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Integrated Inventory Forecasting and Bottleneck Detection Using Predictive Analytics for Supply Chain Optimization

Master of Science in Technology – Industrial Technology and Manufacturing

A Directive Project
By

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All supply chain situations, constraints of systems, and decision variables modeled in this project were created for the sake of experimental analyses under educational fair use guidelines. Any insights or conclusions derived from this paper are theoretical, not intended to find or fulfill any direct industrial application without further validation.

The datasets utilized in this study were derived from the Unilever Supply Chain Management & Analytics program on Coursera, and are intended for non-commercial, educational research purposes only. These raw datasets simulate real-world operational conditions and were used to test forecasting models, detect systemic bottlenecks, and evaluate inventory optimization strategies in a controlled academic environment.

The entity name “Prosacco” is a hypothetical industrial firm created solely for the purpose of simulation-based research. It has no affiliation, endorsement, or connection with any existing company or organization, past or present, that shares a similar name.

All supply chain scenarios, system constraints, and decision variables modeled in this project are developed for experimental analysis under educational fair use guidelines. Any insights or outcomes derived from this work are theoretical in nature and not intended for direct industrial application without further validation.

Integrated Inventory Forecasting and Bottleneck Detection Using Predictive Analytics for Supply Chain Optimization

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Dedication

I want to dedicate this work in the first place to my parents, with whom I have shared everything as my biggest support system. Moving all the way across the world was no easy task. As an international student felt sometimes lost, sometimes senseless, sometimes burdened beyond any limits. But when these thoughts crossed my mind, I thought of you. The sacrifices you made to put me here. The faith you had in me. And that was what kept me going.

You both have given me more than love; you have taught me resilience. You taught me how to stand my ground when the going got tough. Your love has always been felt by me, even from thousands of miles away. This degree is not mine alone; it is ours.

And I would like to write this to someone who has quietly stood with me through thick and thin—someone who has never asked for recognition but without this page, it would be incomplete. I thank you for your presence, checking on me when I went quiet, cheering for me when I couldn't, and reminding me to keep moving when I felt stuck. You have made me a stronger, more focused, and more confident individual. Your belief in me was what made me believe in myself. I am still in the process of figuring myself out, and much of who I am is because of you.

This work is for everyone who stood with me, sometimes behind the scenes, sometimes very quietly, but always sincerely. For the ones reminding me why I began this journey and for the ones who fuelled my fire to keep progress no matter how hard the times were.

I cherish every call, every kind word, every moment when I felt the patience. Every late night, every early morning, and everything in between—thank you.

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I express my gratitude to Coursera and Unilever for providing access to raw case data and materials that made the foundation of analysis and project execution possible.

My heartfelt thanks also reached my academic advisor. Dr. Hongli Luo, for consistently guiding and supporting me through my graduate program. Her mentorship was instrumental in navigating the academic requirements and completing my MS journey with clarity and focus.

It was not only through this research but also through the entire phase with all people's collective wisdom, mentorship, and encouragement that the accomplishment was made possible. I hold their contributions with a very high degree of appreciation.

Executive Summary

This project, “Integrated Inventory Forecasting and Bottleneck Detection Using Predictive Analytics for Supply Chain Optimization,” addresses a core challenge in supply chain management system: the misalignment between demand and supply due to reactive planning and production delays. Using Prosacco, a fictional multinational consumer and goods company, as a case model, the study investigates how organizations can utilize real-time data and predictive analytics to not only forecast inventory needs but also detect and resolve operational bottlenecks before they impact customer fulfilment.

The impetus for this project arises from the increasing complexities and performance expectations placed on modern supply chains, particularly the need to enhance agility, precision, and operational resilience in response to dynamic and often unpredictable market forces. Factors such as natural climatic disruptions, sudden demand surges driven by promotional campaigns or discount events, and unforeseen external variables frequently challenge the ability of supply chains to align production, inventory, and customer service levels. In this context, the analysis of high-demand SKUs such as FP2020—a Fresh Packaged product—revealed significant planning and execution gaps: orders spiked unexpectedly in Week 41, but the production plan was not positioned to support the surge, and inventory reserves were insufficient to bridge the gap. This shortage led to customer deprivation and a measurable erosion of trust in the Prosacco brand. These operational vulnerabilities mirror broader supply chain risks observed across industries, emphasizing the importance of predictive analytics, proactive inventory strategies, and integrated planning frameworks for achieving customer-centric supply chain performance.

This study utilized three interconnected datasets—Prosacco’s Order Report, Forecasting Report, and Customer Impact Report—to comprehensively analyze demand patterns, production planning, and service outcomes. The Order Report provided historical sales and regional demand trends, while the Forecasting Report offered weekly forecasted demand, production plans, and PSI simulations to identify inventory shortfalls and bottlenecks. The Customer Impact Report quantified service failures resulting from stockouts. Analytical techniques such as PSI flow modeling, regression analysis, and forecast error metrics (MAPE, bias) were applied to diagnose gaps between planning and execution. Synthesizing these data sources enabled a full-cycle evaluation of demand forecasting reliability, production responsiveness, and customer service impact, leading to targeted recommendations for supply chain optimization.

Ultimately, this project demonstrates that aligning forecasting, production planning, and inventory management—following industrial supply chain norms—is critical for improving service levels and minimizing lost sales. By identifying bottlenecks through PSI modeling and forecast error analysis, the study highlights the need for predictive planning and dynamic stock strategies to build a resilient, customer-centric supply chain.

Table of Contents

List of Tables

- **Table 1. Recommended Inventory Strategies by Product Type**
  Table 1 summarizes the recommended inventory management strategies tailored to different product types based on demand patterns and perishability. For high-demand, perishable goods, a combination of safety stock and FIFO (First-In, First-Out) ensures availability while reducing spoilage. For high-demand, non-perishable items, the EOQ (Economic Order Quantity) model combined with a reorder point maintains optimal stock levels. Low-demand, perishable products benefit from Just-In-Time (JIT) procurement to avoid waste, whereas low-demand, non-perishable goods are best managed using a Min-Max system to balance inventory levels with minimal intervention.

- **Table 2. Correlation Matrix of Demand, Production, Ending Inventory, and Uncovered Demand**
  Table 2 presents the correlation matrix illustrating the relationships among demand, production, ending inventory, and uncovered demand. Notably, the ending inventory shows a strong negative correlation with uncovered demand (-0.92), indicating that higher inventory levels significantly reduce unmet demand. Demand and production display a moderate negative correlation (-0.38), reflecting the production system's challenge in flexibly matching demand fluctuations. Meanwhile, demand and uncovered demand are weakly correlated (+0.05), suggesting that variability in uncovered demand is more influenced by inventory and production dynamics than by demand alone. These insights help identify where operational improvements can most effectively reduce stockouts and improve service levels.

