

A Study on Modular Jig Design Systems: Enhancing Productivity through Component Standardization

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Abstract. This study explores strategies to maximize design efficiency through the standardization of jig parts. To resolve critical issues such as increased design lead time, SKU proliferation, and on-site assembly errors caused by rampant non-standard design practices, we standardized the technical specifications (size, form, tolerance) of highly reusable core jig parts and established a modular design system. Utilizing these standardized components successfully shortened design time and optimized work processes. Verification through real-world application cases demonstrated quantitative results, including a 42% reduction in design lead time and a 66% decrease in design error rate.

Keywords; Jig, Standardization, Design Efficiency, Productivity Improvement, Modular Design

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1. Introduction

Recently, in line with the trends of Industry 4.0, there have been ongoing attempts in manufacturing sites to optimize the number of parts and maximize assembly efficiency by applying Design for Manufacturing and Assembly (DFMA) principles right from the jig design stage [1],[2]. A jig is an essential auxiliary device used in factories or construction sites to enhance product accuracy and productivity, serving as a key tool for securing quality stability and precision in the production process [3][4]. Jigs primarily function to maintain machining precision and reduce reliance on operators by fixing the position of workpieces or providing references. However, in industrial settings, jig parts are often designed and manufactured as individual custom orders to accommodate diverse product lines and working environments, resulting in a lack of standardized design criteria [5][6].

In particular, the standardization of jig design has a direct impact on Lean Manufacturing performance, and recently, research has been actively conducted to drastically shorten lead times through Automated Fixture Design (AFD) beyond manual design [7],[8].

These non-standard design practices often rely on the empirical judgment or conventions of designers, frequently resulting in parts that perform the same function but have slightly different specifications or shapes depending on the designer [9]. As a result, design consistency is not secured, leading to structural inefficiencies such as reduced compatibility between parts and difficulties in recycling. Specifically, the non-standardization of jig parts seriously affects overall manufacturing efficiency and leads to problems such as repetitive design, unnecessary reviews, and rework [9][10]. This non-standard practice causes four core problems in manufacturing efficiency: 1) increased lead time due to unnecessary design repetition, 2) a surge in SKUs and rising inventory costs due to minute differences in specifications, 3) frequent on-site assembly errors due to tolerance mismatches, and 4) increased maintenance and training costs for non-standard parts.

Recent studies have highlighted the standardization and modular design of jig parts as key means of enhancing industrial competitiveness to solve these problems [7][8]. Establishing a standardized parts system can reduce design repetition and enable the implementation of automated design processes through linkage with CAD and PLM systems, which leads to shortened manufacturing lead times and improved quality stability [9][12].

Therefore, the purpose of this study is to achieve shortened design time and optimization of work methods through the standardization of jig parts, and to

quantitatively analyze the resulting productivity improvements and cost reduction effects. Furthermore, this study aims to present technical elements to be considered when promoting standardization and verify its effectiveness through actual corporate application cases.

2. Analysis of Jig Design Problems

As a core tool that determines the accuracy and efficiency of the production process, jigs directly impact overall manufacturing quality if design consistency and precision are not secured. However, jig design currently practiced in industrial fields often lacks systematic standards, leading to various technical and managerial problems. Figure 1 illustrates the typical design process of a jig system used for automotive chassis work.

