A Criteria-Based CAD Pre-Modeling Decision Method (CBPMDM) for Early-Stage Industrial Product Design

Konstantinos Bailas[1] and Ioannis Xenakis[2]

[1] Integrated Industrial Design Lab, Department of Product and Systems Design Engineering, University of the Aegean, kbail@aegean.gr
[2] Complex Systems and Service Design Lab, Department of Product and Systems Design Engineering, University of the Aegean, ixen@aegean.gr

Corresponding author: Kostantinos Bailas, kbail@aegean.gr

Abstract. The transition from conceptual product definitions to parametric CAD models that are both adaptable to change and visually consistent with the original design concept remains a critical challenge in industrial design practice. This challenge primarily arises because design intent, defined as the underlying rationale governing features, constraints, parameters, and reference structures, is not systematically defined prior to geometry creation. This paper introduces the Criteria-Based Pre-Modeling Decision Method (CBPMDM), a structured decision method that supports designers in defining CAD modeling strategies before geometry generation. By guiding the pre-modeling phase through predefined criteria, the method enables designers to more easily identify appropriate approaches and embed design intent from the earliest stages of the process. The method links product characteristics, such as geometric complexity, feature recognizability, and design context, to suitable CAD environments, feature routines, and command sequences. CBPMDM is demonstrated through reference scenarios, showing how it can support clearer and more consistent representation of design intent during pre-modeling decision-making. Compared to conventional workflows, the method provides a structured basis for planning feature organization and encoding design intent before geometry creation. As a result, it is intended to support controlled parameter adjustments, reduce modeling uncertainty, and limit the need for later reconstruction. The proposed approach reframes CAD development as a strategy-driven engineering process, enabling designers to transition from reactive, command-based workflows to structured and predictable design practices. The paper positions CBPMDM as a contribution to CAD education and industrial design practice by providing a repeatable decision procedure for early-stage modeling planning.

Keywords: parametric CAD modeling, design intent, strategic design, modeling strategy, conceptual design
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1 INTRODUCTION

The increasing complexity of industrial product design, combined with the widespread adoption of parametric CAD systems, has significantly transformed the way digital models are created and utilized within engineering workflows. Despite continuous advancements in CAD technologies, the transition from conceptual design to robust and adaptable parametric models remains a persistent challenge in both educational and industrial contexts [1], [2], [3]. A central concept in addressing this challenge is design intent, which refers to the explicit representation of how and why a model should behave under modifications. In parametric CAD, design intent is not an external description of the product, but the internal logic encoded in the model that controls change behavior. It is expressed through the definition of parameters, constraints, reference geometry, and feature dependencies that determine how dimensions, proportions, and geometric relations are preserved or allowed to vary when the model is edited. Design intent governs the relationships between geometric entities, the structure of feature dependencies, and the parametric logic embedded within the model [15], [16]. Foundational work in feature-based and parametric modeling has established that the quality of a CAD model is not solely determined by its geometric accuracy, but also by the organization of its internal structure and constraints [10], [11]. Subsequent research has further emphasized that models with well-defined design intent exhibit improved robustness, reusability, and adaptability to design changes, whereas poorly structured models often lead to instability and increased modeling effort [12], [14].

In practice, however, design intent is rarely defined explicitly at the early stages of the modeling process. Designers typically begin by constructing geometry based on visual approximation, progressively introducing constraints and parametric relationships as needed [1], [6]. This sequential modeling approach results in geometry-driven workflows, where the feature tree reflects the order of command execution rather than a structured representation of design logic [13]. As a result, constraints and parameters are often added as corrective actions to stabilize an already formed feature structure, rather than being established as prior commitments that shape the organization of the model. This leads to models that may visually resemble the intended product but lack the internal organization required for efficient modification and reuse.

Existing CAD research has addressed feature recognition, parametric robustness, and model quality assessment [8], [9], [6], while more recent studies have examined modeling strategies, constraint definition, and design intent representation to improve CAD model performance [3], [7], [15]. However, these approaches mainly focus on evaluating or improving models during or after geometry creation, offering limited support for defining modeling strategies before CAD execution. This lack of structured pre-modeling guidance becomes particularly evident in complex or unknown geometries, where multiple modeling alternatives may exist but differ in their ability to preserve design intent. Consequently, designers often rely on trial-and-error workflows, leading to inefficient and non-optimized model structures [3]. Nevertheless, trial-and-error should not be treated simply as a modeling deficiency, since early concepts are frequently incomplete and their geometric definition evolves during product development. CBPMDM does not seek to eliminate iteration or assume that geometry is fully specified before CAD execution. Instead, it structures the modeling decisions that become possible as the product concept progressively stabilizes.