- **Table 3. Weekly Inventory Performance and Uncovered Demand for SKU FP2020**
  Table 3 details the weekly inventory movements and uncovered demand for SKU FP2020 across weeks 39–48. Initial inventory begins at 4,063 units, with production delays in weeks 39–40 (0 units produced), triggering negative inventory balances and rising uncovered demand from week 41 onward. While production resumes intermittently, the mismatch between production and sales demand leads to persistent stockouts, with final inventory showing negative values in multiple weeks. Notably, uncovered demand spikes to over 3,000 units in week 46, highlighting a critical bottleneck in meeting customer needs. This table illustrates the importance of synchronized production planning and demand forecasting to avoid service failures.

- **Table 4. Impact of Updated Production on Final Inventory and Uncovered Demand for SKU FP2020**
  Table 4 presents the results of an updated production plan designed to address prior inventory shortages for SKU FP2020. Increased production in critical weeks—particularly week 44 (4,000 units) and week 46 (3,000 units)—leads to a substantial improvement in final inventory levels, with positive balances sustained through week 48. Notably, the updated plan effectively eliminates uncovered demand during this period, as flexible inventory levels meet or exceed weekly sales needs. This table highlights how proactive production adjustments can stabilize supply chain performance, reduce stockouts, and improve overall service reliability.

- **Table 5. Customer-Level Sales Impact Analysis**
  Table 5 summarizes the sales impact analysis at the customer level, detailing monthly sales, absolute impact, percentage contribution, and each customer's share of the overall impact. The total monthly sales across all customers amount to ₹12,72,375, with a cumulative sales impact of ₹2,85,375, representing 22% of total sales. This analysis helps identify key customers contributing disproportionately to the overall impact, enabling prioritization of retention strategies, targeted outreach, or service recovery efforts to mitigate sales losses.

List of Figures

- **Figure 7. Total Ordered Quantity by SKU and Delay Status** This bar chart shows the total quantity ordered across multiple SKUs, with a clear distinction between those without delays (blue) and those where delays occurred (red). Notably, SKUs HB1016 and OY2545 lead in total order volume without delays, while FP2020 and OP8025 experienced significant delays despite high demand. This figure helps pinpoint which products faced with supply chain challenges and underscores the importance of focusing mitigation efforts on high-impact SKUs.

- **Figure 8. PSI Chart: Weekly Sales and Final Inventory Levels** This figure shows a PSI (Production, Sales, Inventory) line chart tracking weekly sales and final inventory levels for Weeks 39–48. The blue line represents sales, while the red line shows final inventory, which turns negative starting in Week 41, indicating severe stockouts. The chart highlights the rapid depletion of inventory during Weeks 41–42, followed by persistent negative inventory levels, signaling an ongoing backlog. This figure is critical for visualizing the imbalance between sales and inventory and underscores the need for improved production planning and safety stock buffers.

- **Figure 9. Impact Share by Customer** This pie chart illustrates the distribution of uncovered demand or lost sales among Prosacco's customer base during the FP2020 shortage period. The chart shows that two major customers, Customer1 and Customer2, absorbed nearly all of the impact, with shares of 46% and 45% respectively. The remaining ten customers (Customer3–Customer12) collectively account for less than 9% of the total impact, each contributing just 0–2%. This figure highlights the disproportionate effect of the supply disruption on the company's most critical accounts, emphasizing the need to prioritize high-value customers in recovery planning and to strengthen service level agreements with key partners.

- **Figure 10. Flexible PSI: Sales and Final Inventory Levels** This figure presents a line chart comparing weekly sales with two inventory measures: final inventory (flexible) and final inventory (fixed) from Weeks 44–48. The orange line shows sales, the blue line represents a flexible inventory that adjusts to real-time demand, and the purple line shows fixed inventory levels. The chart demonstrates that while flexible inventory management helped smooth out fluctuations in some weeks (notably Weeks 45–46), it was insufficient to fully prevent stock depletion by Week 48. This figure highlights the benefits and limits of flexible inventory strategies and suggests that additional safety stock or agile replenishment processes may be required to meet demand consistently.

Introduction

Modern supply chains face increasing complexity and volatility, making effective inventory management and timely identification of process bottlenecks critical for operational success as noted by *Gennaro Cuofano and Abby Jenkins, 2023*. Aligning demand forecasting with production planning is pivotal, as any failure in the chain—such as a production delay on a high-demand item—can create a bottleneck, limiting throughput and damaging customer service levels as critiqured by *Tredence, 2023*.

Advances in predictive analytics offer new opportunities to address these challenges. Rather than relying on reactive measures after stockouts occur, organizations can leverage historical data, statistical models, and machine learning algorithms to forecast supply-demand mismatches and detect capacity constraints before they escalate, as noted by *(1)Adedoyin Tolulope Oyewole, (2)Chinwe Chinazo Okoye, (3)Onyeka Chrisanctus Ofodile and (4)Emuesiri Ejairu, 2024*. Integrating inventory forecasting with bottleneck detection enables proactive supply chain optimization, aligning with global best practices such as Sales and Operations Planning (S&OP) and the Supply Chain Operations Reference (SCOR) model, as explained by *ACR Journal - (1)Hatim Kagalwala (2)G V Radhakrishnan (3)Irshadullah Asim Mohammed (4)Rishi Reddy Kothinti (5) Nirzar Kulkarni (2022)*.

This research centres on Prosacco, a multinational consumer goods company with operations in the United States, Mexico, and Canada. The study investigates how predictive analytics can be integrated into inventory forecasting and bottleneck detection to enhance supply chain performance. Prosacco manages a diverse product portfolio-including fresh packaged foods, organic frozen goods, healthy beverages, baby products, beauty items, and pet care products-which are distributed through a variety of sales channels such as closeouts, e-commerce, direct-to-consumer (D2C), major distributors, and retail partners. A detailed breakdown of Prosecco's product categories and sales channels is provided in *Appendix A*.

The impetus for this study comes from clear inconsistencies in Prosacco's supply chain operations, as revealed through recent data analysis: while some SKUs like HB1016 (Healthy Bath product) flow smoothly through the supply chain with high fulfilments, others like FP2020 (Fresh Packaged) face critical production delays and stockouts, despite overall capacity being available. Simultaneously, sales through the Closeout channel show significantly higher average order values, indicating surplus inventory liquidation, which further reinforces the imbalance in supply and demand planning. (See Figure. 1.)

