surveyors (RICS, 2016) provides a cost breakdown structure for the components of LCC of a building in the RICS professional guidance for life cycle costing. It includes four major categories of LCC of a building: construction, maintenance, operation, and end-of-life costs. Under each category, more detailed cost components are proposed to cover all the relevant costs associated with owning a building throughout its life cycle; pre-use, use, operation, and end-of-life phases (RICS, 2016).

Further, RICS (2016) mentioned that LCCA is used for both budgeting purposes and selecting the preferable option in terms of cost among several alternatives. Similarly, Petrović et al. (2021) also highlighted that LCCA is an economic appraisal technique used to evaluate various investment alternatives by accounting for costs and savings throughout the analysis period. Since the research focused on identifying the cost-benefit of using an RMB site office over a conventional site office and finally choosing the most economical option, the LCCA technique was considered. Annexure 1 illustrates the equations that are followed in the LCCA.

3.3.2 Sensitivity Analysis
Due to data uncertainty, the sensitivity analysis assesses the LCCA robustness (Islam et al., 2016). Sensitivity is associated with risk management due to data uncertainty. It is primarily connected with changing factors like periods of analysis and interest rates, particularly in the context of LCC (RICS, 2016). Further, the researchers identified that

project duration of the construction project in which the site office is utilised affects the LCC. Accordingly, since LCCA is sensitive to the changes in the discount rate, analysis periods, and project durations, it significantly affects the future operation, maintenance, and end of life costs. Hence, a sensitivity analysis was conducted to identify the impact of these key variables on the appraisal decision.

4. Research Findings and Discussion

To conduct the LCCA, cost data, analysis periods, base date, and discount rate are required as inputs. This section discusses all relevant inputs to the study along with assumptions, simplifications, and limitations.

4.1 INITIAL CONSTRUCTION COST ESTIMATION

C1 was used in 2020 for the first time in a construction project and is currently in operation. It means that the actual construction cost is already expended and known. However, the actual construction cost breakdown was unavailable at the site, and the BOQ includes a lump sum amount for constructing, maintaining, and dismantling the site office. Therefore, a cost breakdown was prepared mainly based on data collected through document review. Further, site preparation cost was obtained through BOQ, and the project quantity surveyor provided transport and unloading cost.

Since the C2 is a hypothetical building designed for research purposes, construction cost was estimated. According to The Sri Lankan Standard Method of Measurement of Building Works - SLS 573 (The Institute for Construction Training and Development [ICTAD], 1999), cost components were broken down, and quantities were extracted from design drawings. Further, the rates were taken from the Building Schedule of Rates for construction works of government buildings (Department of Buildings, 2021). Table 2 illustrates the summary of the Initial Construction Costs (ICC) calculated based on the data collected.

Table 2: Summary of the construction cost of RMB site office and conventional site office

RMB Site Office (C1)		Conventional Site Office (C2)	
Cost Component	**Amount (Rs.)**	**Cost Component**	**Amount (Rs.)**
Site preparation cost	6,644.98	Excavation and Earthwork	7,836.13
Purchase cost	1,020,000.00	Concrete work	266,737.67
Initial cost of AC unit	85,000.00	Masonry work	90,580.79
Transport and unloading cost	15,000.00	Metalwork	71,433.69
		Woodwork	68,553.01
		Ceiling	38,646.84
		Roof covering	165,462.90
		Mechanical Installation	110,000.00
		Electrical installation	30,000.00
		Painting	4,213.06
PV of total construction cost	**1,126,644.98**	**PV of total construction cost**	**853,464.10**

*Purchase cost is the cost of customs duty paid cargo worthy condition 20 feet refurbished container box, including assembly cost at the site, excluding the furniture and any other equipment not mentioned in Table 1.

4.2 MAINTENANCE COST ESTIMATION

Maintenance cost includes the cost of redecoration, planned periodic maintenance, and component replacement activities. Regarding C1, time intervals of maintenance activities were identified through interviews with the project manager and the quantity surveyor. Maintenance cost details were gathered through interviews with the project manager and the project quantity surveyor, market survey, and Building Schedule of Rates for urgent exceptional repairs, renovations, additions and improvements, minor works, and maintenance to government buildings (Department of Buildings, 2021b). Cost details gathered to calculate the maintenance cost of two cases are depicted in Table 3.