The difficulty is therefore not only geometric but also representational. The transition from conceptual ideas to CAD geometry is not a direct translation of form into modeling commands, but a reasoning process in which designers progressively construct internal representations, decisions, and relationships before externalizing them into geometry. Because early concepts are often incompletely defined, this process naturally involves iteration. Since this reasoning is often implicit rather than systematically structured, CAD workflows frequently become command-driven instead of strategy-driven. This observation supports the need for methods that externalize modeling decisions before geometry creation, while allowing their revision as the concept develops, and make design intent explicit from the early stages of development [17].

To address these interrelated difficulties, this paper introduces the Criteria-Based Pre-Modeling Decision Method (CBPMDM), a structured decision method that supports designers in defining modeling strategies prior to CAD execution. The method is based on predefined criteria that link product characteristics, such as geometric complexity, feature recognizability, and modeling context, to appropriate CAD environments, feature routines, and command sequences in relation to design intent. The CBPMDM is demonstrated using reference models that illustrate the application of the method across different geometric configurations. These examples highlight how the method enables the systematic identification of geometric features, the selection of appropriate modeling tools, and the explicit embedding of design intent within the model structure. The examples are intended to demonstrate the application of the method rather than provide empirical validation of its performance. In this sense, the method supports a proactive modeling approach by moving strategy definition and design-intent encoding upstream, before geometry creation.

The contribution of this work lies in introducing a criteria-based pre-modeling decision procedure that reframes CAD modeling as a strategy-driven process by connecting product characteristics with modeling context, feature organization, and design-intent definition before CAD execution. This approach provides a structured basis for developing parametric models intended to support robustness and adaptability, offering practical value for both CAD education and industrial design practice.

The paper proceeds by outlining the role of design intent (Section 2), contrasting conventional workflows with CBPMDM (Section 3), detailing the CBPMDM stages and criteria (Section 4), discussing comparative observations and limitations (Sections 5), and concluding with implications and future work (Section 6).

2 THE ROLE AND IMPORTANCE OF DESIGN INTENT IN PARAMETRIC CAD MODELING WORKFLOWS

In parametric CAD modeling, design intent defines the internal logic that governs how a model behaves under modification through constraints, parameters, and feature relationships [10], [11]. Within feature-based modeling environments, geometry is generated through structured feature operations and constraint mechanisms that establish dependencies between model entities [1]. This structure enables predictable model regeneration and controlled design changes Figure 1(b). In contrast, sequential and unstructured modeling often results in unstable behavior, regeneration failures, and limited reusability Figure 1(a) [12].

Despite its importance, design intent is rarely defined explicitly during the early stages of modeling. Designers often construct geometry incrementally without establishing feature organization or constraint strategies in advance [1], [6]. Since only a limited set of structured modeling approaches leads to robust and reusable models [3], feature trees frequently reflect command order rather than design logic [13]. As a result, model behavior under modification depends not only on geometry but also on the organization of features and dependencies, making explicit design intent essential for stable and predictable CAD models.

2.1 Comparative Positioning of Existing CAD Modeling Approaches and the Proposed CBPMDM

Existing studies have contributed significantly to improving parametric CAD modeling through approaches focused on model robustness, feature recognition, design intent representation, and model quality assessment [3], [6], [8], [15]. However, these approaches primarily address models during or after geometry creation and offer limited explicit support for defining modeling decisions before CAD execution begins.

To clarify the positioning of the proposed method, Table 1 summarizes the focus of representative approaches and contrasts them with the scope of the Criteria-Based Pre-Modeling Decision Method (CBPMDM). The comparison considers the principal contribution of each approach, the extent to which it supports pre-modeling decisions, and the way in which it addresses design intent.