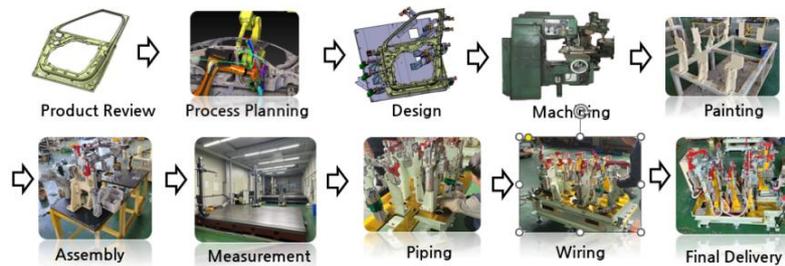


Figure 1. Process flow of Jig Design

First, the product to be fixed to the jig is reviewed. Next, the work processes of various stages, such as the welding process, are examined. Once the product and work process reviews are complete, the overall jig and its individual parts are designed. Each designed part is then manufactured through machining according to the design drawings. Subsequently, a painting process is carried out to protect the manufactured jig base and parts from external factors. After painting is finished, the individual parts are assembled into their respective type units. An inspection is then performed to check the degree to which the assembled jig parts match the designed 3D data and the actual manufactured jig. Finally, air cylinders are used to fix the product; piping work is done to connect air hoses for air supply to the cylinders, and wiring work is performed for electrical supply, completing the entire jig design.

In this section, the major problems emerging in the jig design process are structurally analyzed. First, the personalization of the design process is the most prominent issue. Jig design often relies on the experience and intuition of the designer, frequently resulting in parts that perform the same function but are manufactured with different shapes or specifications depending on the designer. These personal design

practices not only reduce compatibility between parts but also cause repetitive modification work during the design review and manufacturing stages. Furthermore, design change histories or design intents are not sufficiently documented, creating an inefficient structure where subsequent designers experience the same problems repeatedly.

Second, there is the problem of inconsistency in tolerances and specifications. For some parts, tolerance standards are not clearly defined, or different standards are applied even to parts with the same function. This causes interference or play issues during assembly, which degrades quality stability. Particularly during the on-site assembly stage, adjustment work occurs frequently due to minute dimensional errors between parts, resulting in an increase in the overall production lead time.

Third, inefficiency in parts management is also pointed out as a major problem. Due to non-standardized designs, a large number of parts performing similar functions exist in different specifications, leading to redundant production of the same parts and an unnecessary increase in inventory. This generates unnecessary costs in terms of logistics and material management and complicates the parts procurement process. Moreover, because the part identification system is inconsistent, it is difficult to reuse parts from existing designs, creating a vicious cycle of repeatedly designing new parts.

Fourth, unsystematic management of design data also acts as a cause of the problem. Most jig design data is managed in a dispersed manner within designers' personal folders or on a project-by-project basis, without a clear database system in place. Consequently, unnecessary time is spent searching past design histories or attempting to reuse similar parts. This not only lowers design efficiency but also results in a structural limitation where the company's design assets are not systematically accumulated.

Fifth, there is difficulty in process automation due to the absence of design standards. While design automation through CAD and PLM systems and data-driven production management have been spreading recently, system integration cannot be achieved smoothly if part shapes, specifications, and naming conventions are not standardized. In practice, it is difficult to apply automated design or assembly simulations because the same parts are registered under different codes or names, resulting in designers repeatedly adjusting data manually.

Lastly, these non-standard design methods cause inefficiency from an organizational perspective. When new designers perform tasks without standardized guidelines, it takes a long time to gain proficiency, and frequent communication and reviews are required during collaboration between designers. Such a structure

eventually expands the deviation in design quality and undermines product reliability and the stability of production schedules.

In summary, problems in jig design are not simply a matter of individual designers' competence or mistakes, but can be seen as structural problems due to the absence of a standardization system. These issues have a chain-reaction effect on the entire process, including design, manufacturing, procurement, assembly, and quality control, leading to a decline in a company's productivity and competitiveness. Therefore, to improve the efficiency of jig design in the future, the standardization of part specifications and tolerances must be accompanied by the establishment of a design data management system and organizational standard operating procedures.

3. Design Direction for Jig Part Standardization

A. Necessity and Goals of Standardization

The core objective of jig design standardization lies in maximizing commonality and minimizing design repetition. In this study, approximately 500 types of non-standard jig parts were analyzed, and 50 core part groups with a reuse frequency of over 80% were selected for standardization. While these 50 types represent only about 10% of the total variety, they were analyzed to influence more than 70% of the overall design efficiency.

B. Selection Criteria for Standardization

Table 1. Selection Criteria for Standardization

Category	Selection Criteria	Detailed Description
Frequency	Reuse rate of 80% or higher	Components that can be commonly used across multiple projects
Function	Performance of core functions	Components performing critical functions such as positioning, clamping, or supporting.
Design Repetition	Parts designed repeatedly 3 or more times	Targets suitable for design automation.

