Research Inventy: International Journal of Engineering And Science
Vol.15, Issue 10 (October 2025), PP 50-55
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Bridging Efficiency and User Experience: A Critical Synthesis of Effective Design Methodologies in Modern Industry

Anak Agung Alit Triadi[1*], Fikrihadi Kurnia[2]
[1,2] Department of Industrial Engineering, Faculty of Engineering, Universitas Mataram
**Corresponding Author*

Abstract:*This systematicliteraturereviewaims to criticallyidentify, synthesize, and evaluate the effectiveness of industrialproduct design methodologies in addressing modern marketcomplexity. Through the analysis of ten key academic documents spanning the researchperiodbetween 2010 and 2024, the studycategorizesmethodologicaleffectivenessintothree main domains: Engineering &Manufacturing Performance, Consumer-CentricQuality, and Advanced Design Thinking. Findingsindicatethateffectivenessiscontextual: engineering-orientedmethods like Design for Manufacture and Assembly (DFMA) are quantitativelyproven effective in cost and process optimization (e.g., an increase in design efficiencyfrom 33% to 35%), whileKansei Engineering and the Kano Model are strategically effective in bridging subjective consumer emotionwith objective design specifications. For digital innovation, new frameworkssuch as Objectomy are deemed effective in managing the form-functiondecouplinginherent in smart products. The principal conclusion isthat no single methodissuperior; the most effective practice is an integratedmethodological architecture thatdynamically combines engineering rigorwith HCD sensitivity and adaptive frameworks for digital complexity management. The studysuggests the necessity of developing quantitative models to guide future methodintegration.*

Keywords:*Product, Design, Methodology, Review, Engineering.*

Date of Submission: 08-10-2025 Date of acceptance: 19-10-2025

I. INTRODUCTION

In the increasingly competitive and complex global market, effective product design has transitioned from a routine operational function to a critical strategic capability for industrial firms. The rapid evolution of technology and consumer demands necessitates that companies not only meet functional requirements but also deliver products that are aesthetically pleasing, emotionally engaging, and cost-efficient (Ravasi & Stigliani, 2012). This complexity mandates systematic approaches to product development, as conventional or ad-hoc methods are often found to be ineffective and inefficient (Jagtap et al., 2014). Consequently, a substantial body of academic research has emerged, which can be broadly categorized into three core areas: the study of design activities, design choices, and the ultimate design results on business performance. This ongoing research underscores the perpetual need to identify, evaluate, and adopt design methodologies that yield superior commercial and engineering outcomes.

A primary focus within industrial design methodology is enhancing technical performance and manufacturing efficiency. Engineering-driven methods, such as the VDI-Methodology, Pahl and Beitz, and Design for Manufacture and Assembly (DFMA), provide structured frameworks to manage complex technical problem-solving. The effectiveness of these methods can be quantitatively demonstrated in practical applications. For instance, in a study focusing on optimizing product components using DFMA and Material Selection, measurable improvements in assembly efficiency were achieved, with the total design efficiency increasing from 33% to 35% (Ginting et al., 2024). Such results illustrate the tangible benefits of adopting rigorous methodologies in terms of cost reduction and streamlined processes, highlighting the instrumental role of these tools in the success of product development companies (Jagtap et al., 2014).

While technical efficiency remains vital, market success in the contemporary industrial era is increasingly dictated by user satisfaction and emotional connection, requiring a shift toward Human-Centered Design (HCD) principles. This paradigm recognizes that superior product quality is determined by both technical compliance and the fulfilment of explicit and latent consumer needs. Methods like Kansei Engineering and the Kano Model are specifically employed to translate subjective consumer emotions and psychological demands into concrete product specifications (Soenandi et al., 2021). Furthermore, robust product design evaluation methods, spanning qualitative, quantitative, and comparative approaches, are necessary to monitor design processes and ensure the final solution meets user experience (UX) and safety requirements (Mustafa, 2023).

The proliferation of various design tools necessitates a continuous review of methodological trends in New Product Development (NPD). A literature review covering the period between 2010 and 2019 identified that research on NPD is heavily reliant on applied studies, with 28 out of 50 selected papers categorized as case studies (Khannan et al., 2021). This dominance of case studies indicates an active academic interest in applying and validating diverse methodologies, including Life Cycle Assessment (LCA) for sustainability, Design for Six Sigma (DFSS), and various Multi-Criteria Decision-Making (MCDM) approaches. However, despite the acknowledged academic benefits of these structured methods, their uptake and implementation across all product development companies remains a documented challenge (Jagtap et al., 2014).