Table 3: Maintenance cost details

RMB Site Office (C1)		
Cost component	**Time interval**	**Amount (Rs.)**
Periodic maintenance	Every 3 months	10,000.00
Redecoration		
Painting to ceiling	Every 10 years	7,218.00

Painting to external walls	Every 3 years	23,052.00
Component replacement activities		
Floor carpet	Every 5 years	78,400.00
Door	Every 15 years	37,102.00
Windows	Every 15 years	16,730.00
Conventional Site Office (C2)		
Cost component	**Time interval**	**Amount (Rs.)**
Periodic maintenance	Every 3 months	8,000.00

As per the collected data, C1 requires periodic maintenance every 3 months. Periodic maintenance of C1 includes cleaning the roof and air conditioning system, clearing rust on walls, and deep cleaning the office. Further, the periodic maintenance cost of C2 was assumed with the basis of that cost, including cleaning the roof, air conditioning system, and deep cleaning of the office. The redecoration cost of C1 consists of painting to ceiling and wall. Further, only floor carpet should be replaced within 15 years of its functional life. Moreover, it is assumed that the cost of redecoration and component replacement is not incurred in C2 because C2 will be demolished at the end of the project's construction period.

4.3 OPERATION COST ESTIMATION

Operation cost mainly includes energy costs and daily cleaning costs. The cost of relocating the RMB site office within its functional life is contained additionally in C1. The annual lighting and air conditioning cost of C1 was estimated according to the capacities and average usage of lighting accessories and the air conditioning unit. Required data were gathered through interviews, observations, and the Ceylon Electricity Board (CEB) website.

As the first step, monthly energy consumption was calculated.

Monthly energy consumption of lighting accessories (kWh)

$$= \frac{Wattage\ (W) \times No\ of\ bulbs \times Average\ usage\ per\ day \times 30}{1000}$$

$$= \frac{12W \times 3 \times 3\ h \times 30}{1000}$$

$$= 3.24\ kWh$$

Monthly energy consumption of air conditioning unit (kWh)

$$= \frac{Capacity\ (BTU) \times 2.9307x\ 10^{-4} \times Average\ usage\ per\ day \times 30}{1000}$$

$$= \frac{12000\ BTU \times\ 2.9307x\ 10^{-4} \times 11.5 \times 30}{1000}$$

$$= 1213.31\ kWh$$

Accordingly, monthly energy consumption is 1216.55 kWh. Then, the energy cost was estimated based on the assumption; electricity is supplied for the site office from the main supply line of the CEB.

The electricity supply used in the site office is covered under general-purpose tariffs. Contract demand is less than or equal to 42 kVA. Based on the assumptions, the tariff applicable for energy consumption of the site office is shown in Table 4.

Table 4: Tariff applicable for energy consumption [Ceylon Electricity Board, 2017]

Consumption per month (kWh)	Energy charge (LKR/kWh)	Fixed charge (LKR/month)	Maximum demand charge per month (LKR/kVA)
<301	18.30	240	-
>301	22.85		

Accordingly, the following equation calculated the annual cost of energy consumption as Rs. 336,458.09.

$$\textbf{Annual energy cost} = [(Monthly\ energy\ usage \times Energy\ charge) + Fixed\ charge] \times 12$$

The annual cleaning charge for both cases was roughly calculated based on the assumption that unskilled labour spends half a labour hour for daily cleaning activities. Accordingly, the annual cleaning cost is Rs. 31,500.00, with the basis of unskilled labour rate per day being Rs. 1,400.00. Regarding C1, relocation cost is additional. According to the project quantity surveyor, dismantling, loading, transporting, and unloading costs are incurred once the site relocates. Accordingly, relocating cost was estimated as Rs. 27,500.00 at once. Further, it is assumed that C1 will serve for 5 projects of 3 years within its lifetime. However, this cost may be considerably changed because transportation cost for the upcoming four projects is unpredictable.

4.4 END-OF-LIFE COST ESTIMATION

According to RICS (2016), end-of-life costs include disposal, demolition, and end-of-life revenues. The end-of-life cost of C1 was estimated based on the assumption that the RMB site office will be used as a storeroom at its functional life of 15 years. Hence, disposal and demolition costs were assumed as Rs. 12,500.00 based on current market prices. Here the cost includes dismantling, loading, unloading, and transporting to the nearest store yard of the contractor. Further, according to the project manager, second-hand 20 feet RMB already used for nearly 10 to 15 years can be bought at Rs. 450,000.00. Therefore, that amount was identified as the present value of end-of-life income (salvage value). Regarding C2, demolition and salvage values were estimated using current market prices. Further, it is assumed that the contractor can reuse several items such as aluminium doors and windows, ceiling boards, timber on the roof, asbestos roofing sheets, and split air conditioning unit after 3 years of functional life of C2. Accordingly, salvage value was estimated.

