PARAMETRIC DESIGN FOR RESILIENT DESIGN IN LATIN AMERICA

DESIGN PARAMÉTRICO PARA DESIGN RESILIENTE NA AMÉRICA LATINA

DISEÑO PARAMÉTRICO PARA EL DISEÑO RESILIENTE EN LATINOAMÉRICA

GRACE TIBÉRIO CARDOSO, Dra. | ATITUS – Atitus Educação, Brasil
VALENTINA NIETO BARBOSA, MSc. | ATITUS – Atitus Educação, Brasil

ABSTRACT
In recent years, with the continuous increase in the effects of climate change on people's health, the concept of resilient design has gained traction. However, one of the regions most affected by this phenomenon is Latin America, as it experiences high levels of thermal variability, which negatively impacts the comfort of its inhabitants and increases the energy demand of buildings. In this context, understanding that the use of digital technologies, parametric measures, and optimisation tools allows for designs that respond to various climatic requirements, the aim of this article is to identify the potential of parametric design for resilience in Latin American cities. To achieve this, a systematic review was conducted according to the PRISMA method. As a result, it was found that there are two main approaches to applying resilience through parametric design and a range of specialised software that can be adapted to the objectives set by each author. Finally, it was concluded that, although urban morphology influences the resilience of a place, the building envelope is an essential factor when discussing resilient design, and parametric characteristics make a significant contribution to this in terms of energy efficiency.

KEYWORDS
Parametric design; Resilient design; Energy efficiency; Latin America; Thermal variability..

RESUMO
Nos últimos anos, com o aumento contínuo dos efeitos das mudanças climáticas sobre a saúde das populações, o conceito de design resiliente tem ganhado destaque. No entanto, uma das regiões mais afetadas por esse fenômeno é a América Latina, que enfrenta altos níveis de variabilidade térmica, impactando negativamente o conforto dos habitantes e aumentando a demanda energética dos edifícios. Nesse contexto, compreende-se que o uso de tecnologias digitais, ferramentas paramétricas e métodos de otimização possibilita projetos que respondem a diversas exigências climáticas. Assim, o objetivo deste artigo é identificar o potencial do design paramétrico para a resiliência nas cidades latino-americanas. Para isso, foi realizada uma revisão sistemática conforme o método PRISMA. Como resultado, identificaram-se duas principais abordagens para a aplicação da resiliência por meio do design paramétrico, bem como uma variedade de softwares especializados que podem ser adaptados aos objetivos definidos por cada autor. Conclui-se, por fim, que, embora a morfologia urbana influencie a resiliência de um local, o envoltório dos edifícios é um fator essencial na discussão sobre design resiliente, sendo que as características paramétricas contribuem significativamente nesse aspecto, especialmente em termos de eficiência energética.

PALAVRAS-CHAVE
Design paramétrico; Design resiliente; Eficiência energética; América Latina; Variabilidade térmica.

RESUMEN
Durante los últimos años, con el continuo aumento de los efectos del cambio climático en la salud de las personas, la idea de diseño resiliente ha incrementado. Sin embargo, una de las regiones más afectadas por este fenómeno, es América

http://dx.doi.org/10.29183/2447-3073.MIX2025.v11.n1.263-271
ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)

Latina, pues presenta altos niveles de variabilidad térmica, perjudicando el confort en sus habitantes e incrementando la demanda energética de los edificios. En este sentido, entendiendo que el uso de tecnologias digitales, medidas paramétricas y herramientas de optimización, permiten diseñar para responder a los diversos requisitos del clima, el objetivo de este artículo es identificar el potencial del diseño paramétrico para la resiliencia en las ciudades latinoamericanas. Para esto, se realizó una revisión sistemática de acuerdo al método PRISMA. Como resultado, se encontró que existen dos enfoques principales del diseño paramétrico para aplicar la resiliencia y una serie de software especializados que se pueden adaptar a los objetivos planteados por cada autor. Finalmente, se concluyó que, aunque la morfología urbana influye en la resiliencia de un lugar, la envolvente es un factor indispensable a la hora de hablar de diseño resiliente y, las características paramétricas un aporte importante para ello en términos de eficiencia energética.

PALABRAS CLAVE
Diseño paramétrico; Diseño resiliente; Eficiencia energética; América Latina; Variabilidad térmica.