The current literature presents a fragmented view on methodological effectiveness, showcasing strong evidence for performance gains in specific areas—be it in manufacturing efficiency through DFMA or consumer satisfaction via Kansei Engineering. However, the rise of "smart products" and digital artifacts presents a new set of challenges, including the decoupling of form and function and the necessity of an ecosystem-framed approach (Bangle et al., 2022). This evolving landscape creates a critical gap: there is a need for a unified, comparative review that synthesizes the measured effectiveness of traditional engineering methods with modern HCD and digital-era methodologies. Therefore, this literature review aims to systematically analyze and evaluate the most effective methods in industrial product design to provide a comprehensive framework for academics and industry professionals facing the multidisciplinary demands of modern product innovation.

II. RESEARCH METHOD

2.1. Research Design and Review Type

This study employs a Literature Review (LR) methodology, which is an explicit, systematic, and reproducible approach to identify, evaluate, and synthesize the existing body of knowledge (Khannan et al., 2021). The primary goal is not merely to list existing methodologies but to conduct a critical narrative synthesis of their demonstrated effectiveness within the context of industrial product design. The approach ensures that the review is comprehensive, minimizes bias, and provides a robust foundation for comparative analysis. The effectiveness of each method—such as DFMA, Kansei Engineering, or Pahl and Beitz—will be evaluated based on the quantifiable outcomes and qualitative insights reported in the collected literature.

2.2. Data Source and Selection Criteria

The core literature for this review consists of ten peer-reviewed academic documents provided as initial input. These documents cover essential domains of product design, including general product design management (Ravasi & Stigliani, 2012), engineering design processes (Nasution et al., 2022), human-centered methods (Soenandi et al., 2021), manufacturing efficiency tools (Ginting et al., 2024), and new technology-driven frameworks (Bangle et al., 2022). To ensure the review's relevance and quality, the selected papers were required to meet the following criteria: (1) Directly discuss specific design methods, models, or frameworks (e.g., VDI, Kansei, DFMA); (2) Focus on the design and development of industrial products; and (3) Provide an evaluation of the method's efficacy, either through empirical data (case studies) or critical theoretical comparison.

2.3. Data Extraction and Analysis Protocol

Data extraction was performed using a structured protocol to capture key information from each article. The following variables were extracted:

1. Methodological Classification: Identifying the method type (e.g., Engineering, HCD, Decision-Making).
2. Reported Effectiveness Metrics: Quantitative results (e.g., increase in efficiency, cost reduction, quality percentage) and qualitative benefits (e.g., user satisfaction, complexity management). For example, the increase in design efficiency from 33% to 35% reported in the DFMA study was a key metric extracted (Ginting et al., 2024).
3. Application Context: The type of product or industry where the method was applied (e.g., *desk organizer*, *machine tools*, *smart products*). The extracted data were then subjected to a Thematic and Comparative Analysis. Thematic grouping helped categorize the methods based on their primary focus (e.g., *Technical Performance*, *Consumer Experience*, *Innovation Management*), while the comparative analysis assessed the strengths and limitations of distinct methods (e.g., VDI versus French methodology) in achieving specific design objectives.

2.4. Critical Synthesis and Evaluation Framework

The final stage involves a critical synthesis guided by a three-dimensional framework adapted from general product design literature: Effectiveness in Design Activities, Design Choices, and Design Results (Ravasi&Stigliani, 2012). This framework allows the review to move beyond simple description and critically evaluate why certain methods are more effective than others in specific phases of product development. The analysis specifically addresses the effectiveness criteria highlighted by Jagtap et al. (2014), which include cost reduction, better product quality, and faster lead times. The conclusion of the methodology is a synthesized framework illustrating the appropriate application and potential for integration of these diverse methods in modern industrial settings.

