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# 재배치 가능한 모듈식 학교의 적응형 파사드 적용: 에너지 성능 개선을 위한 매개변수 평가

# Application of Adaptive Façade in Relocatable Modular School: A Parametric Assessment for Improving Energy Performance

○팜 투안 안* 오진웅* 권나현** 안용한***
Pham, Tuan An Oh, Jin-Woong Kwon, Na-Hyeon Ahn, Yong-Han

Abstract

The educational landscape is rapidly changing with the rise of relocatable modular schools (RMS), offering mobility and flexibility. However, there's a crucial need to enhance adaptability, especially in facade design, impacting environmental performance. This study investigates facade adaptability in RMS, focusing on energy consumption. By evaluating three Adaptive Facade (AF) systems, it aims to optimize energy performance. Results highlight the significance improvement in energy efficiency and enhancing performance of RMS across all AF types. Methodology involves assessing base case models, analyzing AF performance factors, and proposing optimal settings. The research not only advances AF for RMS but also provides insights for architects, educators, and policymakers. The findings offer practical strategies for designing sustainable and efficient RMS, crucial for relocation in diverse conditions.

키워드 : 적응형 외관, 재배치 가능한 모듈식 학교, 실내 환경 품질
Keywords : Adaptive façade, Relocatable Modular School, Indoor Environmental Quality

## 1. Introduction

The landscape of education is evolving rapidly, and one notable development is the increasing prevalence of relocatable modular schools (RMS)[1]. Compared to permanent modular classrooms, the relocatability makes relocatable modular classrooms more flexible due to their ability to deal with changing demography. However, as these modular schools become more commonplace, a critical need arises to address the limitations associated with their adaptability, particularly in the context of their facade design. Despite the advantages of RMS, a significant challenge lies in their ability to respond effectively to diverse environmental conditions and evolving educational needs. The facade, with its potential to influence natural lighting, thermal comfort, and energy consumption, emerges as a focal point for enhancing the overall sustainability of modular schools [2]. AF represents an innovative approach to smart facade design, actively adjusting its key functional parameters in response to dynamic changes in situations and climate [3].

The objective of this study is to (1) investigate the potential of applying AF to RMS by assessing the performance of improving daylighting, thermal and energy of three types of AF systems integrated in a modular classroom. This will be achieved by conducting simulations in various scenarios with different climate conditions. And (2) propose optimal settings for key parameters that affect to AF performance by evaluating the relationship between AF parameters and energy performance.

## 2. Materials and Method

The experimental process of this study comprises three main phases: firstly, evaluating the base case model; secondly, assessing the base case model with various facade types (Table 1) ; and finally, analyzing the impact factors on AFs' performance and providing optimal settings for key parameters. Tools utilized include Rhino/Grasshopper, Ladybug, and Honeybee. Weather data from Seoul and Busan in Korea (temperate climate zone) and Hanoi and Ho Chi Minh in Vietnam (tropical climate zone) were employed for the study.

* 한얀대학교 대학원 석사과정 스마트시티공학과
** 한양대학교 에리카산학협력단, 공학박사
*** 한양대학교 건축학부 건축공학과 교수, 공학박사
(Corresponding author: Department of Architecture, Professor, Hanyang University, yhahn@hanyang.ac.kr)

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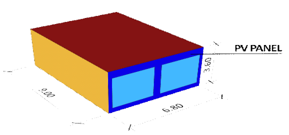
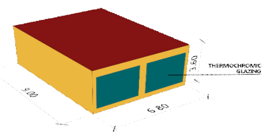
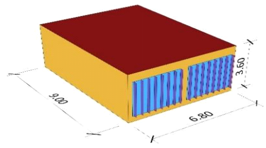
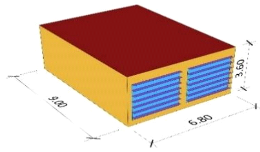
Table 1. Total energy consumption of different AF types in Seoul, Busan, Hanoi, Ho Chi Minh compared to the base case

| **Opaque Dynamic Façade (ODF)** | **Transparent dynamic façade (TDF)** | **Semi-transparent dynamic façade (S-TDF)** | |
|---|---|---|---|
| | | Vertical shading | Horizontal shading |
|  |  |  |  |

## 3. Results

EUI of various AF integrated models at different locations is synthesized and compared (Figure 1). Specifically, the values of HEUI, CEUI, lighting energy use intensity (LEUI), and Electricity equipment energy use intensity (EEUI) for different locations are stacked to assess the potential energy improvement across different adaptive façade types. The results indicate that S-TDF (Horizontal) and TDF demonstrate optimal energy performance for the model when applied in various locations (Table 2), with the total Energy for each city compared to the base case showing improvements of -548.388 kWh/m2 and -491 kWh/m2, respectively.

Table 2. Total energy consumption of different AF types in Seoul, Busan, Hanoi, Ho Chi Minh compared to the base case (kWh/m2)

| AF Type | Seoul | Busan | Hanoi | Ho Chi Minh | All locations | Energy saving (%) |
|---|---|---|---|---|---|---|
| BC | 308.5 | 295.98 | 400.633 | 529.452 | 1534.565 | - |
| ODF | 236.61 | 251.26 | 305.69 | 444.169 | 1237.729 | 19.34 |
| TDF | 199.35 | 202.25 | 257.35 | 384.3 | 1043.25 | 32.02 |
| S-TDF (Ver) | 213.14 | 213.14 | 261.53 | 389.61 | 1077.42 | 29.79 |
| S-TDF (Hor) | 207.43 | 140.82 | 255.627 | 382.3 | 986.177 | 35.74 |

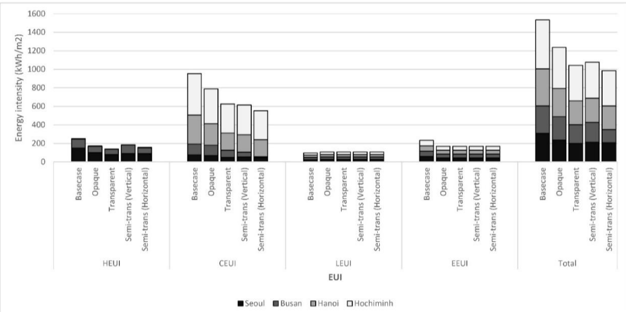



Figure 1. EUI of various AF integrated models in Seoul, Busan, Hanoi, and Ho Chi Minh

## 4. Conclusion

The specific adaptability of RMS is often overlooked in the literature, necessitating focused exploration. This study addresses these gaps by aiming to address challenges in the adaptability of existing facade designs for RMS and proposes and evaluates AF design strategies to enhance the environmental responsiveness of this innovative educational structure. The three types of AF significantly contribute to improving the energy performance of RMS when applied under different conditions compared to RMS using conventional facades. Through research, proposals for applying AF to RMS have been presented. This aids in optimizing the development of RMS with applied AF, making it easier to formulate strategies for relocating RMS in different conditions.

## 참고문헌

1. ································ Nguyen, T.D.H.N., et al., An innovative approach to temporary educational facilities: A case study of relocatable modular school in South Korea.Journal of Building Engineering, 2023. 76: p. 107097.

2. ································ Yu, H., et al., Lean transformation in a modular building company: A case for implementation.Journal of management in engineering, 2013. 29(1): p. 103-111.

3. ································ Badeche, M. Integrated Adaptive Facades for Building Energy Efficiency and User's Thermal Comfort. in Artificial Intelligence and Heuristics for Smart Energy Efficiency in Smart Cities. 2022. Cham: Springer International Publishing.