Enhancing Planning and Control for Sustainable Custom and Project-Based Furniture Manufacturing

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Abstract

This study investigates production planning and control (PPC) challenges in the Thai furniture industry, particularly in custom and project-based manufacturing. A mixed-methods approach was adopted, combining structured interviews, on-site observations, and the analysis of historical production data to identify inefficiencies in scheduling, task coordination, and resource utilization. The factory implemented integrated PPC strategies such as standardized task planning, workforce optimization, and refined scheduling. As a result, it achieved a 23.58% reduction in delivery delays, a 14% improvement in labor utilization, and a 77.78% increase in the production rate. These outcomes highlight the effectiveness of agile coordination and structured planning in enhancing operational efficiency and supporting more sustainable manufacturing operations in high-variability, make-to-order environments.

Key Words: Custom Orders, Project-Based Manufacturing, Make-to-Order (MTO), Flexible Production, Sustainable-Furniture Manufacturing

1. Introduction

Post-COVID-19 recovery has challenged the Thai furniture industry with slowed domestic sales [1], despite growth opportunities in the real estate and tourism sectors. As demand for custom and project-based furniture manufacturing increases, manufacturers must balance flexibility, efficiency, and sustainability to remain competitive. However, many factories still struggle with inefficient production planning and control (PPC), leading to delays, resource misallocation, and inconsistent production performance [2]. The Thai furniture manufacturing industry has both advantages and disadvantages, as illustrated in **Figure 1** below.

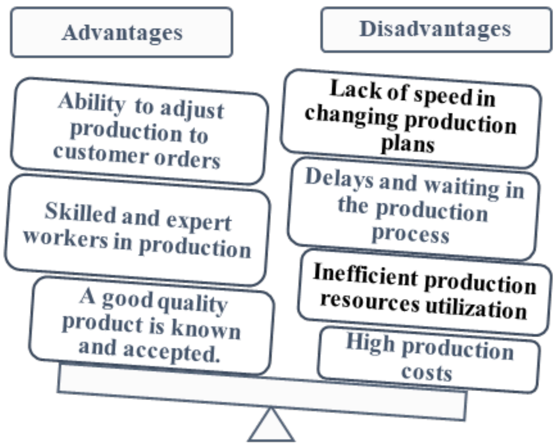

Figure 1 Advantages and disadvantages in the furniture manufacturing industry in Thailand

These strengths and weaknesses shape the industry's production landscape. While opportunities exist for growth and international expansion, manufacturers face critical challenges in workflow optimization, workforce adaptability, and supply chain integration. These factors highlight the importance of enhancing PPC strategies to address inefficiencies and to support sustainable production practices, aligning with Sustainable Development Goals (SDG) 9 (Industry, Innovation, and Infrastructure) [3].

Unlike mass production, custom and project-based manufacturing faces unique challenges due to its high variability, non-repetitive workflows, and fluctuating demand [4]. Traditional PPC methods, often designed for standardized production environments, lack the agility needed to handle dynamic scheduling constraints and human resource limitations [5]. As a result, manufacturers experience frequent schedule disruptions, inefficient labor utilization, and production bottlenecks [6].

Recent studies in the Thai manufacturing sector have highlighted the growing complexity of production planning under mass customization demands. While traditional PPC models are well-suited for standardized workflows, their application in project-based environments remains limited due to frequent order changes, unstable lead times, and high variability [7]. Moreover, research in related fields has shown that even small operational mismatches—such as unclear task sequencing or poor interdepartmental communication—can lead to significant delivery delays [8]. To address these gaps, several Thai factories have begun experimenting with hybrid scheduling models, lean-inspired coordination, and localized task feedback systems [9]. These insights underscore the urgency for a refined, context-specific PPC framework tailored to high-variability industries like furniture manufacturing.

Traditional PPC models assume stable workflows and automated processes, making them less effective in environments requiring high adaptability, rapid response to design changes, and workforce-driven production flexibility [2],[5]. This shift has driven furniture manufacturers to reconsider how they define project scopes, plan timelines, and coordinate interdependent tasks, even in the absence of formalized systems [10]. Agile project management approaches, as increasingly adopted in Thai industries, offer flexible planning and collaborative frameworks that help to manage uncertainty and resource limitations in project-based manufacturing [11].

This study aims to develop an adaptive PPC framework tailored to the needs of custom and project-based manufacturing, with a focus on the following:

- Enhancing scheduling efficiency by improving task planning and real-time production monitoring [6].
- Optimizing labor utilization through skill-based workforce allocation and cross-training strategies [2].
- Reducing delivery delays by implementing structured production updates and proactive bottleneck management [4].

By integrating structured PPC methodologies with agile scheduling strategies, this research addresses key inefficiencies in task sequencing, workforce coordination, and shop floor execution. The proposed framework ensures better synchronization across production processes, enabling manufacturers to improve planning accuracy, reduce lead times, and enhance operational resilience in dynamic manufacturing settings [2],[12]. Additionally, by promoting efficient resource allocation and by minimizing waste, this study supports sustainable manufacturing practices, aligning with SDG 9 [3].

2. Background of the case study and Research Methodology

2.1 Background of the Case Study

Thai furniture manufacturing plays a significant role in both domestic and international markets, incorporating custom, project-based, and mass production models. With increasing competition, manufacturers must improve production planning and control (PPC) to optimize resource utilization, reduce lead times, and enhance operational flexibility. These insights reflect national reports highlighting rising expectations for eco-friendly and customized furniture production in Thailand's domestic sector [13].