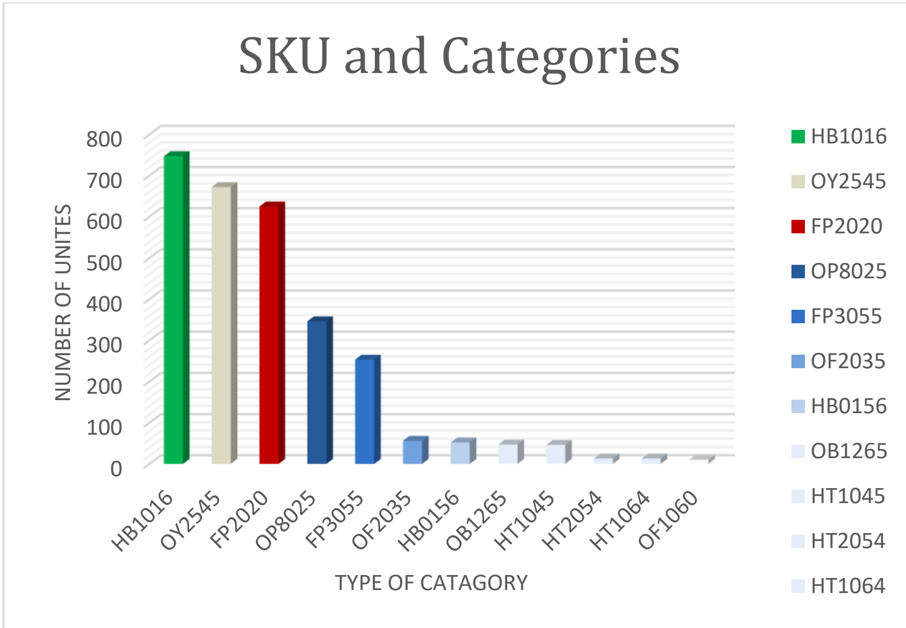

Figure 1. Total Ordered Quantity by SKU and Product Category

The central premise is that data-driven insights can identify hidden inefficiencies—such as under forecasted high-demand products, late production schedules, or inventory misallocations across regions—and guide targeted, category-specific interventions. This is particularly essential for Prosacco's product mix, where perishability and demand variability differ significantly across SKUs. For example, Fresh Packaged items require just-in-time forecasting and safety stock strategies, while Organic Beauty products can be handled with a leaner Min-Max system due to longer shelf life and lower turnover.

A notable example uncovered in the PSI (Production-Sales-Inventory) report is a bottleneck involving SKU FP2020, where zero production in weeks 39–41 led to a cumulative uncovered demand of 2,283 units (valued at over $285,000 in lost revenue), significantly impacting Prosacco's top customers. The forecasting and planning systems failed to anticipate a demand surge, especially in regions like Memphis, which registered the highest average order value (~$77,000) among all cities. These findings highlight not just a forecasting gap, but also a missed opportunity to pre-empt stockouts through predictive planning and safety buffers.

In response, this study applies supply chain optimization frameworks—such as the SMART goal structure, 5W1H root cause analysis, and segmented inventory replenishment strategies—to develop corrective and preventive actions. For instance, holding 2 weeks of safety stock for high-demand perishables like FP2020, improving forecast agility, and differentiating inventory control by SKU category can enhance Prosacco's responsiveness while reducing excess stock.

The Introduction highlights the urgent need for effective solutions to supply chain challenges, framing this research as a critical step toward resolving systemic inefficiencies at Prosacco. As illustrated in Figure 2, Prosacco’s distribution network spans the United States, Mexico, and Canada, reflecting the complexity of its cross-border operations and the importance of efficient logistics. By integrating predictive analytics with real-time PSI (Production, Sales, Inventory) monitoring and customized inventory strategies, Prosacco can proactively prevent customer dissatisfaction and build a more agile, cost-effective supply chain. The report then progresses to a detailed examination of research questions, data methodologies, results from forecasting and bottleneck detection, and prescriptive actions designed to align Prosacco's planning processes with leading global practices.

Figure 2. Distribution in Motion: Prosacco’s Integrated Supply Chain Network

Research Questions and Hypotheses

Research:

- **RQ1a:** What are the key drivers behind stockouts and production delays for specific SKUs like FP2020 despite available production capacity?
- **RQ1b:** How can SKUs be classified based on demand and perishability to implement differentiated inventory replenishment strategies (e.g., JIT, EOQ, Min-Max)?
- **RQ1c:** What forecasting adjustments are required to capture demand variability across Prosacco's key markets (USA, Mexico, Canada) and sales channels (e.g., D2C, E-comm, Closeouts)?
- **RQ1d:** What measurable improvements in supply chain KPIs (e.g., service level, uncovered demand, inventory turnover) can be expected after applying predictive analytics and inventory policy segmentation?

Hypothesize:

- **H1 – Forecasting Optimization Hypothesis:** Applying predictive analytics to demand forecasting will significantly reduce uncovered demand and stockout occurrences, particularly for high-demand, perishable SKUs like FP2020.
- **H2 – Inventory Segmentation Hypothesis:** Segmenting inventory strategies by SKU category (based on demand and perishability) will improve inventory turnover and reduce reliance on Closeout channels.
- **H3 – Bottleneck Mitigation Hypothesis:** Identifying production planning gaps through PSI analysis and introducing proactive safety stock for top-selling SKUs will eliminate service disruptions and ensure on-time fulfilment for key customers.
- **H4 – Regional Forecasting Hypothesis:** Forecasting adjustments that account for regional demand surges (e.g., high average order value in Memphis) will improve customer-specific service levels by at least 20%.

Assumptions

- **Data Accuracy and Completeness:** All data provided in the three Excel files (Order Report, Forecasting Report, and Customer Report) is assumed to be accurate, clean, and representative of Prosacco's typical operations during the period analysed.
- **Product Classification Is Fixed:** SKUs have been accurately classified into demand and perishability categories (e.g., Fresh Packaged as high-demand/perishable, Organic Beauty as low-demand/non-perishable), and these classifications remain valid for the study duration.
- **Forecasting Method Consistency:** Forecasted demand values used in the PSI report are assumed to have been generated using a consistent forecasting methodology across SKUs and weeks.

- **Uncovered Demand = Lost Sales:** All unmet demand recorded as “Uncovered Demand” is treated as **lost sales**, with no backorders or delayed fulfilment beyond the data period.
- **No Major External Disruptions:** The analysis assumes no extraordinary events (e.g., natural disasters, supplier strikes, pandemics) disrupted the supply chain during the evaluated timeframe.
- **Fixed Production Capacity:** It is assumed that Prosacco had sufficient production capacity available overall and that the bottleneck with FP2020 was due to **scheduling or forecasting issues**, not due to plant or resource limitations.
- **Inventory Flows Logically:** Inventory calculations in the PSI report (i.e., Starting Inventory + Production – Sales = Ending Inventory) are assumed to follow standard logic with no anomalies like inventory write-offs or transfers unaccounted for.
- **Customer Behaviour Is Predictable:** Customers will not reattempt purchases if their orders are not fulfilled, meaning lost demand has a direct impact on both revenue and customer satisfaction metrics.