1. INTRODUCTION

In recent years, the global climate has been changing at a faster rate than before, bringing with it effects such as an increase in the planet's average temperature and a higher frequency of extreme temperatures. Additionally, the environmental conditions for thermal comfort are critical for most Latin American countries, as they are among the most affected by climate change (Calvo et al., 2021). From this perspective, to protect human health and reduce energy demand in buildings, it is necessary to anticipate future discomfort conditions (Hernández Moreno et al., 2021).

One measure is to opt for resilient design, which seeks the adaptation of projects to be more resistant to the consequences of climate change (García, 2019; Rajkovich & Holmes, 2021), without compromising indoor air quality and health. In this regard, Januszkiewicz (2019) states that with the use of digital technologies, parametric and multicriteria approaches, and optimisation tools, buildings can be designed to meet diverse climate requirements.

Thus, considering that the world is experiencing the so-called digital age, in design and architecture, digital technologies range from Computer-Aided Design (CAD) to mass customisation, including Building Information Modelling (BIM) and Parametric Modelling (Willis & Woodward, 2010). CAD was initially perceived as a drawing and representation tool that allows architects and designers to save time when presenting architectural projects.

In the case of technologies such as BIM and Parametric Modelling, there is a growing use as generative instruments rather than mere representational tools. This is because they accommodate more complex design conditions interactively. According to Chen et al. (2019), digital design through parametrics and fabrication technologies such as robotics, integrating software and hardware, enables opportunities for creative experimentation. It also requires clear design objectives so that, according to established parameters, necessary variables can be manipulated, increasing the pace of the creative process.

As such, there are significant advantages to adopting parametric design tools to achieve resilient projects, as they grant the necessary flexibility in design and contribute to speeding up processes such as modularisation (Habibi Rad et al., 2021). Therefore, the aim of this study is to identify the potential of parametric design for resilience in Latin American social housing. To this end, a systematic review was conducted following the PRISMA method. The methodology is described below, followed by the results and discussion, and finally, the conclusions and references.

2. METHODOLOGY

The methodology of this study is qualitative and exploratory in nature, employing bibliographic research to gather data. For its development, the PRISMA method (Moher et al., 2009) was used as a reference, which consists of a checklist for the selection and review of documents distributed over four phases: 1) identification, 2) screening, 3) eligibility, and 4) inclusion.

In the identification phase, the Scopus database was used to obtain structured data sources, and Google Scholar was also consulted. The review was filtered for open-access publications from the last five years (2018–2022), excluding theses and dissertations. Seven keyword-based reviews were conducted. Two of these yielded no results (see Table 1).

Keywords		1. Screening	
		Database Records Scopus	Records from Other Sources Google Scholar
Review 1	Climate Change Parametric design Social housing	(n = 0)	(n = 4)
Review 2	Climate Change Parametric design	(n = 9)	(n = 13)
Review 3	Resilient Design Parametric design social housing	(n = 0)	(n = 0)
Review 4	Resilient Design Parametric design	(n = 0)	(n = 0)
Review 5	Resilience Parametric design Social housing	(n = 0)	(n = 2)

265

Keywords		1. Screening	
		Database Records Scopus	Records from Other Sources Google Scholar
Review 6	Resilience Parametric design	(n = 2)	(n =20)
Review 7	Parametric design Social housing	(n = 0)	(n = 4)

Table 1: Identification Stage according to PRISMA.
Source: The authors.

Consequently, the five searches that yielded results greater than zero were pursued, leading to an initial set of 54 articles in total. Through the subsequent phases of screening, eligibility, and inclusion, this number was reduced to 19 documents for full review, as shown in Tables 2 and 3. After the review, the relevant texts were classified and synthesised according to their main approach. Similarly, it is worth noting that the results and discussion sections primarily explored the software and methodologies used by the authors, as well as their objectives and main conclusions.

Keywords		2. Screening	2. Eligibility
		Duplicates Removed	Full-text Articles
Review 1	Climate Change Parametric design Social housing	(n = 4)	(n = 0)
Review 2	Climate Change Parametric design	(n =13)	(n = 9)
Review 3	Resilience Parametric design Social housing	(n = 1)	(n = 1)
Review 4	Resilience Parametric design	(n =16)	(n = 6)
Review 5	Parametric design Social housing	(n = 1)	(n = 3)

Table 2: Screening and Eligibility Stages based on PRISMA.
Source: The authors.