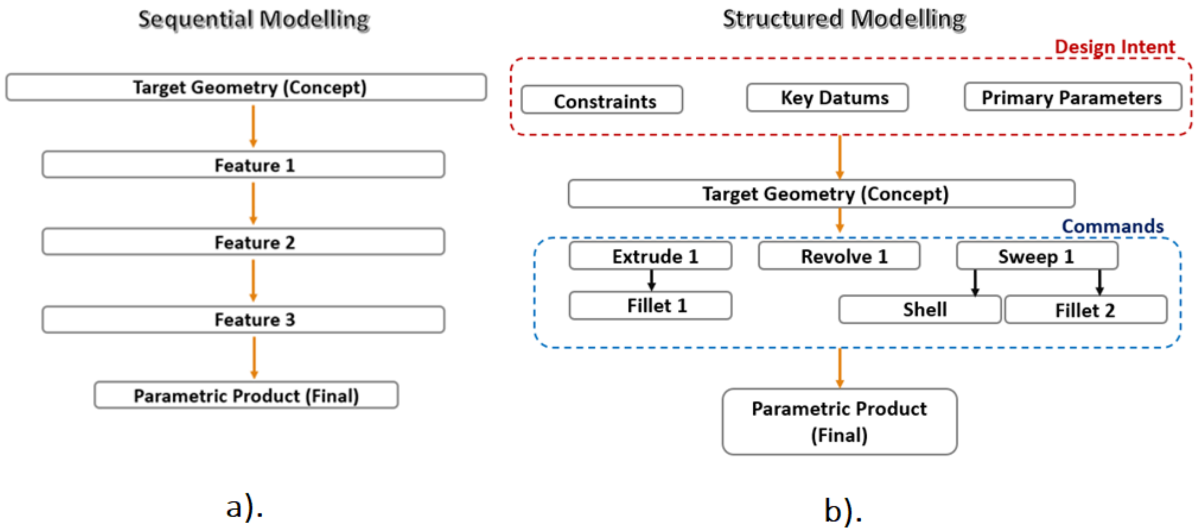

Figure 1: Comparison of sequential and structured parametric CAD modeling. (a) Sequential modeling, in which geometry is built feature-by-feature, and the feature tree primarily reflects command order. (b) Structured modeling, in which design intent is defined early through constraints, key datums, and primary parameters that guide feature sequencing and improve model stability under change.

CBPMDM introduces a structured pre-modeling decision stage that supports the systematic definition of modeling context, feature routines, and design intent prior to geometry generation. In contrast to the approaches summarized in Table 1, its primary focus is the explicit organization of this decision before CAD execution, enabling the systematic selection of modeling strategy and early integration of design intent.

Approach	*Main Contribution*	*Pre-modeling support*	*Design intent*
Feature recognition [8], [9]	Geometric feature identification	No	Limited
CAD quality / robustness [4], [6]	Model evaluation and optimization	No	Indirect
Parametric strategy methods [3], [14], [16]	Modeling efficiency and reusability	Partial	Moderate
Design intent methods [15]	Design intent representation	Limited	Explicit
CBPMDM (proposed)	Criteria-based modeling strategy definition	Yes	Embedded before modeling

Table 1: Comparative positioning of representative CAD modeling approaches and CBPMDM.

As shown in Table 1, feature-recognition approaches primarily support the identification of geometric features in existing CAD representations, but do not define the modeling strategy before geometry creation [8], [9]. CAD quality and robustness approaches assess model structure and performance after or during model development [4], [6]. Parametric strategy methods address modeling efficiency, reusability, and the cost of change, and therefore provide partial support for early strategic decisions [3], [14], [16]. Design-intent approaches make parameters, constraints, and feature relationships explicit, but they do not provide a complete criteria-based procedure for selecting modeling context and feature routines before CAD execution [15]. CBPMDM differs by integrating these decisions within a single pre-modeling stage, in which product characteristics guide the selection of modeling context, feature routines, and the early definition of design intent

3 CONVENTIONAL CAD WORKFLOWS COMPARED TO CRITERIA-BASED PRE-MODELING DECISION METHOD (CBPMDM)

Within traditional CAD workflows, design intent is rarely defined at the beginning of the modeling process and is often introduced later, once the geometry has already taken shape. In practice, designers tend to focus on quickly building the model, creating features step by step to achieve the desired form, while postponing decisions related to constraints and parametric relationships [14]. This results in geometry-driven models, where the feature tree reflects the sequence of actions taken during modeling rather than a planned and structured strategy. Although such models may visually match the intended product, they often lack clear internal logic, making them difficult to modify, less adaptable to design changes, and prone to instability, as illustrated in Figure 2.

Figure 2 contrasts two conventional modeling workflows. In the first, feature creation begins without an initial definition of design intent, and problems are addressed through trial-and-error adjustments after they emerge. In the second, design intent and skeleton geometry are defined earlier, providing a more structured basis for feature creation and subsequent modification. However, trial-and-error remains part of both workflows, since geometric definitions and modeling decisions may continue to evolve during model development.

