Design of a Lean Capacity Optimization Strategy for Machines Under No Mixing Policies

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Abstract *— Manufacturing systems operating under fixed batch sizes and strict no-mixing requirements often experience capacity losses due to misalignment between production order quantities and machine cycle capacity. This research examines a three-machine manufacturing system where recurring idle machine cycles lead to underutilized assets, increased lead times, and elevated work-in-process levels. Using the Define, Measure, Analyze, Improve, Control (DMAIC) methodology, the study identifies traceability limitations within machine cycles as the primary root cause of capacity loss. A traceability-based feeding system is developed that enables multiple production orders to be processed within the same cycle while maintaining compliance with quality, process, and documentation requirements. The solution incorporates uniquely identified trays, enhanced documentation, and 5S-based preparation to eliminate idle machine cycles without changing batch sizes or adding equipment. The results demonstrate that hidden capacity can be unlocked through process redesign and improved traceability in constrained manufacturing environments.*

Keywords *— DMAIC, Fixed batching, Lean manufacturing, Machine utilization, No-mixing policy, Traceability*

INTRODUCTION

Manufacturing systems that operate under strict batching and traceability requirements often face significant challenges in aligning production capacity with fluctuating customer demand. The manufacturing company examined in this research operates three identical machines, each capable of processing 150 units per production cycle, for a total system capacity of 450 units per cycle (Figure 1). Due to a strict no-mixing policy, each production cycle must be dedicated to a single production order. In practice, production order quantities have a fixed order quantity of 7,800 units per production order, and this fixed quantity does not align with the fixed cycle capacity of the machines.

Because of this misalignment, the system experiences recurring inefficiencies. Every 17 production cycles, two of the three machines remain idle for an entire cycle, resulting in the loss of two machine cycles of available capacity (Figure 1). This systematic underutilization of assets leads to increased average lead times and elevated work-in-process (WIP), which is currently 57,000 units of backorder for the company.

The challenge has become more critical due to a recent increase in customer demand. While this additional volume does not yet justify the capital investment required to add a fourth machine, the organization would significantly benefit from recovering the capacity that is currently lost due to batching inefficiencies. However, modifying batch sizes or relaxing the no-mixing constraint is not feasible, as these rules are tied to stringent process, quality, and traceability requirements. These constraints severely limit operational flexibility and hinder the system's ability to absorb growing demand using the existing equipment.

This situation highlights a common but underexplored manufacturing problem: how rigid batching and sequencing rules can lead to persistent capacity loss, underutilized assets, longer lead times, and increased risk to on-time delivery performance. Addressing this issue without altering batch size, adding equipment, presents both a practical industrial challenge and an opportunity for methodological advancement.

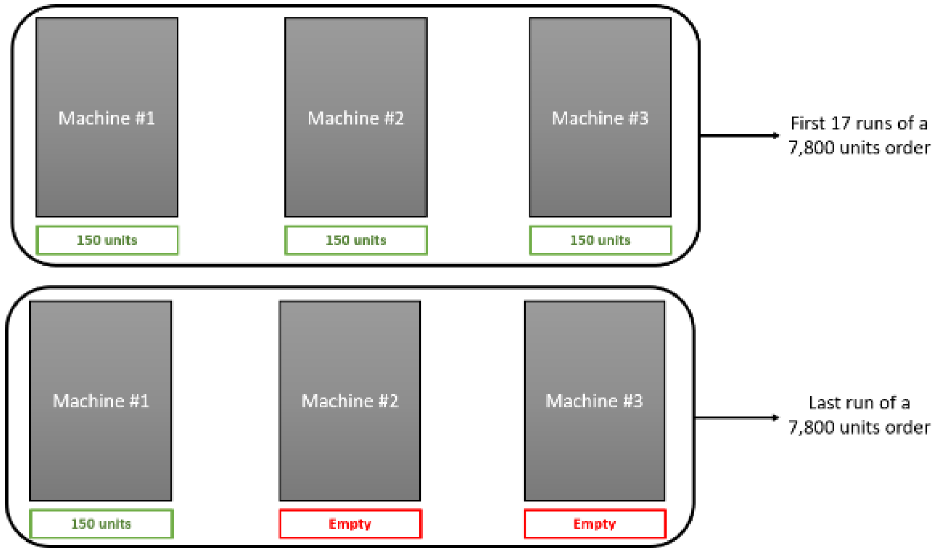

Figure 1
Current Capacity

Objectives

The objective of this research is to propose a systematic approach to mitigate capacity losses arising from no-mixing production constraints under fixed batching conditions, enabling improved machine utilization without additional capital investment.