Limitations

- **Short-Term Forecast Horizon:** The forecasting and bottleneck analysis covers a short window (primarily weeks 39–48), limiting insights into long-term seasonality, product lifecycles, or strategic supply shifts.
- **Focus on Finished Goods Only:** This study examines only **finished goods inventory**. It does not analyse **raw materials**, **work-in-progress (WIP)** inventory, or upstream supplier performance, which could also contribute to production delays.
- **FP2020 as Primary Case Study:** While other SKUs were reviewed, SKU FP2020 served as the primary bottleneck example. Findings may not generalize to all SKUs, especially low-volume items.
- **No Cost-Based Optimization:** Inventory strategies were recommended based on demand behaviour and availability—not on precise **cost-benefit analyses** of holding costs, order costs, or spoilage.
- **Limited Geographic Granularity:** Although data shows demand by city, the report does not incorporate **region-specific warehouse constraints**, transportation costs, or lead-time variability across the USA, Mexico, and Canada.
- **Lack of Real-Time System Integration:** The predictive analysis is conducted retrospectively using historical data; in practice, live system integration would be required to enable real-time forecasting adjustments.
- **No Machine Learning Forecasting Models Built:** Although predictive analytics is a core theme, this study did not build or train machine learning models. Instead, it analysed existing forecasts and provided logic for improvement strategies.

- **Customer Satisfaction Not Measured Directly:** The impact of stockouts on customer satisfaction or loyalty is inferred from lost sales data; no direct customer survey or Net Promoter Score (NPS) data was available.

Delimitations

- **Single-Product Bottleneck Focus:** While Prosacco manages a wide SKU portfolio, this study zooms in on **SKU FP2020** as the primary case for bottleneck analysis due to its critical stockout and demand shortfall. Other SKUs were evaluated for volume and demand patterns, but no detailed PSI or root cause analysis was performed on them individually.
- **Fixed Period of Analysis:** The research is delimited to a specific operational period (mainly **Weeks 39–48**), focusing on a recent quarter. This excludes broader seasonality trends or long-term demand cycles, which might impact forecasting models in a full-year or multi-year view.
- **North American Market Only:** The study analyses sales and demand patterns solely within **USA, Mexico, and Canada**. Global Prosacco operations (if any) are not included. Therefore, findings and recommendations apply to North American supply chain decisions only.
- **No Cross-Functional Collaboration Study:** While internal coordination issues (e.g., between sales and production planning) are discussed, this project does **not directly analyse internal communication workflows** or decision-making governance structures such as S&OP (Sales and Operations Planning) meetings or ERP-based planning hierarchies.
- **Static Classification of Product Categories:** Product categories (e.g., Fresh Packaged, Organic Frozen, Healthy Beverage) are classified **once** based on current demand and perishability. The analysis assumes these characteristics are **temporarily stable**, though in reality, product lifecycles may shift categories over time.
- **Simplified Financial Modelling:** While lost sales revenue is estimated and inventory strategies are proposed, the study **does not perform full financial modelling** (e.g., cost of capital tied in inventory, margin erosion from closeouts, or ROI calculations on forecasting systems).
- **System Constraints Assumed Constant:** The study assumes that **production capacity, lead times, and warehousing capabilities** remain fixed and are not operational constraints. It does not delve into manufacturing lead time variability, workforce shortages, or distribution disruptions.
- **Technology Implementation Out of Scope:** Recommendations such as predictive analytics dashboards, PSI automation, or forecast error tracking are **proposed conceptually**. The study does not include implementation roadmaps, IT infrastructure planning, or cost assessments of deploying such tools.

- **No Supplier Network Analysis:** This report is confined to **demand, inventory, and production-side data**. Supplier performance, material lead times, or procurement bottlenecks (e.g., raw material unavailability) are outside the scope, even though they may impact fulfilment capability.
- **No Logistics Routing or Transport Optimization:** While geographic demand patterns are analysed (e.g., Memphis), the study does **not explore transportation modes, route optimization, or delivery lead-time variability** across regions.

Definition of Key Terms

To ensure clarity, we define important terms as used in this report (consistent with supply chain analytics and industrial engineering standards):

- Lean Manufacturing is a production philosophy and set of principles focused on maximizing customer value while minimizing waste. Originating from the Toyota Production System, lean manufacturing aims to streamline processes, reduce non-value-added activities, and continuously improve operations. The core idea is to eliminate muda (waste) – which can be in the form of excess inventory, unnecessary motion, waiting time, overproduction, defects, over-processing, or unused talent – so that every step in the production process adds value from the customer's perspective. By doing so, organizations can increase efficiency, reduce costs, and respond faster to customer demand.

  Lean is often summarized by **five key principles**:

  i. **Value:** specify what creates value for the customer. Identify which features or services the customer truly pays for and prioritize those.
  ii. **Value Stream:** Map out the entire value stream for each product or service, which means detailing every step in the process from raw material to delivery. Identify **value-added** steps versus wasteful steps and eliminate the latter.
  iii. **Flow:** Make the value-creating steps flow smoothly without interruptions. Once waste is removed, the production process should proceed in a continuous flow (rather than in batches with delays).
  iv. **Pull:** Establish a pull system where production is driven by actual customer demand, not forecasts. In practical terms, this is Just-in-Time production – produce only what is needed, when it is needed, and in the amount needed, thereby avoiding overproduction and excess inventory.
  v. **Perfection:** Pursue continuous improvement (Kaizen) to reach a state of perfection where every asset and every action maximizes value. This involves regularly finding and eliminating new sources of waste and reducing variability.

- Supply Chain Bottleneck: A supply chain bottleneck is any resource, facility, or process step whose limited capacity restricts the overall flow and performance of the supply chain, as described in academic and public sources *Wikipedia, 2024*. It causes congestion, leading to slower throughput and potential build-up of work-in-progress or backorders. In this case, the bottleneck manifested as a production halt for SKU FP2020, limiting the supply relative to demand , as emphasized by *Kamil j.mizgier, 2024*

- Inventory Forecasting: The process of predicting future inventory needs, typically based on demand forecasts, historical sales, and lead time information. Integrated inventory forecasting refers to aligning these predictions with supply planning so that production and replenishment decisions are informed by expected demand. The goal is to have the right stock in place to meet customer needs without overstocking.

- Predictive Analytics: Predictive analytics is a category of data analytics that focuses on using historical data, statistical algorithms, and machine learning techniques to predict future events or trends, as emphasized by leading research from *McKinsey & Company*. In supply chain management, predictive analytics can forecast demand, detect potential delays, and identify early warning signs of bottlenecks so that proactive actions can be taken, providing significant operational and financial improvements.

- SCOR Model: The Supply Chain Operations Reference (SCOR) model is a process reference framework developed by APICS for supply chain management. It defines the standard processes (Plan, Source, Make, Deliver, Return, Enable) and provides metrics and best practices for each (). SCOR is used in this study as a lens to ensure our approach aligns with best practices – for example, *Plan* (demand forecasting) is integrated with *Make* (production scheduling) and *Deliver* (order fulfilment) processes.

