

The Study of Parametric Applications in Indonesian Scientific Publications

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Abstract

The development of discussions on the application of parametric architecture methods in scientific paper publications in Indonesia has increased over the last 10 years. This is greatly influenced by technological developments that have had an impact on helping visualise design ideas in the field of architecture. The purpose of this study is to analyse the development of the application of parametric architecture in Indonesia through data on the discussion of scientific papers published on Google Scholar in the last 10 years. The study also aims to determine how technology has been applied in the development of this method. With 86 publications related to the theme of discussion, the study employed bibliometric analysis methods and literature studies to help observe the purpose of the application and the use of digital technology. The results show that the majority of scientific publications are still concentrated in the context of conceptual design rather than constructive design. This study also highlights the potential for further research on parametric architecture in the use of parameters and algorithms for design exploration, shape optimisation, and material efficiency. These findings can be integrated with the context of local culture, climate, and the social needs of the Indonesian people.

INTRODUCTION

Along with the development of science and technology (science and technology), technology has an important role that assists architects in designing buildings. The entry of digital technology allows architects to design more efficient and effective designs to improve design quality. In addition, architects in the modern architectural era can be more flexible in developing ideas when designing designs for shapes and landscapes (Ibadi et al., 2023). The influence of technology in the world of architecture has given rise to a new view or design method, namely digital architecture that utilizes technology as a visual representation of design design. In its development, there is a parametric design concept that allows architects to expand their creativity by getting assistance through digital tools or software for the design conceptualization process, design study and development, design optimization, and digital fabrication (Sunarya et al., 2022).

The trend of computational design has increased in the last 10 years around the world, including in Indonesia (Michelle & Gemilang, 2022). Computational design with parametric methods has developed into one of the standard abilities that must be possessed in the world of architecture, even various universities in various countries have included parametric design in the architecture education curriculum (Sunarya et al., 2022). However, there is still little research related to parametric design in Indonesia, which indicates a lack of awareness of the need for the use of parametric science at the university level. In this case, there are various parametric design approaches that can be practiced in architecture (Sunarya et al., 2022). Based

on the phenomenon and the lack of research, this study aims to find out the majority of the objectives of the application and utilization of parametric architecture, as well as to find out the processing of these methods with the use of digital technology researched in scientific publications in Indonesia.

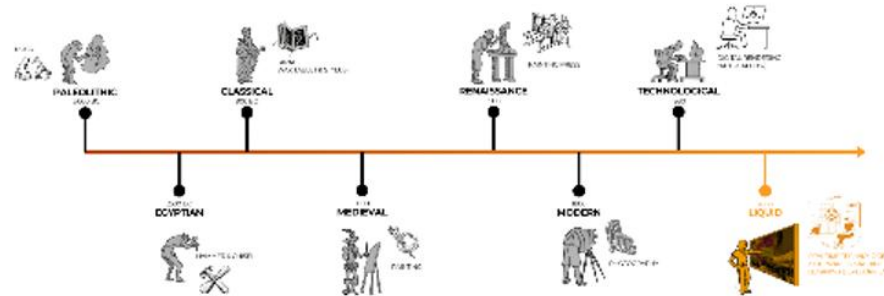


Figure 1. Transformation of architectural design methods from manual to digital era

Source: Adapted from Yogapriya et al. (2021) and Putra (2018)

The history of architectural development shows the major transformation from manual methods to the digital era shown in Figure 1. Initially, architects used large drawing boards for design visualization, but technological developments, starting from the Paleolithic era with stone carvings to the digital era since 1980, have changed the way designing is done (Yogapriya et al., 2021). Early technology only functioned as a visualization tool, but now it plays a role in the creative thinking process that allows the exploration of new designs and innovations (Putra, 2018). With technological advancements such as machine learning and advanced software, architecture is entering a "liquid" era where real-time technology supports the development of more innovative designs. The concept of digital architecture, which includes the use of information and communication technologies in design and construction, allows for more efficient planning and design and leads to the potential for new theories and revolutions in this field (Satwiko, 2009; Basuki & Purwanto, 2022). One significant innovation is computational design, a programming logic-based method of solving design problems, which includes a rapidly evolving parametric approach to creating modern and modular architectural designs (Michelle & Gemilang, 2022).