As illustrated in **Figure 1**, the industry faces both opportunities and challenges. While demand for high-customization products is growing, manufacturers struggle with high production costs, inefficient workflows, and supply chain disruptions. These issues necessitate structured PPC approaches to enhance scheduling, workforce management, and production optimization.

In recent years, Thai furniture manufacturers have had to adjust their production strategies to align with global market trends and sustainability requirements. Reports from the Department of International Trade Promotion (DITP) indicate that international demand favors flexible, sustainable, and high-customization production models, which significantly impact production planning strategies [14]. To remain competitive, firms in custom and project-based furniture manufacturing must transition from traditional, rigid PPC models to adaptive, data-driven approaches. The case study factory examined in this research represents a furniture production unit tasked with handling project-based and custom furniture. This unit faces challenges in scheduling, resource allocation, and meeting delivery deadlines, prompting the need for systematic PPC improvements. This study investigates the implementation of structured PPC enhancements and evaluates their impact on production efficiency, workforce utilization, and delivery performance.

The case study focuses on an existing production unit that is undergoing transformation to accommodate increasing demand for customized furniture. Unlike the mass production section, which focuses on large-scale, repetitive manufacturing, this unit specializes in Made-to-Order (MTO) tasks, requiring greater flexibility in scheduling and resource allocation. The shift toward high-customization manufacturing has introduced new challenges, particularly in regard to workflow efficiency, delivery reliability, and workforce utilization, necessitating improvements in PPC strategies.

This research focuses on the custom and project-based section, which follows non-continuous production schemes like Job Shop and Batch Production. The production process is divided into two primary workflows:

- Non-assembly Job (cutting, edge wrapping, drilling, finishing, packing).
- Assembly Jobs (preparation, assembly, inspection, finishing, packing).

As illustrated in **Figure 2**, these workflows involve multiple sequential processes that require precise scheduling and coordination. Delays in any stage, particularly in assembly tasks, can significantly impact overall production efficiency. Therefore, optimizing these workflows through improved PPC strategies is crucial to ensuring timely delivery and resource utilization.

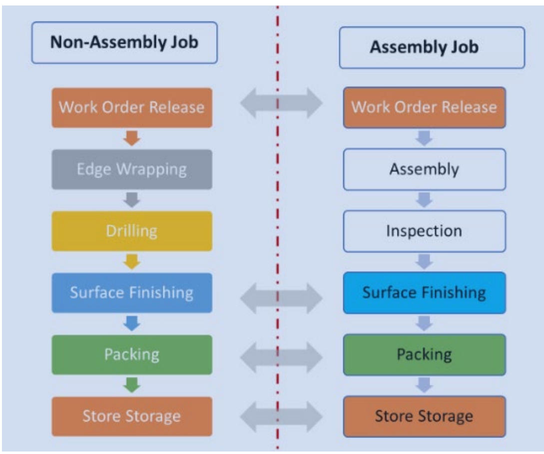

Figure 2 Production Planning and Control Workflow for Custom Orders and Project-based Furniture Manufacturing

Production orders are categorized based on work type and lead times:

- Assembly tasks: 50+ pieces, 3–10 days.
- Customer repairs: 1-8 pieces, 6–8 days.
- Prototypes and samples: Varying quantities, dependent on project needs.

Common causes of production delays include the following:

(a) Unstructured scheduling, leading to frequent rescheduling.
(b) Resource conflicts arise from unclear task priorities, which cause production bottlenecks.
(c) Insufficient risk management, such as unexpected disruptions (e.g., machine failures).
(d) Frequent order changes, requiring continuous plan adjustments.

These challenges are prevalent in Job Shop and Batch Production environments, where scheduling inefficiencies often cause production disruptions [6]. Agile production concepts, focusing on flexibility, real-time adjustments, and cross-functional coordination, can help mitigate these issues [4].

2.2 Research Methodology

This study employs a structured research methodology to evaluate the effectiveness of production planning and control improvements at the case study factory. The research framework consists of three key components: data collection, performance measurement, and comparative analysis.

(a) ***Data Collection Process:*** A performance assessment was conducted using a before-and-after analysis. Baseline data were collected from historical production records over a six-month period prior to implementation, capturing pre-existing operational conditions. Post-implementation data were obtained from a three-month trial period after applying the proposed strategies to ensure process stabilization and reliable measurement of improvements.

(b) ***Key Performance Indicators (KPIs) Selection:*** The study focuses on three primary KPIs that reflect production efficiency and workforce utilization:

- Delivery Delay (%) – Measures the effectiveness of scheduling improvements in reducing late deliveries.
- Labor Utilization (%) – Evaluates workforce flexibility and efficiency in minimizing idle time.
- Production Rate (units/hour) – Assesses the impact of workflow optimization on manufacturing throughput.

These indicators were selected because they align with the core operational challenges in custom and project-based manufacturing, where scheduling complexity and resource allocation directly affect performance.

(c) ***Comparative Analysis Approach*:** A before-and-after comparative analysis was conducted to quantify improvements. Percentage change calculations were applied to evaluate KPI variations across the baseline and post-implementation periods. To enhance the reliability of results, data were collected over multiple production cycles and validated against historical records, ensuring a robust evaluation of the implemented strategies.