- APICS & Industrial Best Practices: APICS (now part of ASCM) is a leading professional association for supply chain and operations management. APICS standards (such as maintaining safety stock, measuring fill rates, conducting S&OP meetings) inform our approach. For instance, industrial best practices call for cross-functional coordination (through S&OP) to pre-empt bottlenecks, as well as maintaining key performance indicators like fill rate, forecast accuracy, and production schedule adherence.

- SKU FP2020: A specific Stock Keeping Unit (SKU) under study – FP2020. “FP” denotes *Fresh Packaged* (a category of goods), and 2020 is its identifier code. It is a finished product produced at Prosacco’s Kern facility. FP2020 is significant to this project due to a notable production shortfall event that led to inventory depletion.

- Backlog (Backordered Demand): The accumulation of unfulfilled orders due to insufficient supply, often represented as negative inventory in planning calculations. In this study, when we say uncovered demand or backlog, we refer to customer orders (or portions of orders) for FP2020 that could not be filled on time and were left outstanding. We quantify backlog in units (number of items short) and sometimes in financial terms (revenue lost or delayed).

- Fill Rate (Service Level): The percentage of customer demand that is met from available inventory within the requested time frame. A 100% fill rate means all demand was satisfied immediately, whereas a lower fill rate indicates some orders were unfilled (contributing to backlog). We use this concept to evaluate the impact of the bottleneck – for example, the fill rate for FP2020 plummeted when inventory was exhausted, and production could not keep up.

Formula:

$$\text{Fill Rate (\%)} = \frac{\text{Demand Fulfilled}}{\text{Total Demand}} \times 100$$

Where:

- Demand Fulfilled = Orders covered from inventory
- Total Demand = Total orders placed

- Correlation Analysis: A statistical analysis to measure the strength and direction of relationship between two or more variables. In the context of this study, we compute correlation coefficients between demand, production output, inventory levels, and backlog. This helps in understanding how closely variations in one (e.g. production) are associated with changes in another (e.g. inventory or unmet demand).

- Inventory Forecasting: The process of estimating future product demand to determine how much inventory should be carried. Effective forecasting balances having enough stock to meet demand (avoiding stockouts) with not holding excessive inventory.

- SMART Framework: An acronym for Specific, Measurable, Achievable, Relevant, Time-bound. It is a criterion used to set clear and attainable goals. For example, “reduce the stockout rate of SKU FP2020 to less than 2% by the end of next quarter” is a SMART goal (clear target, quantifiable, realistic, relevant to performance, and with a deadline).

  Breaking down each component of SMART:

  i. **Specific:** The goal or metric should be clear and unambiguous. It answers *what* needs to be accomplished, *who* is responsible, *where* it applies, and *which* constraints or requirements are involved. For example, instead of saying “Improve inventory”, a specific goal would be “Reduce finished goods inventory of Product X at Warehouse A”.

  ii. **Measurable:** The objective must have criteria for measurement so progress can be tracked. This often means assigning a numeric target or KPI. For instance, “Reduce finished goods inventory of Product X at Warehouse A **by 15%**”. Measurability ensures everyone can assess whether the goal is on track or achieved, using data.

  iii. **Achievable (Attainable):** The goal should be realistic given available resources and constraints. It should stretch the team but still be within reach. If historical data shows only a 5% reduction is feasible without impacting service, setting 15% might require additional initiatives or might be overly ambitious. A discussion on what’s achievable ensures buy-in and motivates performance.

  iv. **Relevant:** The goal should matter to the business and align with higher-level objectives or strategies. It asks *why* the goal is important. For example, reducing inventory should tie into broader goals like freeing up working capital or improving supply chain efficiency. If a goal doesn’t align with company strategy or the immediate project, it might not be worth pursuing. Relevant goals also consider the current economic or business context (no point in setting a goal that isn’t pertinent to current challenges or opportunities).

  v. **Time-bound:** There must be a clear deadline or time frame for achieving the goal. This creates urgency and allows for scheduling milestones. For example, “Reduce inventory by 15% **by the end of Q4 2025**.” Time-bound goals help in planning review points (e.g., monthly check-ins on progress) and prevent goals from dragging on indefinitely.

- 5W1H: A problem-solving and analysis framework standing for *Who, What, When, Where, why, how*. It is used to comprehensively understand an issue. In this report, 5W1H is applied to analyse the FP2020 bottleneck: Who is affected (key customers), What happened (stockout), When/Where (week 41–42 in the supply chain, at the finished goods stage), Why (forecast underestimation and no safety stock), and how to address (ramp up production, hold buffer stock).

    i. **Who:** Identifies the people or stakeholders involved or affected. In a supply chain context, "who" might refer to which department, supplier, or customer is part of the process or problem. For example, *who* is responsible for inventory accuracy, or *who* experiences the impact of a late delivery (which customers or regions).
    ii. **What:** Describes the issue at hand or the object under consideration. For instance, *what* is the problem (e.g., a bottleneck at a warehouse, or a spike in demand for a product), *what* is the process being analyzed, or *what* are the key performance metrics to improve. This ensures clarity on the subject matter or the goal.
    iii. **When:** Establishes the timeline or timing elements. This could include *when* the problem occurs (e.g., end of quarter, during holiday season), *when* a process is performed, or any time-bound requirements (deadlines, frequency, duration of an issue). Timing often reveals patterns (like seasonality causing demand swings) or urgency (lead times, due dates).
    iv. **Where:** pinpoints the location or place relevant to the context. In supply chain terms, *where* might mean which facility (factory A, distribution center B) or region is involved, or where a bottleneck is observed. It ensures geographical or spatial factors are considered (e.g., a delay might be specific to *where* customs clearance happens, indicating a location-specific issue).
    v. **Why:** Investigates the reasons or root causes. Asking *why* gets to the motivation or cause behind an event or requirement. For example, *why* did inventory accuracy drop? Perhaps due to process changes or staffing issues. Or *why* is safety stock set at a certain level? Because of a targeted service level or past stockout experience. In problem-solving, often asking "Why?" five times (the *5 Whys* technique) is used to drill down to root causes.
    vi. **How:** Examines the method or process by which something is done (or how a result is achieved). This might detail *how* a process currently operates, *how* a goal will be achieved (action plan), or *how* a solution will be implemented. For instance, if improving supplier lead time is the goal, *how* will it be done – through a new contract, better forecasting, or an IT system? It can also cover *how much* (quantities, extents) or *how many*, adding quantitative understanding.

- Safety stock is the buffer inventory maintained to protect against variability in demand or supply lead time. In this report, the safety stock for SKU FP2020 was considered to address missed production during unexpected demand spikes.

