



Section 1. Architecture

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PARAMETRIC MODELLING AS A METHOD FOR EXPLORING AND COMPARATIVELY EVALUATING ARCHITECTURAL DESIGN ALTERNATIVES

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Abstract

This article aims to establish a methodological basis for aligning the parametric generation of alternatives with architectural evaluation criteria at the early stages of design. The study uses conceptual analysis, a comparison of scholarly publications, and theoretical synthesis. It distinguishes between dimensional variation, transformations of spatial relationships allowed by the model, and revision of the model structure. A sequence of problem formulation, parameterisation, model verification, alternative generation, and comparative evaluation is proposed. The study identifies conditions for combining quantitative indicators with qualitative analysis of functional and spatial organisation, composition, and context. The author's contribution lies in relating types of design change to the conditions required for comparing alternatives and the procedures used to select them. The findings are theoretical and methodological; their practical effectiveness requires empirical validation.

Keywords: *parametric modelling, architectural design, design exploration, design space, comparative evaluation*

Introduction

Parametric modelling enables the exploration of interrelated changes in a building's functional and spatial organisation and its volumetric composition. Formalising dependencies allows elements to be updated consistently (Jabi, 2013; Woodbury, 2010). However, the number of generated alternatives alone does not indicate the diversity of

architectural exploration. Numerous geometric configurations may reproduce the same layout, while an improvement in one indicator may be accompanied by deterioration in other properties.

The research problem concerns the alignment of a parametric model's capabilities with the grounds for architectural decision-making. The aim is to establish

a methodological approach to generating and comparatively evaluating alternatives at the early stages of design. To this end, the study clarifies the conceptual boundaries of parametric exploration, distinguishes types of design change, and identifies the conditions under which alternatives are comparable. The subject of the study is the relationship between parametric dependencies and architectural evaluation procedures.

Research Method

The study is based on a targeted analysis of nine publications from 2010–2025, selected for their relevance to parametric representation, model flexibility, and the evaluation of alternatives. Available full texts were used alongside abstracts and publishers' descriptions for some sources; the corresponding claims are restricted to the information provided in those materials. This selection does not constitute a systematic review. Conceptual analysis is supplemented by a comparison of parameter sets, dependencies, available transformations, and selection criteria. Theoretical synthesis is used to formulate the methodological sequence; no computational experiment was conducted.

Theoretical Background

Woodbury (2010) and Jabi (2013) explain the parametric approach through relationships between elements of an architectural model. In this article, the design space denotes the set of configurations accessible within specified variables, ranges, and rules. It represents the capabilities of a particular model rather than every potential solution to the design problem. Drawing on the terminology distinguished by Caetano et al. (2020), parametric modelling is understood as the representation of dependencies, algorithmic design as the formalisation of operations, and generative design as the organisation of alternative generation. Optimisation additionally requires objective functions, constraints, and a search procedure.

Oxman (2017) relates parametric design to design thinking; Davis (2013) investigates model flexibility, while Harding and Shepherd (2017) examine meta-parametric design. Turrin et al. (2011) combine parametric geometry with genetic algorithms. The Design Space

Construction approach aligns problem formulation, alternative generation, and the assessment of their value (Haymaker et al., 2018). Bunt et al. (2025) address the interaction between design thinking and optimisation. These publications provide a basis for interpreting the limits of variation and the grounds for selection in architectural terms.

Results and Analysis

Parameters and Types of Design Change

The architectural meaning of a parameter is determined by the property it represents: building depth describes an overall dimension, column spacing defines the structural and planning grid, and the position of a circulation core determines its relationship to functional zones. The model distinguishes between input data, independent variables, derived characteristics, constraints, and criteria. Constraints establish feasibility, whereas criteria identify the relative merits of alternatives. Mandatory requirements are separated from the architect's working assumptions, the revision of which defines a distinct exploration scenario.

Drawing on studies of the flexibility and structure of parametric models (Davis, 2013; Harding & Shepherd, 2017), three types of design change are distinguished. Dimensional variation alters dimensions and proportions while retaining the existing system of spatial relationships. Transformations of spatial relationships alter zone adjacency, access sequences, or circulation routes within the possibilities already allowed by the model's rules. Revision of the model structure introduces new variables or dependencies to enable previously unavailable transformations. The boundary between the second and third types depends on the initial model: changing the number of circulation cores requires restructuring only if this possibility has not already been parameterised.

The distinction between dimensional and organisational change is determined by its spatial consequences. Moving an entrance constitutes a dimensional change if the access sequence remains unchanged; it becomes an organisational change when it alters the relationship between the entrance, shared spaces, and private zones. Differences in co-

ordinates alone are therefore insufficient for assessing diversity. Changes in zoning principles, spatial hierarchy, and relationships between functional components are significant for architectural exploration.

This distinction is neither a universal classification nor a mandatory sequence of stages. It establishes the basis for comparison: dimensional alternatives are assessed in terms of the consequences of changing values, while organisational alternatives are assessed as different spatial relationships within a shared brief. After restructuring a model, the comparability of input conditions and indicator calculation methods must be checked. A common design task and shared criteria thus ensure comparability even when the algorithmic structures of the models differ.

