A SIMULATION-BASED APPROACH TO ILLUMINATE INVENTORY CONTROL DECISIONS: POLICY IDENTIFICATION AND OPTIMISATION FOR STAKEHOLDER INFORMED STRATEGIES

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ABSTRACT

This paper utilises a simulation-based approach to address challenges in identifying inventory control strategies for modern manufacturing companies. It follows a systematic framework, beginning with a critical analysis of traditional inventory control methods and their inherent complexities. By drawing from diverse research sources, it investigates the root causes of shortcomings in current inventory management practices. The study presents a dynamic simulation model designed to capture the intricate dynamics of inventory control policies. Leveraging stakeholder engagements and input data, the simulation model functions as a virtual laboratory for testing and refining strategies. Evaluation of these strategies identifies strengths, weaknesses, and opportunities for optimisation. By integrating rigorous analysis with stakeholder insights, the resulting strategies are theoretically robust, practically feasible, and aligned with organisational goals. The paper offers a comprehensive framework for developing informed and adaptive inventory control strategies, combining empirical research with simulation-based insights. The findings aim to advance the field of inventory management, offering actionable recommendations for optimising inventory control practices in manufacturing contexts.

Keywords: Inventory Control Policies, Policy Identification, Simulation-Based Methodology, Stakeholder-Informed

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1 INTRODUCTION

From Axsäter [1], it can be learned that inventory control is the conductor of a stock orchestra. It orchestrates the seamless flow of goods within an organisation. Axsäter further expresses how crucial it is to manage the flow of materials from suppliers to customers. A lot of money is invested in inventory, including raw materials, work-in-progress, and finished goods. Controlling inventory better can save costs and give manufacturing companies an edge by reducing costs, improving customer satisfaction, and enabling quicker responses to market changes [2]. Chaouch [3] explains that inventory control does not happen in isolation. It involves handling purchasing, production, and marketing. Often, there are conflicting goals. Ideally, it is necessary to keep inventory levels low to save money, but the purchasing department might want to buy in bulk to get discounts.

2 PROBLEM, AIM, OBJECTIVES AND STUDY CONTRIBUTIONS

This paper will explore the various aspects of enhancing inventory management practices in the upcoming sections. Beginning with a root cause analysis (RCA), the focus will be on uncovering the underlying factors contributing to inventory inefficiencies. The discussion will then progress to existing inventory control policies, providing an overview of current methodologies to lay the foundation for developing more effective strategies. Following this, the conceptual design of the simulation model will be outlined, and its theoretical framework will be explained. Practical implementation of the simulation model will be discussed in detail, alongside verification and validation techniques, to ensure its accuracy and reliability. Subsequently, simulation evaluation will analyse the outcomes of simulation experiments to inform the policy implementation plan, facilitating the translation of findings into actionable strategies. Finally, the paper will provide conclusions, recommendations, key insights, and topics for future research and application in inventory control optimisation.

2.1 Industry Gap

The absence of inventory control can result in a multitude of adverse consequences, including heightened costs, compromised inventory tracking, imbalanced stock levels, prolonged time consumption, strained vendor-customer relations, diminished employee productivity, impaired decision-making processes, decreased warehouse organisation, extended lead times, stockouts, and delays in shipping and delivery [4].

2.2 Research Gap

The literature does not have thorough studies on the creation and use of dynamic simulation models to identify inventory control strategies in modern manufacturing. This paper addresses the gap by combining empirical research and simulation-based insights to provide practical recommendations for improving or implementing inventory management practices. By testing and validating strategies in a simulated environment that reflects real-world complexities, this research contributes to advancing both theory and practical applications in inventory management within manufacturing contexts.

2.3 Aim

This paper aims to develop a simulation-based approach to improve inventory control decisions, identify policies, and optimise strategies to address the complexities of implementing inventory control within a manufacturing company.

2.4 Objectives

This paper sets out to achieve the following objectives:

- To outline what RCA tools can be used to identify the underlying factors contributing to inventory inefficiencies.
- To explore existing inventory control policies, providing an overview of current methodologies.
- To outline the design and execution of a dynamic simulation model to capture the intricate interplay between inventory control policies.
- To evaluate and compare inventory control policies to identify strengths, weaknesses, and opportunities for optimisation.
- To develop a policy implementation plan based on simulation outcomes, facilitating the translation of findings into actionable strategies.

2.5 Contribution to Industry

The paper aims to equip manufacturing companies with the following tools and insights:

- Enhanced Decision-Making: By providing a comprehensive framework for developing informed inventory control strategies, companies can make better decisions regarding inventory management, leading to improved operational efficiency and cost savings.
- Risk Mitigation: The simulation-based approach allows companies to assess the potential risks associated with different inventory control policies, enabling them to mitigate risks such as stockouts or excess inventory proactively.
- Adaptability: Companies can use the insights gained from the simulation model to adapt their inventory control strategies in response to changing market dynamics, ensuring they remain agile and competitive.
- Optimised Resource Allocation: By identifying optimised inventory control policies, companies can allocate resources more effectively, minimising waste and maximising productivity.
- Stakeholder Involvement: The stakeholder-informed approach ensures inventory control strategies align with organisational objectives and stakeholder preferences, fostering buy-in and collaboration across departments.