Keywords		3. Inclusion		
		Quantitative Synthesis	Qualitative Synthesis	Mixed Synthesis
Review 1	Climate Change Parametric design Social housing	(n = 0)	(n = 0)	(n = 0)
Review 2	Climate Change Parametric design	(n = 8)	(n = 9)	(n = 0)
Review 3	Resilience Parametric design Social housing	(n = 0)	(n = 1)	(n = 0)
Review 4	Resilience Parametric design	(n =16)	(n = 6)	(n = 0)
Review 5	Parametric design Social housing	(n = 1)	(n = 3)	(n = 0)

Table 3: Inclusion Stage based on PRISMA.
Source: The authors.

3. RESULTS

According to the review carried out, two main approaches were identified in studies on parametric design aimed at addressing the impacts of climate change on human comfort and health. On the one hand, there is the use of parametric tools in the building envelope, focusing on its adaptation to external climate conditions. On the other hand, the second approach addresses this form of design on a broader scale, through the exploration of alternatives in urban morphology within cities (see Table 4).

https://doi.org/10.29183/2447-3073.MIX2025.v11.n1.263-271

Approach	No. of Articles
Parametric Design for:	
1. Resilience in the Envelope for Indoor Comfort	10
2. Resilience through Urban Morphology for Comfort	9

Table 4: Inclusion Stage based on PRISMA.
Source: The authors.

In the same vein, it was observed that most of the reviewed studies are quantitative syntheses (12 articles), although a significant number of qualitative explorations were also found (7 articles). The quantitative articles were characterised by simulations carried out using different software and specialised plugins, depending on the approaches mentioned above (see Figure 1). The most commonly used software for modelling was Rhinoceros, supported by the Grasshopper plugin, which functions as a visual programming language and was mainly used in studies related to the first approach (envelope).

Additionally, the Grasshopper plugin Ladybug was widely employed in both approaches (envelope and urban morphology) to analyse climatic data from locations defined by each author. Following this, the Honeybee plugin stood out, enabling energy simulations using the EnergyPlus and OpenStudio engines, and its use was more focused on the architectural object and its envelope. Similarly, Autodesk CFD software appeared, used to simulate ventilation conditions in articles linked to both the envelope and urban morphology.

Furthermore, three software tools were specifically applied to the second approach: 1) CitySim, for simulating buildings at the urban district scale and estimating their energy demand; 2) Envi-met, for analysing the environmental impact of design on the local context and determining sustainable living conditions in scenarios of constant change; and 3) CityEngine, for simulating large-scale urban environments using GIS[1].

