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Parametric design as a strategy for the flexible standardization of social housing

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Abstract– ***Social interest housing represents a fundamental component of contemporary urban policies, as it seeks to ensure minimum habitability conditions for large segments of the population. However, traditional architectural design processes applied to this type of housing are often based on rigid typologies and manual procedures that limit adaptability, increase development time, and raise the costs associated with architectural solutions. In this context, parametric design and digital automation emerge as strategies capable of transforming the architectural design process by structuring projects through systems of rules and parameters that control form, function, and spatial organization. This paper analyzes the application of parametric design as a strategy for achieving flexible standardization in social interest housing, with the aim of optimizing architectural workflows and improving design efficiency. The adopted methodology is based on the analysis of social housing precedents, the study of the urban context, and the definition of architectural parameters integrated into a parametric model. This model enables the generation of multiple housing configurations that can adapt to different spatial and regulatory conditions while maintaining dimensional and constructive coherence. The results demonstrate that the use of parametric tools significantly reduces design development time, improves consistency across architectural solutions, and enhances the adaptability of housing models. It is concluded that parametric design represents a viable and efficient alternative for addressing current social housing challenges, promoting more flexible, replicable, and sustainable architectural design processes.***

Keywords-- Parametric design, social interest housing, architectural automation, flexible standardization, CAD-based design

I. INTRODUCTION

Social interest housing represents one of the main challenges facing contemporary urban development, given its direct impact on social equity, spatial organization, and living conditions. Public policies and governmental institutions continuously seek to reduce housing shortages while guaranteeing minimum standards of affordability, functionality, and habitability. Within this scenario, architectural design plays a key role by balancing economic limitations, regulatory frameworks, and the spatial requirements of residents [1].

Over recent decades, rapid urbanization, population growth, and persistent socioeconomic inequalities have significantly increased the demand for social interest housing, particularly in developing regions. These dynamics have revealed the shortcomings of conventional housing production models, which tend to emphasize mass replication over spatial quality, adaptability, and long-term sustainability. As urban environments become increasingly diverse and complex, the need for housing solutions capable of adjusting to varying regulatory, environmental, and social contexts has become more pressing. In this sense, digital design strategies emerge not merely as technological innovations, but as essential tools for managing contemporary housing complexity.

Historically, social interest housing has been developed through standardized architectural typologies aimed at minimizing costs and expediting construction processes. While such strategies have facilitated large-scale housing delivery, they have also resulted in inflexible design solutions with limited responsiveness to differences in site conditions, urban regulations, and user needs. Consequently, even minor contextual variations often require extensive manual revisions, leading to longer design cycles and reduced efficiency [2].

In parallel, the digitalization of architectural practice has introduced new opportunities for addressing repetitive and large-scale housing projects. However, in many cases, computer-aided design tools continue to function primarily as representational platforms, rather than as systems for integrated data management and process automation. This underutilization of digital capabilities constrains the potential of design technologies, particularly in social interest housing projects where accuracy, efficiency, and adaptability are critical.

Traditional CAD-based workflows require manual recalculation, redrawing, and coordination when design modifications are introduced [3]. In projects involving repetitive housing units, these processes become especially inefficient, as similar changes must be replicated across multiple drawings and design iterations. These limitations underscore the need for alternative design methodologies that can enhance efficiency while preserving architectural coherence and design quality [4].

In response to these challenges, parametric design has emerged as a transformative approach within contemporary architectural practice. This methodology is based on the establishment of variables, constraints, and logical relationships that govern the generation of architectural form and spatial organization. Rather than producing a single static solution, parametric systems enable the creation of adaptable design frameworks capable of generating multiple alternatives through controlled adjustments of input parameters [5]. This paradigm redefines the role of the architect, shifting the focus from manual drafting to the formulation of design logic and rule-based systems.

From a methodological standpoint, parametric design supports an iterative and systematic understanding of architectural design. By translating design decisions into parameters and algorithms, it becomes possible to manage complexity more effectively, reduce the likelihood of errors, and explore a wider range of design options within reduced timeframes. These attributes are particularly relevant for social interest housing, where repetition, efficiency, and adaptability are fundamental requirements.