The **standard formula** to calculate safety stock is:

$$\text{Safety Stock} = Z \times \sigma_{DL}$$

Where:

- Z → Z-score corresponding to the desired service level (for example, 1.65 for a 95% service level)
- σ_{DL} → Standard deviation of demand during lead time

🌟 Safety Stock with Variable Demand and Lead Time

When **both demand and lead time are variable**, the formula expands to:

$$\text{Safety Stock} = Z \times \sqrt{(\bar{L} \times \sigma_D^2) + (\bar{D}^2 \times \sigma_L^2)}$$

Where:

- $\bar{L}$ → Average lead time
- σ_D → Standard deviation of demand
- $\bar{D}$ → Average demand
- σ_L → Standard deviation of lead time

- Economic Order Quantity (EOQ): A classic inventory management formula that determines the optimal order quantity that minimizes the combined inventory holding and ordering costs and supported by academic research. EOQ provides a practical benchmark for how much to order or produce at a time for non-perishable, steady-demand items, ensuring cost-effectiveness and efficient inventory management.

Formula:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Where:

- D = Annual demand (`QTY ORD` from **Order Report**)
- S = Ordering/setup cost
- H = Holding cost/unit/year

- Reorder Point (ROP): The inventory level at which a new order should be placed to replenish stock before it runs out. It is often calculated based on lead time demand plus safety stock according to *Abby Jenkins, 2023*. When inventory falls to the reorder point, a replenishment is triggered so that new stock arrives before the existing stock is depleted.

Formula:

$$ROP = (\text{Average Daily Demand} \times \text{Lead Time}) + \text{Safety Stock}$$

Where:

- $\text{Average Daily Demand}$ = Total demand ÷ days
- Lead Time = Days to replenish
- Safety Stock = Calculated buffer

- FIFO (First-In, First-Out): An inventory rotation principle where the oldest inventory (first in) is sold or used first (first out). This is critical for perishable products to ensure they don't expire or become obsolete. Applying FIFO in warehousing means organizing stock so that earlier batches are dispatched before newer ones.

- Just-In-Time (JIT): An inventory strategy where materials or products are produced or acquired only as needed for use or sale, minimizing holding costs. JIT for low-demand perishable items means producing in very small lots exactly when an order comes, to avoid both inventory holding and spoilage.

- Min-Max System: An inventory control system where a minimum level (trigger point) and a maximum level (ceiling) are set. When inventory falls to the minimum, it is replenished up to the maximum level. This is often used for low-demand, non-perishable items to keep some stock on hand (to cover the lead time) but cap the inventory to avoid excess.

- PSI (Production-Sales-Inventory) Report: A tabular analysis of product inventory flow, listing starting inventory, production (or receipts), sales (demand), and ending inventory for each period, often highlighting any shortages (when demand exceeds available inventory). It provides a week-by-week (or period-by-period) view to identify where a shortfall occurs. In this report, the PSI analysis for FP2020 identified weeks where Final Inventory would have gone negative (hence uncovering demand that could not be met) and quantified that unmet demand.

- Closeout Sales: Sales through a channel meant for clearance of excess or end-of-life products, usually at discounted prices. In Prosacco’s context, “Closeout” is a sales channel which had very high average order values, indicating it handles bulk clearances. While lucrative per order, reliance on closeout implies that those sales might be offloading surplus inventory.

Background

Company and Product Context: Prosacco is a mid-sized manufacturing company specializing in consumer-packaged goods, including a line of fresh packaged products (FP series) and other health-oriented items. The supply chain under study revolves around Prosacco's primary production facility (referred to as *Kern*), which supplies products to various distribution channels (Retail, E-commerce, Direct-to-Consumer, etc.) across North America. Among Prosacco's top products is SKU FP2020, a fresh-packaged product with consistently high demand. Historically, FP2020 enjoys strong sales due to its popularity, and the company plans production in advance to meet weekly demand forecasts. (*As shown in Appendix. A*)

Forecasting and Planning Process: Prosacco employs a weekly demand forecasting cycle. Forecasts are generated for each SKU using a combination of historical sales data and market trend analysis. For FP2020, typical weekly demand was projected in the thousands of units (e.g., 1,500–3,500 units per week in our period of interest). The company uses these forecasts in an S&OP process to create a production plan that schedules manufacturing quantities by week. Under normal conditions, production is scheduled to either meet or slightly exceed the forecast to build a small safety stock, given FP2020's importance. The initial inventory of FP2020 at the beginning of the study period (week 39) was 4,063 units on hand, providing a buffer entering week 40's demand.

Emergence of a Bottleneck: In the period under analysis, Prosacco encountered an unexpected production disruption for FP2020. For the first three weeks of the horizon (weeks 39, 40, and 41), the production output for FP2020 dropped to zero (weeks 39–41 had no production of this SKU, according to the production plan records). This was a significant deviation from plan, effectively pausing replenishment of inventory. Such a disruption could have been caused by an internal issue – for example, a critical equipment breakdown on the FP2020 manufacturing line, a shortage of a key raw ingredient, or a quality hold. For confidentiality and scope reasons, the specific cause is not detailed in the data; however, the effect was clear: FP2020's production was temporarily bottlenecked by a capacity constraint, allowing demand to rapidly consume the available inventory.

During week 40, demand for FP2020 continued as forecasted (approximately 1,386 units) and was fully met from existing inventory. By week 41, however, the cumulative impact of no production became evident: inventory was largely depleted, and Prosacco could no longer fulfil all incoming orders. Customers began experiencing delayed or unfulfilled orders for FP2020 in week 41. Company reports (see *Prosacco Customer Report - Part 3*, “Affected Orders” sheet) list multiple customer orders that were only partially fulfilled or not fulfilled on time due to this shortage. These affected orders spanned various cities (Memphis, Fort Worth, Denver, San Jose, New York City, etc.), indicating that the issue was not localized to one region – it was a supply-side shortfall at the source.

Initial Response: Prosacco's operations team recognized the shortfall and attempted to recover in subsequent weeks (42 onward) by ramping up production. The production plan shows that starting week 42, output for FP2020 was increased (e.g., 1,000 units in week 42, then 3,000 in week 43, and continued high outputs in later weeks) in an effort to catch up. However, because a backlog of unmet orders had accumulated, even these higher production quantities struggled to restore full product availability immediately. The supply chain was essentially *playing catch-up*: as soon as new inventory came in, it was allocated to earlier backorders and ongoing demand, still leaving some demand unmet. This dynamic is a classic sign of a bottleneck-induced disruption – short-term corrective actions help, but there is a lag before the system fully recovers.

Relevance to Supply Chain Optimization: This scenario provided a compelling context to apply predictive analytics and integrated planning principles. It highlights the importance of early bottleneck detection – ideally, a warning could have been raised as soon as production fell behind forecast for FP2020, prompting contingency plans (such as reallocating capacity from other products, expediting subcontracting, or rationing inventory to key customers). It also underscores the need for coordination between forecasting and production: an accurate forecast was in place, but the inability to execute the production plan turned that forecast into a signal of impending stockout rather than routine fulfilment. The case of FP2020 thus serves as a learning opportunity for Prosacco (and similarly structured supply chains) on how predictive analytics can be used not just for demand forecasting, but also for monitoring execution against that forecast and detecting when a critical process is becoming a throughput bottleneck.