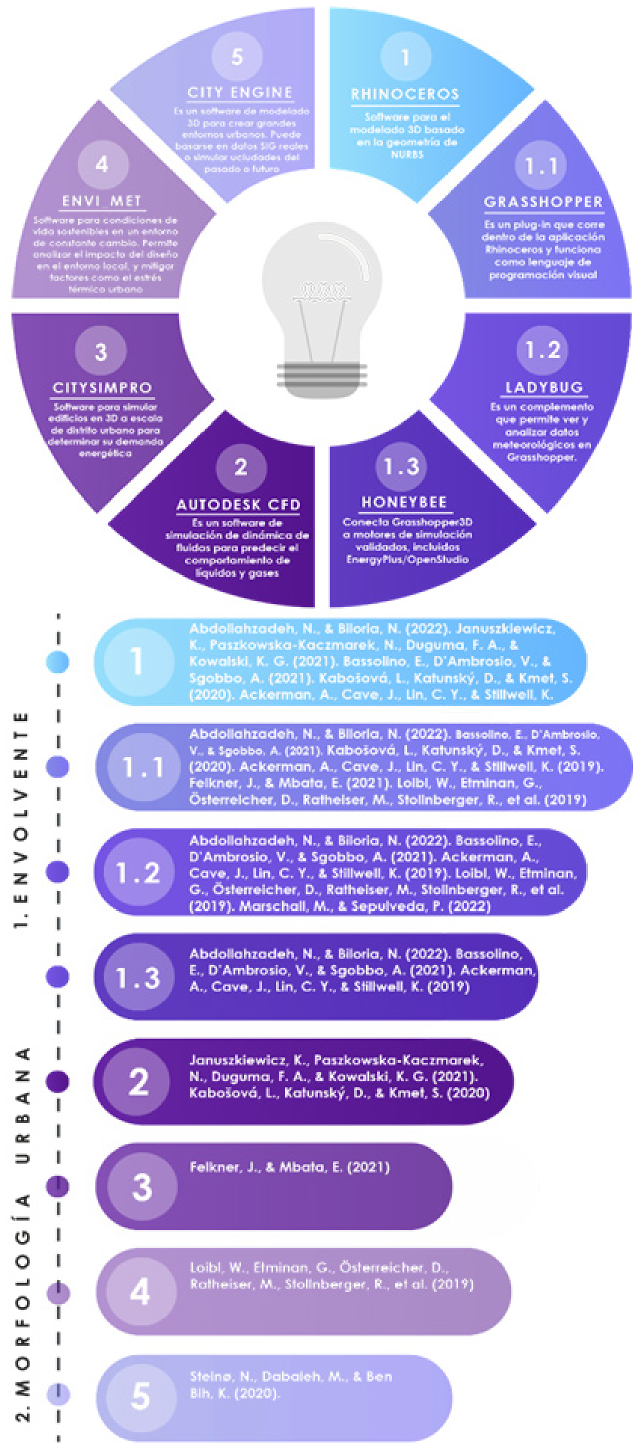

Figure 1: Summary of the most used parametric design software and plugins for resilience.
Source: The authors.

[1]Sistemas de Información Geográfica - SIG: consiste en un conjunto de herramientas que relacionan elementos para la organización y análisis de datos sobre una referencia espacial determinada.

Based on the above, it can be stated that the various software tools involved in parametric design can be applied to resilience practices depending on the case, and can be combined according to the objectives set. For instance, Abdollahzadeh and Biloria (2022) used Rhinoceros and the Grasshopper plugin to optimise design factors based on thermal conditions in outdoor spaces and the energy used for cooling and heating indoor spaces, simulating the Australian urban microclimate and the energy efficiency of its buildings using the Ladybug and Honeybee plugins.

Similarly, Bassolino, Ambrosio, and Sgobbo (2021) employed the same tools to define critical aspects of urban spaces in response to heatwave phenomena and subsequently, with the help of GIS, transformed the results into databases, maps, and potential levels of adaptation for climate-oriented projects. Regarding the building envelope, Rossi-Schwarzenbeck and Figliola (2019) used these software tools to develop a methodology for designing energy-efficient buildings with façades capable of dynamically responding to changing climate conditions. In turn, Marschall and Sepulveda (2022) employed Grasshopper and Ladybug to enhance dynamic models in order to detect overheating risks in buildings and propose appropriate mitigation strategies.

On the other hand, some authors (Januszkiewicz et al., 2021; Kabošová et al., 2020; Palusci & Cecere, 2022) used Rhinoceros and CFD to design with consideration for local wind microclimates, evaluating both the disadvantages and opportunities presented by wind effects in urban and architectural projects. In contrast, Felkner and Mbata (2021) applied Grasshopper and CitySim to assess energy performance and overheating in urban renewal scenarios. For this purpose, they also relied on PostgreSQL and PostGIS to analyse large datasets, and on QGIS to spatially link the information.

Lastly, Loibl, Etminan, Österreicher, Ratheiser, and Stollnberger (2019) used Envi-met to analyse the relationship between urban densification and climate under climate change conditions, as well as to examine necessary mitigation and adaptation measures. Additionally, they opted for the use of Grasshopper and Ladybug for local microclimate calculations. To achieve a similar objective, Steinø, Dabaieh, and Ben Bih (2020) used CityEngine in combination with ArcGIS Online as their main parametric urban model.

Finally, it is worth noting that most of the articles involving simulations for specific climates were developed primarily in European countries (8), particularly in Italy (3), followed by studies carried out in Australia (2), North Africa (1), and lastly, the United States (1), as shown in Figure 2. This highlights the limited interest among authors in conducting studies of this nature in Latin American countries.