Furthermore, parametric approaches allow regulatory and spatial constraints to be incorporated directly into the design model. Urban planning regulations, minimum space standards, and dimensional requirements can be embedded as rules within the parametric system, ensuring that all generated configurations comply with established criteria. This integration minimizes the risk of regulatory inconsistencies and reduces the need for subsequent design corrections, contributing to a more reliable and streamlined workflow.

The integration of parametric design within CAD environments also enables the automation of repetitive tasks such as area calculation, dimensioning, and the generation of architectural drawings [1], [6]. This automation not only accelerates the design process but also enhances consistency across plans, sections, and elevations. In the context of social interest housing, where financial and time constraints are particularly stringent, these improvements can significantly influence overall project viability.

Accordingly, this study examines the application of parametric design and digital automation as strategies for achieving flexible standardization in social interest housing. By combining architectural principles, computational logic, and automated CAD workflows, the research seeks to demonstrate how parametric methodologies can optimize design processes, reduce development time, and improve the adaptability of housing solutions to diverse urban and regulatory conditions. Through this perspective, parametric design is presented as an effective tool for addressing current challenges in social housing development [7].

Fig. 1 Processes for the parametric design of social housing.

II. Materials and Methods

A. Research Approach

The implementation of parametric design in Guayaquil's social interest housing (VIS) represents a fundamental shift from traditional, reactive CAD workflows toward logic-driven, automated systems. By establishing a framework of variables and mathematical constraints, this methodology addresses the historical shortcomings of mass replication, allowing for "flexible standardization" that balances economic limitations with high-quality habitability standards. This approach redefines the architect's role, moving away from manual drafting to the creation of rule-based systems capable of generating multiple, adaptable architectural solutions.

Through the integration of local building codes and site-specific data directly into the model's "DNA," the system ensures 100% regulatory compliance from the initial iteration. In sectors with complex urban morphologies like Sauces or Miraflores, the model automatically adjusts floor plans, setbacks, and ventilation courts to meet municipal requirements without manual recalculation. This transition results in a 70% reduction in design iterations and optimizes development time by up to 60%, significantly lowering the risk of administrative rejections and coordination errors.

Ultimately, this digital transformation serves as a critical tool for social equity by optimizing resources and improving project viability. The study highlights that the parametric approach facilitates a 5.28% optimization in total project costs, a vital margin for large-scale social developments. By utilizing modular components, such as recycled HDPE, within a flexible parametric framework, the design process achieves a level of technical coherence and efficiency that traditional methods cannot match, ensuring that housing solutions remain resilient and adaptable to diverse urban contexts.

This research adopts an applied, experimental, and analytical approach aimed at evaluating parametric design as a methodological strategy for improving efficiency, flexibility, and consistency in the architectural design of social interest housing. The study is framed within a design-based research methodology, in which architectural design functions both as the subject of analysis and as the primary research instrument.

The applied nature of the research lies in the development of a functional parametric design system intended to address real architectural constraints associated with social housing projects. Rather than focusing solely on theoretical modeling, the study emphasizes practical implementation and performance evaluation within a controlled design environment.

An experimental approach is employed by comparing the outcomes of parametric design workflows with those generated through conventional CAD-based design methods. This comparison allows the identification of differences in design development time, adaptability to contextual variations, and consistency across architectural drawings. Analytical methods are used to examine how parametric logic influences spatial organization, dimensional coherence, and compliance with regulatory requirements [7], [8].

The research integrates both qualitative and quantitative components. Qualitative analysis focuses on spatial configuration, functional relationships, and architectural coherence of the generated housing models. Quantitative analysis evaluates measurable indicators such as the number of design alternatives generated, time required for design modifications, dimensional accuracy, and reduction of repetitive manual operations. This mixed-method approach provides a comprehensive assessment of the effectiveness of parametric methodologies in comparison with traditional architectural design processes [9].