2.6 Industry Case Studies

Case studies are powerful tools for illustrating the practical advantages of inventory control within manufacturing contexts. Three such case studies arise, each offering insights into the transformative impact of implementing effective inventory control strategies.

a) Company X (Animal Feed Manufacturer) [5]:

The initial case study examines an animal feed manufacturing plant that struggled to meet its monthly production target of 15,000 tonnes. Using a simulation-based approach, the study developed tailored inventory control policies to address this challenge. The evaluation of these policies meticulously tackles the production capacity shortfall faced by Company X's feed plant. The (s, S) min/max inventory policy emerged as a standout performer, showcasing its ability to boost production capacity, reduce average inventory levels, and shorten waiting times for products awaiting production. This comprehensive evaluation provided valuable insights into the effectiveness of inventory control policies in addressing Company X's production shortfalls.

b) Company Y (Manufacturer of consumer products for big boxes) [6]:

This case study examines a manufacturing plant's struggles with inventory control and accounts receivable management following a significant ownership change. The company faced challenges maintaining accurate inventory counts, leading to a substantial financial hit and increased stakeholder scrutiny. The study identified key recommendations to improve inventory control through meticulous analysis, such as implementing cycle counting and providing incentives for warehouse workers. Additionally, the study addressed accounts receivable chargebacks by creating a logbook to track reasons and ensure prompt follow-up on discrepancies. These measures led to significant improvements, including reduced chargebacks and enhanced profitability. The study emphasises the importance of individual accountability and engagement in driving organisational success, highlighting the cumulative impact of small procedural changes on overall profitability.

c) Company Z (Start-up company that commercialises gift items) [7]:

The study found that implementing an inventory control policy outperformed focusing solely on container sizes, offering variable order sizes. A manual method was also devised to integrate minimum order quantities into Joint Replenishment Problems (JRPs), even with complex transportation costs. By exploring the use of intermediate stocks to mitigate minimum order constraints, the study achieved improved supply chain control, resulting in shorter lead times and enhanced inventory strategies. Implementing the inventory control policies led to substantial cost savings of up to 44%.

3 ROOT CAUSE ANALYSIS TOOLS

Andersen [8] expresses that RCA comprises a systematic method for problem-solving within various disciplines. In contrast to traditional approaches that focus on the problem's outward signs, RCA looks deeper to find the root cause of a problem. By preventing recurrence, this proactive strategy seeks to maximise resource allocation and performance [8]. The four steps of the RCA process are usually problem formulation, data gathering, data analysis, and solution execution.

By examining the underlying causes of inventory-related difficulties, RCA can be utilised in inventory control to verify whether a manufacturer is experiencing problems with inventory control policies. Confirming the presence of inventory control problems within a company through RCA is a crucial prerequisite before determining relevant inventory control policies.

From a study done by Percarpio [9], it can be learnt that finding the source of complex inventory problems requires a diversified RCA strategy. This calls for using several instruments, each of which has a unique benefit in revealing the underlying causes of disparities. Andersen [8], and Percarpio [9] have identified various inventory control RCA tools that can be employed to ascertain inventory control as a root cause of the challenges encountered by a manufacturer.

These RCA tools consist of the following [8], [9]:

- Pareto Charts: Identify significant contributors to inventory issues (e.g., stockouts, overstock) for focused solutions.
- FMEA: Analyse potential failures and their consequences on inventory.
- 5 Whys: Ask "why" repeatedly to peel back layers and reach the root cause of inventory problems.
- Fishbone Diagram: Organise potential causes (People, Methods, Machines, Materials, Measurement, Environment) visually.
- Fault Tree Analysis: Map how numerous factors lead to specific inventory control failures.
- 8D Report: A structured framework to document the entire RCA process for inventory control issues.
- DMAIC: A problem-solving methodology (Define, Measure, Analyse, Improve, Control) applied to inventory control.
- Scatter Diagram: Reveal relationships between factors like inventory discrepancies and sales forecasts.

4 EXISTING INVENTORY CONTROL POLICIES

After selecting RCA tools, looking at relevant inventory control policies that can be presented within a simulation environment is essential. Hopp's [10] study explores various inventory control policies, offering valuable options for easy implementation. Relevant control policies are followed in the proceeding sections.

4.1 Reorder Point/Order Quantity (R, Q)

An order for a fixed quantity (Q) is placed per the reorder point/order quantity inventory control policy when the inventory level reaches a reorder point (R). By simulating alternative values of R and Q, the user can assess how well this technique performs under different demand patterns, lead times, and safety stock levels. The simulation's insights into the trade-offs between holding costs, stockouts, and the frequency of replenishment orders will make it possible to identify the optimal (R, Q) combination.

