



Engineering Management in High-End Custom Furniture Manufacturing: Improving Project Performance Through Design-to-Manufacturing Translation

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Abstract

High-end custom furniture manufacturing represents a highly customized engineer-to-order (ETO) environment in which each project requires unique engineering solutions before manufacturing can begin. Unlike serial production, project performance depends not only on manufacturing capability but also on the completeness of engineering preparation during project development. This study investigates the role of an integrated engineering management framework in improving operational performance within a company specializing in high-end custom furniture manufacturing. The proposed framework integrates engineering review, design-to-manufacturing translation, production planning, project coordination, quality management, and installation preparation into a unified engineering workflow. The research was conducted as an industrial case study based on operational performance indicators routinely monitored during project execution. Implementation of the framework shifted engineering decision-making from the manufacturing stage to project preparation, ensuring that technical solutions were completed, verified, and approved before production began. As a result, workflow stability improved, engineering-related production interruptions and corrective manufacturing were largely eliminated, coordination between engineering and manufacturing functions became more effective, and installation readiness increased. The findings suggest that, in highly customized manufacturing, engineering completeness before production is a key determinant of project performance. The study contributes to engineering management by demonstrating that project optimization in engineer-to-order manufacturing should focus not only on manufacturing operations but also on the completeness of engineering preparation before fabrication begins. Although developed within the custom furniture industry, the proposed framework may also be applicable to other engineer-to-order production environments.

Keywords: Engineering management, Engineer-to-order (ETO), Design-to-manufacturing translation, Custom furniture manufacturing, Production planning, Project performance

1. Introduction

High-end custom furniture manufacturing differs fundamentally from serial furniture production. Each project combines unique design concepts, engineering requirements, manufacturing constraints, site-specific installation conditions, and individual client expectations. Unlike repetitive manufacturing, where products and production processes are largely standardized, every project requires dedicated engineering solutions and production planning. Consequently, each order represents a new engineering challenge rather than the repetition of an established manufacturing process.

Many of the decisions that determine project cost, product quality, production time, and installation accuracy

are made before manufacturing begins. During this stage, the design concept is evaluated, engineering solutions are developed, materials and hardware are selected, manufacturing methods are defined, and production documentation is prepared. Decisions made at this stage influence every subsequent phase of the project. Engineering deficiencies identified after production has started often result in material waste, manufacturing delays, rework, installation difficulties, and additional project costs.

Engineering management therefore plays a central role in custom furniture manufacturing. Its function extends beyond production planning by integrating architectural design, engineering, manufacturing, quality control, procurement, and installation within a unified project workflow. The objective is not only to manufacture furniture but also to ensure that the final product faithfully reflects the original design intent while remaining technically feasible, manufacturable, and economically viable.

Lean Manufacturing, Design for Manufacturing (DFM), Concurrent Engineering, and quality management have been widely adopted to improve manufacturing performance. These approaches have proven effective in reducing waste, improving production consistency, and increasing operational efficiency across a wide range of industries. However, most published research focuses on serial or repetitive manufacturing, whereas relatively few studies examine engineering management in highly customized furniture production, where every project requires substantial engineering effort before manufacturing can commence.

In this study, the term design-to-manufacturing translation refers to the engineering activities required to transform an architectural or interior design concept into complete manufacturing documentation while preserving the intended appearance, functionality, manufacturability, structural integrity, and quality of the finished product. These activities include engineering review, technical adaptation, material and hardware selection, preparation of manufacturing documentation, production planning, and coordination of installation requirements.

This study investigates how an integrated engineering management framework influenced project performance in a company specializing in high-end custom furniture manufacturing. The framework combines design-to-manufacturing translation, production engineering, project coordination, quality management, and selected Lean Manufacturing practices within a unified engineering workflow.

The aim of this study is to evaluate how this integrated approach influenced production efficiency, product quality, and production losses during the execution of complex custom furniture projects.

The conceptual framework proposed in this study is presented in Figure 1.