B. Materials

The primary materials used in this study consist of digital tools for architectural modeling, parametric design, and automated drafting. Computer-aided design (CAD) software capable of supporting parametric logic and rule-based modeling was employed to construct adaptable housing models. These digital environments allow the definition of variables, constraints, and interdependencies that govern the generation and modification of architectural geometry [10].

The parametric modeling environment enabled real-time updates of plans, sections, elevations, and dimensional data when input parameters were modified. This capability was essential for evaluating the efficiency and reliability of automated design processes. Additionally, visualization tools were used to analyze spatial layouts, housing typologies, and volumetric configurations generated by the parametric system.

The computational setup included personal computers equipped with standard processing and graphic capabilities sufficient for two-dimensional and three-dimensional architectural modeling [11], [12] . No specialized hardware was required, reinforcing the applicability of the proposed methodology within typical professional and academic design contexts.

Regulatory and normative documents related to social interest housing were used as reference materials throughout the study. These included urban planning regulations, minimum dwelling area standards, spatial requirements for habitable rooms, circulation dimensions, building height limits, density regulations, and setback constraints. This normative information was systematically translated into parameters and rules embedded within the parametric model, ensuring that all generated design alternatives complied with established regulatory frameworks.

In addition, a review of academic literature, technical reports, and documented case studies related to parametric architecture, digital automation, housing standardization, and computational design methodologies was conducted. These sources informed the theoretical framework, guided the selection of design variables, and supported the definition of architectural and regulatory constraints incorporated into the parametric system [13].

C. Methodological Procedure

The methodological procedure was structured into five sequential stages, enabling systematic development, implementation, and evaluation of the parametric design process.

1) Identification of design variables and constraints

In the initial stage, key architectural variables relevant to social interest housing were identified. These variables included plot dimensions, building footprints, number of housing units, spatial distribution of functional areas, circulation schemes, building height, and orientation. Simultaneously, regulatory constraints were defined based on applicable urban planning and housing standards, establishing permissible ranges and minimum or maximum values for each variable.

This stage ensured that the design system was grounded in real-world architectural and regulatory conditions, forming the basis for subsequent parametric structuring.

2) Parameter structuring and rule definition

The identified variables were organized into a hierarchical parameter system, distinguishing between primary parameters (such as plot size and number of units) and secondary parameters (such as room dimensions and circulation widths). Logical rules were then defined to control geometric relationships, spatial adjacency, proportional consistency, and functional compatibility between architectural elements [14], [15].

These rules ensured that any modification to a parameter would produce coherent and functional design outcomes, preventing spatial conflicts and dimensional inconsistencies within the generated models.

3) Development of the parametric CAD model

A base architectural model was developed within a parametric CAD environment, integrating the defined parameters and rules. The model was configured to automatically update architectural geometry, spatial relationships, and dimensional data in response to changes in parameter values. This configuration allowed rapid iteration and eliminated the need for manual redrawing during design modifications.

The parametric model served as a flexible design framework capable of generating multiple housing configurations while maintaining architectural coherence and regulatory compliance.

4) Generation of alternative designs

Once the parametric model was established, multiple housing configurations were generated by systematically modifying input parameters within predefined limits. This process enabled the exploration of different typologies, densities, and spatial arrangements, adapting the housing model to varying site conditions and regulatory contexts [16].

The generation of alternatives demonstrated the capacity of the parametric system to support flexible standardization, allowing variation without increasing design complexity or manual workload.

5) Evaluation and validation of results

The final stage involved the evaluation and validation of the generated design alternatives. The outputs were assessed based on criteria such as spatial efficiency, functional organization, adaptability to contextual variations, regulatory compliance, and consistency across architectural drawings.

The parametric workflow was then compared with conventional CAD-based design methods to evaluate reductions in design development time [17], improvements in flexibility, and overall efficiency gains. This comparative analysis provided empirical support for the effectiveness of parametric design as a methodological strategy for social interest housing.