4.5 LIFE CYCLE COST COMPARISON

Comparative LCCA was carried out to compare the related lifetime costs of C1 and C2. Significant facts of LCCA are lined up below as per the previous discussion.

The functional life of C1 and C2 were considered as the periods of analysis. Hence, the analysis period of C1 and C2 is 15 years and 3 years from the base date (01st of January 2022). The discount rate was regarded as 2.85% as per calculations. Site offices are used for projects in which the duration is 3 years. Accordingly, NPV was calculated to evaluate the LCC of C1 and C2. Since the period of analysis of two cases is unequal, AEC was found to better evaluation of costs. Table 5 and Table 6, respectively, illustrate the LCC calculation of C1 and the LCC calculation of C2.

Table 5: LCC calculation of RMB site office (C1)

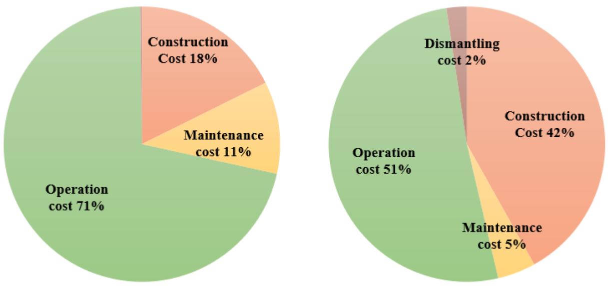
Cost Element	Timing	Amount	DCF @2.85%	PV (Rs)
Initial Construction Cost (ICC)				
Site preparation cost	T=0	6,644.98	1.000	6,644.98
Purchase cost (including taxes)	T=0	1,020,000.00	1.000	1,020,000.00
Initial cost of AC unit	T=0	85,000.00	1.000	85,000.00
Transport cost	T=0	15,000.00	1.000	15,000.00
Present value of total Initial Construction Cost (ICC)				**1,126,644.98**
Maintenance cost				
Periodic maintenance	Annually	40,000.00	12.071	482,827.53
Redecorating activities				
Painting to ceiling	T=10	7,218.86	0.755	5,451.69
Painting to wall	T=3,6,9,12	23,052.29	3.255	75,031.72
Component replacement				
Carpet replacement	T=5,10	78,400.00	1.624	127,339.18
Present value of total maintenance cost				**690,650.12**
Annual Equivalent Maintenance Cost (AEMC)				**57,217.13**
Operation cost				
Lighting and air conditioning	Annually	336,459.09	12.071	4,061,292.81
Cleaning	Annually	31,500.00	12.071	380,226.68
Relocating cost	T=3,6,9,12	27,500.00	4.100	112,744.82
Present value of total operation cost				**4,554,264.31**
Annual Equivalent Operation Cost (AEOC)				**377,299.47**
End of life cost				
Dismantling cost	T=15	12,500.00	1.000	12,500.00
Salvage value	T=15	450,000.00	1.000	(450,000.00)
Present value of total end of life cost				**(437,500.00)**
Net Present Value (NPV)				**5,934,059.41**
Annuity Factor				12.071
Annual Equivalent Cost (AEC)				**491,609.03**

Table 6: LCC calculation of conventional site office (C2)

Cost Element	Timing	Amount	DCF @2.85%	PV (Rs)
Initial Construction Cost (ICC)				
Excavation and Earthwork	T=0	7,836.13	1.000	7,836.13
Concrete work	T=0	266,737.67	1.000	266,737.67
Masonry work	T=0	90,580.79	1.000	90,580.79
Metalwork	T=0	71,433.69	1.000	71,433.69
Woodwork	T=0	68,553.01	1.000	68,553.01
Ceiling	T=0	38,646.84	1.000	38,646.84
Roof covering	T=0	165,462.90	1.000	165,462.90
Mechanical Installation	T=0	110,000.00	1.000	110,000.00
Electrical installation	T=0	30,000.00	1.000	30,000.00
Painting	T=0	4,213.06	1.000	4,213.06
Present value of total Initial Construction Cost (ICC)				**853,464.10**
Maintenance cost				
Periodic maintenance	Annually	32,000.00	2.837	90,781.61
Present value of total maintenance cost				**90,781.61**
Annual Equivalent Maintenance Cost (AEMC)				**32,000.00**
Operation cost				
Lighting and air conditioning	Annually	336,459.09	2.837	954,509.29
Cleaning	Annually	31,500.00	2.837	89,363.15
Present value of total operation cost				**1,043,872.44**
Annual Equivalent Operation Cost (AEOC)				**367,959.09**
End of life cost				
Dismantling cost	T=2	48,438.10	1.000	48,438.10
Salvage value	T=2	(220,948.22)	1.000	(220,948.22)
Present value of total end of life cost				**(172,510.12)**
Net Present Value (NPV)				**1,815,608.02**
Annuity Factor				**2.837**
Annual Equivalent Cost (AEC)				**639,991.49**