(d) ***Qualitative Data Analysis*:** Qualitative data were also analyzed to identify key issues contributing to delivery delays and to trace them back to their root causes in production planning, control mechanisms, and related operational processes. Structured discussions and workflow observations with three production managers, two planning officers, and five shop floor operators—spanning across two production shifts (day and night shifts)—provided insights into operational inefficiencies. The collected data were systematically reviewed to classify recurring problem areas such as scheduling inefficiencies, resource allocation challenges, and bottlenecks in information flow. A root cause analysis (RCA) approach was applied to examine how these inefficiencies led to production delays, helping to pinpoint areas for targeted improvements. These qualitative findings added contextual depth to the quantitative KPI analysis, reinforcing the connection between improved production planning strategies and measurable performance gains.

(e) ***Performance and Data Validation*:** Since custom and project-based manufacturing involves frequent job changes and shifting customer demands, measuring performance reliably requires adjustments in data collection. To keep operations aligned with planned improvements, scheduling methods and workforce coordination were refined to ensure consistent execution. These changes helped to track key performance indicators (KPIs) more accurately in real working conditions. Performance evaluation focused on three KPIs: Delivery Delay (%), Labor Utilization (%), and Production Rate (units/hour), as summarized in **Table 1.** Data sources included historical production records, shop floor observations, and workforce schedules. Baseline values were averaged over a six-month period before implementation while post-implementation values came from a three-month trial period. The percentage change in KPIs quantified the impact of the improvements.

3. The Challenges and Root Causes in Production Planning and Control for Custom Orders and Project-Based Manufacturing

Production planning and control in the case study of custom and project-based manufacturing often face significant challenges that interrupt workflow consistency and productivity. Key issues arise from work systems and methods as well as insufficient resources, all of which reduce operational efficiency. An overview of the interconnections among PPC challenges is illustrated in **Figure 3.** By analyzing these root causes, this study categorizes the challenges into actionable areas, as summarized in **Figure 4**, to enhance work processes and to improve overall production performance.

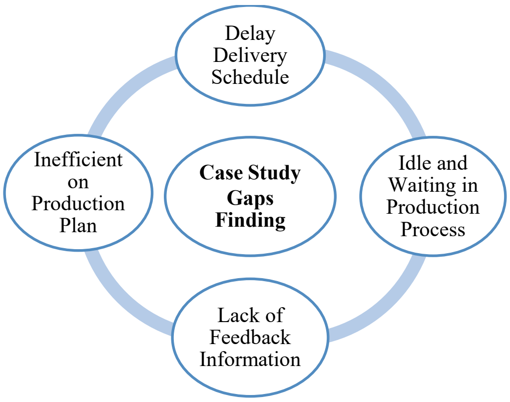

Figure 3 Overview of PPC Challenges Identified in the Case Study

3.1 Production Planning Challenges in the Case Study

Custom orders in furniture manufacturing present unique challenges that require flexible and efficient production planning. The complexity of managing diverse product types and operational steps often leads to the following issues:

(a) ***Non-Continuous Production*** in custom orders requires flexible planning to manage diverse product types and operational steps effectively. Sample orders, originating from purchase orders issued by the sales department, demand multi-department coordination for approval and material preparation. Similarly, customer claims require production adjustments based on QA reports while repair tasks—both internal and external—depend on material availability and approval timelines. These variations highlight the complexity of managing custom orders without standardized workflows.

(b) ***The Lack of Standardized Work Procedures*** affects critical tasks like material preparation and production scheduling, causing frequent delays. Tasks such as organizing raw materials often lack clear timelines, resulting in materials being unavailable when needed. Additionally, inconsistent coordination between the wood-cutting section and production planning delays the release of production orders and complicates adherence to delivery schedules.

(c) ***Gaps in Communication*** between departments delay timely updates and necessary adjustments. For example, the absence of regular production meetings prevents teams from sharing progress or addressing delays, contributing to 65.4% of work orders exceeding scheduled timelines. Establishing clear communication channels is essential to addressing these inefficiencies.

The challenges in production planning for custom orders stem from the lack of standardized workflows, inconsistent communication, and the complexity of managing diverse work orders. These issues affect the ability to create accurate schedules, allocate resources efficiently, and maintain alignment across departments. A previous study [4] highlighted that integrating production scheduling with delivery route planning can mitigate such issues in make-to-order (MTO) environments by improving synchronization between production and distribution. However, while MTO and custom/project-based manufacturing share common scheduling complexities, the latter often involves greater variability in job scope, workforce allocation, and production workflows.

As illustrated in **Figure 3**, addressing these gaps requires structured procedures and enhanced coordination mechanisms to support timely planning and to improve operational flexibility. This study builds upon prior research by incorporating PPC strategies tailored for dynamic scheduling constraints, adaptive workforce utilization, and cross-functional workflow integration, ensuring that production aligns with customer demands and resource availability.

3.2 Production Control Challenges in the Case Study

The production control process for custom orders faces distinct challenges that impact workflow efficiency and timely delivery. These challenges stem from the complexity of managing work orders, delays caused by resource constraints, and inefficiencies in task management, as detailed below.

(a) ***Complexity of Work Orders*****:** The production control process for custom orders involves managing complex work orders that require detailed specifications, such as material requirements, product models, and packaging details. The production team compiles all necessary documentation and coordinates with the warehouse to procure materials. Depending on the requirements, wood cutting is either processed internally or sent for external cutting before undergoing additional steps, including edge wrapping, drilling, coloring, and final assembly. Frequent coordination challenges and material shortages often disrupt this workflow, leading to delays and inefficiencies.