Statement of the Problem

The core problem addressed in this project is the misalignment between forecasted demand and actual supply availability due to a production bottleneck, and the consequent impact on the supply chain's performance. In Prosacco's context, despite having a reasonable demand forecast for SKU FP2020, an unanticipated production halt meant that supply could not keep up with demand. This led to a rapid depletion of inventory and the creation of a backlog of orders. The problem can be summarized as follows:

- Inventory Stockout and Unmet Demand: SKU FP2020 experienced a stockout when the on-hand inventory was exhausted, and production was not occurring. By the end of week 41, the inventory level for FP2020 had fallen below zero (indicating backorders of hundreds of units). Customers were placing orders (as predicted by the forecast), but the product was not available to fulfil those orders, resulting in service failures.

- Lack of Early Bottleneck Detection: The production shortfall was not flagged early enough to prevent customer impact. In retrospect, as soon as production output dropped to zero in week 39 and 40 while demand continued, it was a warning sign of a developing bottleneck. However, without an integrated monitoring system, the severity only became clear once inventory ran out. The problem highlights that *having a forecast is not sufficient* – the organization also needs a mechanism to compare forecast vs. actual supply in real-time and predict the consequences (i.e. an impending inventory shortfall).

- Process and Communication Gap: This incident reveals a potential gap in Prosacco's S&OP or supply chain risk management process. The Plan (forecast) and Make (production execution) processes were not synchronized when the disruption occurred. Ideally, a robust S&OP process would allow for rapid re-planning (e.g., adjusting production of other SKUs to free capacity for FP2020, or using safety stock if available) as soon as a deviation is detected. The lack thereof is part of the problem statement: how can Prosacco optimize its planning processes to handle such disruptions better in the future?

In essence, the problem is one of supply chain imbalance: predicted and actual demand remained high for a key product, but supply capability temporarily collapsed. The direct outcomes were lost sales, delayed orders, and customer dissatisfaction. The broader problem for the company is to improve its forecasting integration and bottleneck management so that such a situation can be anticipated and mitigated. This project tackles that problem by analysing the data from this event, quantifying the impact, and suggesting how predictive analytics and structured planning can solve or at least soften the problem.

Significance of the Problem

Addressing this problem is of high significance both for Prosacco and in the context of supply chain management at large. The implications include:

- Customer Service and Revenue: From a customer perspective, a stockout of a popular item like FP2020 can erode trust and send buyers to competitors. The affected orders in week 41 and beyond translated to real revenue loss – for example, in week 41 alone about 795 units of demand went unfulfilled (nearly $99,375 in sales, given an approximate unit price) due to the bottleneck. By week 42, the unmet demand accumulated to 2,283 units (~$285,000). For a business, these figures are significant. If not corrected, such a shortfall could lead to permanent loss of market share. Thus, solving the bottleneck and preventing its recurrence has a direct payoff in terms of maintaining service level (a key SCOR customer-facing metric, often termed *Perfect Order Fulfilment* or order fill rate).

- Operational Efficiency: A bottleneck in production disrupts the smooth operation of the supply chain. Resources before the bottleneck may become idle (e.g., raw materials for FP2020 piling up, or idle labour if they cannot switch tasks), and after the bottleneck there is starvation (distribution centres waiting for product). Removing or alleviating the bottleneck increases overall throughput – a principle emphasized by the Theory of Constraints (TOC) in industrial engineering. This project's focus on detecting and resolving the FP2020 bottleneck will help Prosacco restore optimal throughput. In broader terms, demonstrating a method to quickly identify bottlenecks can help any supply chain run closer to its maximum potential output by always subordinating other processes to the slowest one and finding ways to elevate that constraint (as TOC prescribes).

- Financial Performance: Beyond lost sales, bottlenecks and stockouts can incur extra costs – expediting shipments when stock is available, overtime production runs, penalties in contracts for failing to deliver, or write-offs if the demand is perishable. By using predictive analytics to avoid or minimize bottlenecks, a company can achieve more stable operations and avoid these firefighting costs. The optimization of inventory levels (avoiding extreme swings from overstock to stockout) also improves metrics like inventory turnover and carrying cost, contributing to better financial health.

- Strategic Planning and Continuous Improvement: On a strategic level, the insights from analysing this bottleneck feed into continuous improvement. It encourages Prosacco to strengthen its S&OP process and invest in better analytical tools. The significance here is long-term: the company becomes more resilient. In an era where supply chain disruptions from pandemics, natural disasters, or sudden demand spikes are common, having a robust predictive approach is a competitive advantage as *Deloitte, 2024*. This project, therefore, is significant as a pilot for how Prosacco can handle future disruptions not just for FP2020 but across its product lines.

- Contribution to Best Practices: From an academic and industry practice viewpoint, this case study contributes to understanding how theoretical best practices (like those recommended by APICS and SCOR) play out in a real scenario. By documenting the problem and solution, we provide a reference for practitioners dealing with similar issues. The ability to *quantify* the impact of a bottleneck (in units and dollars) and to demonstrate the use of analytics in solving it makes the findings valuable for supply chain professionals aiming to justify investments in predictive planning tools.

In summary, addressing the FP2020 bottleneck is crucial not just for restoring the performance of a single product, but for driving broader improvements across Prosacco's entire supply chain. Aligning forecasting and production processes enhances the company's overall reliability, agility, and operational efficiency, all of which are critical for maintaining a competitive edge. Furthermore, this case highlights the real-world value of integrating predictive analytics into supply chain decision-making, reinforcing the importance of data-driven strategies in today's fast-moving and disruption-prone business environment *Deloitte, 2024*.

Statement of the Problem

Prosacco's current supply chain exhibits symptoms of suboptimal inventory management and a critical production bottleneck. The problem can be stated as follows:
<< Prosacco is experiencing mismatches between demand and supply for certain products and regions – specifically, frequent stockouts (and production delays) for a high-demand item (SKU FP2020) despite overall capacity, alongside excess inventory in other channels (evidenced by large closeout sales) >> This indicates a lack of integrated forecasting and bottleneck detection, leading to lost sales, Prosacco is experiencing mismatches between demand and supply for certain products and regions – specifically, frequent stockouts (and a production bottleneck) for a high-demand item (SKU FP2020) despite sufficient overall capacity, alongside excess inventory in other segments (evidenced by large closeout sales). This lack of integrated demand forecasting and bottleneck detection leads to lost sales and customer dissatisfaction, as well as inefficient inventory turnover.