4.2 Min/Max (s, S)

The min/max inventory control policy maintains an inventory level (s) and a maximum level (S). When inventory drops below the minimum level (s), a replenishment order is sent to return the inventory to the maximum level (S). The simulation will examine several (s, S) variables to determine how they impact inventory costs, service levels, and order frequency. The goal is to find the best (s, S) values that strike a compromise between holding costs and stockouts.

4.3 Periodic Order Up To (T, S)

Orders are placed regularly (T) per the periodic order up-to-inventory control policy to increase the inventory level to a maximum level (S). In the simulation, one can experiment with different time intervals (T) and maximum inventory levels (S) to observe how they impact stockouts, order frequency, and inventory costs. The simulation will assist in determining the best combination of (T, S) to minimise holding costs and ensure sufficient stock to meet demand.

By giving a manufacturer, a platform to assess and contrast various inventory control policies, the deliverable of an inventory control Discrete Event Simulation can help determine the best-suited inventory control policy. Such a simulation will enable the analysis of the three inventory control policies.

5 SIMULATION MODEL CONCEPTUAL DESIGN

To quote Robinson [11] from a journal published on conceptual modelling: "The conceptual model is a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model".

5.1 Data

To guarantee that the inventory control simulation model is accurate and dependable, it should be correctly implemented [11]. To make sure the model can recreate the observed behaviour of the real system, it should be evaluated using a range of input and output data. The following sections stipulate the data that is to be collected for the building of the model.

5.1.1 Quantitative Input Data

Law [12] defines quantitative input data as data comprising numerical information that is observable and quantifiable and is crucial for inventory control at a manufacturing facility:

- Sales Volume: Helps understand demand and optimise production/stocking.

- Cost of Goods Sold: Determines profitability and aids in pricing and cost reduction.
- Lead Time Variability: Helps expect supply chain issues and manage stock levels.
- Production Cycle Time: Monitored to identify inefficiencies and improve customer service.
- Return Rate: Shows product quality issues and impacts profitability. Analysed to improve quality.
- Stock Levels: Maintains a balance between fulfilling demand and keeping carrying costs low.
- Reorder Point: Set to avoid stockouts based on lead times, demand, and safety stock needs.
- Lead Time: Impacts order fulfilment and inventory restocking. Crucial for supply chain management.

5.1.2 Qualitative Input Data

As defined by Law [12], qualitative input data provides descriptive information that aids in placing the quantitative data in its proper perspective:

- Product Categories: Analyses product impact on sales and inventory.
- Supplier Names: Track supplier performance, identify bottlenecks and negotiate better terms.
- Inventory Locations: Optimise warehouse layout for efficient product allocation and faster order fulfilment.
- Manufacturing Process Steps: Identify inefficiencies and areas for improvement to streamline production and reduce costs.

5.1.3 Quantitative Output Data

The quantitative output data category shows the numerical outcomes and performance indicators from the inventory control simulation at a manufacturing facility [13].

- Stock Levels: Monitor inventory performance, adjust the reorder point, and optimise stock levels.
- Sales Volume: Track business performance, identify seasonal trends, and plan production/inventory effectively.
- Production Cycle Time: Evaluate process efficiency, identify bottlenecks, and shorten lead times for improved customer service.
- Cost of Goods Sold: Monitor production costs, detect cost overruns, and improve cost efficiency.
- Reorder Point: Maintain ideal inventory levels, prompt timely reorders, and prevent stockouts.

5.1.4 Qualitative Output Data

The simulation's qualitative output data provides detailed feedback and assessments. It includes details about seasonal demand trends, supplier reliability ratings, customer comments, and the risk of stockouts or shortages [13].

- Supplier Reliability: Assesses supplier performance, identifies risks, and facilitates backup strategies.
- Seasonal Demand: Tracks demand fluctuations to adjust production, marketing, and inventory.
- Stockout Likelihood: Predicts potential shortages and enables proactive inventory planning.

5.2 Design Requirements

Law [14] asserts that to develop a proficient inventory simulation, it is imperative to fulfil several design requirements:

- Inventory Control: Model the manufacturer's inventory system accurately if one exists.
- Demand Forecasting: Implement forecasting mechanisms based on market trends, historical data, and relevant variables.
- Production Capacity: Ensure the simulation respects manufacturer capacity, including workforce and equipment limitations.
- Raw Material Acquisition: Include systems to procure necessary raw materials for manufacturing.
- Wait Times: Account for delays in the supply chain, including raw material procurement and manufacturing.
- Quality Control: Incorporate techniques to maintain product quality during manufacturing.
- Storage Restrictions: Prevent overstocking or under-stocking based on available storage space.
- Cost Analysis: Enable examination of costs related to raw materials, production, storage, and other relevant fees.

5.3 Simulation Model Selection

Barrett [15] described discrete event simulation (DES) as analysing real-world systems by breaking them into discrete events. Weizhuo [16] demonstrates DES's effectiveness in inventory control, enabling manufacturers to optimise outcomes and minimise stockouts. Paid options like FlexSim and Simio offer user-friendly interfaces and support but lack the cost-free and community-driven development of open-source alternatives. FlexSim facilitates inventory control optimisation, allowing for policy evaluation and efficiency gains.