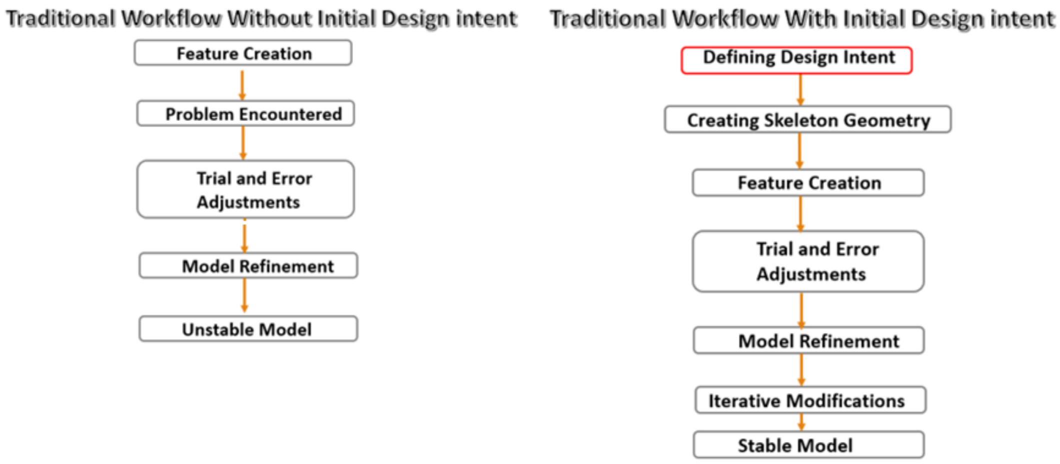

Figure 2: Comparison of conventional CAD workflows with and without an initial definition of design intent.

This limitation becomes more evident in complex or free-form geometries, where multiple modeling approaches may be technically feasible but differ in their ability to preserve design intent. In traditional workflows, design intent may be introduced through parameters or reference geometry; however, these decisions are typically made during modeling and often rely on trial-and-error processes. As a result, a methodological gap remains between the conceptual definition of design intent and its practical implementation within CAD environments. Addressing this gap requires shifting from a reactive, command-driven workflow to a structured approach in which modeling decisions are defined and revised systematically as the concept develops [15].

In contrast, the Criteria-Based Pre-Modeling Decision Method (CBPMDM) introduces an explicit pre-modeling decision stage composed of three sequential steps (Figure 3). Using predefined criteria, the method links product characteristics to modeling context, feature routines, and command strategy before CAD execution. This structured planning enables the systematic embedding of design intent and provides a basis for developing parametric CAD models intended to support greater robustness and adaptability.

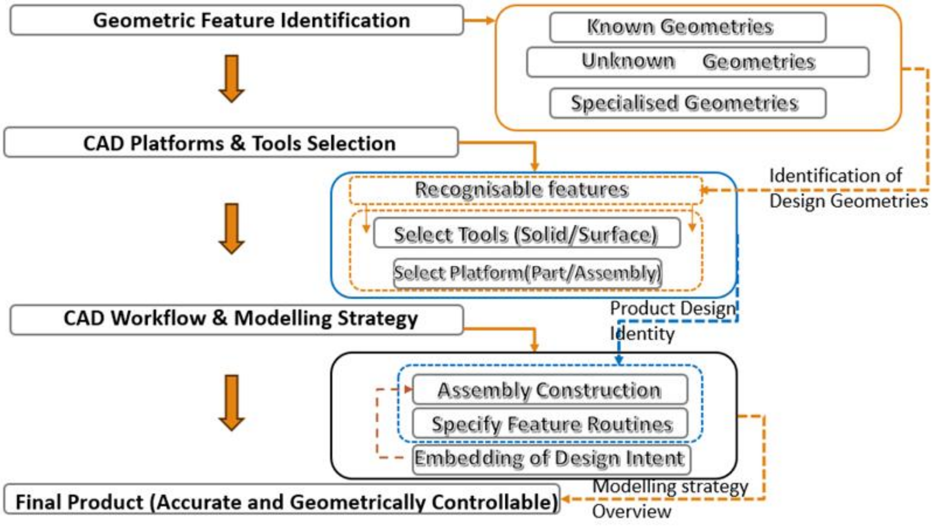

Figure 3: The Workflow of the Criteria-Based Pre-Modeling Decision Method (CBPMDM).

4 THE CRITERIA-BASED PRE-MODELING DECISION METHOD (CBPMDM)

The Criteria-Based Pre-Modeling Decision Method (CBPMDM) is a structured decision-making method that supports designers in defining a complete CAD modeling strategy prior to geometry creation Figure 3. The method is based on the principle that effective parametric models are not the result of isolated command execution, but of a predefined sequence of decisions that align product characteristics with appropriate modeling contexts, tools, and feature routines, while explicitly supporting the embedding of design intent in the CAD model. The method is organized into three sequential stages, each addressing a distinct aspect of the modeling process: geometric feature identification, CAD platform and tool selection, and the definition of CAD workflow and modeling strategy, including the explicit embedding of design intent. These stages collectively form a systematic workflow that transforms the modeling process from a reactive activity into a proactive, controlled, and strategy-driven procedure.

As illustrated in Figure 3, each stage produces information that informs the next. Geometric feature identification establishes the design geometries of the product. CAD platform and tool selection combines this information with decisions concerning modeling environments and tools to establish the product design identity. The final stage uses these outputs to define the assembly structure, feature routines, and design-intent relationships that constitute the modeling strategy.