Parametric architecture is a design method based on certain variables in the form of dimensions, quantities, and geometry (Michelle & Gemilang, 2022). It can also be interpreted that in this method an algorithm is used consisting of variables, functions, and geometry including bound and independent comparator variables that produce a design model. Some of its independent variables can be highlighted as the main variables in answering the design objectives. The conceptual relationship between technology, algorithmic elements, and building design is illustrated in Figure 2 and Figure 3. According to Frazer (2016), the concept of parametrics comes from a mathematical term that utilizes the use of certain parameters/variables that can be changed to manipulate the results of equations (Frazer, 2016). The typological nature of itself requires digital modeling specific character parameters &

algorithms to define designs that cannot be achieved with manual modeling (Liberotti & Gusella, 2023).

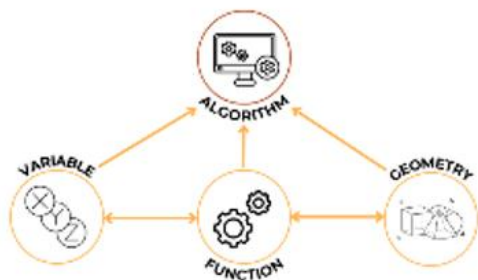


Figure 2. Conceptual relationship between technology and building design

Source: Author's elaboration (2024)



Figure 3. Algorithmic elements in parametric design

Source: Author's elaboration based on Frazer (2016) and Eltaweel & Su (2017)

According to Lynn (1999), parametric architecture has a non-uniform pattern design applied to symmetrical and asymmetrical surfaces, but they are interconnected and have complex and unusual shapes (Hibatullah & Aqli, 2024). Since this method is defined as mathematical design, the relationships between design elements are displayed as parameters that can be reformulated to produce complex geometries. The geometry of the design is based on the parameters of elements that can create a variety of new shapes in a short time. Some of the principles of parametric architecture concepts in general are having different but interconnected geometric shapes (unusual and complicated), having a base of parameters and variables in design design, using computational modeling, and the design process is iterative (Jaya & Aqli, 2021). These parameters can be in the form of dimensions, shapes, positions, and environmental conditions.

There is a significant difference in the design process using parametric and conventional design methods. The design process with parametrics can be interconnected in finding the most optimal design, while in conventional designs there can only be a 1-way process to reach the final model. Mainly, this has a very significant difference in time efficiency. In addition, using parametric methods can handle high-complexity details in the use of the human brain's imagination which would be very difficult if done with conventional methods (Eltaweel & Su, 2017). With this method of approach, architects can explore various parameters and modify them quickly for time efficiency that adapts to design needs.

With how parametric design methods have influenced the development of digital architecture, this method itself can be poured into 2 design contexts, namely conceptual design and constructive design (Stavric & Marina, 2011). Conceptual design focuses on the early stages of design with the aim of exploring form, aesthetics, and the development of spatial ideas. Meanwhile, constructive design focuses on practical aspects for the construction process, materials, and fabrication methods with the aim of material optimization, structural integrity, and efficiency in assembly. It can be concluded that the application of conceptual design is towards the realm of design exploration, while constructive design ensures that design design can be realized efficiently and effectively in the real world.

EFFICIENTLY AND EFFECTIVELY IN THE REAL WORLD.

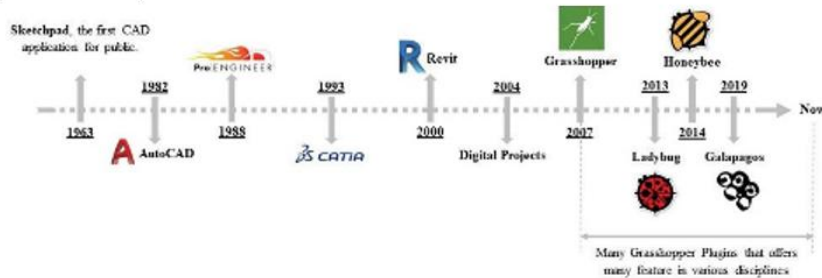


Figure 4. Development timeline of parametric modeling software

Source: Compiled from M. W. Rezk, (2023)