6 SIMULATION MODEL DESIGN AND EXECUTION

The approach to the design and execution of an inventory control Discrete Event Simulation model consists of two models: a current state model and an inventory control model. A Current State Model will accurately represent the existing inventory control system. This initial model establishes a baseline for comparison and clarifies current limitations. An Inventory Control Model can be built using Discrete Event Simulation principles. This enhanced model will incorporate potential solutions and simulate their impact on the system, identifying the most effective strategies to optimise inventory control for a manufacturer.

6.1 Current State Model

The Current State Model is the benchmark against which proposed inventory control solutions will be evaluated. By meticulously analysing current procedures, limitations, and challenges that restrict a manufacturer from achieving its full inventory capability, this model establishes a foundation for understanding the complexities of the existing system. This analysis forms the starting point for developing a revised inventory control strategy to address the identified problems [14].

6.1.1 System Components

Establishing a robust foundation for the company's inventory control simulation model begins with identifying key system components such as:

- Inventory Levels: Analyse stock levels, including raw materials, work-in-progress, and finished items.

- Ordering Processes: Understand order steps and quantities, as detailed in Table 15, and estimate arrival intervals through statistical analysis.
- Demand Forecasting: Examine forecasting techniques and sources, utilising all recipes and ingredients to replicate production.
- Inventory Control Policies: Review existing procedures, including replenishment plans and safety stock levels, to simulate inventory replenishment accurately.

Maintaining flexibility in system modelling is vital to ensure accuracy and responsiveness to changes [17]. The following factors are therefore applicable [17]:

- Adaptation to Changes: Consider changes in supplier relationships, demand patterns, and operational limitations.
- Scenario Testing: Test various inventory control policies and techniques under different circumstances.
- Parameters: Use adjustable parameters for easy testing in different settings.
- Sensitivity Analysis: Assess how changes in factors affect inventory control performance.
- Continuous Improvement: Continuously refine the model based on added information and evolving operational environments.

6.1.2 Model Formulation

A successful model is built upon a foundation of clearly defined needs, which stems from thoroughly investigating the system itself [18]. To ensure the simulation accurately reflects a company’s inventory control system, clear boundaries are established:

- Included Components: The model focuses on critical elements like inventory storage, material flow (incoming deliveries, production, outgoing shipments), ordering and replenishment processes, and supplier lead times.
- Excluded Components: Processes unrelated to inventory control, such as employee management, financial accounting, marketing, and sales, are excluded.

A one-month timeframe creates a practical model aligned with production planning, enabling in-depth analysis, streamlined cost tracking, effective scenario testing, and maximising inventory control effectiveness.

6.1.3 Modelling Assumptions

As Monroe shows [19], a simulation model's assumptions are crucial. They form the model's bedrock and significantly impact its results' validity. Unrealistic assumptions can lead the model astray, providing an inaccurate system picture.

The following are assumptions that may become applicable to the current state model:

- Demand: Demand for products/services is assumed to be constant or follow a known probability distribution (independent or dependent).
- Lead Times: Lead times for material deliveries or processing times are assumed to be constant or follow a known probability distribution.
- Resource Availability: Resources (machines, workers) are assumed to be always available and have a constant processing rate.
- Capacity: Production or service capacity is assumed to be constant and not a limiting factor.
- Quality Control: Perfect quality control is assumed, with no defective products or rework.
- Handling and Storage: Standard handling and storage requirements are assumed for all materials/products.

6.1.4 *Model Translation*

Once all conceptual steps have been completed, the translation of models becomes workable. Illustrated in **Figure 1** is the current state of a company's inventory system transformed into a discrete event simulation model using the FlexSim process flow environment. This model was developed by the main author and was used to successfully identify a best suited inventory control policy for a manufacturing company.