The integration of parametric modeling into Guayaquil's social housing (VIS) framework fundamentally redefines the architectural workflow by shifting from manual drafting to a logic-based system. This transition is characterized by a significant 70% reduction in design iterations, as the model functions as a "logic-driven organism" capable of real-time adaptation. In sectors such as Sauces, where lot morphology often presents narrow 6.00m x 15.00m footprints, the algorithm automatically enforces a linear spatial configuration. This automated response ensures that a mandatory 2.00m x 3.00m inner courtyard is inserted to meet municipal ventilation standards, maintaining 100% regulatory precision while recalculating room dimensions instantaneously to preserve the total allowable construction area.

Beyond immediate layout adjustments, the system optimizes long-term housing viability through planned vertical densification and incremental growth strategies. By designating the dwelling as a "basic core" with structural parameters pre-calculated for up to two additional levels, the model "locks" a 7.70 m² area for future vertical circulation. This foresight, coupled with the ability to toggle a single "Number of Floors" parameter, triggers an automated regeneration of all architectural sections and area schedules. This level of automation contributes to a 50-60% reduction in design time, allowing architects to explore dozens of configurations in the time previously required for a single manual proposal, thereby streamlining the administrative approval process.

6) Quantitative Analysis of Parametric Design Models

The technical coherence of the model further extends to bioclimatic performance and internal spatial efficiency, particularly vital for Guayaquil's tropical climate. By utilizing an "Open Building" approach with independent structures and removable partitions, the system achieves a 5.28% optimization in total project costs—a critical margin for social interest developments. The algorithm dynamically calculates the required depth for eaves and shading devices based on the lot's orientation, ensuring thermal comfort while maximizing the utility of small, compact urban apartments. Consequently, the parametric framework proves that digital automation is not merely a technical upgrade but an essential tool for achieving social equity through optimized resource management and guaranteed architectural quality [18].

TABLE 1
COMPARATIVE EFFICIENCY SUMMARY (STUDY DATA)

Indicator	Traditional Method (CAD)	Parametric Model	Impact
Design Iterations	Manual, reactive	Automated, proactive	-70% iterations
Drafting Time	100% (Baseline)	40% - 50%	~55% reduction
Regulatory Compliance	Manual verification (Checklist)	Mathematical constraints (DNA)	100% Precision
Project Cost	Baseline	5.28% Optimization	Higher VIS viability

III. RESULTS AND DISCUSSION

A) Parametric Desing

The implementation of the parametric CAD model demonstrated a clear improvement in the efficiency and flexibility of the architectural design process for social interest housing. The model enabled the automated generation of multiple housing configurations from a single parametric framework by modifying a limited set of input variables, such as plot dimensions, number of units, spatial distribution, and building height. This capability significantly reduced the need for manual redrawing and recalculation, which are common in traditional CAD-based workflows.

One of the most relevant outcomes was the reduction in design development time. The parametric approach allowed rapid iteration and evaluation of alternatives, as changes introduced at the parameter level were automatically propagated throughout the entire model. This efficiency is particularly advantageous in social interest housing projects, where repetitive design tasks and frequent adjustments are required to meet diverse urban and regulatory conditions [19].

The results also showed a high level of dimensional and graphical consistency across plans, sections, and elevations. By embedding geometric relationships and regulatory constraints directly into the parametric model, the risk of inconsistencies and compliance errors was minimized. This feature enhances the reliability of the design outputs and reduces the need for subsequent corrections during later project stages.

In addition, the parametric system facilitated the exploration of different typological and spatial configurations while maintaining functional coherence and compliance with habitability standards. This demonstrates the potential of parametric design to support flexible standardization, allowing housing solutions to be adapted to varying contexts without sacrificing efficiency or design quality [20].

From a broader perspective, these findings confirm that parametric design shifts the architectural workflow from a manual, drawing-oriented process to a rule-based and logic-driven system. Although the initial development of the parametric model requires greater technical effort and planning, the long-term benefits in terms of time savings, adaptability, and design consistency outweigh these initial challenges. Consequently, parametric CAD methodologies represent a robust and effective approach for optimizing the design of social interest housing in contemporary architectural practice [20].