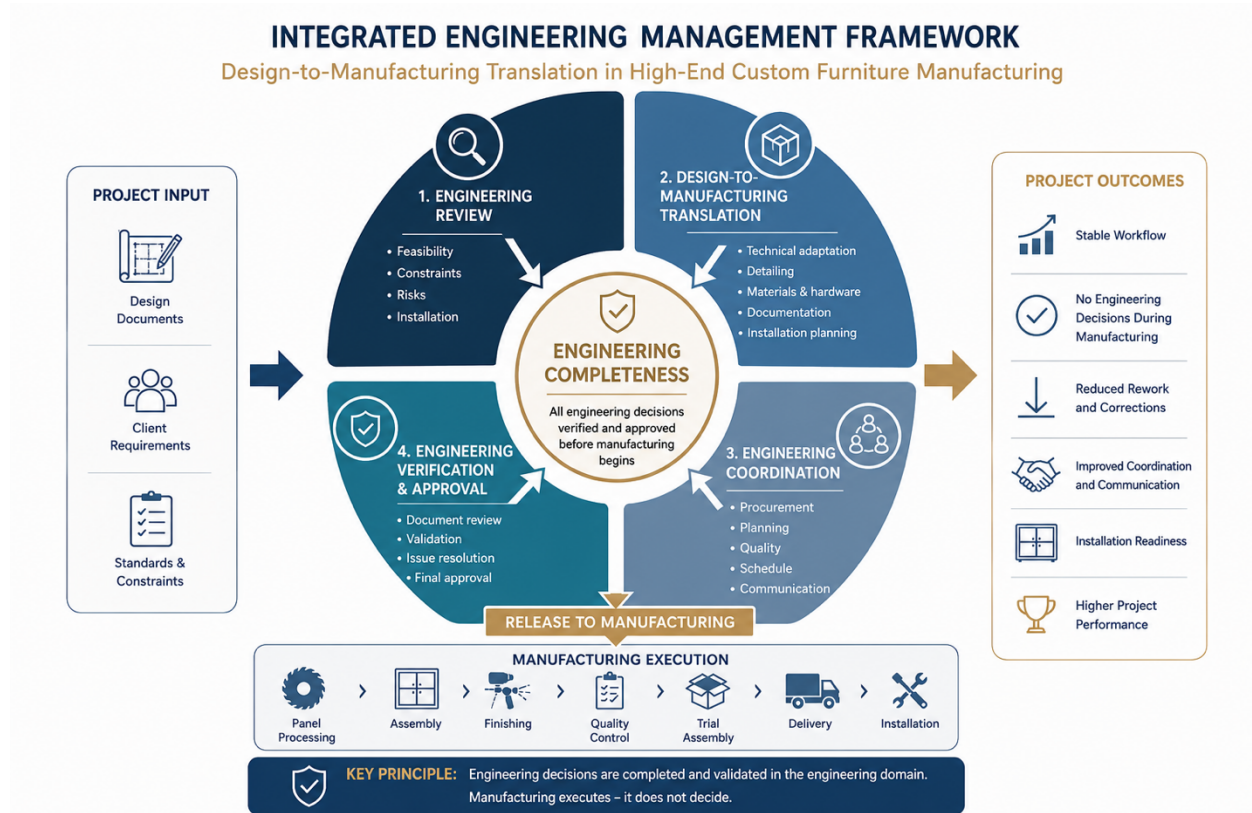


Figure 1. Conceptual framework of integrated engineering management for design-to-manufacturing translation in high-end custom furniture manufacturing.

2. Methods

This study was designed as an industrial case study to examine the role of engineering management in the execution of complex custom furniture projects. The methodology focused on documenting the engineering management process within a real manufacturing environment and evaluating its influence on production performance using operational indicators collected during routine production activities. The following sections describe the study design, production environment, engineering management process, and the performance indicators used in the analysis.