Methodology

This research adopts the Define, Measure, Analyze, Improve, Control (DMAIC) methodology to systematically address capacity loss caused by idle machine cycles in a manufacturing system governed by fixed batch sizes and a strict no-mixing policy. This methodology has been adopted by the industry as a business management tool to improve operational capabilities and reduce defects in any process [1]. DMAIC is well suited for this study as it provides a structured, data-driven approach for process improvement while ensuring control and sustainability in regulated manufacturing environments.

Another methodology that will be used in this project also integrates lean manufacturing principles, Good Documentation Practices (GDP), and stakeholder engagement to ensure compliance with process, quality, and traceability requirements. The accurate capture of information (GDP) plays an important part in any GMP based industry that is part of quality assurance, which ensures products are produced to the appropriate quality standards of the intended industry [2]. Integration of adequate product segregation is also necessary for the successful implementation of this system, therefore, 5S methodology: a practice that originates from Japanese quality management culture, which name derives from the first letters of five Japanese words: Seiri (sorting), Seiton (set in order), Seiso (sweeping/cleaning), Seiketsu (standardization), and Shitsuke (self-discipline) [3] will also be applied. This technique prioritizes ongoing equipment inspection and maintenance, reinforced by the creation of documented standards. This helps reduce downtime and enhance output quality [4], which is aligned with the purpose of this project.

Following the Define phase of the DMAIC approach, as stated in Table 1, the first step for this project was to define the problem and identify stakeholders. For the problem, it was identified that the underutilization of the machines was contributing to the backorder of the product, and it needs to be understood the extent of that contribution. Therefore, stakeholders of operations, quality and engineering were identified to guide towards an analysis of the problem and a feasible solution. For the measuring phase, the purpose was to understand the impact of the problem and the benefit of the solution.

Table 1
DMAIC Approach

DMAIC phase	Objective	Key activities	Tools and data sources	Outputs
Define	Define problem, scope, and constraints	Problem definition, stakeholder identification	Process documentation, stakeholder input	Defined scope, problem statement
Measure	Establish baseline performance	Data collection on utilization and idle cycles	Production records, system logs, observations	Baseline utilization metrics
Analyze	Identify root causes of idle cycles	Interaction analysis, root cause identification	Fishbone diagram, 5M framework	Prioritized root causes
Improve	Reduce idle cycles and improve utilization	Solution development, lean integration, pilot testing	Lean tools, GDP, performance comparison	Reduced idle cycles, improved utilization
Control	Sustain improvements	Procedure updates, KPI monitoring, training, hypercare	SOPs, visual controls (forms).	Sustained performance and final evaluation

Given that the last run of a production order has an unused capacity of 300 units, each cycle has a calculated duration of 48.4 minutes, and the company operates at a 8 hour 5 days a week schedule (2,080 hours), it can be calculated that the yearly loss of capacity (1) given this inefficiency is 43,000 units (2).

$$x=\frac{(PO\ capacity\ loss)(yearly\ labor\ (hrs))}{cycle\ time\ (min)} \quad (1)$$

$$x=\frac{(300)(2,800)}{(48.4)}=43,000\ units \quad (2)$$

This represents 75.4% of the current back order for the company. An analysis of all the contributing factors of this problem was documented on a fishbone diagram, further discussed below. Cycle utilization improvements were then made on the basis of lean tools such as 5S systems and good documentation practices, and their effectiveness was then monitored through hypercare activities of the change implementation, and control was ensured by making procedure updates and implementing documentation forms.

RESULTS

Current availability for production is of three machines. As represented in Figure 1, each machine can fit 3 trays of product, and these trays can fit 50 units each, which makes for a total of 150 units per machine, giving an overall total capacity of 450 units per run. A production order has a fixed size of 7,800 units. With this information, it is calculated that the last run (17th run) of a production order will run with only one machine due to the no-mixing policy. Therefore, there is a production loss of 300 units in the last run of every production order. The following fishbone diagram (Figure 2) [5] was made to identify all areas of opportunity and develop a plausible solution.

The different categories represented in Figure 2 are discussed below for better visualization.

Method

- The fixed batch sizes that do not align with machine cycle capacity prevent cycle run optimization.
- Strict no mixing policy requiring one order per cycle.
- Rigid scheduling rules that prioritize due dates over capacity balance.
- Lack of alternative sequencing logic to absorb partial batches.
- Limited flexibility to relocate production against machines.

Machine

- Identical machines operate independently without shared workload logic.
- Inability to partially load machines without violating mixing policy.
- No automated balancing mechanism across the three machines.

Man

- Operators follow procedures with no discretionary flexibility.
- Schedulers are constrained by compliance and traceability requirements.

Figure 2
Fish Bone Diagram: Capacity Loss

- Limited cross-functional visibility between operations and planning.

