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Architectural design principles of a University Campus that create an educational atmosphere

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ABSTRACT

Architectural design holds a pivotal role in shaping the development of university campuses. This study critically examines the extent to which the architectural plans of four campuses correspond with the conceptual framework of an educational campus. The evaluation of design quality is crucial, as it significantly influences both academic and non-academic environments, thereby contributing to the overall enhancement of higher education quality. Adopting a mixed methods research (MMR) approach, the initial phase employs the Analytic Hierarchy Process (AHP) to establish the Priority Design Principles for Educational Campuses. Subsequently, the quantitative phase focuses on formulating a decision-making model to assess the quality of the educational atmosphere through the application of a fuzzy logic system. The findings of this research reveal that the top three design criteria, identified as having the highest priority, serve as the basis for developing a comprehensive model to evaluate campus designs grounded in the educational campus paradigm. These three key criteria functions as benchmarks for determining whether a campus's architectural design satisfies the essential standards of an educational campus. An empirical assessment conducted across four university campuses indicates that only the campus design of Malikussaleh University falls short of meeting the educational campus design criteria. In contrast, the remaining three universities have successfully adhered to the principles underpinning the educational campus concept.

Introduction

Architectural design, both conceptually and practically, must place humans at the center as primary users (Laurens and Tanuwidjaja 2012; Laurens 2004). Beyond merely accommodating physical activity through structural form, utility systems, and functional arrangements, architecture must also cultivate a psycho-socio-spatial atmosphere especially within educational environments such as university campuses.

A higher education campus should be envisioned and developed as an educational campus. Such a campus signifies a commitment to academic excellence and is dedicated to the intellectual, social, and psychological growth of its academic community. It offers a space where creativity and innovation are nurtured, ultimately contributing to institutional distinction (Karim 2020).

From an architectural standpoint, educational facilities possess unique characteristics that distinguish them from other public infrastructures. According to Sotelo (2010), there are ten defining parameters of the educational campus concept: utopia and integrated planning,

community of learning, spatial harmony, emotional and intellectual harmony, nature and art, image and accessibility, sustainability and environmental adaptation, memory and avant-garde, university–city synergy, and innovative teaching and learning modalities.

Utopia and Integrated Planning (EC1)

A visionary framework is required, supported by integrated planning and concrete objectives that are adaptable to the evolving demands of science and the academic community. Campus planning should foster an architectural environment that facilitates human activity, encourages collaboration, and promotes a sustainable and inclusive academic culture.

Community of Learning (EC2)

The design of physical facilities, educational practices, campus culture, and student engagement are interconnected aspects that shape the overall learning environment (Baldwin 2022; Gillason 2010; Sage 2021). Architectural features that embrace transparency and collaborative spatial arrangements blur traditional boundaries between faculty, students, campus, and the broader community (Quirk 2012; Sager 2023).

Spatial Harmony (EC3)

University architecture must harmonize with environmental aesthetics and the urban context (Liauw 2019; Amirshekari and Pourmand 2015; Cusumano 2023). This integration demands a thoughtful and responsive approach to collective identity and individual preference (Lambe and Dongre 2019).

Emotional and Intellectual Harmony (EC4)

A campus must serve as a metaphorical environment that fosters both emotional and intellectual equilibrium. Architecture must create "sensing spaces" spaces that emotionally, psychologically, visually, and intellectually engage with users (Glancey 2014).

Nature and Art (EC5)

Incorporating natural elements enhances the educational ambiance of a campus. Environmental aesthetics studies emphasize the importance of visual composition, form, and focus in spatial design (da Luz Reis and Dias Lay 2010). Green spaces enrich campus life, positively influencing human health and well-being (Shanahan et al. 2015; Kaplan 1993).

Image (EC6) and Accessibility (EC7).

A university must project a distinct image that embodies its core missions: education, research, and community engagement. Architectural works evoke associative and emotional responses, often tied to memory and place (Bruno 2007). Accessibility both physical and conceptual is an essential design component. While widely recognized in theory, the actual implementation of inclusive design practices remains limited. Inclusive architecture must address physical, sensory, cognitive, and sociological factors (Zallio and Clarkson 2021).

Sustainability and Environmental Adaptation (EC8)

University campuses should align with broader urban plans and adapt to their geographic and climatic contexts. Given that buildings are major contributors to climate change (Röck et al. 2020), campuses must not only adopt sustainable design strategies but also serve as models of ecological responsibility.