From Table 5 and Table 6, it can be concluded that the AEC of C1 is lesser than C2. Accordingly, an annual cost saving of Rs. 148,382.46 is for using an RMB site office. Further, it is 23% of annual cost saving rather than using a conventional site office.

Figure 1 illuminates how the LCC of two cases are spread among cost categories. Though the salvage value was taken into the LCC calculations, it is not considered for Figure 1 since it is not a cost for the contractor. It is deduced that the operation and maintenance cost of the C1 is 82% of its total LCC for 15 years of functional life. Compared to construction cost, it is nearly 4.7 times. Further, the dismantling cost of C1 is negligible since it is incalculably less. Regarding C2, construction cost is lesser than its operation and maintenance cost (56% of LCC) even for 3 years of lifetime.



RMB site office (C1) Conventional site office (C2)

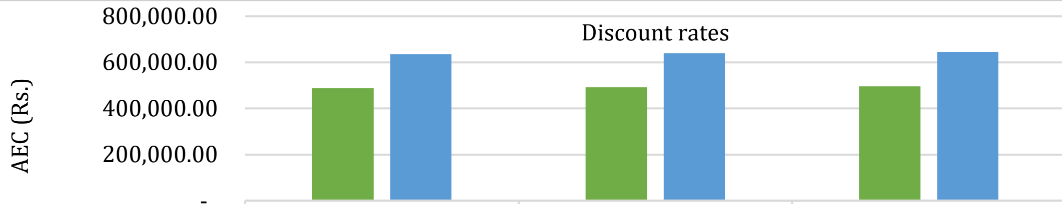
Figure 1: Cost percentages at various LCC stages

4.6 SENSITIVITY ANALYSIS

LCCA is sensitive to changes in the discount rate, analysis periods, and project durations. Since the discount rate is unpredictable, discount rate differences can affect the LCC and research findings. Consequently, the researcher assumed the discount rate would differ within the range of 1.85% to 3.85% since the average is 2.85%.

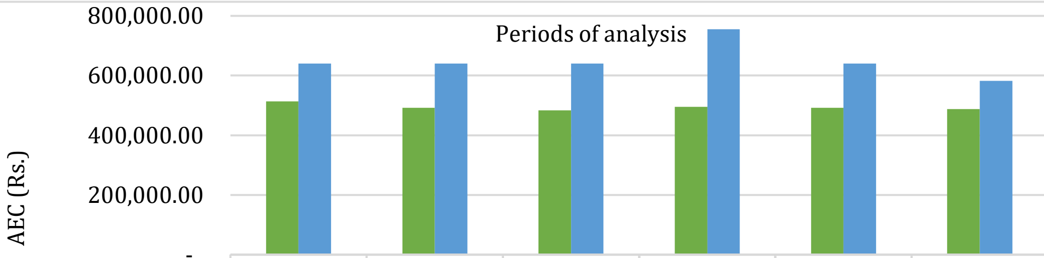
Figure 2 indicates how the AEC of C1 and C2 change with the discount rate at 1.85%, 2.85%, and 3.85% while other factors are constant. Since the discount rate increases with AEC of C1 and C2, AEC shows a direct relationship with discount rates. Further, C1 indicates a lesser AEC than C2 in every discount rate.

The analysis period is another critical variable that is unpredictable at the initial stage of a project. The functional life of C1 (15 years) and C2 (3 years) were considered the period of analysis in the LCCA. In the sensitivity analysis, 10, 15, and 20 years of periods for C1 and 2, 3, and 4 years of periods for C2 were considered. As depicted in Figure 3, when the functional life of C1 changes from 10 years to 20 years, the AEC of C1 decreases while C2 is constant since no variable is changed in the LCCA of C2. However, an increase in the functional life of C2 results in a decrease in the AEC of both C1 and C2. Hence, it can be concluded that using an RMB site office is more economical for contractors than using a conventional site office, even at different discount rates, functional lifetimes, and project durations.