4.1 Geometric Feature Identification

The first stage of the CBPMDM involves systematic observation and classification of the target product geometry. The objective is to decompose the object into identifiable geometric categories that can be associated with known or unknown modeling geometries. Based on predefined criteria, geometric features are classified into distinct categories, including:

- Known geometries, such as primitives and standard feature-based elements that can be directly associated with established CAD commands and repeated geometric patterns.
- Unknown or difficult geometries, which cannot be immediately mapped to predefined modeling feature routines and require isolated analysis. These may include organic or free-form geometries, typically requiring surface-based modeling tools.
- Specialized geometries, such as sheet metal structures and generative forms.

This classification enables the designer to anticipate modeling complexity and to determine whether specific parts of the geometry require independent modeling before integration into the overall model. Unknown or difficult geometries are treated as independent modeling tasks so that an appropriate feature routine can be established before being integrated into the overall modeling workflow. The distinction does not imply that these geometries are necessarily unfamiliar in their final form, but that their construction cannot be mapped immediately to a clear and established sequence of CAD operations.

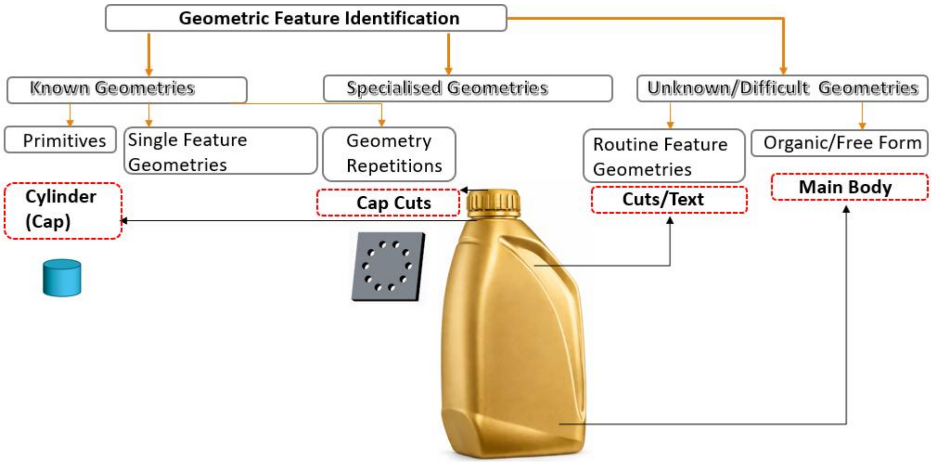

Figure 4: The first stage of the Criteria-Based Pre-Modeling Decision Method (CBPMDM) applied to a reference model (oil bottle).

Based on the criteria defining geometric characteristics, geometries can be systematically identified and classified into distinct categories. In this study, a representative product (an oil bottle) is employed to demonstrate the application of these criteria in the identification of geometric features, Figure 4. Through this process, design geometries of the product are identified as follows. The product consists of two separate components; each developed within a part-modeling environment. The first component (the cap) exhibits a well-defined cylindrical geometry and incorporates repetitive features distributed around its central axis. Its base form is therefore classified as a known primitive, while the repeated cap cuts are treated as specialized repetitive geometry. The second component is characterized by a free-form geometry, comprising complex features generated through the combination of multiple surface-based modeling operations. Additional cuts and text applied to the bottle are classified as difficult routine-feature geometries because their final form is recognizable, but their construction requires a planned combination of standard operations.

By applying the same criteria to other products, their geometric features can be systematically described, located, and categorized, leading to the identification of the product's design geometries. This output facilitates the subsequent steps of the proposed method.

4.2 CAD Platform and Tool Selection

Following geometric classification, the second stage of CBPMDM focuses on selecting the appropriate CAD environment/platforms and modeling tools Figure 3. These decisions are guided by stage-specific criteria related to product structure, feature distribution, and modeling complexity as shown below. The identification of design geometries produced during the first stage of the method serves as the input for these decisions. Based on this information, the designer determines the required Part and Assembly modeling environments and selects the modeling tools appropriate to each geometry. The primary criteria are:

- Number of Part modeling environments, suitable for single geometries.
- Number of Assembly and Sub-Assemblies required where needed.
- Selection of modeling tools based on geometry type, such as solid modeling for volumetric forms, surface modeling for complex or free-form geometries, and hybrid approaches as a combination of both solid and surface modeling.

These decisions define the modeling context in which all subsequent operations will be carried out. By selecting the appropriate platforms and tools, the designer minimizes inefficient transitions between modeling environments and ensures consistency in feature definition and dependency management. As summarized in Table 2, the output of this stage is the product design identity, which combines the design geometries identified during the first stage with the required part and assembly environments and the selected modeling tools. This product design identity becomes an input to the third stage, where the complete CAD workflow and modeling strategy are defined.

