SM Paints

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Introduction

SM Paints is currently unable to consistently meet its goal of delivering orders to distribution centers within three working days. This shortfall affects the company's lean initiative aimed at reducing inventory while maintaining service levels to retail stores. The existing manufacturing process, which includes four key stages mix and grind, thinning, holding, and filling faces capacity and scheduling limitations. These constraints create delays and inefficiencies in order fulfillment. The company seeks to understand what system changes are necessary to meet a 98% on-time delivery target.

Key Elements of the Model

Batch Creation & Attributes: Orders are generated based on a Poisson distribution and classified into batch sizes (small, medium, large) with specific gallon ranges.

Mix and Grind Operations: A limited number of mixers are available and operate only 16 hours per day. Transfer to a thin tank is not allowed until a suitable tank is seized.

Thinning Process: Liquid is added to the mix at a constant rate and batches are blended. Transfer to hold tanks occurs after thinning, constrained by tank capacity.

Hold Tanks and Final Delay: Once in the hold tank, batches undergo a delay represented by an exponential distribution before being disposed of, simulating the remaining fill process.

Tank Assignment Rules: Orders are assigned to available tanks based on size constraints and operational logic.

Simulation Setup: The model is run for 5 replicates of 60 days each, with performance metrics tracked and confidence intervals reported for key statistics.

Results & Analysis

QUESTION #1

- **Type:** This is a **terminating simulation**.
  We run the model for a fixed time horizon—5 replications of two months each—so there is no need for a warm-up period typical of steady‑state analysis.
- **Warm-Up (if needed):** If we were to consider a steady‑state analysis, we would have performed a preliminary run to determine the point at which the initial transient effects subside. However, because our simulation is terminating, we simply analyze the outputs over the fixed period.

QUESTION #2

- **BatchSize**: Total volume of the order (in gallons), determined by a discrete distribution that reflects the probabilities of small, medium, and large batches.
- **HasQuarts**: A binary indicator (0/1) to show whether the order requires quart packaging.
  - HasQuarts = DISC(0.25, 0, 1.0, 1) (representing a 75% chance of requiring quarts).
- **HasQuarts**: A binary attribute (0 or 1) indicating whether the order requires quarts.
  - HasQuarts = DISC(0.25,0, 1.0,1) (25% → 0, 75% → 1).
- **HasBuckets**: A binary attribute (0 or 1) indicating whether the order requires buckets.
  - HasBuckets = DISC(0.60,0, 1.0,1) (60% → 0, 40% → 1).
- **QuartFraction**: Calculated by multiplying HasQuarts by a random fraction from 0.10 to 0.40.
  - QuartFraction = HasQuarts * UNIF(0.10, 0.40)
  - This way, if HasQuarts=1, we get a fraction in [0.10, 0.40]; if HasQuarts=0, the result is 0.
- **BucketFraction**:
  - BucketFraction = HasBuckets * UNIF(0.05, 0.20)
  - Yields 0 if HasBuckets=0, or a fraction in [0.05, 0.20] if HasBuckets=1.
- **QuartSize**:
  - QuartSize = BatchSize * QuartFraction
- **BucketSize**:
  - BucketSize = BatchSize * BucketFraction
- **GallonSize**:
  - GallonSize = BatchSize - QuartSize - BucketSize

QUESTION #3

- **Order Arrival & Batch Composition:**
    - Orders are generated once at the **beginning of each day**, with the daily count following a Poisson distribution (mean ≈ 23 orders per day).
- **Tank Assignment for Thinning and Hold Tanks:**
    - Orders are assigned to thin and hold tanks based solely on whether a tank's capacity is sufficient for the order's BatchSize. Specifically, we use a **Preferred Order** rule that assigns orders to tanks in order from the smallest to the largest available tank. This approach ensures that smaller tanks are used first, leaving larger tanks available for orders that require greater capacity when there is an overlap in tank requirements.
- **Filling Operation:**
    - The detailed filling process is approximated by a Delay block with an Expo(2.5) hour delay after the order is transferred to a hold tank.
- **Equipment Reliability:**
    - We assume that all machines and tanks operate flawlessly with no malfunctions, breakdowns, or repair requirements beyond the scheduled cleaning cycles. All equipment remains fully functional throughout the simulation run.

QUESTION #4

Logic Breakdown:

1. **Input Order Volume:**
   The order volume is checked against predefined tank capacities (6k, 10k, 14k, 20k).

2. **Decision via Decide Block:**
   A **Decide Block** evaluates the volume and routes the order to the appropriate Thin Tank based on the following logic:

    - If the volume is ≤ 6000 gallons → Route to 6k10k Thin Tank Set.
    - If the volume is ≤ 10000 gallons → Route to 10k14k Thin Tank Set.
    - If the volume is ≤ 14000 gallons → Route to 14k20k Thin Tank Set.
        i. Contain only 2 of the 3 20k tanks
    - If the volume is ≤ 20000 gallons → Route to 20k Thin Tank Set.