Figure 2: Geographic distribution of reviewed quantitative synthesis articles.
Source: The authors.

4. DISCUSSION

In line with the results obtained, it can be stated that the variation of urban design factors that alter the urban configuration or morphology enhances its potential for adaptation to climatic conditions through parametric design (Abdollahzadeh & Biloria, 2022). In this context, the exchange of data between ICT tools based on GIS, as seen in the Italian case studies, may also prove valuable for analysing microclimatic behaviour and the performance of urban spaces (Bassolino et al., 2021).

Similarly, with the use of these multicriteria tools, buildings can be designed to adapt to a wide range of requirements, bearing in mind that the capacity of a building's envelope to support its energy balance is crucial for the future wellbeing of occupants (Januszkiewicz et al., 2021). This means that such optimisation processes generate variations and outcomes that may allow for the formulation of general rules or recommendations for architects (Rossi-Schwarzenbeck & Figliola, 2019).

In addition, digital design processes based on wind data make it possible to estimate the influence of wind conditions during the conceptual design phase (Kabošová et al., 2020). However, in these cases, the properties of envelope materials are not taken into account, which reduces the reliability of such simulations from a resilience perspective; nevertheless, this approach can help identify areas potentially exposed to poor air quality and therefore vulnerable to pollution and heat stress (Palusci & Cecere, 2022).

That said, parametric design facilitates the generation of different scenarios through the variation of parameters.

This enables the rapid creation of generic designs at various scales, such as district and neighbourhood plans, as well as buildings and construction elements (Steinø et al., 2020), with its principal advantage being the flexibility in data input (Felkner & Mbata, 2021). From this perspective, resilient design through parametric modelling can also be enhanced when integrated with BIM tools, enabling a coordinated design dynamic. To this end, it is necessary to progressively incorporate parametric design into practice, using more detailed and realistic data (Tronchin et al., 2018).

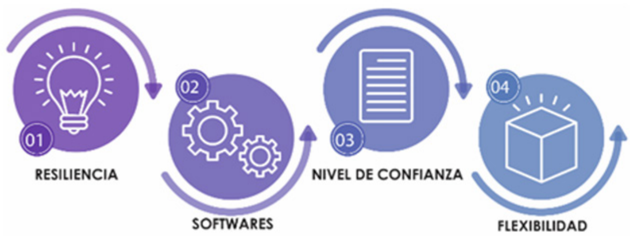

Figure 3: Discussion synthesis.
Source: The authors.

5. FINAL CONSIDERATIONS

Parametric design, through specialised software, enables the generation of a large number of design alternatives and simulations within short periods of time. In the fields of urbanism and architecture, particularly from the perspective of resilient design, this represents a significant development potential, as it facilitates the creation of multiple responses for both urban morphology and architectural objects. These responses can address the effects of climate change on comfort and human health according to specific locations. In this regard, the Grasshopper plugin, along with its Ladybug and Honeybee extensions, becomes a highly valuable tool, as it supports simulations under changing climate conditions with projections based on location-specific meteorological data.

Additionally, it is important to highlight that, although there are digital programmes for parametric modelling in large-scale design proposals involving variations in urban morphology, the absence of detail regarding architectural object properties—such as materiality—may increase the level of uncertainty surrounding resilience to climate change in such cases. For this reason, the building envelope is an indispensable factor when discussing resilient design, and parametric characteristics offer a significant contribution to this, particularly in terms of energy efficiency.

However, although it is an emerging topic, studies of this nature have mainly been carried out in European countries, especially those addressing the Italian climate. Similarly, in the Americas, only one related study was identified, conducted in Texas (United States). This points to a great potential for exploration in this region—particularly in Latin America—given its vulnerability to phenomena such as climate change. Nevertheless, this also implies a need for greater training and research in the field among the professionals involved.

To conclude, and in line with the foregoing, parametric modelling requires clear design objectives and prior reflection, as the use of programming languages can otherwise lead to meaningless automation. The use of these new digital technologies alone does not necessarily lead to better architecture, but it does represent an important aid. Therefore, it is necessary to promote their use critically and consciously in design processes, in order to support the creation of resilient and sustainable projects over time.