Sub-Stage	*Sub-Process*	*Key Actions*	*Purpose*
CAD Platform and Tools Selection	Number of part-modeling environments	Determine the total number of separate parts required for the final product	Define how many independent part-modeling environments are required and establish the component-level structure used in the subsequent CAD workflow
	Number of assemblies and subassemblies	Determine whether an assembly is required and define the total number of assemblies and subassemblies	Establish the preliminary assembly hierarchy and identify the component relationships that must be developed during the modeling strategy stage
	Selection of modeling tools	Select the tools required for feature generation: solid modeling, surface modeling, hybrid solid-surface modeling, or specialized modeling tools	Match each identified geometry with an appropriate construction approach and provide the basis for defining the feature routines in the subsequent stage

Table 2: Stage two-CAD platform and Tools Selection (Product Design Identity).

4.3 CAD Workflow and Modeling Strategy

The Criteria-Based Pre-Modeling Decision Method (CBPMDM) structures the final stage of the modeling process into a sequence of clearly defined sub-stages, each addressing a critical aspect of model development. The objective is to establish a comprehensive modeling strategy that transforms conceptual design into a fully parameterized product, enabling controlled and predictable geometric modifications. Tables 3–5 present the sub-processes, key actions, and purposes associated with each sub-stage. The main sub-stages are as follows:

- Assembly Construction, if needed;
- Feature Routine Definition, beginning with unknown or difficult geometries;
- Design Intent Embedding, applied across the preceding sub-stages.

At Sub-Stage one, Assembly Construction establishes the foundational structure of the modeling strategy by defining how the product will be organized at the assembly level. At this stage, all components are identified and named, and a primary reference part is selected to serve as the basis of the assembly. Based on design intent, decisions are made regarding which components should be modeled directly within the assembly environment, and which should be developed independently. In parallel, the assembly sequence is defined according to boundary conditions and functional relationships between parts. This structured planning defines a clear hierarchy, controlled dependencies, and a consistent structure for integrating components, providing the basis for a stable and logically organized parametric model from the outset, as summarized in Table 3.

Sub-Stage	*Sub-Process*	*Key Actions*	*Purpose/Design intent integration*
Assembly Construction	Component Definition	Name all parts and identify the primary component for the assembly	Establish a clear assembly hierarchy and modeling starting point
	Assembly Planning	Decide which parts will be created in the assembly environment (based on design intent)	Align modeling location with functional relationships
	Sequence Definition	Define the assembly sequence according to boundary conditions	Ensure controlled integration and correct dependency structure

Table 3: CAD workflow and modeling strategy: Assembly construction.

The second sub-stage, Feature Routine Definition, focuses on establishing a structured approach for generating geometry through well-defined sequences of CAD operations. At this stage, complex, unknown, or difficult geometries are addressed first and treated as independent modeling tasks to reduce uncertainty and prevent downstream issues. For each geometric element, the required features (CAD commands) are identified and organized into coherent feature routines. The execution order of these features is then explicitly defined based on design intent, ensuring that the modeling process follows a logical and controlled sequence. This approach transforms geometry creation from an ad hoc procedure into a predictable and strategy-driven process, resulting in models with improved structural clarity and parametric robustness, as summarized in Table 4.

Sub-Stage	*Sub-Process*	*Key Actions*	*Purpose/Design intent integration*
Feature Routine Definition	Complex Geometry Handling	Solve unknown or difficult geometries first	Reduce modeling uncertainty and avoid later restructuring
	Feature Identification	Determine required features (CAD commands) for each geometry	Translate geometry into structured feature routines
	Execution Strategy	Define feature execution order (design intent) for each part	Ensure logical feature hierarchy and stable parametric behavior

Table 4: CAD workflow and modeling strategy: Feature routine definition.

The final sub-stage, Design Intent Embedding, focuses on integrating the functional logic of the product directly into the CAD model through parameters, constraints, and reference geometries. At this stage, key dimensions and relationships between features are defined to control how the geometry behaves under modification. Geometric and dimensional constraints are systematically applied to ensure consistency and maintain the intended design logic. Additionally, reference geometry is established both within individual parts and across different components in the assembly, enabling accurate positioning and interaction through assembly constraints. This structured embedding of design intent ensures that the final model is not only geometrically accurate but also stable, adaptable, and capable of supporting predictable and efficient design changes, as summarized in Table 5.

Sub-Stage	*Sub-Process*	*Key Actions*	*Purpose/Design intent integration*
Design Intent Embedding	Parameter Definition	Define parameters and reference geometries between features	Enable controlled and predictable modifications
	Constraint Application	Apply geometric and dimensional constraints and relationships	Maintain consistency and design logic
	Inter-Part Relationships	Define reference geometry between different parts (assembly constraints)	Ensure correct positioning and functional interaction between components

Table 5: CAD workflow and modeling strategy: Design intent embedding.

Design intent is embedded not only at the level of individual features but also across the entire modeling structure. This includes the definition of relationships between different parts, the control of feature hierarchies, and the alignment of modeling routines with expected product behavior.