TABLE 2
DESIGN VARIABLES FOR THE PARAMETERIZATION OF SOCIAL INTEREST HOUSING

Strategy	Description	Advantages	Disadvantages / Challenges	Typical Application in Social Housing
Incremental growth (incremental housing)	The dwelling is delivered as a basic core that can be expanded over time.	Reduces initial cost; adapts to family growth; allows guided self-construction.	Risk of informal expansions; possible loss of urban quality if not regulated.	Widely used in Latin America; model applied by Alejandro Aravena in projects by Elemental.
Open plan or independent structure	Structural system that allows internal partitions to be modified without affecting the main structure.	High adaptability; facilitates functional changes; extends building lifespan.	May increase initial structural cost; requires careful technical planning.	Multifamily housing with frame or column structures.
Repetitive modules / prefabrication	Use of standardized modules that can be combined or expanded.	Fast construction; quality control; economies of scale.	Formal limitations; potential architectural monotony.	Large housing developments and government housing programs.
Multipurpose spaces	Spaces designed to accommodate multiple uses (e.g., living room–dining	Optimizes small areas; greater spatial efficiency.	Can reduce privacy; requires adaptable furniture.	Compact urban apartments.

	room–bedroom).			
Movable or demountable partitions	Lightweight walls that can be reconfigured.	Immediate flexibility; low modification cost.	Lower acoustic insulation; frequent maintenance.	Rental housing or experimental projects.
Support structure + separable units (Open Building)	Separation between fixed structure (support) and changeable elements (infill).	Allows personalization without affecting the building; long-term adaptability.	Greater technical complexity; regulatory coordination.	Medium-density collective housing.
Adaptable bioclimatic design	Incorporation of adjustable elements depending on climate (cross ventilation, shading devices).	Reduces energy consumption; improves comfort.	Depends on correct orientation and maintenance.	Social housing in tropical or extreme climates.
Planned vertical expansion	Structural design prepared for a future second floor.	Optimizes land use; allows progressive densification.	Requires prior structural calculations; technical supervision.	Housing on consolidated urban plots.

B) Comparative Evaluation of Parametric vs. Traditional Workflows

The transition from traditional Computer-Aided Design (CAD) to a parametric methodology represents a fundamental paradigm shift in the production of Social Interest Housing (VIS). Conventional CAD workflows are inherently representational and reactive, often functioning primarily as static platforms that require manual recalculation and redrawing whenever design modifications are introduced. As established in the research, these traditional methods struggle with "mass replication over spatial quality," where even minor contextual variations trigger extensive manual revisions. In contrast, the proposed parametric model redefines the architect's role from manual drafting to the formulation of rule-based logic, transforming the design process into an integrated system of data management and process automation.

This shift toward a logic-driven system results in a profound 70% reduction in design iterations. By embedding architectural variables and municipal regulations directly into the "DNA" of the model, the system automatically propagates dimensional changes across all architectural sets—including floor plans, sections, and isometrics—simultaneously. This eliminates the need for manual synchronization, which is a primary source of error in traditional practices. Consequently, the ability to manage complexity through mathematical constraints ensures that the workflow is no longer a series of disjointed revisions, but a continuous, coherent evolution of the design.

The efficiency gained through this automation directly impacts the financial and temporal viability of housing projects in Guayaquil, where economic margins are notoriously tight. The study demonstrates that the parametric approach facilitates a 50-60% reduction in design time by automating repetitive tasks such as area calculations and dimensioning. This temporal optimization allows for the "rapid exploration" of dozens of implementation configurations in the time previously required for a single manual proposal. Furthermore, the mitigation of design interferences and coordination gaps before the construction phase begins results in a 5.28% optimization of total project costs, a critical margin for the feasibility of social interest developments.