2.1 Study Design

This research was conducted as an industrial case study within a company specializing in high-end custom furniture manufacturing. The study examined the implementation of an integrated engineering management framework in an engineer-to-order (ETO) production environment, where each project required unique engineering solutions before manufacturing could begin.

Rather than evaluating individual engineering activities, the study assessed the integrated engineering workflow as a unified management system. The analysis focused on how engineering review, design-to-manufacturing translation, project coordination, production planning, quality management, and installation preparation collectively influenced project execution.

Project performance was evaluated using operational indicators routinely monitored during project implemen-

tation. These indicators reflected workflow stability, engineering-related production interruptions, corrective manufacturing, interdisciplinary coordination, and installation readiness.

2.2 Industrial Setting

The study was carried out in a company specializing in the design, engineering, manufacture, and installation of high-end custom furniture. The company operates exclusively in an engineer-to-order production environment, where every project is developed according to client-specific architectural and interior designs.

Projects typically involve multiple engineering disciplines, custom manufacturing processes, and complex installation requirements. As a result, engineering preparation represents a critical stage of project execution, ensuring that design intent is translated into technically feasible, manufacturable, and installation-ready solutions before production begins.

The integrated engineering management framework examined in this study had been fully implemented before data collection. Consequently, the research evaluated routine industrial practice rather than a controlled experimental intervention.

2.3 Integrated Engineering Management Framework

The integrated engineering management framework investigated in this study is presented in **Figure 1**. The framework organizes all engineering activities required before manufacturing into four interconnected components: **engineering review**, **design-to-manufacturing translation**, **engineering coordination**, and **engineering verification**.

Engineering review evaluates technical feasibility, manufacturing constraints, installation requirements, and project-specific risks before engineering development begins.

Design-to-manufacturing translation transforms architectural and interior design concepts into complete manufacturing documentation through technical adaptation, structural detailing, material and hardware specification, production planning, and preparation of manufacturing drawings.

Engineering coordination integrates procurement, production planning, quality requirements, scheduling, and installation planning to ensure consistency across all project participants.

Engineering verification represents the final engineering assessment before manufacturing is released. At this stage, all technical documentation is reviewed, validated, and approved to ensure engineering completeness.

Within the proposed framework, manufacturing begins only after engineering verification has been completed. Consequently, engineering decisions are finalized before production starts, while manufacturing focuses exclusively on executing approved engineering solutions.

2.4 Performance Indicators

The effectiveness of the integrated engineering management framework was evaluated using operational performance indicators routinely applied within the company. Rather than measuring isolated manufacturing parameters, the assessment focused on indicators reflecting the overall effectiveness of project execution.

The selected indicators included workflow stability, engineering-related production interruptions, corrective manufacturing, coordination between engineering and manufacturing functions, and installation readiness. Together, these indicators provided a comprehensive assessment of how engineering preparation influenced project performance.

3. Results

3.1 Engineering Completeness Before Manufacturing

Implementation of the integrated engineering management framework resulted in the completion and verification of engineering documentation before manufacturing commenced. Technical decisions concerning construction, materials, hardware selection, manufacturing methods, and installation requirements were finalized during project preparation rather than during production.

As a result, manufacturing was performed using complete and approved engineering documentation, eliminating the need for engineering decision-making during production.

3.2 Workflow Stability

The implementation of the framework improved workflow stability throughout project execution. Because engineering issues had been resolved before manufacturing began, production progressed with fewer interruptions associated with incomplete documentation or unresolved technical questions.

The separation of engineering preparation from manufacturing execution contributed to a more predictable production process and reduced workflow variability.

3.3 Reduction of Corrective Manufacturing

Completing engineering preparation before manufacturing substantially reduced the need for corrective manufacturing activities. Since engineering decisions were finalized in advance, production personnel could focus on executing approved technical solutions rather than resolving engineering problems during fabrication.

This resulted in fewer engineering-related modifications and a reduction in manufacturing rework.