Design intent is therefore not introduced only after the modeling strategy has been defined. It informs assembly planning, feature-routine definition, and the organization of parameters, constraints, and reference geometries throughout the final stage. During controlled feature execution, these decisions are encoded within the CAD model so that the resulting structure remains aligned with the intended functionality of the product, as reflected across Tables 3–5.

4.4 Application of the CBPMDM to an Example Reference Model

Figure 5 presents a modeling strategy overview produced by applying the criteria of the three CBPMDM stages to a reference product consisting of two parts. The modeling and assembly process begins with the identification of the two constituent components, hereafter referred to as Part A and Part B. Based on the defined design intent, Part B is developed within the part modeling environment, whereas Part A is created directly within the assembly environment to satisfy design intent constraints.

The modeling process starts with Part B, which serves as the primary and fixed component of the assembly. Its geometry is constructed incrementally, beginning with the base feature generated through an extrusion operation. The geometry is then progressively refined through successive additive and subtractive extrusion features. Reinforcing ribs are subsequently created and, where applicable, replicated using symmetrical operations. Functional features, including holes with a specific diameter value, are then introduced, followed by the application of chamfers. Repetitive geometric elements are finally generated using a circular pattern around a defined axis, with four instances.

Parametric relationships are embedded during the dimensioning phase to support controlled modification of the model. Specifically, the length of Part B is defined as twice its height and five times its width, enabling controlled and efficient modifications. Following the completion of Part B, Part A is created by defining its base profile and generating its solid geometry using a single extrusion feature within the assembly context. The assembly process proceeds by inserting Part B as the reference (fixed) component, followed by the insertion of Part A as a floating component. Proper positioning is achieved by aligning the corresponding holes of the two parts using concentric and coincidence constraints, ensuring correct spatial relationships and functional fit.

The example also illustrates how the predefined strategy can support subsequent model modifications. A change to the primary dimensions of Part B can propagate through the specified parametric relationships, while the concentric and coincidence constraints maintain the intended alignment between Parts A and B. Because chamfers and other secondary features are introduced after the primary geometry, they can also be modified or suppressed without redefining the main component structure. These examples demonstrate the intended behavior of the modeling strategy rather than experimentally validated performance outcomes.

This structured modeling strategy establishes a well-defined parametric architecture, supports the explicit representation of design intent, and provides a basis for controlled modifications during subsequent product-development activities Figure 5.

5 DISCUSSION AND METHODOLOGICAL IMPLICATIONS

5.1 Comparative Discussion with Conventional CAD Workflows

The proposed CBPMDM introduces a different perspective on parametric CAD development compared to conventional geometry-driven workflows. In traditional CAD practice, designers frequently construct geometry incrementally and define constraints, parameters, and feature relationships during later stages of modeling. As a result, design intent is often introduced progressively and remains embedded within command sequences rather than explicitly represented in the model structure. CBPMDM proposes an alternative approach in which modeling decisions are externalized before geometry creation through predefined criteria and structured planning stages. Rather than prescribing a fixed modeling sequence, the method aims to support designers in identifying appropriate modeling contexts, selecting suitable feature routines, and defining design intent prior to CAD execution.

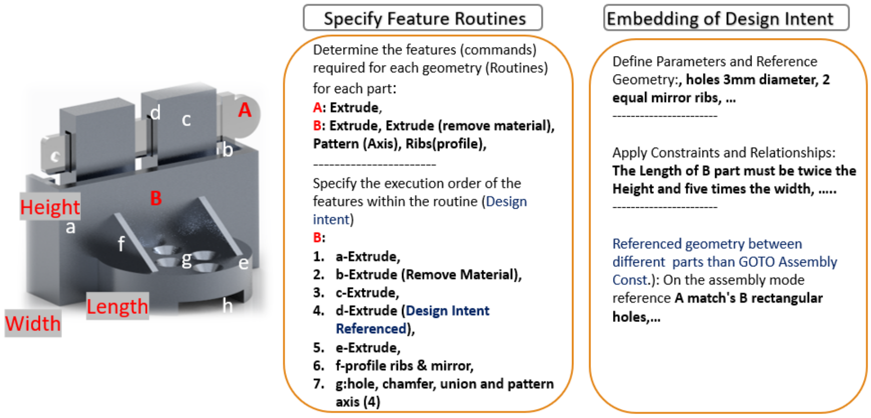

Figure 5: Application of feature routines and design-intent embedding to the reference model.