(b) ***Frequent Delays and Bottlenecks*** arise from material shortages, staffing limitations, and machinery constraints. Delays often occur due to unprepared materials or miscommunication between departments, with 86% of jobs failing to meet deadlines. Additionally, inadequate task preparation in the assembly group and understaffing in the packaging unit further exacerbate these inefficiencies. **Figure 5** illustrates the specific causes of delays in production delivery, including material shortages, task preparation gaps, and staffing limitations.

(c) ***Inefficiencies in Task Management,*** caused by the lack of standardized time allocation for tasks, lead to inconsistent material preparation and workflow disruptions. These inefficiencies significantly contribute to delays and bottlenecks, emphasizing the need for clear timelines and structured task management.

These challenges collectively reduce production control efficiency by creating inconsistencies and delays across workflows. As illustrated in **Figure 3**, these interconnected challenges highlight the need for standardized procedures, effective coordination, and resource readiness to address delays and to improve overall production efficiency.

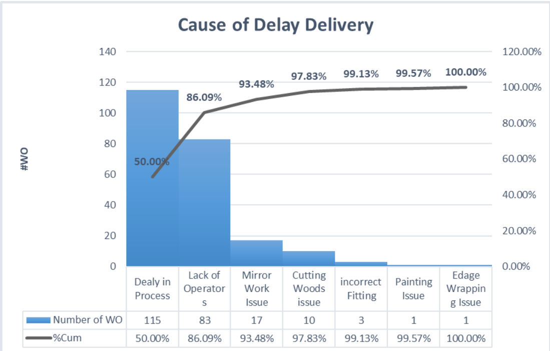

Figure 4 Causes of Production Delays

3.3 Causes Related to the Work System and Work Methods in the Production Planning and Production Control in the Case Study

An analysis of production planning and control processes revealed key gaps in preparation, coordination, standardized timelines, and progress tracking. These inefficiencies disrupt workflows and contribute to delays, emphasizing the need for targeted improvements to streamline operations, as summarized in **Figure 6.**

(a) ***Insufficient Preparation***: The lack of clear steps and timelines for material preparation affects production readiness, often delaying operations. For instance, undefined procedures for withdrawing raw materials from the warehouse lead to unavailability during critical production phases. Establishing structured timelines can mitigate these disruptions.

(b) ***Poor Coordination***: Ineffective collaboration between departments, especially in material requisition and external wood cutting, frequently hinders progress. Tasks relying on multiple departments often face delays, emphasizing the need for improved interdepartmental coordination.

(c) ***Absence of Standardized Timelines***: Undefined task durations make it difficult to ensure timely completion, leading to inefficiencies in the workflow. Standardized timelines for each production step in regular workflows, such as clearly defined start and finish times for individual tasks, would enhance predictability and reduce delays.

(d) ***Inadequate Progress Information***: Limited visibility into work progress impairs resource allocation and adjustment capabilities. Enhanced tracking systems for both internal and external operations are crucial in improving real-time decision-making and minimizing delays.

The workflow gaps in preparation, coordination, standardized timelines, and progress tracking disrupt production planning and control, causing delays and inefficiencies. **Figure 3** highlights these challenges, emphasizing the need for structured workflows, effective communication, and enhanced tracking systems to meet the demands of custom and project-based manufacturing.

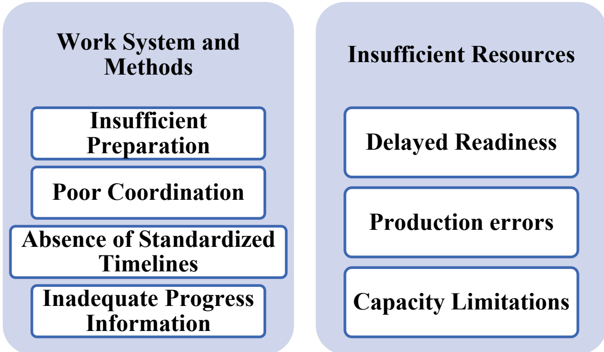

Figure 4 Root Causes of Production Issues

3.4 Causes of Resource Insufficiency in the Production Planning and Production Control Process in the Case Study:

Resource insufficiency disrupts workflows and delays production in custom orders and project-based manufacturing. **Figure 4** highlights key issues, including delayed readiness, production errors, and capacity limitations, which underline the need for better resource planning and allocation to improve efficiency.

(a) ***Delayed Readiness***: Delays in assembly and packaging occur when workers are preoccupied with other tasks, causing a shortage of available staff. For instance, while the assembly unit may be ready to proceed, assigned employees are often engaged in unrelated activities, leading to schedule disruptions.

(b) ***Production Errors***: Production errors lead to wasted time, materials, and effort, often stemming from unclear working procedures or the use of improper materials. These mistakes result in lost work and necessitate additional time and resources to rectify, thereby compounding inefficiencies within the production process.

(c) ***Capacity Limitations***: Capacity constraints in machinery and production capabilities disrupt workflows. For instance, wood-cutting machines may be limited to processing wood pieces of certain sizes, which can hinder the ability to handle smaller dimensions. Additionally, bottlenecks often occur in specific processes, such as drilling, further complicating the production flow and contributing to delays.