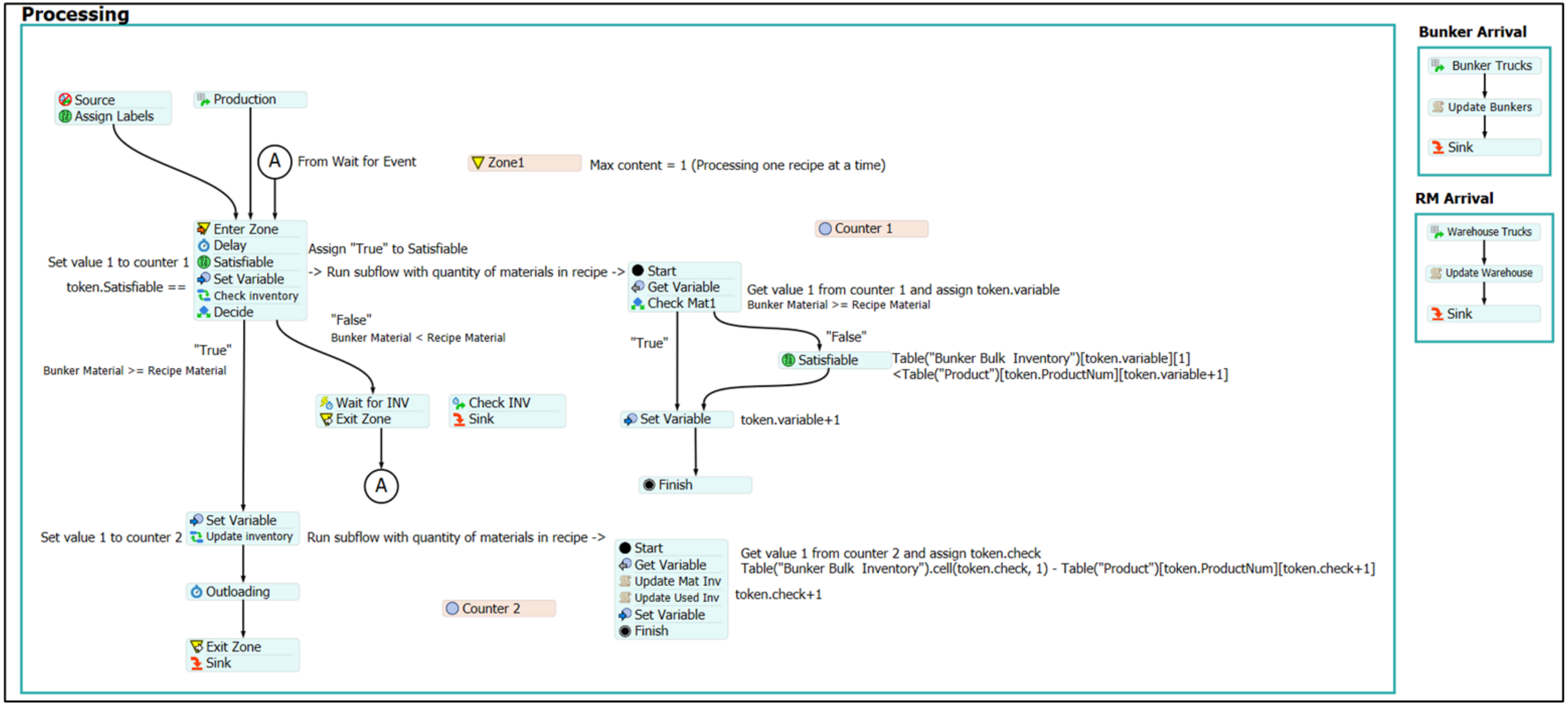


Figure 1: Example of a Current State Discrete Event Simulation Model

a) **Discrete Event Simulation Definitions:**

The following list aims to improve the understanding of the current state model in **Figure 1** by providing brief definitions of each process flow activity type used in the model [20]:

- **ASSIGN LABELS:** Create or change labels on various objects. Labels are used to store essential data about different objects.
- **COUNTER:** This shared asset allows the modeller to store any data and then read or change that data.
- **CUSTOM CODE:** The Custom Code activity can create custom behaviour in the Process Flow module. Pre-defined picklist options can be selected, or customised code can be written in FlexScript.
- **DECIDE:** Based on defined conditions; the Decide activity sends a token to one or more activities.
- **DELAY:** During the Delay activity, the token will be held for a specified period. The delay time can be fixed or created dynamically using a token value from a statistical distribution.
- **ENTER ZONE:** Tokens can enter the zone through this activity.
- **EXIT ZONE:** Tokens can exit this activity if they are part of a Zone shared asset.
- **GET VARIABLE:** This activity gets the value of a variable shared asset.
- **RUN SUB-FLOW:** The Run Sub Flow activity starts a subprocess flow. Until all its child tokens have finished their sub-flows, the entering token will stay in the Run Sub Flow activity.
- **SCHEDULE SOURCE:** The Schedule Source activity creates tokens according to the Arrivals table's instructions.
- **SET VARIABLE:** This activity determines a variable shared asset's value.
- **SINK:** Tokens are destroyed during the Sink activity, erasing all data.
- **ZONE:** The Zone keeps statistics for activities within a process flow. Optionally, it can restrict access to those activities based on the tokens within those activities.

b) **Modelling data sources:**

The following data sources in a manufacturing environment are used for the model translation:

- **Formulations:** Detailed formulas for product recipes.
- **Priority:** Rules for sequencing production runs.
- **Inventory Levels:** Real-time availability of raw materials.
- **Properties:** Costs, storage needs, and restocking lead times.
- **Constraints:** Limits on inventory levels and safety stocks.
- **Control Policies:** Replenishment rules like reorder points.
- **Capacity:** Production capabilities and scheduling details.
- **Scheduling:** Plans for production runs and resource allocation.
- **Demand Profiles:** Historical and forecasted customer demand.
- **Customer Orders:** Specific order details influencing production priorities.
- **Time Parameters:** Duration and event triggers for simulations.
- **Stochastic Variables:** Random variations in demand and lead times.
- **Production Records:** Past production details for validation.
- **Inventory Metrics:** Performance data on stock levels and costs.

c) **Raw Material Arrival and Processing:**

The simulation model initiates with the arrival of raw materials, a crucial precursor to a complete model run. These materials originate from two distinct sources: bunker materials

(Bulk materials) delivered via trucks and warehouse materials (Smaller Materials) brought in various quantities by delivery trucks.