Compared with existing approaches focused on model evaluation, feature recognition, parametric reusability, design-intent representation, or post-modeling optimization, CBPMDM primarily addresses the decision-making phase preceding geometry generation. As summarized in Table 1, feature-recognition and CAD-quality approaches primarily operate on existing or developing models, whereas parametric-strategy and design-intent approaches provide only partial support for selecting modeling environments and feature routines before CAD execution [3], [4], [6], [8], [9], [14]–[16]. CBPMDM does not replace these approaches, but organizes the relevant pre-modeling decisions within a single criteria-based procedure. In this sense, the proposed method should be interpreted as a methodological framework intended to support strategy definition rather than as a validated performance optimization technique. Although the conceptual comparison suggests potential advantages in terms of model organization and design intent visibility, no quantitative benchmarking or controlled comparison with conventional workflows was conducted within the scope of the present study. Therefore, conclusions regarding efficiency, robustness, or modeling performance should be interpreted as theoretical implications derived from the proposed framework rather than experimentally demonstrated outcomes.

5.2 Methodological Implications and Expected Contributions

The main contribution of CBPMDM lies in repositioning CAD modeling as a strategy-oriented process in which decisions related to geometry decomposition, modeling context, and design intent are considered before feature execution begins. From a methodological perspective, the proposed workflow establishes a structured connection between product characteristics, modeling strategy, and parametric organization. This may support designers in reducing ambiguity during early-stage modeling and encourage more explicit reasoning regarding feature dependencies and model behavior under change.

However, the method also introduces additional analytical effort before CAD execution. For users accustomed to direct, command-based modeling, this additional pre-modeling activity may initially appear less efficient. The expected trade-off is that greater upfront effort may reduce later restructuring, regeneration failures, and modification effort, although this remains to be evaluated empirically.

An additional implication of the proposed method concerns downstream engineering activities in which the CAD model serves as the central product representation and is reused for simulation, redesign, analysis, or iterative product development. By encouraging earlier consideration of parameters, constraints, and feature hierarchy, the method provides a structured basis for generating CAD models that may facilitate subsequent modifications and model reuse. For example, non-essential geometric details such as fillets or secondary features can be isolated and modified without restructuring the overall model, improving model reusability across product development stages. The proposed framework may also provide educational value by helping novice designers understand that effective CAD modeling involves decision-making processes beyond command execution and geometry construction.

5.3 Limitations and Future Validation

The present study introduces and theoretically positions the CBPMDM framework; however, it does not include experimental validation, quantitative performance measurement, or controlled comparison against existing CAD workflows. As a result, claims regarding improved robustness, reduced modeling uncertainty, or increased modification efficiency cannot yet be generalized beyond the conceptual scope of the method. The examples presented in this work serve as illustrative demonstrations of method application rather than empirical proof of superiority.

Future research should therefore focus on validating CBPMDM through controlled user studies and comparative experiments involving conventional CAD workflows. Such studies should compare both novice and experienced CAD users and should include tasks involving initial model construction, geometric modification, model simplification, and preparation for downstream applications such as simulation. Potential evaluation criteria may include modeling time, number of reconstruction iterations, feature-tree stability, modification success rate, model reusability, and perceived cognitive workload during modeling activities. This would allow the additional pre-modeling effort introduced by CBPMDM to be evaluated against its expected benefits during later modification and reuse. Such validation would enable a more rigorous assessment of the practical advantages and limitations of the proposed method and clarify its position relative to existing state-of-the-art CAD methodologies.

6 CONCLUSIONS

This paper presented the Criteria-Based Pre-Modeling Decision Method (CBPMDM), a structured decision method that enables the explicit definition and systematic embedding of design intent prior to CAD modeling. By introducing a criteria-driven decision process, the method supports the alignment of product characteristics with appropriate modeling strategies, feature routines, and parametric structures. Using reference products as examples, the proposed method is applied to extract structured information regarding their strategic construction. This strategy-driven approach supports the systematic implementation of design intent across multiple levels of the modeling structure, including feature definition, parameter organization, and relational dependencies. As a result, it supports improved pre-modeling decision making, enhances clarity and control of design intent, with the aim of reducing modeling uncertainty and later modification effort. In contrast to conventional geometry-driven workflows, CBPMDM enables a strategy-driven approach in which modeling decisions are defined before geometry creation, providing a structured basis for developing more stable and adaptable parametric models.

The proposed method contributes to both CAD education and industrial design practice by supporting earlier planning of modeling strategy and design-intent encoding, reducing reliance on trial-and-error during CAD execution. In addition, CBPMDM can support studio-based ideation and concept development by helping students translate early concepts into coherent CAD modeling strategies before geometry creation. While further validation across different product types and user expertise levels is required, the findings indicate that early-stage decision-making plays a critical role in bridging the gap between concept and parametric design product. It shifts the modeling paradigm from a reactive, command-driven process to a proactive, strategy-driven approach.

Konstantinos Bailas, https://orcid.org/0000-0002-5473-5067
Ioannis Xenakis, https://orcid.org/0000-0001-5607-3514

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