The resource insufficiencies identified—delayed readiness, production errors, and capacity limitations—disrupt production planning and control, as shown in **Figure 4**. Addressing these challenges through improved resource management and capacity planning is essential to reduce inefficiencies and to support sustainable operations in custom and project-based manufacturing. As illustrated in **Figure 6**, the key success factors for sustainable production in the furniture industry include efficient resource allocation, cross-functional coordination, and continuous workforce development. These factors closely align with the root causes identified in this study—particularly issues related to fragmented scheduling, inconsistent task planning, and inadequate feedback mechanisms. The lack of alignment between departments, unclear production priorities, and reactive decision-making collectively undermine planning effectiveness. Addressing these systemic weaknesses is therefore essential not only to enhance operational performance, but also to support long-term sustainability.

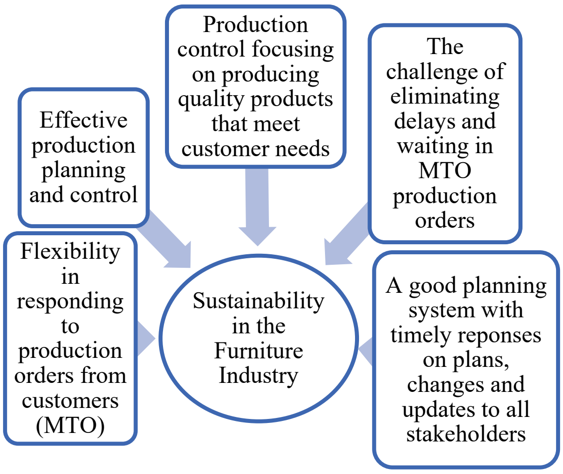

Figure 5 Key Success Factors for Sustainable Production

4. Approaches and Solutions for Enhancing Production Planning and Control for Custom Orders and Project-Based Manufacturing in the Case Study to lead to Sustainable Management

This section presents a structured framework to address the challenges and root causes identified in production planning and control. The solutions are categorized into four distinct areas to ensure a comprehensive approach to sustainable management and operational efficiency. A visual summary of planning and control improvement strategies, showing how task flows and feedback loops integrate with operational responsibilities, is illustrated in **Figure 7**.

4.1 Enhancing Production Planning Efficiency:

Enhancing production planning for custom orders and project-based manufacturing requires a structured approach addressing current challenges. The key strategies include the following:

(a) ***Defining Clear Timelines:*** Establishing specific timeframes for production steps minimizes delays and aligns departmental responsibilities. Deadlines for material preparation, scheduling, and execution must be clearly defined. For instance, sample production (MG) jobs are prioritized based on customer needs, claim jobs (R) require eight days plus material preparation, and large orders (10+ pieces) are scheduled over 10–20 days.

(b) ***Standardizing Workflows:*** Implementing standard operating procedures (SOPs) ensures consistency and efficiency in production planning. SOPs should define steps like creating detailed work documents, verifying materials, and coordinating with departments. Preparation timelines, such as 1–3 days for wood cutting, 7–14 days for glass procurement, and up to 14 days for painted wood, should be specified to streamline workflows.

(c) ***Strengthening Communication for Operational Efficiency:*** Effective communication is critical for aligning departmental activities and addressing operational challenges. Regular planning meetings and feedback loops serve as key mechanisms to improve collaboration and responsiveness. Bi-weekly or every-three-day meetings provide a platform for sharing production updates, identifying bottlenecks, and synchronizing schedules across teams. Additionally, establishing real-time communication tools, such as centralized dashboards or instant messaging platforms, enables teams to share progress updates, adjust plans proactively, and resolve issues quickly. For instance, timely updates on material shortages allow departments to reschedule tasks, thus minimizing delays and enhancing workflow efficiency.

4.2 Addressing Bottlenecks in Resource Allocation:

To effectively resolve resource-related challenges, the following strategies are recommended:

(a) ***Manpower Allocation:*** Properly assigning workers to critical tasks helps to address shortages in assembly and packaging. A detailed production schedule should consider work volume and the number of operators required for each step. Ensuring that skilled workers are assigned to complex tasks at the right time minimizes delays and supports smooth operations.

(b) ***Capacity Planning Evaluation:*** Evaluating machinery constraints and identifying process bottlenecks, such as drilling and wood cutting, are essential steps in capacity planning. Implementing Rough-Cut Capacity Planning (RCCP) enables the assessment of production demands and helps to mitigate potential delays. This systematic approach ensures effective resource allocation and smoother production flows.

(c) ***Improving Workforce Skills to Promote Flexibility:*** Enhancing employee skills is essential for promoting flexibility in the production process. Training programs should focus on developing diverse capabilities, enabling workers to perform multiple roles effectively. This adaptability reduces reliance on specialized personnel and ensures smoother operations during peak workloads or unexpected changes. A multi-skilled and adaptive workforce also supports production schedules, minimizes delays, and enhances overall efficiency

4.3 Tools and Techniques for Lifted Sustainable Production:

Specific tools and techniques can significantly improve sustainable production practices:

(a) ***Leveraging RCCP to Address Bottlenecks and Elevate Sustainable Production:*** RCCP helps to anticipate production demands and identify bottlenecks before they disrupt workflows. Recognizing these bottlenecks allows the team to focus on critical areas, ensuring timely resolution and preventing delays or additional complications in the production process. By addressing bottlenecks effectively, RCCP contributes to resource optimization and elevates sustainable practices by reducing waste, improving efficiency, and supporting long-term operational stability.