Arrivals from both sources are processed similarly. Each arrival from the bunker or warehouse is tagged with a material type and quantity, ensuring accurate inventory updates. In the case of bunker arrivals, each truck is assumed to carry a whole load of its corresponding material type, maintaining a consistent supply. Conversely, warehouse arrivals, arriving in trucks of varied sizes and frequencies, are allocated specific delivery quantities sourced from a global table.

Upon arrival, each batch undergoes inventory update procedures. Inventory values are directly incremented in a "Bunker Bulk Inventory" global table for bunker arrivals, which holds all these values. Similarly, warehouse inventory updates follow suit, incrementing corresponding material types using pre-defined delivery quantities.

d) Production Arrival and Pre-Production:

In parallel with raw material arrivals, customer orders trigger production activities; each assigned a unique production number corresponding to one of the possible producible products. These production numbers are cross-referenced with a "Product" global table outlining the required materials for each product.

Pre-production processes involve translating conceptual activities into concrete implementations within FlexSim. Entities representing product numbers, each comprising various materials, enter the pre-production zone. These entities are initially labelled as "True" and undergo inventory checks for each material, ensuring availability. Entities progress through decision activities based on material availability. If inventory meets requirements, entities proceed; otherwise, they wait for updates. This iterative process continues until all materials are confirmed satisfiable.

e) Product Production:

Upon confirming material availability, entities progress to the production phase. Here, variables are set, and inventory updates are executed via custom code activities. The first code subtracts used inventory from the company's inventory table, updating stocks. The second code records these subtracted values in a "Produced Inventory" global table for efficiency analysis. Entities undergo production activities and exit the zone upon completion, allowing the cycle to repeat for subsequent orders. Subsequent models build upon this framework, assessing different inventory control policies' impacts on operations.

6.2 Discrete Event Inventory Control Model

Expanding on Hopp's [10] inventory control policies, subsequent models build upon the current state model, representing a company's existing inventory practices. These policies are seamlessly integrated into the FlexSim simulation model, interacting with pre-production, production, and demand processes. The figures presented in the following sections represent distinct control policy models created by the primary author of this paper and have been used in practice. Assessing how the inventory control policy impacts inventory levels, costs, and operational efficiency is crucial and will be evaluated alongside other policies in the upcoming sections.

6.2.1 (R, Q) Inventory Control Model

The (R, Q) Inventory Control Model is a cornerstone strategy for enhancing inventory management practices. It focuses on continuously adjusting the reorder point (R) and order quantities (Q) to optimise inventory replenishment while balancing stock levels and holding costs [21]. **Figure 2** depicts an example of how an (R, Q) inventory control policy can be implemented within the current state model.

Reorder Point/Order Quantity (R, Q): When the inventory level hits a reorder point (R), an order for a fixed quantity (Q) is placed according to the reorder point/order quantity policy.

1. Check for reorder point R and order if GT (Bunker Bulk Inventory) <= GT (ReoderPoint)

2. Order quantity Q from global table OrderQuantity

Ordering Policy

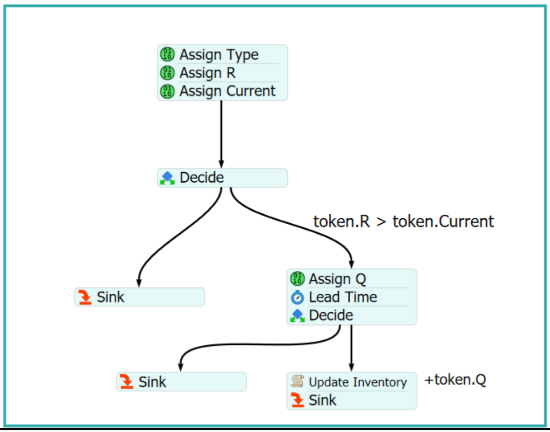


Figure 2: (R, Q) Ordering Policy Implementation

6.2.2 (s, S) Inventory Control Model

The (s, S) Inventory Control Model adopts a just-in-time strategy by setting minimum (s) and maximum (S) stock levels. This approach minimises holding costs while ensuring sufficient inventory to meet demand fluctuations [21].