Software is a tool in design to achieve the goals or objectives of design using parametric methods. Each software has a different focus in its use, such as being able to direct and evaluate the performance of science, structure, and shape optimisation. As seen in Figure 4 regarding the development of software, in 1988 Professor Samuel Geisberg succeeded in founding PTC or Parametric Technology Corporation and created the first parametric modelling software, named Pro/ENGINEER (Eltaweel & Su, 2017). This marks the beginning of the formation of AutoCAD, Revit, Rhinoceros, Grasshopper, and other software developed with machine learning technology. Machine learning is a subfield of Artificial Intelligence (AI), a field of science used as a solution for solving various problems (Roihan et al., 2020). Based on its development, machine learning technology contained in parametric software programming can not only provide information and create models, but can currently also improve the overall development of design styles. This can help architects to be more efficient in carrying out the design process with parametric methods.

Based on the background and phenomena described above, this study aims to analyse the development of parametric architecture applications in Indonesia through scientific publications indexed by Google Scholar over the last 10 years (2014–2024), to identify the majority of objectives in the application of parametric methods whether in the context of conceptual design or constructive design, and to examine how digital technology, particularly software such as Rhinoceros and Grasshopper, is utilised in the application of parametric architecture methods in Indonesian scientific publications. The benefits of this research are twofold. Theoretically, this study contributes to the body of knowledge on digital architecture and computational design by mapping the trends, research gaps, and potential future directions of parametric architecture in Indonesia, while also providing a bibliometric analysis that can serve as a reference for researchers interested in the development of parametric methods in architectural education and practice. Practically, the findings offer insights for academics, practitioners, and policymakers to understand the current state of parametric design adoption in Indonesia; for universities, the results can encourage the integration of parametric design into the architecture curriculum; for architects and designers, this study highlights the potential of parametric methods for design exploration, material efficiency, and sustainable design; and for future researchers, it identifies opportunities for further research linking parametric architecture to local cultural contexts, climate adaptation, and community needs in Indonesia.

METHOD

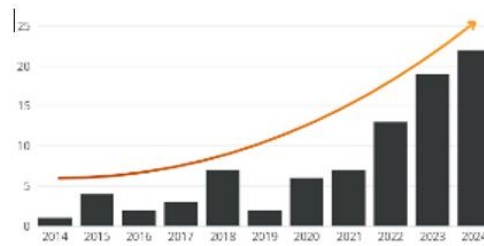


Figure 5. Trend of scientific publications on parametric architecture in Indonesia (2014–2024)

Source: Google Scholar search results (2024); processed by author

Table 1. Number of Scientific Papers in Indonesia with Discussion of Parametric Based on Google Scholar

Year	Number of Scientific Papers
2014	1
2015	4
2016	2
2017	3
2018	7
2019	2
2020	8
2021	7
2022	13
2023	17
2024	22
TOTAL	86

Source: Researcher Data Processing (2024)

Table 2. Number of Scientific Papers in Indonesia with Keyword “Parametric Architecture” & “Indonesia” on Google Scholar

Year	Number of Scientific Papers
2014	1
2015	3
2016	1
2017	2
2018	3
2019	2
2020	5
2021	5
2022	10
2023	17
2024	18
TOTAL	67

Source: Researcher Data Processing (2024)

Table 3. Number of Scientific Papers in Indonesia with Keyword “Parametric Architecture” & “Indonesia” on Google Scholar

Years	Number of Scientific Papers
2014	0
2015	1
2016	1
2017	1
2018	4
2019	0
2020	1
2021	2
2022	3
2023	2
2024	4
TOTAL	19

Source: Researcher Data Processing (2024)

The development of parametric architecture in Indonesia over the last 10 years has generated increasing interest in its applications in the world of design and in the field of scientific paper writing. Based on a search of the Google Scholar journal search engine using specific keywords, namely "Parametric Architecture," "Arsitektur Parametrik," and "Indonesia," from 2014 to 2024, a total of 86 scientific papers were found, with a considerable increase in number each year, particularly in the last 5 years, as shown in the publication trend in Figure 5. Details of the distribution of the number of papers per year can be seen in Table 1. These results are an accumulation of searches using two specific keyword combinations. As summarised in Table 2, searches with the keywords "Parametric Architecture" and "Indonesia" yielded 67 publications. Meanwhile, Table 3 shows the search results with the keywords "Arsitektur Parametrik" and "Indonesia," which resulted in 19 publications.