(b) ***Scheduling for Reducing Idle Time:*** Adopting simple sequencing techniques such as First-Come-First-Serve (FCFS) or Shortest Processing Time (SPT) provides an easy-to-implement and structured approach to task allocation, reducing idle time and improving workflow efficiency. These straightforward methods establish clear criteria for scheduling, making them practical for shop-floor implementation. By using such techniques, production planners and supervisors can avoid the inefficiencies of manual or unstructured scheduling, ensuring tasks are completed in a timely and organized manner.

(c) ***Agile and Flexible Planning:*** Adapting plans quickly and maintaining flexibility are crucial in responding to both internal production changes and external factors, such as customer demand or supplier adjustments. By incorporating agile planning principles, production systems can swiftly adjust to unforeseen circumstances, thus reducing delays and enhancing efficiency. This approach minimizes disruptions, optimizes resource utilization, and supports sustainable production practices by ensuring smoother workflows and by reducing waste.

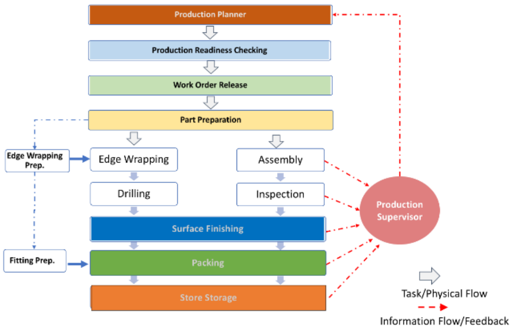

Figure 6 Planning and Control Improvement Guidelines

4.4 Improving Shop-Floor Scheduling and Control:

Effective shop-floor management is critical for optimizing production workflows, reducing delays, and ensuring operational efficiency. This section focuses on strategies for improving shop-floor scheduling and control, including the development of clear daily and weekly scheduling frameworks, tracking progress and performance, and integrating feedback from the shop floor to enhance resource management and production alignment.

(a) ***Daily and Weekly Scheduling Planning Frameworks:*** Developing effective daily and weekly scheduling planning frameworks is essential for ensuring efficient workflow and resource utilization. These frameworks should include:

- Detailed task assignments
- Clear deadlines
- Specified locations for each activity

Planning tools such as Gantt charts enable production planners to visualize tasks, align worker availability with production requirements, and address potential conflicts proactively. By incorporating structured planning, shop-floor management can minimize idle time, improve task prioritization, and ensure timely task completion.

(b) ***Progress and Performance Monitoring for Shop-Floor Management:*** Establishing a monitoring system for progress and performance is critical in maintaining efficiency and minimizing delays. This system should provide real-time updates to identify bottlenecks and adjust resources proactively. By tracking product progress through each production stage and comparing actual performance with planned targets, shop-floor managers can pinpoint inefficiencies and implement corrective actions promptly. Regular monitoring ensures all departments remain aligned and enhances overall production performance.

(c) **Integrating Closed-Loop Feedback to Promote Sustainable Production:** Feedback is crucial in creating sustainable production systems. Transitioning from one-way communication to a closed-loop feedback system ensures that insights and challenges are shared among all relevant stakeholders, enabling better collaboration and proactive adjustments. This approach helps to address bottlenecks, optimize resources, reduce waste, and align workflows with sustainability goals, thus promoting a more flexible production process.

Conclusion: By systematically implementing these strategies, the case study demonstrates significant improvements in production planning and control. The key results include the following:

- A reduction in overdue jobs from 63.34% to 39.76%.
- An increased production rate, from 9 products per hour to 16 products per hour (a 77.78% improvement).
- Enhanced operational flexibility through better resource allocation and skill development.

These improvements contribute to a more sustainable and efficient production environment, resulting in better service delivery and increased customer satisfaction. **Figures 7–8** highlight the improved shop-floor control and operator schedules, demonstrating the effectiveness of these approaches in achieving sustainable management in the furniture manufacturing industry.

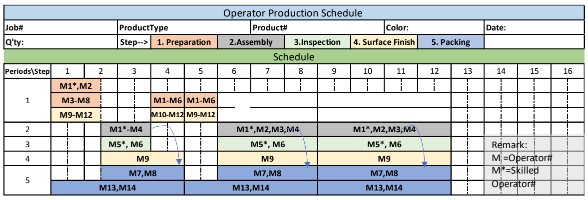

Figure 7 Sample Daily Operator Schedule

5. Results of Problem-Solving Strategies for Custom Orders and Project-Based Manufacturing in the Furniture Industry (Case Study)

This section summarizes the outcomes of the implemented strategies aimed at improving production planning and control for custom orders and project-based manufacturing. The results are categorized into three key areas as follows:

5.1 KPI Improvements and Implementation Outcomes:

The effectiveness of the production planning and control improvements is reflected in the changes observed in the key performance indicators (KPIs). **Table 1** summarizes the major improvements resulting from the structured implementation of task planning, workforce optimization, and scheduling enhancements.