The targets for standardization were selected based on the following three criteria, as shown in Table 1. For the selected parts, consistency in product specifications was secured by unifying standards for size, shape, and tolerance. Furthermore, a standard part database (DB) that can be integrated with 3D design programs was established.

C. Modular Design and System Construction

Standardized parts were reorganized into modular units to ensure design flexibility for application in various projects. Figure 2. summarizes the part names for each type of standardized component.

Category	UNIT ASSY	ANGLE BRKT	LACATOR & PLATE	CATCH & PLATE	SHIM
Type A					
Type B					

Figure 2. Jig Parts of Type 1 (Clamp Module) and Type 2 (Positioning Module)

Type 1 is the Clamp Module, which performs the function of fixing parts during assembly. Type 2 is the Positioning Module, which ensures the precision of product placement. Standard modules can be easily applied by jig designers using a "drag-and-drop" method within 3D programs, leading to increased design speed and a reduced error rate. In addition, a foundation for future maintenance and training was established by documenting the standard part list and design guidelines. Figure 1 illustrates the jig parts for Type 1 and Type 2.

Figure 3 shows the overall configuration of the jig system for the processing of automotive chassis parts reviewed in this study. Each jig is arranged considering the type and model of the jig required for the specific process operations of the automotive chassis.

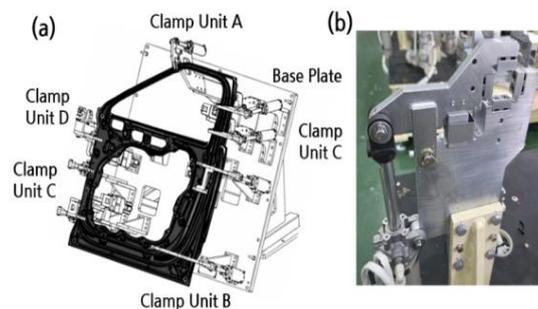


Figure 3. Jig System and Jig Modules for Automotive Chassis Work

4. Case Studies and Results (Dual Case Analysis)

To verify the effectiveness of this study and demonstrate the impact of standardization across various dimensions—such as design efficiency and inventory management—the jig standardization projects of Company A and Company B were analyzed in depth.

A. Case Study A: *Intensive Analysis of Design Time and Error Rate Improvement*

A deep-dive analysis was conducted on an assembly automation process jig design project at Company A. This case demonstrates the direct impact of standardization on design phase efficiency.

Before Standardization: Inefficient Customized Design Due to existing non-standard design practices, designers at Company A spent an average of 10 hours applying new dimensions or minutely modifying existing drawings for core parts such as clamps and bushings for every project. The subtle tolerance errors occurring during this process led to frequent on-site assembly reviews and revisions (average of 4 times), resulting in a high design error rate.

After Standardization: Rapid Module-Based Design As a result of applying a database consisting of 50 types of standardized parts and modularized design guidelines, designers were able to shorten the time to configure jigs to an average of 6 hours by selecting standard parts via a "drag-and-drop" method. This was the key driver for a 40% reduction in design time. Furthermore, the use of standardized parts reduced the number of design reviews to an average of 2, significantly decreasing on-site assembly errors.

B. Case Study B: *Improvement in Inventory and Project Response Lead Time*

A new production line establishment project at Company B was analyzed. This case illustrates the impact of standardization on procurement and supply chain management. **Before Standardization: High Inventory Management Complexity** At Company B, the number of SKUs (Stock Keeping Units) for non-standard parts reached 200. The accumulation of dead stock caused by frequent ordering resulted in high inventory carrying costs. Additionally, the procurement lead time for non-standard parts required for new projects averaged 3 weeks, creating a bottleneck in shortening the overall project response period.