Memory and Avant-Garde (EC9)

A campus, as a locus of formative experiences, should leave lasting impressions on its students. As such, campus design must reflect the heritage of local or traditional architecture while embracing forward-thinking innovation. Modern architectural expression need not forsake local richness but should explore harmony between contemporary design and natural environments through diverse materials, forms, and creative ideation (Barliana et al. 2023; 2020).

University–City Relationship (EC10)

A strong, symbiotic relationship between university and city enhances social and spatial connectivity (Sunaryo 2010). Campus architecture can elevate urban identity by becoming a cultural landmark that enriches the surrounding community. Iconic architecture not only shapes city imagery but also contributes to citizens' quality of life (Elhagla et al. 2020).

Innovative Teaching and Learning Modalities (EC11)

An innovative campus design catalyzes the evolution of teaching and learning practices. The swift advancement of global technology has transformed human lifestyles (Hanafizadeh et al. 2020). In the era of the Fourth Industrial Revolution and Society 5.0 defined by

digitalization, automation, and artificial intelligence campus design must respond to these shifts by adapting learning environments accordingly.

When implemented effectively, these eleven principles of an educational campus can facilitate the development of a dynamic and creative learning ecosystem. The quality of education becomes a measurable outcome of architectural performance (Suryadi et al. 2020). It is assumed that when other factors such as curriculum, teacher quality, and student capabilities are strong, high-performing buildings will enhance educational outcomes.

Within the Indonesian higher education context, a significant gap persists between the ideal requirements for quality educational infrastructure and the actual conditions, both in public and private institutions. According to a BAN-PT report in 2002, the overall quality of most Indonesian higher education institutions remains low. Only 15.73% of public and 5.26% of private institutions achieved an A accreditation. One critical assessment factor is the quality of infrastructure and institutional management (Wicaksono and Friawan 2008).

In light of these conditions, identifying architectural design priorities based on the educational campus concept is essential to guide campus development. Amid constrained state budgets, one strategy to enhance campus facilities and infrastructure is through foreign loan and grant financing (PPHLN). Unlike domestic funding, which typically supports phased construction, PPHLN facilitates the comprehensive and simultaneous development of higher education campuses.

This raises a fundamental question: Does architectural transformation contribute equitably to improving the tridharma of higher education education, research, and community service? This article, based on research findings, seeks to examine the relationship between architectural transformation, educational campus principles, and the academic performance of higher education institutions.

This study aims to evaluate the extent to which the architectural designs of four PPHLN-funded campuses align with the concept of the educational campus. The findings are expected to offer insight into the effectiveness of development financing strategies in enhancing the overall quality of higher education.

Methods

The methodology employed in this research adopts a Mixed Methods Research (MMR) approach, utilizing a sequential exploratory design in which qualitative and quantitative data are collected in distinct phases (Tashakkori and Teddlie 2010; Creswell et al. 2014).

In the initial phase of the sequential exploratory strategy, the study aims to formulate Priority Design Principles for Educational Campus Architecture through a qualitative descriptive approach. Expert perspectives on the priority principles or criteria for designing educational campuses are elicited through Focus Group Discussions (FGDs). These discussions involve twelve professional architects, each possessing a minimum of five years of architectural practice experience and registered as members of the Indonesian Institute of Architects (Ikatan Arsitek Indonesia – IAI). The data obtained from the FGDs are subsequently analyzed using the Analytic Hierarchy Process (AHP) method.

In the subsequent quantitative phase, the study focuses on the development of a decision-making model to evaluate the quality of the educational atmosphere on campus, employing a fuzzy logic system. Following this, the Mamdani fuzzy logic model is tested on the architectural designs of four campuses involved in the AKSI-ADB Project, in alignment with the educational campus concept.

The assessment phase evaluates the architectural designs of four university campuses included in the ADB AKSI Project Scheme: Malikussaleh University (UNIMAL), Jambi University (UNJA), Riau University (UNRI), and the Indonesia University of Education (Universitas Pendidikan Indonesia – UPI). The evaluation utilizes a range of visual materials including master plan illustrations, site plans, pre-designs, and three-dimensional visualizations or animations.