- Delivery Delay (%) was reduced by 23.58% due to the integration of standardized task planning, refined scheduling criteria (e.g., EDD, FCFS), and periodic production updates (every 3 days). These measures ensured better synchronization between workflow stages and enabled real-time progress tracking, thereby reducing delays. This finding is consistent with previous studies on agile and lean-inspired coordination [6],[15],[16].
- Labor Utilization (%) improved by 14% as a result of cross-training initiatives and optimized manpower allocation. Employees were reassigned based on skill levels and workload, enhancing operational flexibility and minimizing idle time. This aligns with workforce adaptability concepts in custom-order environments [6],[15].
- Production Rate (units/hour) increased by 77.78%, driven by improved shop-floor scheduling and labor deployment. Streamlined task assignments and reduced waiting times allowed for better throughput, which is consistent with literature supporting agile scheduling in dynamic production settings[16].

5.2 Performance Improvements

Following the implementation of planning and scheduling strategies, performance improvements were assessed based on key indicators. These improvements reflect the impact of structured task planning, better workforce allocation, and enhanced scheduling mechanisms.

(a) ***Delivery Delay (%) Improvement*:**

- The reduction in delivery delays resulted from better-defined scheduling criteria, which provided a clearer framework for prioritizing tasks.
- The introduction of periodic production updates allowed for real-time tracking, enabling early identification and correction of scheduling deviations.

(b) ***Labor Utilization (%) Improvement:***

- Cross-training initiatives enhanced workforce adaptability, allowing employees to shift between roles efficiently.
- This flexibility minimized idle time and increased the proportion of productive work hours.

(c) ***Production Rate (units/hour) Improvement:***

- As a direct result of better workforce flexibility, the production rate increased significantly.
- The streamlined task allocation ensured that manpower was optimally utilized, reducing unnecessary waiting times and maximizing throughput.

These findings reinforce the importance of well-structured production planning and control mechanisms in custom and project-based manufacturing environments where operational flexibility and efficiency are key to improving productivity.

5.3 Implications for Sustainable Management:

The findings of this study provide valuable insights into sustainable management practices in the furniture industry. By optimizing production planning and control mechanisms, the proposed strategies enhance both operational efficiency and long-term sustainability.

(a) ***Efficient Resource Management to Promote Sustainable Furniture Production*:** The implementation of structured production processes has significantly improved resource efficiency by minimizing waste from overproduction and idle time. These advancements align with Sustainable Development Goals (SDGs) related to responsible consumption and sustainable industrialization, thus ensuring long-term environmental and economic benefits for the industry.

Table 1 KPI Summary and Improvement Outcomes

KPI	Baseline	Result	% Change	Key Improvement Strategies
Delivery Delay (%)	63.34%	39.76%	Reduced by 23.58%	- Standardized Task Planning → Optimized workflow planning to align with job characteristics, established task planning standards, ensured critical information flow, and implemented structured feedback mechanisms. - Defined clear scheduling criteria, incorporating methods such as EDD and FCFS- Implemented periodic production updates (every 3 days) to track progress and mitigate scheduling deviations.
Labor Utilization (%)	72%	86%	Improved by 14%	- Enhanced operational flexibility through optimized manpower allocation & skill development. - Cross-training employees to improve adaptability and reduce idle time.
Production Rate (units/hour)	9	16	Improved by 77.78%	- Reduced idle time by improving labor allocation. - Increased workforce flexibility through better scheduling strategies.

(b) ***Enhancing Workforce Flexibility and Skills for Sustainable Operations**:* Investments in workforce training and cross-functional skill development have enhanced labor flexibility, enabling employees to adapt to fluctuating production demands. This adaptability not only improves day-to-day operational resilience, but also prepares the workforce for evolving industry challenges, thus fostering long-term sustainability.

(c) **Adopting Flexible Production in Furniture Manufacturing**: The study highlights a growing shift toward flexible production systems that respond swiftly to changing customer demands. To achieve this adaptability, production workflows must integrate real-time scheduling adjustments and enhance collaboration among team members. The development of a skilled, versatile workforce through cross-training initiatives further supports this transition, ensuring an agile and competitive manufacturing environment.

(d) **Integrating Agile Planning for Sustainable Growth:** This study demonstrates that traditional planning and control methods often struggle to accommodate fluctuating production demands, leading to inefficiencies in resource utilization. In contrast, the proposed framework, which integrates agile planning principles and dynamic workflow adjustments, allows for real-time decision-making, increased flexibility, and a more resilient production process. These improvements position the factory for long-term sustainability and adaptability in an increasingly dynamic market landscape.

6. Summary, Discussion of Results and Recommendations

This study aims to identify the challenges and provide guidelines for planning and controlling production for custom orders and project-based manufacturing in the furniture industry. This case study seeks to promote sustainable management and enhance the understanding of the importance of operational flexibility in adapting to changes in the future development of the furniture manufacturing sector. The issues, solutions, and results are summarized in **Figure 9.**

6.1 Summary of Key Findings*:*

The study demonstrates significant improvements in production planning and control for custom orders and project-based manufacturing in the furniture sector. The key findings include the following:

(a) ***Reduction in Delivery Delays for Custom Orders***: Structured workflows and enhanced preparation protocols reduced late deliveries from 63.34% to 39.76% (a 23.58% improvement). These results align with the findings in [17], which emphasized the role of workflow standardization in minimizing production delays.

These improvements were achieved through the concurrent implementation of several strategies, including standardized task planning, periodic production updates, and clear scheduling criteria. As this study was designed to address practical, systemic challenges in a live manufacturing environment, these strategies were applied in combination rather than in isolation. Consequently, the 23.58% reduction in delivery delay should be interpreted as a cumulative result of integrated planning and control enhancements, rather than being attributable to individual strategies.