III. RESULTS AND DISCUSSIONS

3.1. Production of Ibuprofen derivatives

The review of the selected literature reveals that methodological effectiveness in industrial product design is not monolithic but rather **context-dependent**, correlating strongly with the primary design objective—be it technical efficiency, consumer delight, or innovation readiness. The findings are synthesized into three main thematic categories for critical analysis: Engineering Performance, Consumer-Centric Quality, and Advanced Design Thinking.

3.2. Synthesis and Comparative Analysis of Design Methodologies

The following table summarizes the primary methods identified, their application context, and the reported metrics or mechanisms of effectiveness based on the literature reviewed.

Table 1.

Category	Methodology	Application Context	Mechanism of Effectiveness	Findings
I. Engineering Performance	DFMA (*Design for Manufacture and Assembly*)	Mechanical/Industrial products (e.g., Blender)	Simplifies product structure, optimizes material selection, and reduces part count.	Increased total design efficiency from 33% to 35%; reduced assembly cost (Ginting et al., 2024).
	VDI-Methodology	General Mechanical Engineering Design	Highly structured process model (more complex than French or Pahl&Beitz).	Provides a systematic, complex framework to avoid design mistakes, especially for novice engineers (Nasution et al., 2022).
	PFA & Systematic Evaluation	Machine Tool Industrial Design	Standardizes and modularizes component configuration to enhance flexibility.	Validated decision-making framework using Entropy-TOPSIS to enhance industrial design competitiveness (Yao et al., 2023).
II. Consumer-Centric Quality	Kansei Engineering & Kano Model	Consumer products (e.g., Desk Organizer)	Translates subjective consumer emotion (*Kansei*) into objective design parameters.	Identifies Must-Be and One-Dimensional quality attributes crucial for customer satisfaction; links psychological demand to physical form (Soenandi et al., 2021).
	Product Design Evaluation Methods	General Product Design	Utilizes qualitative (e.g., interviews), quantitative (e.g., surveys), and human factors evaluation techniques.	Ensures compliance with safety, customer, and legal requirements; provides timely, cost-effective solutions for optimization (Mustafa, 2023).
III. Advanced Design Thinking	Objectomy	Smart Products / Digital Artifacts	Addresses form-function decoupling and ecosystem-framed design challenges.	Offers a new mindset necessary to manage complexity inherent in networked, service-enabled products (Bangle et al., 2022).
	Systematic Literature Review (SLR)	General NPD (2010–2019)	Identifies methodological trends (LCA, MCDM, DFSS) and research gaps.	Highlights the dominance of case studies (28 out of 50 papers), suggesting strong academic interest in applied validation (Khannan et al., 2021).

3.3. Critical Analysis of Methodological Effectiveness

3.3.1 The Measured Efficacy of Engineering-Centric Methods

The review confirms that the effectiveness of methods aimed at internal process optimization is often directly measurable. DFMA is a prime example of a method whose value lies in its quantifiable impact on cost and efficiency. The reported increase in design efficiency from 33% to 35% in a single case study (Ginting et al., 2024) is compelling evidence that a structured focus on simplifying manufacturing and assembly is highly effective for reducing *unit cost* and *lead time*—key metrics for competitive industrial products (Jagtap et al., 2014).

Furthermore, the complexity of the VDI-Methodology, while potentially burdensome, is viewed as effective for its formalization and rigor. As Nasution et al. (2022) suggest, complex frameworks are crucial for avoiding critical mistakes in the early, abstract stages of engineering design, particularly for less experienced practitioners. This highlights that *effectiveness* can also be defined by the method's ability to reduce risk and structure uncertainty, not just optimize cost. The application of Product Family Architecture (PFA) coupled with evaluation tools like Entropy-TOPSIS (Yao et al., 2023) extends this engineering focus into strategic domain, proving effective for managing product variation and standardizing platforms for competitive advantage.

3.3.2 Effectiveness in Capturing Subjective Quality and User Experience

In contrast to the clear, metric-driven effectiveness of engineering tools, methods like Kansei Engineering define effectiveness through the successful capture and operationalization of subjective and emotional quality. The integration of Kansei and the Kano Model is highly effective because it acts as a crucial link between the psychological domain (consumer desire) and the technical domain (design features). By identifying latent or Must-Be quality attributes, these methods prevent market failure that might occur even with a technically perfect product (Soenandi et al., 2021).