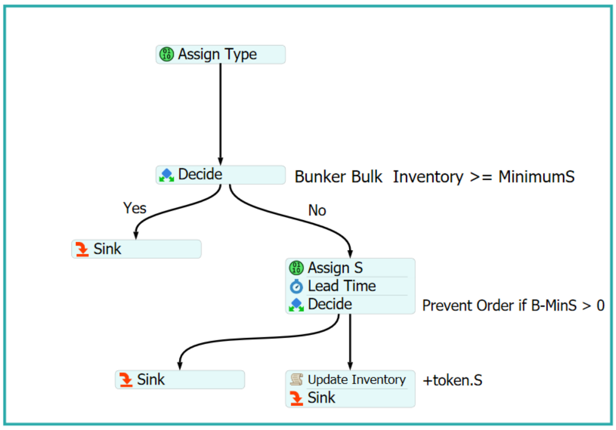
Figure 3 depicts an example of how an (s, S) inventory control policy can be implemented within the current state model.

Min/Max (s, S) : A replenishment order is sent to raise the inventory level back to the maximum level (S) when it falls below the minimum level (s).

1. Check for level s and order if global table (Bunker Bulk Inventory) <= global table (MinimumS)

2. Reorder to S with value global table (MaximumS) - global table (Bunker Bulk Inventory)

Ordering Policy



Order if B-MinS < 0

Order = MaxS - B

Figure 3: (s, S) Ordering Policy Implementation

6.2.3 (T, S) Inventory Control Model

A (T, S) Inventory Control Model implemented at a manufacturer emphasises maintaining target inventory levels (T) and order-up-to-levels (S) to balance stock availability and cost control [21].

Figure 4 depicts the completed (T, S) inventory control policy implemented in the current state model.

Periodic Order Up To (T, S) : By the periodic order up-to policy, orders are placed at regular intervals (T) to raise the inventory level to a specified maximum level (S).

1. Wait for interval T
2. Reorder to S with (MaximumS) - (Bunker Bulk Inventory)

Ordering Policy

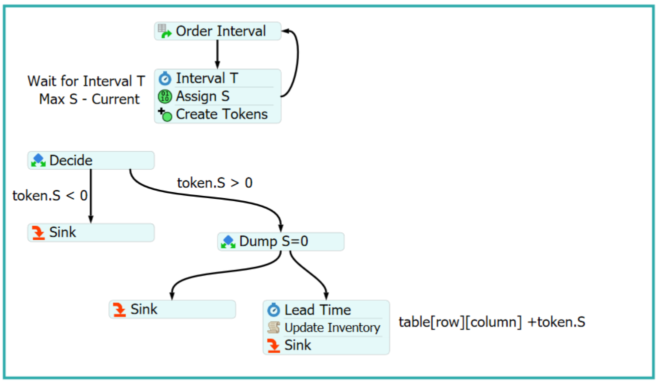


Figure 4: (T, S) Inventory Control Policy Implementation

Figure 4 shows that the (T, S) inventory control policy starts at the scheduled source, which assigns pre-defined interval labels for each material type. These entities are sent to a delay activity before looping back to the scheduled source, ensuring the creation of entities after each delay.

7 VERIFICATION TECHNIQUES

Verification is essential in constructing a reliable and effective inventory control simulation model. This verification ensures the reliability and accuracy of the intricate algorithms and procedures governing the model, ensuring its validity to the real-world inventory system it aims to emulate. Law [14] has shown that there are various foundational techniques and strategies within the simulation verification process.

- Incremental Development: Rather than attempting to construct an entire simulation model simultaneously, incremental development advocates for building and debugging it in smaller, iterative steps. This method begins with core components and verifies each one thoroughly before moving on, resulting in a more robust and reliable model.
- Collaborative Review: Involving multiple individuals in a code review through structured walkthroughs ensures comprehensive scrutiny, preventing developer tunnel vision and ensuring thorough validation of each logical path.
- Parameter Exploration: Testing the simulation with input parameter values helps assess its responsiveness and output sensitivity, ensuring accurate representation of real-world scenarios and identifying anomalies.
- The Power of Trace: Using a "trace" to record the simulation's state after each event allows for thorough analysis, comparing the data with manual computations to confirm the program's performance and uncover any faults.
- Assumption Verification: Evaluating the model under simplified assumptions helps validate its correctness, ensuring accurate results even with streamlined components.
- Visualisation through Animation: Dynamic animation provides a visual representation of the system's behaviour, aiding in detecting anomalies or unexpected behaviours that may be difficult to identify through static analysis.

- Leveraging Simulation Packages: While commercial simulation software can streamline programming efforts, caution is advised because of potential inaccuracies. Interactive debugging features allow for pause, evaluation, and adjustments during simulation.