The first procedure in establishing the priority of indicators is the implementation of pairwise comparisons among all criteria within each hierarchical subsystem. These comparative judgments between hierarchical criteria are conducted using a scale ranging from one to nine, as detailed in table 1.

Table 1. Pairwise comparison rating scale

Level	Definition

1	Equal
3	moderate
5	Strong
7	Very strong
9	Extreme
2, 4, 6, 8	Intermediate values
Reverse	Reverse If element i gets one number when compared with element j, then j has the opposite value when compared with.

Source: (Saaty 2006)

The comparison rating scale is derived from the standard Analytic Hierarchy Process (AHP) scale, which is used to evaluate each criterion based on its level of importance. From this assessment, a decision can subsequently be determined by referencing the priority weight. The AHP method is implemented through the use of Expert Choice 2020 software, employing a pairwise comparison model.

The following stage involves developing a Fuzzy Logic Design to assess the Quality of University Campus Design. The fundamental motivation behind the application of fuzzy logic theory is to establish a mapping between an input space and an output space through the use of IF-THEN rules. This mapping process is executed within a Fuzzy Inference System (FIS) a system that evaluates all rules simultaneously to derive conclusions, with the rule order being non-hierarchical or arbitrary (Naba 2009). The parameter ranges within the fuzzy system are defined based on data obtained from expert and practitioner evaluations.

Table 2. Norms for design achievement criteria

FIS editor	Code	Input Variable	Mean ± SD	Unit	Test
Educational campus	EC1	Utopia and integrated planning	72,3 ± 2,77	Point	Expert assessment
	EC8	Sustainability and adaptation to the environment	63 ± 5,17	Point	Expert assessment
	EC11	Innovative teaching and learning	65,4 ± 5,09	Point	Expert assessment

Results and discussion

Hierarchy of priority criteria for educational campus design quality

The results of the data analysis, reflecting the depth of expert input, present the geometric mean values derived from the pairwise comparisons of the primary criteria aligned with the overarching objective the quality of design grounded in the educational campus concept. This analytical phase constitutes a critical component of the research, as it facilitates the determination of the relative priorities of the key indicators through the computation of their respective priority weights (figure 1).

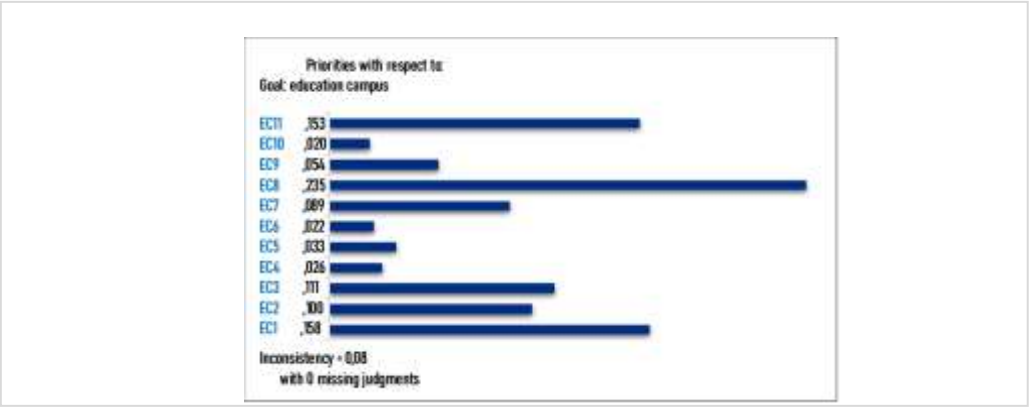

Figure 1. Comparison of matrix pairs of main criteria with priority weights for goals (quality of education campus design)

The priority ranking of criteria pertaining to the principles of educational campus design is established and presented in table 3.

Table 3. Priority weights for educational campus design criteria

Code	Final criteria order (Empirical)	%
EC8	Sustainability and adaptation to the environment	23.5
EC1	Utopia and integrated planning	15.8
EC11	Innovative teaching and learning	15.3
EC3	Spatial harmony	11.1
EC2	Community of learning	10.0
EC7	Accessibility	8.9
EC9	Memory and avant-garde	5.4
EC5	Nature and art	3.3
EC4	Emotional and intellectual harmony	2.6
EC6	Image	2.2
EC10	The university/city relationship	2.0

The empirical findings of this study reveal several compelling insights. The professional architects, serving as assessors, identified sustainability and environmental adaptability as the top-priority criteria in educational campus-based design. Notably, in the prior theoretical framework, this criterion was ranked only eighth in importance.