In support of the research objectives, the bibliometric analysis method is applied to present data from a number of studies systematically, in order to identify trends and directions of research development from scientific papers. Metadata was taken manually from the Google Scholar journal search engine, with a total of 86 scientific papers written over the last 10 years, from 2014 to 2024. Based on data retrieved on November 7, 2024, using the keywords "Parametric Architecture" and "Indonesia," a total of 67 scientific papers were found. Meanwhile, using the keywords "Arsitektur Parametrik" and "Indonesia," a total of 19 scientific papers were found. Google Scholar was selected as the journal search platform on the basis that it can exert considerable influence in observing citation development trends, thereby providing a foundation for determining potential research themes for future study (Allo & Ahmad, 2020).

After obtaining data in the form of titles, keywords, and abstracts from all collected works, they were processed using VOSviewer software. The use of this software aims to produce a visual map identifying the most frequently occurring words in the discussion of scientific papers based on the search keywords. In this study, keywords serve as the primary reference for classifying the VOSviewer analysis map. Keywords in publications are considered a fundamental element in the representation of knowledge concepts for uncovering the knowledge structure of a research domain (Chen & Xiao, 2016). Therefore, keywords are used as a reference for consistency to minimise bias during the search and analysis process. In

particular, the aim of this research is to determine how the foundational application of parametric architecture has developed through scientific works published in Indonesia. To obtain more comprehensive results, a literature review method is also employed to provide an evaluative overview of the selected papers. Papers are filtered based on their relevance to the main topic, the researcher's keywords, and the results of the VOSviewer visual map.

RESULTS AND DISCUSSIONS

In the search for scientific papers based on Google Scholar with the theme of Parametric Architecture discussion, a total of 86 works were found that had complete data on keywords and abstracts from each researcher. The use of VOSviewer helps to produce a keyword visualization map that identifies 15 main keywords (thresholds) in existing discussions.

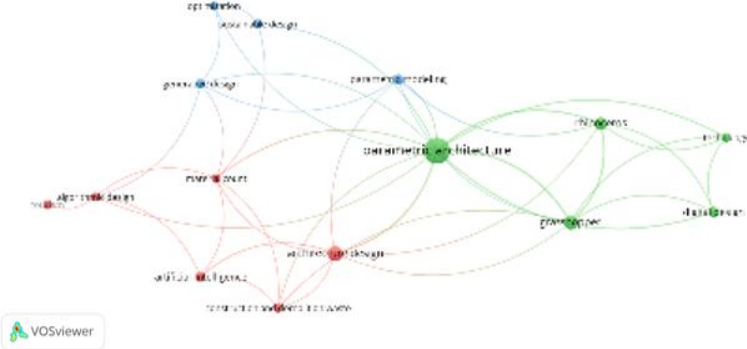


Figure 6. VOSviewer keyword visualization map (3 clusters)

Source: VOSviewer analysis based on 86 publications from Google Scholar (2024)

Figure 6 shows there are 3 cluster main on the results mapped with the main one in green which directs how parametric architecture methods in Indonesia have a network or close discussion relationship to the use of digital software or software Rhinoceros and Grasshopper to digital design that follows technological developments. There is also a parametric architecture relationship to cluster red and blue. Second cluster has a difference with a fairly close connection where the two cluster discuss the context of the design. Cluster blue is more directed towards the utilization of conceptual design contexts, while cluster red leads to the use of a constructive design context. As the majority of the keywords are interrelated to achieve the goal of efficient, effective, and sustainable design by utilizing technology in its design.