3.4 Interdisciplinary Coordination

The integrated engineering management framework improved coordination among engineering, manufacturing, procurement, quality control, and installation functions. The availability of complete engineering documentation before production facilitated communication between project participants and reduced uncertainty during project execution.

Consequently, production planning and installation activities became more predictable and better coordinated.

3.5 Installation Readiness

Engineering verification performed before manufacturing ensured that installation requirements had been considered during project preparation. Consequently, manufactured components were delivered to the installation stage with a higher degree of technical readiness and fewer engineering-related issues requiring correction on site.

Overall, the findings indicate that completing engineering preparation before manufacturing contributed to improved project execution across multiple operational dimensions.

4. Discussion

4.1. Engineering Completeness as the Primary Driver of Project Performance

The findings indicate that project performance in highly customized engineer-to-order manufacturing is determined not only by manufacturing capability but also by the completeness of engineering preparation before production begins. Within the framework examined in this study, engineering review, design-to-manufacturing translation, coordination, and verification collectively ensured that engineering decisions were completed before manufacturing was released.

This shifts the traditional role of manufacturing. Rather than functioning as an environment in which engineering issues continue to be resolved, manufacturing becomes the execution of previously verified engineering solutions. Consequently, workflow stability and installation readiness are achieved through engineering completeness established during project preparation rather than through corrective actions during production.

These findings suggest that **engineering completeness** may be regarded as a central performance factor in highly customized manufacturing environments.

4.2. Relationship to Existing Engineering and Manufacturing Approaches

The proposed framework complements several established approaches in engineering and manufacturing management while addressing a different stage of project execution.

Lean Manufacturing primarily seeks to improve efficiency by eliminating waste during production. Design for Manufacturing (DFM) improves manufacturability through engineering design, whereas Concurrent Engineering promotes parallel development of product and manufacturing processes.

In contrast, the framework presented in this study emphasizes the completion and verification of engineering activities before manufacturing begins. Rather than optimizing manufacturing operations, it seeks to reduce the need for engineering intervention during production by ensuring that technical decisions have already been validated.

Accordingly, the proposed framework should be viewed as complementary to existing manufacturing approaches rather than as an alternative to them.

4.3. Implications for Engineer-to-Order Manufacturing

Although this study was conducted within the high-end custom furniture industry, the proposed framework may also be applicable to other engineer-to-order manufacturing environments characterized by project-specific engineering and a high degree of product customization.

Potential areas of application include architectural millwork, luxury interior fit-out, yacht interiors, museum installations, exhibition systems, and other industries in which manufacturing depends on project-specific engineering documentation.

These findings indicate that improvements in project performance may be achieved not only through manufacturing optimization but also through systematic completion of engineering preparation before production is released.

4.4 Limitations and Future Research

This study is based on a single industrial case study conducted within one manufacturing company. Consequently, the findings should be interpreted within the context of the production environment investigated.

In addition, the analysis relied primarily on operational performance indicators routinely monitored during project execution rather than on large-scale statistical datasets. Although this approach reflects real industrial practice, future research should validate the proposed framework across multiple organizations and engineer-to-order industries.

Further research may also investigate methods for quantitatively assessing engineering completeness and examining its relationship with operational performance, project risk, production efficiency, and installation quality.

Conclusion

This study demonstrates that project performance in highly customized engineer-to-order manufacturing depends not only on manufacturing capability but also on the completeness of engineering preparation before production begins.

The proposed integrated engineering management framework provides a structured approach for organizing engineering activities before manufacturing, ensuring that technical decisions are completed, coordinated, verified, and approved prior to production release.

The industrial case study indicates that concentrating engineering decision-making within the project preparation stage contributed to improved workflow stability, reduced corrective manufacturing, enhanced interdisciplinary coordination, and greater installation readiness.

Beyond the custom furniture industry, the framework may also provide a practical basis for improving project execution in other engineer-to-order manufacturing environments where production depends on project-specific engineering solutions.

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