	1.85%	2.85%	3.85%
RMB site office (C1)	487,455.65	491,609.03	495,898.22
Conventional site office (C2)	635,382.01	639,991.49	644,629.97

Figure 2: AEC of RMB site office (C1) and conventional site (C2) office at different discount rates



	Functional life of C1			Functional life of C2 or Project duration		
	10 yr	15 yr	20 yr	2 yr	3 yr	4 yr
RMB site office (C1)	513,689.34	491,609.03	483,305.37	495,088.54	491,609.03	487,751.37
Conventional site office (C2)	639,991.49	639,991.49	639,991.49	755,046.75	639,991.49	582,486.53

Figure 3: AEC of RMB site office (C1) and conventional site (C2) office at different periods of analysis

5. Conclusions

The existing body of knowledge lacks sufficient empirical evidence to substantiate the cost benefits associated with Relocatable Modular Building (RMB) technology. Consequently, it becomes imperative to identify and analyse the cost advantages of RMB technology compared to conventional approaches, particularly in site office construction, to inform decision-making and select the most cost-effective construction technology. The study demonstrated that the Initial Construction Cost (ICC), Annual Equivalent Maintenance Cost (AEMC), and Annual Equivalent Operation Cost (AEOC) of the RMB site office are respectively 32%, 79%, and 3% higher than the conventional site office as components of LCCA (Life Cycle Cost Assessment). However, the empirical findings revealed that prolonged functional life caused the higher AEMC and AEOC of the RMB site office than the conventional site office. As per the findings of LCCA, it was noted that the salvage value of the RMB site office is higher than the conventional site office, and end-of-life expenses are comparatively lower than the salvage value. Therefore, based on assumptions, the RMB site office marked the highest end-of-life income, 61%, than the conventional site office. Specifically, it appeared that the annual cost saving of utilising an RMB is 23% more than a conventional site office, and the prolonged functional life of the RMB site office caused the cost saving. Moreover, the appraisal decision can be identified as reliable since the sensitivity analysis found that using an RMB site office is more economical for contractors than a conventional site office, even at different discount rates, functional lifetimes, and project durations. Hence, the study's findings can be used as a general overview and assist the contractors in the construction industry in understanding and making better choices for their long-term business strategies. However, the research adopts a single-case comparison; hence, the unique nature of the selected cases can be identified as a study limitation. Further, the cost-benefit analysis of RMBs has been conducted using a rigorous methodology known as LCCA, considering quantifiable costs. However, it is important to note that risks such as market volatility, technological uncertainties, regulatory changes, and some non-quantifiable benefits have not been included in the analysis with time and resource constraints, which may incur deviations and limitations to the current results. This study highlights the need for further empirical research to substantiate the cost advantages of RMB technology, despite the acknowledged substantial cost benefits globally. Consequently, contractors should carefully evaluate the non-transferable risks associated with providing temporary site offices using RMBs. Future research should focus on conducting larger-scale studies to address the empirical data gap and explore integrating sustainability factors into the cost-benefit analysis of RMBs. Additionally, investigating the influence of technological advancements and analysing policy and regulatory frameworks would provide valuable insights for promoting the cost-effective utilisation of RMB technology in the construction industry.

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Annexure 1. Equations used for the LCCA Calculations

No	Equation	Variables		
1	$\mathbf{NPV = C + O + M + E}$	NPV	=	Net Present Value
		C	=	Present value of construction cost
		O	=	Present value of operation cost
		M	=	Present value of maintenance cost
		E	=	Present value of end-of-life cost
2	$\mathbf{AEC = NPV \times \frac{\boldsymbol{d}(1+\boldsymbol{d})}{(1+\boldsymbol{d})^{\boldsymbol{n}} - 1}}$	AEC	=	Annual Equivalent Cost
		NPV	=	Net Present Value
		D	=	discount rate
		n	=	number of years
3	$\mathbf{SPV = A \times \frac{1}{(1+d)^n}}$	SPV	=	Single Present Value
		A	=	Single Future Value
		d	=	discount rate
		n	=	number of years
4	$\mathbf{UPV = \boldsymbol{B} \times \frac{(1+d)^n - 1}{d(1+d)}}$	UPV	=	Uniform Present Value
		B	=	Future Value
		d	=	discount rate
		n	=	number of years
5	$\mathbf{d = \frac{(1+i)}{(1+r)} - 1}$	d	=	discount rate
		i	=	lending rate
		r	=	inflation rate