This shift highlights an increasing awareness among architects regarding the severity of the current environmental and energy crises. These findings align with data reported by Dynata, the world's largest first-party data platform, which indicates that 70% of individuals are now more conscious of human-induced environmental threats, and 40% express a desire to adopt more sustainable lifestyles. Furthermore, nearly 90% believe that corporations should produce more environmentally friendly products and actively support local communities in sustaining a healthier environment.

Maknun et al. (2017) emphasize that environmental literacy encompasses an individual's knowledge and understanding of environmental systems, principles governing ecological processes, and the capacity to take actions that contribute to environmental quality in everyday life.

The second highest-ranked criterion is utopia and integrated planning, which is highly relevant, as the design of a university campus should be guided by a comprehensive vision and a clear long-term perspective.

Another noteworthy finding is the indicator of innovative teaching and learning, which was theoretically placed at rank eleven, yet emerged as the third-highest priority in the empirical analysis. This highlights the growing recognition of the critical role that educational innovation plays in shaping effective and future-oriented campus environments.

Quality of architectural design of four university campuses

Utilizing the AHP method, a hierarchical structure of indicators has been systematically established. The subsequent phase involves implementing the Mamdani fuzzy logic model to support decision-making processes, using the Fuzzy Toolbox within MATLAB software version 2013a developed by MathWorks Inc.

Given the complexity involved in the modeling process, this research concentrates on the three highest-priority criteria as identified in the preceding analysis.

Table 4. Norms for educational campus design criteria, along with the range for each category

Input variables	Mean ± SD	The range of each category	Category
EC1	72,3 ± 2,77	63.96 - 69.5	Does not meet
		66.73 - 72.3	Insufficient
		69.5 - 75.03	Meets
		72.57 - 77.8	Highly Satisfactory
EC8	63 ± 5,17	47.5 - 57.72	Does not meet
		52.6 - 62.8	Insufficient
		57.72 - 67.93	Meets
		63 - 73.37	Highly Satisfactory
EC11	65,4 ± 5,09	50.24 - 60.32	Does not meet
		55.28 – 65.4	Insufficient
		60.33 - 70.4	Meets
		65.4 - 75.45	Highly Satisfactory
Output variable (achievement of educational campus)		0-40	Does not meet
		20-60	Insufficient
		40-80	Meets
		60-100	Highly Satisfactory

Subsequently, a testing phase was conducted by inputting the numerical data from expert evaluations of the four campus designs into the input column of the rule viewer. This process aimed to generate output variable values based on variations across the three prioritized educational campus criteria. The level of adherence to the educational campus concept was measured on a 0–100 scale, categorized as follows:

Table 5. Design Achievement Decision Categories based on educational campus criteria

Category	Decision value
Does not meet	<25
Insufficient	25<x<50
Meets	50<x<75
Highly Satisfactory	75<x<100

Table 6 presents the results of data processing and decision outputs, indicating that the decision column (expressed as a percentage) reflects the outcomes of the fuzzy logic computations. These results serve as a valuable tool for university-level policymakers, enabling them to better interpret and evaluate campus designs in alignment with the principles of the educational campus concept.

Table 6. Recapitulation of design assessment results based on the concept of campus educational

No	Code	Educational campus			Decision (%)	Achievement
		EC1	EC8	EC11		
1	Campus A	69,3	55,7	58,3	29.5	Insufficient
2	Campus B	70,8	67,2	70,3	71,9	Meets
3	Campus C	75,5	66,1	66,7	67,6	Meets
4	Campus D	73,4	63,0	66,1	64.66	Meets

Based on the data presented in table 6, it can be concluded that three campuses namely, the University of Riau (UNRI), the University of Jambi (UNJA), and the Indonesia University of Education (UPI) have successfully fulfilled the educational campus design criteria, as evaluated according to the highest-priority indicators. In contrast, the Malikussaleh University (UNIMAL) campus design is still considered to fall short of meeting the established criteria for an educational campus.