REFERENCES

ABDOLLAHZADEH, N.; BILORIA, N. Urban microclimate and energy consumption: A multi-objective parametric urban design approach for dense subtropical cities. **Frontiers of Architectural Research**, v. 11, n. 3, p. 453–465, 2022. Available at: <https://doi.org/10.1016/j.foar.2022.02.001>. Accessed on Sep. 15, 2024.

BASSOLINO, E.; D'AMBROSIO, V.; SGOBBO, A. Data Exchange Processes for the Definition of Climate-Proof Design Strategies for the Adaptation to Heatwaves in the Urban Open Spaces of Dense Italian Cities. **Sustainability**, v. 13, n. 10, 2021. Available at: <https://doi.org/10.3390/su13105694>. Accessed on Sep. 15, 2024.

CALVO, R. et al. Desarrollo de indicadores de pobreza energética en América Latina y el Caribe. In: **Serie Recursos natural y Desarrollo**, n. 207, 2021. Available at: <www.cepal.org/apps>. Accessed on Sep. 15, 2024.

CHEN, Y. et al. Form-finding with robotics: Rapid and flexible fabrication of glass fiber reinforced concrete panels using thermoformed molds. **Journal of Computational Design and Engineering**, v. 6, n. 3, p. 398–403, 2019. Available at: <https://doi.org/10.1016/j.jcde.2018.10.002>. Accessed on Sep. 15, 2024.

FELKNER, J.; MBATA, E. Energy analysis of Texas metropolitan areas for climate change mitigation using LiDar. **Journal of Physics: Conference Series**, v. 2042, n. 1, p. 0–6, 2021. Available at: <https://doi.org/10.1088/1742-6596/2042/1/012055>. Accessed on Sep. 15, 2024.

GARCÍA, M. G. Paisajes generativos. Del control a lo salvaje mediante el diseño resiliente. **Dearq**, n. 25, p. 200–207, 2019.

HABIBI RAD, M.; MOJTAHEDI, M.; OSTWALD, M. J. Industry 4.0, disaster risk management and infrastructure resilience: a systematic review and bibliometric analysis. **Buildings**, v. 11, n. 9, 2021. Available at: <https://doi.org/10.3390/buildings11090411>. Accessed on Sep. 15, 2024.

HERNÁNDEZ MORENO, S.; HERNÁNDEZ MORENO, J. A.; ALCARAZ VARGAS, B. G. **Reducción de la huella de carbono en las ciudades mexicanas. Enfoque urbano-arquitectónico**. Primera ed. México: Universidad Autónoma del Estado de México, 2021.

JANUSZKIEWICZ, K. Climate Change Oriented Design – Learning from Nature – Nature and Advanced Technology in architecture. In: **4th International Symposium on Innovative Approaches in Architecture, Planning and Design**, 2019, p. 187–193. Available at: <https://doi.org/10.36287/setsci.4.7.049>. Accessed on Sep. 15, 2024.

JANUSZKIEWICZ, K. et al. Living in the "age of humans". Envisioning cad architecture for the challenges of the anthropocene—energy, environment, and well-being. **Energies**, v. 14, n. 19, 2021. Available at: <https://doi.org/10.3390/en14196093>. Accessed on Sep. 15, 2024.

KABOŠOVÁ, L.; KATUNSKÝ, D.; KMET, S. Wind-Based Parametric Design in the Changing Climat. **Applied Sciences**, v. 10, n. 23, 2020. Available at: <https://doi.org/10.3390/app10238603>. Accessed on Sep. 15, 2024.

LOIBL, W. et al. Urban Densification and Urban Climate Change–Assessing Interaction through Densification Scenarios and Climate Simulations. **Proceedings of the REAL CORP**, v. 4, p. 809–817, 2019.

MARSCHALL, M.; SEPULVEDA, P. How to prevent a passive house from overheating. An industry case study using parametric design to propose compliance strategies. In: **27th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA)**, 2022, p. 639–648.

MOHER, D. et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. **PLoS Med**, v. 6, n. 7, 2009. Available at: <https://doi.org/10.1371/journal.pmed.1000097>. Accessed on Sep. 15, 2024.