3. **Tank allocation within a set:**
   Within each set, tanks are organized in order of increasing capacity, with the smallest available tank at the top of the list. A **predetermined preferred order** is then used for allocation. For example, if a batch size is 5k gallons, it will be assigned to one of the 6k tanks—unless both 6k tanks are already in use, in which case the order is routed to the

next available tank in the set (a 10k tank).

QUESTION #5

Logic Breakdown:

1. **Create Hold Tanks as Resources:**
   - Hold8k: 2 tanks available.
   - Hold12k: 4 tanks available.
   - Hold20k: 4 tanks available.

2. **Batch Size Evaluation:**
   A **Decide Block** evaluates the batch size after thinning and routes it to the correct Hold Tank.

   - If batch size ≤ 8000 gallons → Route to 8k12k Hold set.
   - If batch size ≤ 12000 gallons → Route to 12k20k Hold Set
   - If batch size ≤ 20000 gallons → Route to 20k Hold Set.

3. **Tank Allocation within a Set:**
   Within each hold tank set, tanks are organized in order of increasing capacity, with the smallest available tank at the top of the list. A **predetermined preferred order** is then used for allocation. For example, if an order requires 8k gallons of capacity, it will be assigned to an 8k hold tank if one is available. If the 8k hold tanks are fully occupied, then the order is routed to the next available larger tank (a 12k tank), thereby preserving the smaller tanks for orders that specifically require lower capacities.

QUESTION #6

Increasing the delay in the hold tanks from expo (2.5) to expo (10) causes significant congestion in the system. Entities spend much more time waiting, which leads to longer overall processing times. As a result, fewer entities are completed within the same time frame, reducing throughput. The system experiences a buildup of work-in-progress items, overwhelming queues especially before key processing steps like the MG Process. Hold tanks become bottlenecks as they approach or reach full capacity, further slowing down the flow and dramatically reducing the efficiency of the entire system.

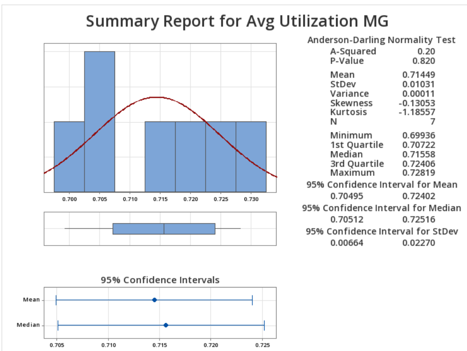
Utilization Statistics

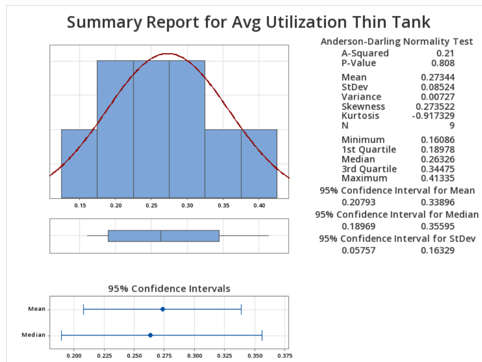
The simulation results provide utilization statistics with 95% confidence intervals for three key resource groups: MGs (Mix and Grind), Thin Tanks, and Hold Tanks.

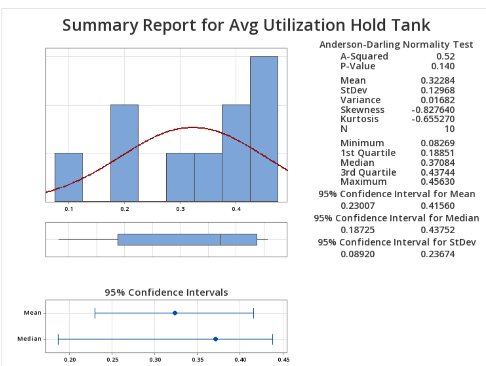
MG Utilization: The average utilization of the MGs is 0.71449, with a narrow 95% confidence interval of (0.70495, 0.72402), indicating consistently high usage across replications.

Thin Tank Utilization: The average utilization is 0.27344, with a wider 95% confidence interval of (0.20793, 0.33896). The data show greater variability (StDev = 0.08524) and slightly positive skewness.

Hold Tank Utilization: The average utilization is 0.32284, with a 95% confidence interval of (0.23007, 0.41560). This group shows the highest variability (StDev = 0.12968) and moderate negative skewness.







Throughput Time Statistics

The average throughput time for orders is estimated at 7.14 hours, with a 95% confidence interval of 6.41 to 7.88 hours. The simulation results show a reasonably consistent process, indicating that the system's performance is stable across replications.