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IDENTIFICATION OF "BOTTLENECKS" IN AUTOMOTIVE ENTERPRISES AND PRODUCTION OPTIMIZATION VIA DRUM-BUFFER-ROPE (DBR) FRAMEWORK

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ABSTRACT: This paper investigates the methodology for identifying stationary and dynamic production bottlenecks in automotive manufacturing enterprises characterized by continuous conveyor systems. Based on one month (37,800 minutes) of empirical data from the Welding Shop of Vehicle No. 1 at Enterprise A, the "Lowest Production Rate" method was applied. The analysis demonstrates that the Under Body (U/B) line is the primary bottleneck, operating at a restricted rate of 17.4 JPH, which consequently induces a 40-minute forced starvation state (Starved State) in downstream lines (Main Body, BIW). The enterprise's composite OEE was calculated at 95.11%, and its internal systemic losses were critically analyzed. To eliminate these losses, an optimization model based on the Theory of Constraints' Drum-Buffer-Rope (DBR) framework is proposed, mathematically proving the capacity to reclaim lost throughput.

Keywords: Theory of Constraints (TOC), OEE, Production Bottlenecks, Shifting Bottlenecks, Enterprise A, Starvation Loss, Drum-Buffer-Rope (DBR).

1. INTRODUCTION

In modern industrial environments, the balancing of production lines is a primary determinant of an enterprise's competitiveness. According to Eliyahu Goldratt's Theory of Constraints (TOC), the throughput of any complex system is limited by its weakest link (bottleneck). In high-intensity facilities such as automotive assembly shops, bottlenecks are not static; rather, they migrate across different stations (Shifting Bottlenecks) due to operator fatigue, material quality fluctuations, and micro-downtimes. This study identifies these bottlenecks using the empirical case of Enterprise A, quantifies their specific impact on Overall Equipment Effectiveness (OEE), and provides a structural DBR-based logistical solution to recover lost operational capacity.

2. METHODOLOGY AND EMPIRICAL ANALYSIS

The object of this research is the Welding Shop of Vehicle No. 1, which covers a physical footprint of 4,608 m² and operates with a workforce of 600 personnel distributed across 3 shifts. The shop is structured into 4 sequential main lines: Side Body, Under Body (U/B), Main Body (M/B), and Body in White (BIW). The design takt time of these lines is 190 seconds, yielding a nominal capacity of 18 JPH.

According to monthly data obtained from the Throughput Improvement Process (TIP) monitoring board, macro-level reporting indicated a Synchronized Asset Availability (SAA) of 100%. However, micro-level analysis revealed severe fluctuations in the Jobs Per Hour (JPH) metric:

- **Maximum Capacity:** 23.7 JPH
- **Minimum Capacity:** 17.4 JPH (observed exclusively on the Under Body line)

Applying the "Lowest Production Rate" criterion, the Under Body line was isolated as the Primary Systemic Bottleneck because it failed to sustain the nominal requirement of 18 JPH. A comparative analytical breakdown across the sequential lines is structured below:

Line Name	SAT JPH	Operating Coefficient	TimeType of Loss (Monthly)
Under Body (U/B)	22.98	99.89%	40 minutes of Technical Downtime
Main Body (M/B)	23.00	99.89%	40 minutes of Starved State
Body in White (BIW)	23.00	99.89%	40 minutes of Starved State

The 40-minute micro-downtime originating in the U/B line triggered a chain reaction, starving downstream operations. The net systemic throughput loss ($L_{throughput}$) per shift was determined as follows:

$$L_{throughput} = (40 \text{ minutes} / 60 \text{ minutes}) \times 18 \text{ JPH} = 12 \text{ finished bodies per shift}$$

3. DYNAMIC EVALUATION OF THE OEE INDEX

The OEE of the Under Body line was evaluated as the product of its three operational sub-components ($OEE = A \times P \times Q$):

- **Availability (A):** $(37{,}800 - 40) / 37{,}800 = 99.89\%$
- **Performance (P):** $22.98 \text{ JPH} / 23.70 \text{ JPH} = 96.96\%$
- **Quality (Q):** Based on First Time Yield (FTY) data, established at 98.20%

$$\text{Composite OEE} = 0.9989 \times 0.9696 \times 0.9820 = 95.11\%$$

4. The analysis revealed a critical trade-off between Performance and Quality. When the U/B line accelerated its operating rate up to 23.7 JPH to recover lost time, geometric defects in manual welding joints intensified. This caused a drop in the quality coefficient (Q) and consequently increased the volume of rework required at the BIW stage.

5. PROPOSED SOLUTION: DRUM-BUFFER-ROPE (DBR) FRAMEWORK

To synchronize the production flow and isolate downstream lines from the volatility of the primary bottleneck, the Drum-Buffer-Rope (DBR) methodology is applied to the workshop:

- **The Drum (The Pace):** The Under Body (U/B) line, operating at its restricted capacity of 17.4 JPH, is officially designated as the "Drum" (the master clock) of the entire manufacturing plant. No other line is permitted to run faster than this pace, establishing a disciplined production rhythm.
- **The Buffer (The Protection):** A physical and temporal inventory buffer is established directly between the Under Body (U/B) and Main Body (M/B) lines. This buffer absorbs micro-downtimes and technical stops originating at the U/B stage, ensuring the downstream lines remain operational.
- **The Rope (The Control Signal):** A digital communication constraint loop (the "Rope") connects the U/B line back to the upstream Side Body and stamping operations. Stamping lines are only signaled to release raw materials when a slot becomes available in the buffer, thereby strictly preventing the accumulation of excess Work-in-Process (WIP).

To completely eliminate the 40-minute starvation loss observed in the downstream lines, the optimal linear capacity of the buffer ($B_{capacity}$) must be calculated based on the Drum's lowest operating rate:

$$B_{capacity} = Drum\ Rate\ (JPH) \times (Maximum\ Starvation\ Downtime\ (minutes) / 60\ minutes)$$

Plugging the empirical data from Enterprise A into the equation:

$$B_{capacity} = 17.4\ JPH \times (40\ minutes / 60\ minutes) = 11.6 \times 13\ to\ 14\ car\ chassis$$

6. CONCLUSION AND RECOMMENDATIONS

The empirical findings indicate that forcing non-bottleneck stations to overproduce in an attempt to boost global efficiency is highly counterproductive for Enterprise A. This practice only inflates Work-in-Process (WIP) inventory within the 4,608 m² floor space, causing severe congestion.

The DBR model demonstrates that global optimization in automotive assembly is achieved not by maximizing the capacity of every single station, but by protecting and controlling the bottleneck. By establishing the calculated buffer of 13–14 chassis, Enterprise A can completely eradicate downstream starvation, recovering a net throughput of **36 additional vehicles per day** (12 bodies/shift across 3 shifts) solely through logistical optimization without requiring additional capital expenditure for factory expansion or labor increases.