PALUSCI, O.; CECERE, C. Urban Ventilation in the Compact City: A Critical Review and a Multidisciplinary Methodology for Improving Sustainability and Resilience in Urban Areas. **Sustainability (Switzerland)**, v. 14, n. 7, 2022. Available at: <https://doi.org/10.3390/su14073948>. Accessed on Sep. 15, 2024.

RAJKOVICH, N. B.; HOLMES, S. H. Climate Adaptation and Resilience Across Scales. From Buildings to cities. In: RAJKOVICH, N. B.; HOLMES, S. H. (Eds.). **Climate Adaptation and Resilience Across Scales**. 1st ed. Routledge, 2021. Available at: <https://doi.org/10.4324/9781003030720>. Accessed on Sep. 15, 2024.

ROSSI-SCHWARZENBECK, M.; FIGLIOLA, A. Adaptive Building and Skin: an Innovative Computational Workflow To Design Energy Efficient Buildings in Different Climate Zones. **Journal of Green Building**, v. 14, n. 4, p. 1–15, 2019.

STEINØ, N.; DABAIEH, M.; BIH, K. Ben. Post-conflict reconstruction in the Middle East and North Africa region: A bidirectional parametric urban design approach. **International Journal of Architectural Computing**, v. 18, n. 1, 2020. Available at: <https://doi.org/10.1177/1478077119899584>. Accessed on Sep. 15, 2024.

TRONCHIN, L.; MANFREN, M.; JAMES, P. A. Linking design and operation performance analysis through model calibration: Parametric assessment on a Passive House building. **Energy**, v. 165, n. A, p. 26–40, 2018. Available at: <https://doi.org/10.1016/j.energy.2018.09.037>. Accessed on Sep. 15, 2024.

WILLIS, D.; WOODWARD, T. Diminishing difficulty: Mass customization and the digital production of architecture. In: **Fabricating architecture: Selected reading in digital design and manufacturing**, 2010, p. 184–208.

AUTHORS

ORCID: 0000-0002-1779-4631
GRACE TIBÉRIO CARDOSO | Doutora | Atitus Educação | Programa de Pós-Graduação em Arquitetura e Urbanismo | Passo Fundo, RS - Brasil | Correspondência para: Rua Senador Pinheiro 304, Vila Rodrigues, Passo Fundo/ RS, 99070-220.
e-maill: gracetiberio@hotmail.com

ORCID: 0000-0003-0067-3769
VALENTINA NIETO BARBOSA | Mestra | Atitus Educação | Programa de Pós-Graduação em Arquitetura e Urbanismo | Passo Fundo, RS - Brasil | Correspondência para: Rua Senador Pinheiro 304, Vila Rodrigues, Passo Fundo/ RS, 99070-220.
e-maill: valentina.nieto22@gmail.com

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support provided by the Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), under the FAPERGS 09/2023 call – Gaúcho Researcher Program (PqG), Brazil (Grant Agreement No. 24/2551-0001129-3).

Los autores agradecen con gratitud el apoyo financiero brindado por la Fundación de Apoyo a la Investigación del Estado de Rio Grande do Sul (FAPERGS), en el marco de la convocatoria FAPERGS 09/2023 – Programa Investigador Gaúcho (PqG), Brasil (Acuerdo de Subvención Nº 24/2551-0001129-3).

HOW TO CITE THIS ARTICLE:

CARDOSO, G. T.; BARBOSA, V. N. Parametric Design for Resilient Design in Latin America. **MIX Sustentável**, v.11, n.1, p.263-271. ISSN 2447-3073. Disponível em: <http://www.nexos.ufsc.br/index.php/mixsustentavel>. Acesso em: _/_/_.

SUBMITTED ON: 15/09/2024
ACCEPTED ON: 15/06/2025
PUBLISHED ON: 05/08/2025
RESPONSIBLE EDITORS: Lisiane Ilha Librelotto e Paulo Cesar Machado Ferroli

Record of authorship contribution:

CRediT Taxonomy (http://credit.niso.org/)

GTC: conceptualization, formal analysis, funding acquisition, investigation, methodology, project management, supervision, validation, visualization, writing - original draft and writing - review & editing.

VNB: conceptualization, data curation, formal analysis, investigation, methodology, project management, resources, validation, visualization, writing - original draft and writing - review & editing.

Conflict declaration: nothing to declare.