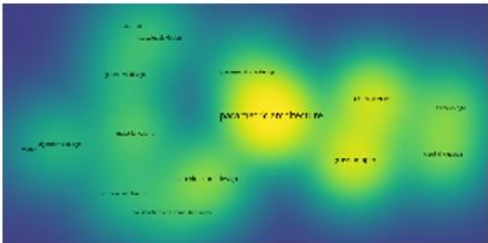


Figure 7. VOSviewer density visualization – conceptual design focus

Source: VOSviewer analysis based on 86 publications from Google Scholar (2024)



Figure 8. VOSviewer density visualization – constructive design focus

Source: VOSviewer analysis based on 86 publications from Google Scholar (2024)

If you look at the visual density, based on figures 7 and 8, it can be seen how the discussion is quite much directed towards parametric modeling or design modeling which leads to the discussion of conceptual optimization for sustainable design and architecture design which leads to material count to minimize construction & demolition waste or construction waste. In addition, the discussion is also quite visible using the use of software or digital software that is currently developing, namely Rhinoceros and Grasshopper software which can help architects in designing designs computationally. Both software are used in processing the design process more efficiently and effectively. In the existing discussion, it is also often discussed how parameters for variables and the use of algorithms in carrying out the design process. In addition, the purpose of the implementation is also quite much directed towards the increase in the number of tourists who are interested in building design even though the discussion does not directly have a network relationship with the word parametric architecture.

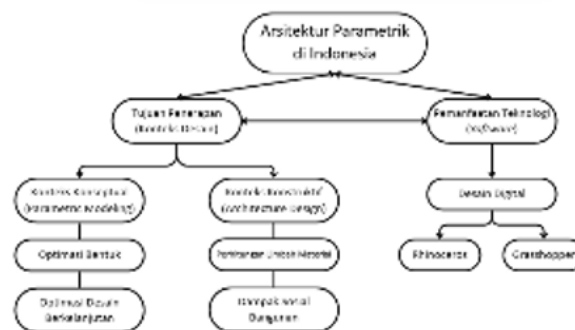


Figure 9. Relationship diagram between objectives and technology utilization in parametric architecture

Source: Researcher Data Processing (2024)

Based on the data found through VOSviewer, a diagram of a close relationship can be mapped as shown in Figure 9, how to depict the purpose of the application and utilization of technology in the discussion of parametric method approaches in the field of architecture through scientific papers in Indonesia. However, this does not deny that the two things are interconnected due to the use of software development or software so that the discussion will be tied together to produce the desired product.

Objectives of Implementing Parametric Architecture

Based on the results of the most cited keywords, several objectives of the application were found using the parametric method. However, of course, this is based on the intended design context. There are 2 main contexts in the discussion in the majority of papers that lead to the context of conceptual design and constructive design concepts.

Conceptual Design Context

In the publication of the paper, a number of works apply the purpose of using the parametric method with generative design which has a focus on the exploration of various design ideas through optimization. What can be obtained with generative design is the potential to foster creativity and innovation in product design (Eri Mardiani & Nindy Puspitasari, 2023). Through a study entitled "Parametric Architecture with Rhinoceros and Grasshopper: Workflow Study from Design, Fabrication to Calculation of Material Needs" by Atthaillah, it

can be studied how researchers try to conduct research on workflow exploration with parametric methods on conventional buildings in Aceh province that are efficient in terms of design form and time (Atthailah, 2016).

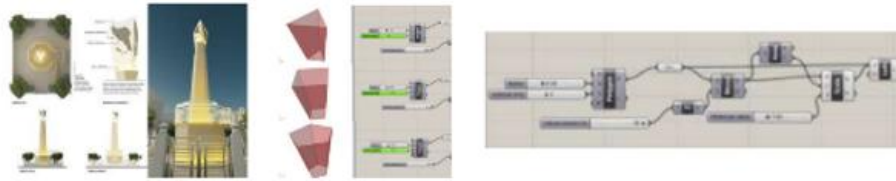


Figure 10. Compilation of the results of the Exploration of the Crown Shape of the Simpang Monument of KKA Aceh

Source: Atthailah (2016)