The importance of this subjective evaluation is further underscored by Mustafa (2023), who emphasizes that evaluation methods are essential for monitoring compliant design processes and ensuring user experience (UX). This confirms the Ravasi and Stigliani (2012) framework point that Design Choices (related to form and function) must be continuously validated to ensure favorableDesign Results (consumer response). The most effective HCD-centric methods are therefore those that can successfully bridge the inherent gap between abstract human needs and concrete product specifications.

3.3.3 The Effectiveness of Adapting to Digital Complexity

A critical finding in the modern context is the need for entirely new methods to address the complexities of Smart Products and digital artifacts. The emergence of Objectomy (Bangle et al., 2022) highlights a significant limitation of both classic engineering and traditional HCD methods. Smart products introduce form-function decoupling and require an ecosystem-framed approach, rendering many conventional, linear design processes ineffective.

The effectiveness of *Objectomy* lies not in optimizing a mechanical structure, but in providing a new cognitive framework for designers to manage the infinite, interconnected, and potentially "never-ended" nature of digital product development. Similarly, the systematic review of NPD trends (Khannan et al., 2021) suggests a move towards integrated methodologies, often requiring the use of Multi-Criteria Decision-Making (MCDM) tools like AHP or TOPSIS, which are effective in prioritizing conflicting criteria (e.g., cost vs. sustainability) that characterize complex, modern industrial projects.

3.4. Synthesis: A Framework for Integrated Effectiveness

In conclusion, an "effective method" in modern industrial product design is rarely a singular tool but rather an integrated methodological architecture tailored to the problem phase.

- For optimizing production and internal cost structures, DFMA and structured engineering methods (VDI/Pahl and Beitz) remain the most effective tools, providing measurable ROI.
- For ensuring market acceptance and brand loyalty, Kansei Engineering and Kano Analysis are highly effective in translating human factors into design requirements.
- For tackling next-generation challenges like IoT and AI integration, novel frameworks like Objectomy are essential for providing the necessary mindset and conceptual structure.

Therefore, the most effective practice is the selective integration of these methods, moving beyond the linear application of a single model and embracing a dynamic process that leverages engineering rigor in the structural phase and HCD sensitivity in the conceptual phase, all framed by a contemporary approach to manage digital complexity.

3.5. Limitations and Future Research

This systematic literature review, while providing a critical synthesis of effective design methodologies, operates under specific constraints that influence the scope and generalizability of its findings. The primary limitation stems from the focused scope of literature, which relied on ten core academic papers emphasizing methodologies within mechanical engineering and New Product Development (NPD). While this provided depth on methods like DFMA and VDI, it limits the generalizability to related but distinct fields, such as highly specialized service or electronic hardware design. Furthermore, a significant challenge arises from the heterogeneity in measuring "effectiveness." Since effectiveness is defined differently across the literature—

ranging from quantifiable cost reduction (e.g., DFMA's 33% to 35% efficiency boost) to the qualitative capture of emotional value (Kansei Engineering)—a direct, head-to-head performance comparison between all methodologies remains inherently complicated. This ambiguity requires future research to move toward unified metrics.

Based on these limitations, the most critical avenue for future research involves transforming the recognized need for methodological integration into a prescriptive, data-driven tool. The core finding is that effectiveness lies in the optimal combination of methods (e.g., using Kansei to define requirements before moving to DFMA implementation). Therefore, future studies must develop and validate a quantitative decision model—potentially utilizing Multi-Criteria Decision-Making (MCDM) techniques like AHP or TOPSIS—to assign weights to crucial project variables (such as cost constraints, emotional impact required, and technological complexity). This model should provide clear recommendations on the optimal sequence and mix of methodologies for any given industrial project, thereby translating the current qualitative understanding of integration into a truly prescriptive framework for design management.

Finally, two practical gaps must be addressed to ensure the widespread adoption and validation of effective methods. Firstly, the new frameworks developed for digital complexity, like Objectomy for Smart Products, are currently conceptual and require urgent empirical validation within organizations developing IoT and AI-enabled industrial products. Future work must establish quantitative metrics to measure efficiency in these never-ended design environments. Secondly, despite the clear benefits of methods like DFMA, the literature suggests that real-world implementation is limited. Research is needed to systematically investigate the organizational and cultural barriers that prevent the routine uptake of structured methodologies in small and medium-sized enterprises (SMEs), allowing researchers to develop targeted strategies and toolsets to close the persistent gap between academic theory and industrial practice.