Organising Design Exploration and Evaluation

The hierarchy of parameters should correspond to the scale of the question being investigated. The building as a whole, its functional components, and its individual elements require different levels of detail. Introducing secondary variables prematurely complicates concept revision and the interpretation of results. Analysis of individual parameters should be supplemented by testing their combinations: an acceptable change in one dimension may produce an undesirable outcome under a different circulation configuration or functional zoning arrangement.

To align problem formulation, modelling, and evaluation (Haymaker et al., 2018), exploration begins by defining the architectural question, the limits of variation, and the criteria. Parameterisation establishes variables, ranges, and dependencies; conflicting conditions are resolved before alternatives are generated. Computational correctness and the model's adequacy for the design task are checked at representative and boundary values. These checks address unintended intersections, the preservation of necessary relationships, and consistency with the spatial concept. The sampling method, variation increments, and termination conditions are specified for alternative generation.

Feasibility checks precede ranking. Alternatives that violate the mandatory conditions being checked are rejected or revised. Compli-

ance within the model confirms only that the requirements represented in it have been met; unchecked properties remain undetermined. Alternatives are compared using consistent indicators and graphic representations with comparable scales, viewpoints, and levels of detail. Insufficient diversity or conflicting criteria provide grounds for revising the model. Changes to the conditions require the entire comparison set to be re-evaluated.

The reproducibility of exploration depends on documenting its conditions. The initial brief, variable ranges, method of generating alternatives, and reasons for rejecting options are retained alongside the selected design. Recording this information makes it possible to distinguish the effects of architectural decisions from those of model settings. Terminating generation according to a specified rule does not imply that all possible solutions have been exhausted; conclusions apply to the investigated set and the adopted conditions.

Quantitative indicators require defined units, a comparison baseline, and calculation rules. An aggregate assessment requires justification of normalisation methods, preferred directions of change, and weights. A geometric quantity cannot substitute for the assessment of a performance characteristic: building depth, for example, does not fully describe daylighting conditions. Qualitative analysis considers zone adjacency and accessibility, spatial hierarchy, proportions, rhythm, and relationships with the surroundings. Expert assessments should rely on defined attributes and graphic materials; differences in judgement should be recorded.

To compare functional organisation, the proportion of circulation space is calculated against a consistently defined reference floor area, while route lengths are measured between fixed functional points. A shorter route does not necessarily provide better accessibility: changes in level, passage configurations, and the separation of movement flows must also be considered. Each indicator should therefore be accompanied by an explanation of the property it represents and the aspects it excludes from evaluation.

Where criteria conflict, the sensitivity of the selection to weights and initial assumptions is examined. With multiple numerical indicators, non-dominated alternatives may

be selected: no other alternative in the investigated set performs at least as well on every criterion and better on at least one. This selection describes trade-offs only within the evaluated set. The final decision requires an explanation of the design's functional and compositional advantages and of why losses against other criteria are acceptable.

Compositional analysis involves comparing proportions, rhythm, dominant and subordinate elements in relation to the spatial concept. Contextual assessment considers the scale of the surroundings, the character of the built frontage, and the organisation of open spaces. These properties may be described using expert rating scales, but the meaning of each scale level must be defined. An overall score without an explanation of the assessed attributes and design priorities is insufficient to justify an architectural decision.

The robustness of a comparative conclusion depends on whether a design retains its advantages when priorities are reasonably revised. If changes in weights substantially alter the ranking, the result should be presented as dependent on the evaluation scenario. An increase in usable floor area, for example, may reduce the space reserved for circulation or future adaptation. Choosing between such alternatives requires design priorities to be stated explicitly. Weights express those priorities rather than establishing the universal importance of particular architectural properties.

At the conceptual stage, exploration addresses the arrangement of building volumes, zoning, and access; at the schematic design stage, it addresses dimensions, room configurations, and circulation relationships. Further development involves coordination with structural, building services, and information models. Documenting variables, the model version, and the grounds for selection makes the origins of a design traceable; transferring geometry alone does not guarantee the preservation of parametric dependencies.

Discussion

The author's contribution lies in relating types of design change to conditions of com-

parability and evaluation procedures. The proposed distinction clarifies when changing parameter values is sufficient, when different spatial organisations should be compared, and when the model should be restructured. It supplements existing approaches with an architectural interpretation of transformations and does not constitute a new optimisation algorithm.

The methodological value of the approach lies in linking the assessment of an individual alternative to an analysis of how alternatives are generated. If a model permits only dimensional changes, its results cannot substantiate the superiority of the adopted layout over other layouts. Where spatial organisation changes, a common functional brief must be retained or its revision explicitly identified. This limits the unwarranted transfer of conclusions between different design scenarios.

Further validation should compare processes involving participants with comparable experience and defined time limits. Independent expert evaluation of the final designs should complement analysis of alternative diversity, the reasons for model restructuring, and the reproducibility of calculations. The effort required to establish and revise parametric dependencies must be included in the total workload. This approach would allow testing of whether the proposed organisation of exploration provides practical advantages and under which conditions they arise.

Conclusions

The study establishes a methodological basis for parametric exploration as an iterative process that combines alternative generation, constraint checking, and quantitative and qualitative evaluation. Its methodological conditions are the relevance of parameters to the design task, a common basis for comparison, and a reasoned selection. The findings are limited by the selective literature base and the absence of empirical validation. Further validation requires comparing design processes under a common brief and assessing the diversity of alternatives, their architectural quality, and the total modelling workload.

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