Conclusions

Theoretically, eleven primary parameters determine the quality of a university's architectural environment based on the educational campus concept. However, the empirical findings of this study reveal a reordering of these parameters in terms of priority, starting from the most critical. The revised priority sequence is as follows: sustainability and adaptation to the environment; utopia and integrated planning; innovative teaching and learning; spatial harmony;

community of learning; accessibility; memory and avant-garde; nature and art; emotional and intellectual harmony; image; and the university–city relationship.

The top three highest-priority criteria serve as a model for assessing the quality of university design per the educational campus concept. These three criteria are essential in determining whether a campus design meets the minimum standards required for an educational campus.

The first criterion is sustainability and adaptation to the environment. A campus must be designed in harmony with urban planning principles and local contextual factors, including geographical and climatic conditions. As institutions at the forefront of scientific advancement, campuses must also exemplify the implementation of solutions to global challenges such as through green architecture, biodiversity preservation, environmental conservation, and the efficient use of resources and energy.

The second criterion is utopia and integrated planning. With an ambitious and visionary outlook to establish an ideal academic environment, universities must pursue comprehensive and integrated planning. This involves translating a grand institutional vision into concrete and attainable design goals, while simultaneously maintaining flexibility and adaptability in the use of space and time.

The third criterion is innovative teaching and learning. A university campus designed with innovation at its core will naturally inspire and support creative pedagogical practices. Traditional classroom models must give way to diverse, flexible, and engaging spatial configurations that promote dynamic and interactive learning. The campus environment should function as a smart and healthy space, fostering the exchange of ideas between faculty and students, and cultivating a holistic academic atmosphere.

The results of testing the architectural designs of the four universities receiving PHLN funding under the AKSI ADB project indicate that the campus of Malikussaleh University does not yet meet the educational campus design criteria. In contrast, the campuses of the University of Riau (UNRI), University of Jambi (UNJA), and the Indonesia University of Education (UPI) have successfully conformed to the educational campus design concept.

Based on these findings, the study puts forward the following recommendations: to strengthen the application of the educational campus concept, university-level policymakers must consider the fulfillment of all eleven parameters. If achieving all criteria proves challenging, then priority should be given to the three most critical components identified in this research.

To further enhance the effectiveness and quality of educational environments, future studies are encouraged to explore various forms of Student-Centered Learning Environments. In particular, future research may investigate how spatial design can support active, collaborative, and personalized learning experiences across a broad range of academic disciplines.

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References

Amirshekari, S., & Pourmand, H. 2015. The aspects of biological culture recreating and its relationship with the approach of contextual architecture (Bandar Abbas City). European Online Journal of Natural and Social Sciences: Proceedings, 3(4 (s)), pp-475.

Baldwin, Eric (2022). Gateway to the Future: Rethinking Campus Design. 06 Jan 2022. ArchDaily. Accessed 1 Dec 2023. *<https://www.archdaily.com/974671/gateway-to-the-future-rethinking-campus-design> ISSN 0719-8884*

Barliana, M.S., Purnamaningsih, M., Ramadhan, T., Susanti, I. 2023. Friendly school design of early childhood based on traditional Sundanese architecture typology, Journal of Asian Architecture and Building Engineering. DOI: 10.1080/13467581.2022.2153058

Barliana, M. S., Cahyani, D., & Mardiana, R. 2020. Creative adoption of Sundanese traditional

architecture for architectural and campus interior design development. In IOP Conference Series: Materials Science and Engineering (Vol. 830, No. 2, p. 022064). IOP Publishing.

Bruno, Giuliana. 2007. Public Intimacy: Architecture and the Visual Arts. PublicIA @inproceedings. url={https://api.semanticscholar.org/CorpusID:190081673}

Creswell, J. W., Plano Clark, V. L., Gutmann, M., & Hanson, W. 2014. Advanced mixed methods research designs.

Cusumano, Vincent. 2023. The Importance of Contextual Harmony in Architecture. https://www.cusumano-architect.com/ideas/context-is-key

Elhagla, Khalid., Nassar, Dina M., Ragheb. Mohamed A. 2020. Iconic buildings' contribution toward urbanism. Alexandria Engineering Journal. www.elsevier.com/locate/aej

Glancey, Jonathan (2014). Sensing spaces: Emotional buildings. 21st October 2014. https://www.bbc.com/culture/article/20140130-can-buildings-be-emotional

Gillason, Neil. 2010. Architectural design and the learning environment: A framework for school design research. July 2010. Learning Environments Research 13(2):127-145. DOI: 10.1007/s10984-010-9071-x

Hanafizadeh, P., Khosravi, B., & Tabatabaeian, S. H. (2020). Rethinking dominant theories used in information systems field in the digital platform era. *Digital policy, regulation and governance, 22(4), 363-384.*

Kaplan, Rachel. 1993. The role of nature in the context of the workplace. Landscape and Urban Planning, Volume 26, Issues 1–4, 1993, Pages 193-201, ISSN 0169-2046, https://doi.org/10.1016 /0169-2046(93)90016-7.