(b) ***Boosting Production Efficiency in Furniture Manufacturing:*** Production rates increased from 9 to 16 products per hour, a 77.78% improvement. This is attributed to better manpower allocation and optimized scheduling. This supports the findings of [18], which highlighted resource flexibility and scheduling efficiency as critical factors

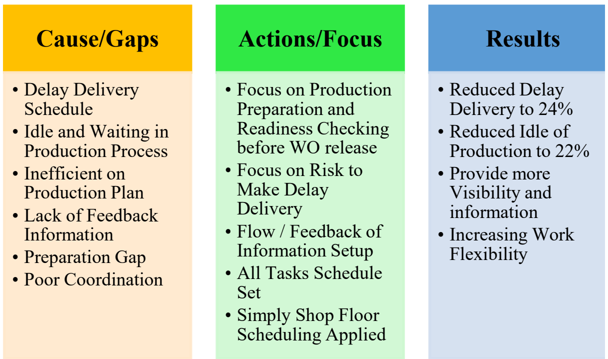

Figure 8 Summary of the issues, solutions, and results

(c) ***Enhancing Flexibility to Respond to Custom Order Changes***: The implemented strategies improved adaptability to customer demands, enabling quicker responses to changes in order specifications. This aligns with [19], which identified operational flexibility as a key to managing market dynamics in project-based manufacturing.

These findings strongly support the research objectives of improving operational efficiency and fostering sustainable practices within the industry.

6.2 Discussion of Results

The findings of this study have significant implications for the furniture manufacturing industry:

(a) ***Comparison with Prior Research in PPC for Custom and MTO Manufacturing***: The results of this study align with and extend prior research in PPC for custom and make-to-order production. For example,[4] emphasized the integration of production and delivery planning. Our findings build upon this by highlighting the importance of structured task planning and human-centric coordination to manage dynamic production requirements.

Additionally, while [6] proposed agent-based and RFID-enabled control systems, our approach demonstrates that even without advanced digital infrastructure, substantial performance gains can be achieved through regular feedback loops, skill-based task assignment, and adaptive scheduling. These results reinforce the importance of context-specific PPC frameworks, especially in high-variability environments like furniture manufacturing. These results reinforce the importance of context-specific PPC frameworks. Related literature also emphasizes the integration of agile multi-agent planning and flexibility in scheduling methods, especially in environments with frequent product variation and shifting priorities [6],[12]. Furthermore, the real-world implementation of planning in MTO settings is shown to benefit from backward scheduling and demand-responsive capacity planning [2],[5].

(b) ***Significance for the Industry***: Improvements in production efficiency and reduced delays highlight the critical role of effective production planning and control in maintaining market position amidst increasing competition and diverse customer demand. This study supports the backward scheduling model for custom orders, as discussed in [20], which emphasized the importance of aligning production timelines with customer requirements. The observed KPI improvements demonstrate the potential of structured scheduling, even in non-automated environments. This aligns with the principles of efficient make-to-order scaling and stakeholder-driven workflows [11],[15].

(c) ***Broader Implications***: The strategies developed in this study can serve as a framework for other industries facing similar production planning challenges. Emphasizing flexibility, resource optimization, and effective communication enhances operational efficiency. This aligns with [21], which highlighted the value of communication tree systems for better stakeholder coordination in complex manufacturing projects. The planning and monitoring practices applied in this study reflect evolving expectations for custom manufacturers to balance innovation, delivery speed, and resource alignment—challenges echoed in global case studies [5],[16].

(d) ***Sustainability Impact***: By integrating resource optimization and adaptive production strategies, the study contributes to sustainable management practices. These findings reflect the framework proposed in [7], emphasizing minimized resource wastage and maximized efficiency in custom manufacturing environments [3],[22].

6.3 Recommendations

To build on the successes of this study and to further enhance production processes, the following recommendations are proposed:

(a) ***Practical Implementation***: Organizations should continue to refine their production planning systems by integrating advanced technologies, such as data analytics and real-time monitoring tools, to improve decision-making and responsiveness to market changes. This recommendation is supported by [18], which suggested that predictive analytics can significantly enhance planning accuracy.

(b) ***Further Research***: Future studies should explore the scalability of these strategies across different manufacturing sectors. Investigating the impact of digital transformation on production planning and control could provide valuable insights into optimizing operations. For example,[19] recommended the exploration of hybrid production models to address the challenges of fluctuating demand.

(c) ***Addressing Challenges***: As organizations implement these strategies, they should be mindful of potential challenges, such as resistance to change among employees and the need for ongoing training. Developing a culture of continuous improvement and adaptability are essential for long-term success, as highlighted in [17].

In conclusion, this study demonstrates that structured problem-solving and adaptive production planning significantly enhance operational performance in custom and project-based furniture manufacturing. Improvements in productivity and reduction in delivery delays confirm the effectiveness of integrated, feedback-driven scheduling and task planning approaches. These results highlight the value of human-centered planning frameworks that align with sustainable management practices.

The proposed framework incorporates agile principles and lean-based task coordination, even without relying on complex digital infrastructure. It directly addresses inefficiencies found in conventional static models by enhancing flexibility, synchronizing workflows, and reducing planning bottlenecks. While the current implementation focuses on practical tools and coordination routines, future research could explore the integration of digital technologies and data analytics to further advance responsiveness and scalability in dynamic manufacturing environments.

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