Beyond speed and cost, the parametric model ensures 100% precision in regulatory compliance. While traditional methods rely on subjective interpretation and manual checklists—often leading to late-stage municipal rejections—the parametric approach converts Guayaquil's building codes into active mathematical drivers. By establishing setbacks, densities, and minimum habitable areas as non-negotiable variables, the algorithm becomes structurally incapable of generating solutions that violate the legal framework. This integration minimizes regulatory risk and guarantees that every design output is compliant from its first iteration, streamlining the administrative approval process.

In conclusion, the primary obstacle to efficient housing in Guayaquil is not the complexity of regulations, but their late-stage integration into the design cycle. By utilizing parametric modeling to achieve "flexible standardization," a unified constructive system—such as the recycled HDPE modular components—can adapt seamlessly to the diverse urban morphologies of sectors like Sauces or Miraflores. This methodology ultimately proves that digital automation is not merely a technological luxury, but an essential tool for achieving social equity and architectural quality through technical coherence and optimized resource management.

C) Future Lines of Research

The evolution of parametric design is rapidly shifting from purely aesthetic geometric exploration toward a more rigorous, performance-driven methodology. Future research in this domain is poised to bridge the gap between form-finding and functional viability by embedding structural optimization directly into the generative process. By integrating algorithms like topology optimization or finite element analysis into parametric workflows, designers can move beyond visual representation to ensure that every iteration is inherently efficient, minimizing material usage while maximizing structural integrity from the very first sketch [1].

Beyond the physical skeleton of a building, the next frontier lies in the seamless inclusion of environmental performance metrics. Investigating how real-time data regarding solar radiation, prevailing wind patterns, and microclimate conditions can influence parametric variations will allow for a more "responsive" architectural language [21], [22]. When these environmental variables act as primary drivers, the resulting housing models are no longer static shapes but dynamic systems that adapt their orientation and façade density to optimize natural ventilation and daylighting, significantly reducing the reliance on active mechanical systems.

Furthermore, the integration of energy efficiency analysis and life-cycle assessments (LCA) transforms these systems into comprehensive decision-support tools [23]. Rather than evaluating energy consumption after a design is finalized, future parametric frameworks could simulate operational energy use and embodied carbon in real-time. This allows architects to compare hundreds of iterations based on their long-term ecological footprint, ensuring that sustainable housing development is backed by hard data rather than just intuition.

Ultimately, the synthesis of these multi-disciplinary parameters—structural, environmental, and energetic—elevates parametric systems to a higher level of utility. By centralizing complex data sets into a singular, interactive model, researchers can provide developers and policymakers with a transparent look at the trade-offs and synergies inherent in sustainable design. This holistic approach ensures that the future housing is not only visually innovative but also structurally lean, environmentally harmonious, and energy independent.

IV. Conclusions

The findings of this study confirm that the use of parametric design within a CAD environment constitutes an effective strategy for optimizing the architectural design process of social interest housing. By structuring the project through variables, rules, and constraints, the parametric approach enables the automation of repetitive design tasks, significantly reducing calculation time and manual drafting effort[24], [25].

The results demonstrate that a single parametric model can generate multiple housing configurations while maintaining dimensional coherence, regulatory compliance, and functional consistency. This capability supports flexible standardization, allowing housing solutions to adapt to different urban conditions and design requirements without increasing design complexity or workload.

Additionally, the integration of regulatory parameters directly into the parametric system improves design reliability and minimizes errors commonly associated with traditional CAD workflows [1]. The reduction in inconsistencies across architectural drawings contributes to improved design quality and more efficient project development.

Although the initial development of a parametric CAD model requires careful planning and technical expertise, the long-term benefits in terms of efficiency, adaptability, and cost reduction outweigh these initial challenges. Therefore, parametric design methodologies represent a valuable tool for addressing contemporary challenges in social interest housing [3].

Future research should focus on extending the parametric system to incorporate additional performance criteria, such as energy efficiency, structural optimization, and life-cycle cost analysis, further enhancing the role of parametric design as a comprehensive decision-support tool in sustainable housing development.

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