Karim, B. A. 2020. Pendidikan Perguruan Tinggi Era 4.0 Dalam Pandemi Covid-19 (Refleksi Sosiologis). *Education and Learning Journal, 1(2), 102-112.*

Lambe, N. R., & Dongre, A. R. 2019. A shape grammar approach to contextual design: A case study of the Pol houses of Ahmedabad, India. Environment and Planning B: Urban Analytics and City Science, 46(5), 845-861.

Laurens, J. M. 2004. *Arsitektur & perilaku manusia*. Grasindo.

Laurens, J. M., & Tanuwidjaja, G. 2012. *Melalui pendekatan desain inklusi menuju arsitektur yang humanis* (Doctoral dissertation, Petra Christian University).

Liauw, F. 2019. Reference for contextual design. *In IOP Conference Series: Materials Science and Engineering (Vol. 508, No. 1, p. 012031). IOP Publishing.*

Maknun, J., Barliana, M.S., Cahyani, D. 2017. The Level of Environmental Literacy toward Vocational High School Students in West Java Province. Innovation of Vocational Technology Education 12(2). Bandung: UPI. DOI: 10.17509/invotec.v12i2.6205

Naba, Agus. 2009. Belajar cepat fuzzy logic menggunakan matlab. *https://api. semantic scholar.org/CorpusID:64403327.*

Quirk, Quirk. 2012. Community-Oriented Architecture in Schools: How 'Extroverted' Design Can Impact Learning and Change the World. *https://www.archdaily.com/213438/*

Reis, A. T. L., & Lay, M.C.D. 2010. *Internal and external aesthetics of housing estates. Environment and Behavior.* Sage Publications: 42, 271- 294.

Saaty, T. L. (2006). Rank from comparisons and from ratings in the analytic hierarchy/network processes. *European journal of operational research*, *168*(2), 557-570.

Sager, Jessica.2023. *Learning Communities*. Center of Developing Child. Harvard University. *https://developingchild.harvard.edu/collective-change/key-concepts/learning-communities/*

Sage, Travis. 2021. From hybrid learning to social hubs, trends are changing how universities operate and are designed. *This article first appeared as "What will campus look like next?" in Stantec Design Quarterly, Issue 13. https://www.stantec.com/en/ideas/what-will-the-future-campus-look-like*

Shanahan, D. F., Fuller, R. A., Bush, R., Lin, B. B., & Gaston, K. J. 2015. *The health benefits of urban nature: how much do we need? BioScience, 65(5), 476-485. https://doi.org/10.1093/biosci/biv032*

Sotelo, P.C.C., 2010. *The concept of" Educational Campus" and its application in Spanish universities.*

Sunaryo, R. G. (2010). *Perubahan Setting Ruang dan Pola Aktivitas Publik di Ruang Terbuka Kampus UGM.*

Suryadi, D., Barliana, M.S., Kudwadi, B., Rahmanullah, F. 2020. Building Performance and Academic Performance in Higher Education: A Post Occupation Evaluation of Overseas Loan Financing Project. *Journal of Engineering Education Transformations.*

Tashakkori, A., & Teddlie, C. 2010. Putting the human back in ''human research methodology'': The researcher in mixed methods research. *Journal of mixed methods research*, *4*(4), 271-277.

Zallio, Matteo & Clarkson, P. John. 2021. Inclusion, diversity, equity and accessibility in the built environment: A study of architectural design practice. Building and Environment. *journal homepage: www.elsevier.com/locate/buildenv*

Author(s) contribution

Diah Cahyani Permana Sari contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Mokhamad Syaom Barliana, contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

Rr. Tjahyani Busono contribute to methodology, supervision, and validation.

Muhammad Aditya Siddiq Alfajr contribute to methodology, supervision, and validation.

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