In figure 10, it can be seen how Atthailah tried to explore the crown shape of the KKA Simpang Monument located in North Aceh by using design parameters that adjust to the development of spatial ideas, functional-aesthetic concepts, and GRC fabrication materials to be used. Atthailah uses the formulation of variables in Grasshopper as a determinant of the geometric shape that will be realized in Rhinoceros which can be done very quickly. According to Atthailah, the development of the use of parametric methods opens up new realms in exploring more innovative things (Atthailah, 2016). There is also a study entitled "Design of the Posh Avenue High-End Shopping Center and Eatery Project with Deepening of Parametric Design by Oshu Studio Architectural Consultants" by C. Gojono and E. Indrawan conducted research on the construction of kinetic facades or kinetic building envelopes.



Figure 11. Compilation of Kinetic Facade Exploration Results with Parametric Method

Source: Gojono and Indrawan, (2023)

This design was carried out to increase business sales and get a futuristic design. Therefore, in Figure 11 Gojono tries to apply the parametric method in designing the façade as the main appearance of the building's exterior. This is aimed at obtaining the most optimal shape with the basic parameters of the material size and to be able to display a 3-dimensional simulation to the client (Gojono & Indrawan, 2023). In addition to individual buildings, the application of conceptual design context can be carried out in the urban realm as in a research by A. S. Depari, Sherlia, and D. Huldiansyah with the title "Rethinking Parametric Design (RPD) for Visualization of Urban 3D Modeling: A Case Study of Balikpapan City". In his research, Depari implemented parametric methods in urban spatial simulations, especially in the southern city of Balikpapan.

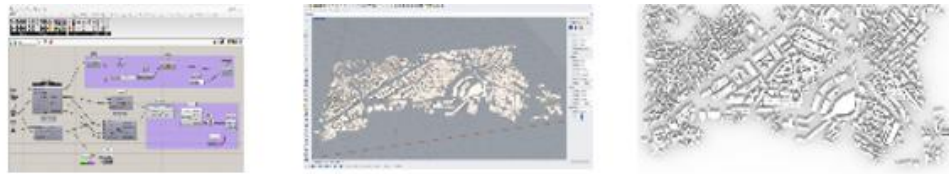


Figure 12. Compilation of Exploration Result of Spatial Planning of Balikpapan City
Source: Depari, (2023)

Figure 12 shows a compilation of the results of Depari's exploration in programming to simulation by determining parameters or variables that have a high level of flexibility in the process. The implementation of this method is used in an effort to manipulate objects in a complex way by adjusting parameters to city regulations and the expected smart city concept. The results of his research for the purpose of optimizing urban spatial planning with sustainable design can be followed up as a technical context analysis for urban environments such as urban comfort thermal (Depari et al., 2023). The application of parametric methods to design contexts conceptually has a great impact on the efficiency of the processing process time and helps architects to explore innovative designs with the use of digital technology.

Constructive Design Context

There are publications of scientific papers emphasizing the purpose of applying parametric methods with algorithmic design to a more constructive design context or a refinement for the purpose of the construction stage of development. In this context, the use of algorithms is emphasized to help design problems with high complexity to provide solutions that create a synergistic relationship between human thinking and computer systems (Daryanto & Utama, 2011). Several studies have led to material optimization to minimize construction waste . In Atthailah's research entitled "Parametric Architecture with Rhinoceros and Grasshopper: Workflow Study from Design, Fabrication to Calculation of Material Needs" there is a study on the application of parametric methods in the calculation of material needs for private residences in Aceh Besar. Material calculations are carried out on structural components in the form of columns, sloofs, and beams.



Figure 13. Compilation of Material Calculation Result on Structures with Parametric Method

Source: Atthailah (2016)

Figure 13 shows the compilation of calculation results and how to work in analyzing material needs with their structure. In completing this project, it is quite complex with the incorporation of component algorithms into clusters so that the existing formulation can be protected (Atthailah, 2016). This shows that parametric methods can help in the formulation

of solutions in solving constructive design problems for development. In addition, in a constructive context, it can also be applied to buildings with a large enough scale as researched by M. Hidayat in a research entitled "Fine Art Gallery in Makassar with Parametric Design Method".