Measurement

- Utilization metrics focused on individual machines rather than system-level performance.
- Limited visibility of "hidden capacity" loss.
- Lead time and WIP increases detected only after performance degradation.

Environment (Management)

- Regulatory and quality requirements enforcing strict traceability.
- No allowance for mixing or batch size adjustment.
- Capital investment constraints (fourth machine not justified).
- Increased demand without corresponding system flexibility.

Based on the information gathered on the fishbone diagram analysis, different plausible solutions were studied. The initial proposed solution was to divide each 7,800 unit production order into smaller sub-batches that better align with the system's 450 unit cycle capacity. Instead of running a single order, the system could process multiple smaller sub lots distributed evenly across cycles. This technique would've ensured all three machines remain fully utilized in every production cycle, thereby eliminating idle machine time. In addition, a dynamic scheduling system could be implemented to interleave sub-batches from different orders within the same production cycle. By continuously balancing workloads across machines and cycles.

However, this idea was turned down by the stakeholders due to the lack of feasibility for implementation since updating the planning system for this capability required significant changes to control systems, documentation practices, and quality assurance protocols. For the final solution, a new feeding system was designed to allow for multiple production orders to run in the same cycle whilst maintaining traceability.

Previously, all units were fed onto the machine in each tray without identification of the production order they were coming from. Since only one production order was processed at a time, there was no risk for mix-up, yet this very thing was causing capacity loss. The solution identified as part of this research project contemplates adding a unique engraving in each of the trays (Figure 3) to match the production order on each tray. All runs will have to document a form where the production order on each tray used will be written down.

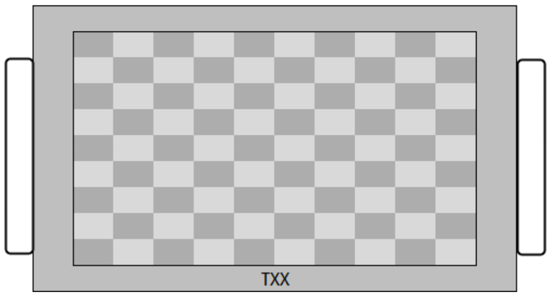

Figure 3
Engraved Tray

This will enable the two remaining machines to be used on the last cycle. Additionally, to comply with line clearance procedures and quality standards, a 5S station was developed to prepare each production order separately before feeding trays into the machines (Figure 4).

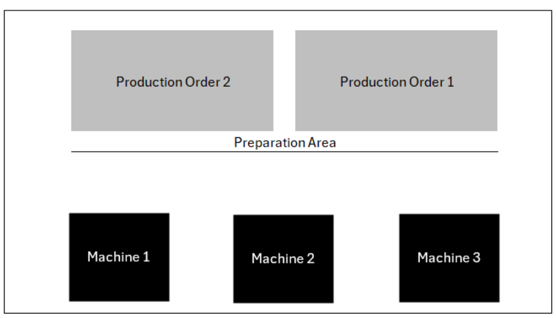

Figure 4
Station Layout (5S)

The 5S system consists of dividing the preparation area into two stations separated by a physical barrier at the time of the last run. In one section, the production order that is already on the machine will be completed, and in the other section, the next production order will be started. This solution will allow for traceability of production orders while in the machines and future documented reference as well, while also ensuring no physical mix-up of the units. Although this solution is tailored to this specific scenario, this method of identification and traceability could be applied to similar challenges in the industry where the risk of mix-up needs to be eliminated while ensuring maximum utilization of assets.

CONCLUSION

This research investigated capacity loss in a manufacturing system operating under fixed batch sizes and a strict no-mixing policy. Misalignment between production order quantities and machine cycle capacity resulted in predictable idle machine cycles, leading to underutilized assets, increased lead times, and elevated work-in-process levels. As customer demand increased, recovering this lost capacity became critical, despite the absence of justification for additional capital investment.

Using the DMAIC methodology, the study identified that the final cycle of each production order utilized only one machine, resulting in a recurring loss of 300 units per order. Root cause analysis showed that limited traceability within machine cycles, rather than equipment capability, was the primary driver of this inefficiency.

To address this issue, a traceability-based feeding system was developed that enables multiple production orders to run within the same cycle while maintaining compliance with no-mixing, quality, and documentation requirements. The introduction of uniquely identified trays, enhanced documentation, and a 5S preparation station allowed full utilization of all three machines during the final cycle without changing batch sizes or adding equipment.

The results demonstrate that hidden capacity can be unlocked through process and traceability improvements rather than capital investment. While tailored to this specific case, the approach is transferable to other manufacturing environments facing similar fixed batching and traceability constraints.

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