IV. CONCLUSION

This review aimed to synthesize and critically evaluate the effectiveness of various methodologies used in industrial product design. The synthesis of ten key academic documents confirms that no single, universally superior method exists; rather, methodological effectiveness is context-specific and measured across three distinct domains: Engineering Performance, Consumer-Centric Quality, and Advanced Innovation Management.For achieving Engineering Performance and cost reduction, quantitative, structural methods like DFMA are proven to be highly effective, delivering measurable outcomes such as the documented increase in design efficiency from 33% to 35% in manufacturing applications. In contrast, for achieving Consumer-Centric Quality, subjective-to-objective methods like Kansei Engineering and the Kano Model are essential, as their effectiveness lies in bridging the gap between emotional demands and technical specifications, thereby preventing market dissatisfaction. Furthermore, addressing the complexities of Smart Products and digital artifacts requires entirely new conceptual frameworks, such as Objectomy, which are effective in managing the characteristic form-function decoupling and the multidisciplinary, ecosystem-framed nature of modern design.The core conclusion is that the most effective industrial product design practice is defined by methodological integration. Companies must move beyond the linear application of single methods and adopt a dynamic architecture that combines the rigor of engineering models (VDI/DFMA) with the sensitivity of human-centered tools (Kansei/Kano) to maximize both internal efficiency and external market success.

Conflict of interest

There is no conflict to disclose.

REFERENCES

[1]. Bangle, C. E., Rosso, M., Montagna, F., &Cantamessa, M. (2022). *Design Methods Review for Smart Product: Objectomy, a New Approach*. International Design Conference - Design 2022, Dubrovnik, Croatia. https://doi.org/10.1017/pds.2022.207

[2]. Ginting, R., Thoha, A., Siregar, D. A., Furqan, H., &Hutabarata, H. G. (2024). PerancanganProdukdenganMetode Design for Manufacture and Assembly (DFMA) dan Material Selection. *TALENTA Conference Series: Energy and Engineering*, *7*(1). https://www.google.com/search?q=https://doi.org/10.32734/ee.v7i1.2307

[3]. Jagtap, S., Warell, A., Hiort, V., Motte, D., & Larsson, A. (2014). *Design Methods and Factors Influencing Their Uptake in Product Development Companies: A Review*. International Design Conference - Design 2014, Dubrovnik, Croatia.

[4]. Khannan, M. S. A., Tontowi, A. E., Herliansyah, M. K., &Sudiarso, A. (2021). New Product Development Method Trends and Future Research: A Systematic Literature Review. *Jurnal Teknik Industri*, *23*(1), 11–24. https://www.google.com/search?q=https://doi.org/10.9744/jti.23.1.11-24

[5]. Mustafa, A. W. (2023). An Overview of Product Design Evaluation Methods and Techniques. *International Design Journal*, *13*(3), 101–110.

[6]. Nasution, Z. M., Sari, D. Y., Nabawi, R. A., &Rifelino. (2022). Jurnal Review: MetodePerancanganProdukdalam Teknik Mesin (Design Methods of Product in Mechanical Engineering: A Review). *VOMEK*, *4*(3).

[7]. Ravasi, D., &Stigliani, I. (2012). Product Design: A Review and Research Agenda for Management Studies. *International Journal of Management Reviews*, *14*(4), 450–470. https://www.google.com/search?q=https://doi.org/10.1111/1468-2370.2012.00330.x

[8]. Soenandi, I. A., Marcelle, Ondang, R. J., &Sundoro, A. N. (2021). Perancangan dan PengembanganProduk Desk Organizer denganMetodeKansei Engineering dan Model Kano. *JurnalIlmiah Teknik Industri*, *9*(2), 117–128.
[9]. Yao, Z., Wu, X., Wu, Y., & Wen, X. (2023). Enhancing Industrial Design Competitiveness: Research and Application of a Machine Tool Industrial Design Decision-Making Method Based on Product Family Architecture and Systematic Evaluation. *Applied Sciences*, *13*(21), 11831. https://doi.org/10.3390/app132111831