After Standardization: Inventory Optimization and Rapid Procurement Company B standardized its highly versatile core parts into 50 types and reorganized the remaining parts, reducing the total SKU count to 140. This led to a 30% reduction in part inventory

and a dramatic decrease in inventory management complexity. Moreover, by utilizing standard parts, the procurement lead time was shortened to 1 week, resulting in a 20% average reduction in the response time for new projects. This translated into an annual cost saving of approximately 15%.

C. Summary of Quantitative Comparison Results

Table 2 presents the results of the standardization project at Company A, which was analyzed in depth earlier, and clearly demonstrates the quantitative achievements of jig part standardization in the design process.

Table 2. Comprehensive Performance Metrics after Standardization

Performance Item	Before Standardization	After Standardization	Improvement Rate (%)	Unit
Design Lead Time	6	3.5	42%	Weeks
Design Error Rate	3.2	1.1	66%	%
Maintenance Time	12	5	58%	Hours/Month
Inventory SKU Count	120	75	38%	Types
Design Review Frequency	4	2	50%	Times/Project

5. Conclusion

This study empirically verified the efficiency of design and manufacturing through the standardization of jig parts. By standardizing only 50 core part types, it was possible to reduce design lead time by 42% and the error rate by 66%, which directly led to an overall improvement in productivity. Furthermore, standardization accompanied economic ripple effects, such as reducing part unit costs, optimizing inventory, and improving ease of maintenance. It also confirmed organizational efficiency by shortening the training period for new personnel.

In future research, it is necessary to evolve this system into one capable of real-time optimal design verification by linking the standardized jig part database with AI-based

design recommendation systems or Digital Twin platforms. Through these advancements, jig standardization will move beyond a simple stage of technical efficiency and establish itself as a core infrastructure for building smart manufacturing and sustainable production systems.

References

- [1] R. Singh et al., "Design for Manufacturing and Assembly of a Jig and Fixture," ResearchGate, 2020.
- [2] M. P. M. de Lemos et al., "Modular Fixture Design in the Industry 4.0 Era," Applied Sciences, vol. 10, no. 19, p. 6731, 2020.
- [3] F. Fiedler and R. Schmitt, "Jigs and Fixtures in Production: A Systematic Literature Review," CIRP Annals – Manufacturing Technology, vol. 72, pp. 185-188, 2023.
- [4] A. D. Ibrahim, H. M. A. Hussein, I. Ahmed, E. A. Nasr, A. Kamrani & S. A. Abdelwahab, "Computer-Aided Design of Traditional Jigs and Fixtures," Applied Sciences, vol. 12, no. 1, article 3, 2022.
- [5] C. C. Okpala & E. O. C. Ezeanyim, "The Design and Need for Jigs and Fixtures in Manufacturing," Science Research, vol. 3, no. 4, pp. 213-219, 2015.
- [6] Bakker, S. Ratchev & S. R. Popov, "State-of-the-art in fixture systems for the manufacture and assembly of large and complex structures," International Journal of Machine Tools & Manufacture, vol. 119, pp. 1-16, 2017.
- [7] J. Smith et al., "Automated Fixture Design (AFD): A Review and Future Prospects," International Journal of Advanced Manufacturing Technology, 2021.
- [8] Kumar et al., "Impact of Standardization on Lean Manufacturing Performance," Journal of Manufacturing Technology Management, 2019.
- [9] H. S. Kwak & K. S. Kim, "A Study on Standardization and Reuse of Jig Parts in Automated Production," Journal of the Korean Society for Precision Engineering, vol. 36, no. 2, pp. 115-124, 2020.
- [10] J. Park & Y. Lee, "Improvement of Production Efficiency through Fixture Standardization in Automotive Manufacturing," KSME International Journal, vol. 35, no. 4, pp. 287-295, 2019.
- [11] D. Ardiansyah et al., "Design of Universal Jig for Standardization and Efficiency of Frame Production," Flywheel: Jurnal Teknik Mesin Untirta, vol. 5, no. 2, pp. 33-41, 2023.
- [12] H. Park & J. S. Choi, "Data-Driven Standardization Framework for Modular Design in Smart Factories," Journal of Manufacturing Systems, vol. 67, pp. 142-153, 2024