8 VALIDATION TECHNIQUES

As referenced by Kleijnen [22], validation involves assessing whether the created model accurately mirrors the simulated underlying real system. The following techniques that were outlined by Sargent [23] can be used for validating the inventory control simulation models:

- Animation: The operational behaviour of the model is visually represented as it progresses through time. Balci [24] depicts that graphical depictions illustrate the movement of parts within a factory throughout a simulation run.
- Comparison to Other Models: The validation process involves comparing the results, such as outputs, of the simulation model under scrutiny to those of other validated models as per Sargent's [23] definition.
- Event Validity: The events generated by the simulation model are those observed in the actual system to discover their similarity.
- Face Validity: Sargent [23] explains that experts familiar with the system should be consulted to provide insights on the model and its behaviour, assessing whether they are reasonable.
- Historical Data Validation: Sargent [23] expressed that should historical data be available, a portion of this data, typically collected for constructing and testing a model, is utilised in building the model itself. Subsequently, the remaining dataset is employed to validate or test whether the model accurately replicates the system's behaviour.
- Sensitivity Analysis: Sargent [23] explained that this method involves altering the values of input and internal parameters within a model to assess their impact on the model's behaviour or output. The aim is to ensure that the relationships observed in the model mirror those in the system. This technique can be applied qualitatively, focusing solely on the directions of outputs, or quantitatively, considering both the directions and precise magnitudes of outputs.
- Predictive Validation: The model is employed to forecast the system's behaviour, and subsequently, comparisons are drawn between the predicted behaviour of the system and the forecasts generated by the model. Balci [24] shows that this comparative analysis aims to discover the similarity between the actual behaviour observed in the system and the forecasted behaviour predicted by the model.

9 SIMULATION EVALUATION

In assessing the effectiveness of inventory control policies in addressing a company's challenges, a set of key performance indicators (KPIs) needs to be identified. As highlighted by Luther [25], these indicators play a crucial role in comparing and assessing inventory control policies. They serve as vital metrics to gauge the outcomes and success of the inventory control policies in addressing the study's aim and problem statement.

- Production Capacity per Month: This KPI evaluates the company's ability to meet the desired monthly production capacity, directly assessing whether inventory control policies have improved production capacity.
- Average Inventory: The average inventory level is a vital metric to assess inventory management effectiveness, with a reduction indicating improved control and potential cost savings.
- Average Recipes Awaiting Production: This KPI evaluates production process efficiency by assessing the average number of recipes awaiting production, indicating smoother operations and reduced waiting times.

- Sell-Through Rate: The sell-through rate measures inventory turnover efficiency, showcasing how quickly products are sold and replaced, with a higher rate implying better inventory control.

While one inventory control policy may appear optimal for the company under evaluation, it is crucial to acknowledge that different companies may find varying policies more suitable based on their unique contexts and goals. Therefore, the evaluation process outlined here offers a comprehensive framework for assessing and selecting the most appropriate inventory control policy for the company under evaluation. By analysing KPIs across different policies, companies can gain valuable insights into their operations, enabling informed decisions to improve efficiency and performance.

10 POLICY IMPLEMENTATION PLAN

The policy implementation plan systematically introduces a novel inventory control system and integrates it seamlessly within the company's operational framework.

The following implementation plan phases detail the steps to be taken over 12 months to successfully adopt an inventory control system within the company.

- **Week 1-2:** Familiarise stakeholders with the inventory control policy, emphasising benefits such as cost reduction and stockout prevention.
- **Week 3-4:** Select a pilot area based on lead time and demand variability, demonstrating the balance between ordering frequency and inventory levels.
- **Month 2:** Test the policy in the pilot area, training staff on adaptability to demand uncertainty.
- **Months 3-4:** Implement and evaluate the policy in the pilot area, adjusting inventory levels as needed.
- **Month 5:** Prepare for company-wide rollout, allocating resources and planning communication.
- **Month 6:** Implement the policy company-wide, conducting comprehensive staff training on technology usage.
- **Months 7-12:** Monitor and optimise the policy, conducting performance reviews and automating data collection to enhance decision-making.

11 CONCLUSIONS

In conclusion, if research endeavours were undertaken to enhance inventory control at a company, they would yield promising results. The paper has laid a solid foundation for improving operational efficiency and meeting production goals by meticulously crafting a tailored inventory control policy and outlining a comprehensive implementation plan. The adoption of an inventory control policy, with its focus on data-driven decision-making and balancing inventory levels, promises to bring about significant gains in efficiency while mitigating risks of stockouts. A company can become well-positioned to navigate dynamic market dynamics, optimise inventory levels, and seize opportunities for sustained success.

12 RECOMMENDATIONS

While this paper yields valuable insights and recommendations for enhancing inventory control within a company and adopting an inventory control policy, there remain avenues for future research and exploration in inventory control. These areas of inquiry present opportunities for further refinement and innovation in pursuing operational excellence.

- Advanced Analytics and Machine Learning: Integrating advanced analytics and machine learning can offer more precise insights into inventory control, enabling proactive responses to changing market conditions [26].

- Ethical and Responsible Sourcing: Future research can explore how inventory control can align with ethical and responsible sourcing principles, mitigating reputational risks and meeting consumer demand for ethically sourced products [27].
- Cross-Industry Benchmarking: Comparing inventory control strategies with leading companies in different industries can provide valuable insights and innovative approaches for optimising inventory control practices [28].

These areas of future research guide the company toward continued excellence and innovation in inventory control, contributing to broader discourse and strengthening competitive positioning in the business landscape.

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