Figure 14. Compilation of Calculation and Strature Design Result with Parametric Method

Source: Hidayat (2023)

According to Hidayat, in designing an art gallery, it must be remembered that the building is the result of art itself (Hidayat, 2023). Therefore, in Figure 14, a parametric method is applied which aims to get a futuristic shape to be an attraction for tourists or tourists in improving the tourism sector and get the most optimal structure configuration so that it can be built with the correct understanding of the concept of structure.

In its application with a conceptual and constructive context, parametric methods are not only useful for the exploration of forms. If the formulation of algorithms and parameters is applied with the use of digital technology in its treatment, this method can also provide various advantages in urban spatial exploration, material calculations, and structural calculations that have an impact on the economic, social, and architectural style of buildings. Currently, there tends to be more discussion of the publication of scientific papers with a conceptual context because the development of the parametric era in Indonesia is still unbalanced, which still lacks understanding in its proper application in the field of architecture (Hibatullah & Aqli, 2024).

The Use of Software Technology in the Application of Parametric Architecture



Figure 15. The Use of Rhinoceros-Grasshopper Software in the calculation of walls, columns. Sloofs, beams

Source: Atthaillah, (2016)



Figure 16. The Use of Rhinoceros-Grasshopper Software in Building from Exploration

Source: Wass and Lambertus, (2018)

Based on the qualification of data from 86 scientific paper publications, it was found that the majority used software technology in conducting their research. Researchers see potential in the use of parametric software that is currently developing, namely Rhinoceros and plugins

such as Grasshopper, which is currently the most popular design visualization tool to help architects innovate and visualize their designs. Rhinoceros-Grasshopper can provide the latest uses because it is currently connected to various other building simulation programs (Sunarya et al., 2022). A view of the algorithmic modeling interface using the software can be seen in Figures 15 and 16. In addition, Rhinoceros-Grasshopper can direct to "Live Connection" directly in parametric modeling (Waas & Enjellina, 2022). According to Alfarij (2024), the use of software can help architects overcome design complexity by considering various existing needs and limitations (Alfarij et al., 2024).

CONCLUSION

The parametric method is currently a growing trend, particularly in Indonesia in the field of architectural design, owing to its role in the development of digital technology. The use of parameters and algorithms in software helps architects to design more flexibly and effectively. Considering the phenomenon of growing discussion, the publication of scientific papers on the theme of parametric architecture applications in Indonesia has increased considerably over the last 10 years, based on data from Google Scholar with adaptive keyword searches.

In various discussions, publications reveal that the parametric approach does not only focus on aesthetics or modern-futuristic architectural styles. Existing publications explain how parametric methods can be utilised through innovative conceptual and constructive design contexts for the integration of sustainable design, material efficiency, and the social impact of buildings. The application of this method can also vary in scale, ranging from residential houses to urban planning. The support of software, particularly Rhinoceros-Grasshopper, encourages architects to explore innovative and effective design ideas. However, this returns to the context of the design outcomes achieved, where it is found that the majority of discussions tend to be applied in the context of conceptual design and have not been realised constructively, due to an uneven understanding of how this method works across Indonesia.

Despite the growing interest in the discussion of parametric methods, the number of scientific publications remains relatively limited. The findings of this study open up opportunities for a greater number of studies to be conducted on parametric methods in Indonesia. The various benefits of this method, which have been demonstrated both abroad and in Indonesia, have a significant impact on buildings, their users, and the surrounding environment, while also contributing new scientific knowledge. Based on the literature review and keyword analysis from VOSviewer, the use of parametric methods reveals great potential for advanced research. The domain of parametric design development can be more closely linked to local cultural contexts, climate adaptation, and the fulfilment of community needs. Furthermore, the scope of discussion can also be directed towards measuring the impact of this method's application on environmental sustainability and energy efficiency. In the field of education, the findings of this mapping study are expected to encourage universities in Indonesia to begin integrating a parametric design teaching framework into their learning curricula, so that academic awareness of the trends and benefits of computational approaches continues to grow (Sunarya et al., 2022).

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