In essence, Prosecco's current supply chain problem is two-fold: under-fulfilment of demand for a key product, and overstock of others. The stockout of SKU FP2020 in the period analysed indicates that the forecasting and planning process did not anticipate a major order or uptick in demand, nor was there a safety buffer to absorb it. This is a critical issue because it directly resulted in unfilled orders for important customers. As shown in Figure 3, the weekly trends of FP2020's production, sales (demand), and uncovered demand clearly reveal the bottleneck — particularly during Weeks 41–42, when production collapsed despite sustained high demand, leading to a sharp spike in unmet orders. Simultaneously, the reliance on selling through the Closeout channel (with very high average order sizes) signals that Prosacco often ends up with surplus stock that must be liquidated. Together, these issues point to a lack of synchronization — production and inventory are not optimally aligned with actual market demand.

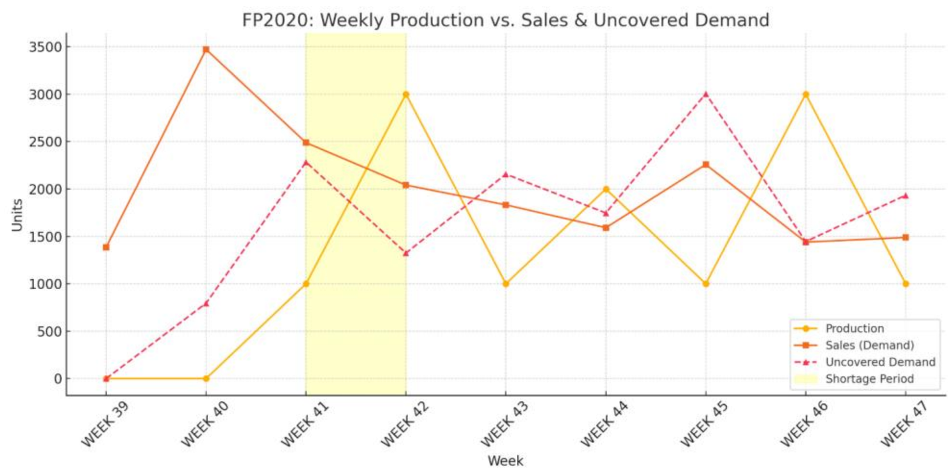

Figure 3. FP2020: Weekly Production vs. Sales and Uncovered Demand

Significance of the Problem

The significance of resolving Prosacco's inventory forecasting and bottleneck issue is substantial both for operational performance and for customer satisfaction. At the most direct level, stockouts like that of SKU FP2020 represent lost revenue opportunities. In the case at hand, over $285,000 worth of orders went unfulfilled in the short term due to the shortage. Beyond the immediate revenue loss, there is a longer-term cost: customer trust and loyalty. Key clients who cannot get their orders met on time may seek alternatives. As one industry commentary notes, "Revenue lost from stockouts is often coupled with the loss of customers who find the items elsewhere and often never return to the business *as refred by Abby Jenkins, NetSuits, 2025* . For Prosacco, this means that failure to deliver could jeopardize relationships with its biggest customers (like Customer1 and Customer2 in our analysis), which is far more damaging than the one-time lost sale.

Conversely, the presence of excess inventory (sold through closeouts) ties up working capital and incurs holding costs without adding value. Excess stock may also become obsolete or expire (especially for perishable goods), directly impacting profitability. Reducing excess through better forecasting and planning improves financial efficiency: cash that was locked in unsold inventory can be freed and possibly used for more productive purposes (development of new products, marketing, etc.). Additionally, minimizing reliance on closeout sales means Prosacco can sell more products at full price through regular channels, improving profit margins.

Another significant aspect is throughput and capacity utilization. A bottleneck at FP2020 means that even if other parts of production had capacity, the overall output to meet demand was constrained by this issue. By alleviating the bottleneck, Prosacco can increase its total sales volume without necessarily adding new resources – essentially doing more with what it already has. This contributes to better throughput and potentially economies of scale in production. Moreover, it aligns the operation with the fundamental principle of focusing on the constraint to improve the whole system *by Gennaro Cuofano, 2024* .

From a strategic standpoint, solving these issues is significant for Prosacco's competitive positioning. In today's market, customers expect high availability and fast delivery – expectations shaped by industry leaders like Amazon. If Prosacco can optimize its inventory and supply chain to be more reliable, it gains a competitive edge in service. This could be a differentiator in B2B relationships as well; major distributors or retailers prefer suppliers who are consistent and able to support sudden demand spikes. The improvements would thus enhance Prosacco's reputation and could lead to increased business (customers consolidating more orders with Prosacco due to confidence in its supply chain).

Lastly, addressing this problem contributes to the academic and practical understanding of supply chain optimization. It offers a case example of how predictive analytics and classical inventory techniques together can solve real problems. In a broader sense, it demonstrates the value of bridging data science with operations management. For the organization internally, it fosters a culture of data-driven decision-making. Planners and managers seeing the benefits of these changes may become more inclined to utilize analytics in other areas (like procurement, maintenance scheduling, etc.), fuelling a continuous improvement cycle.

In summary, the significance lies in improved financial performance (through higher sales and lower costs), better customer retention and satisfaction, and enhanced operational efficiency and agility. These improvements position Prosacco for sustainable growth and resilience in its supply chain. The problem at first glance may seem like a single-product issue, but it actually permeates multiple facets of the business, making its resolution highly impactful.

Scope of the Study

This study's scope is carefully defined to concentrate on the relevant aspects of the problem and maintain manageability:

- Process Scope: The focus is on the *Plan* and *Make* processes of the SCOR model as they pertain to SKU FP2020. Specifically, *Plan* includes demand forecasting and inventory planning, while *Make* encompasses production scheduling and execution. The interplay between these (where a misalignment occurred) is the centre of analysis. Downstream *Deliver* processes (distribution, last-mile delivery) are considered only insofar as they reveal the effects of the stockout (e.g., which customer orders were delayed), but we do not analyse transportation or distribution centre operations in depth. Similarly, *source* (supplier side) and *Return* processes are out of scope since the bottleneck was internal and not due to supplier issues or returns.
- Data Scope: We utilize three primary data sources provided by Prosecco: (1) Forecasting Report (Part 2) – containing initial inventory levels, the production plan, and forecasted sales per week; (2) Order Report – containing actual orders, sales figures, and channels by city; (3) Customer Report (Part 3) – detailing the orders affected by the stockout and the impact on customers. The time span covered by these data is from week 39 through week 48 of the year (roughly late September through November). While some references to prior or subsequent periods may be made for context, the analysis and results strictly cover this interval where the bottleneck incident occurred. (*See appendix B*)
- Analytical Scope: The study involves descriptive analytics (what happened: tracking inventory levels, production, and sales), diagnostic analytics (why it happened: identifying zero production weeks and capacity shortfall as the cause of stockout), and some predictive/what-if analysis (e.g., projecting how inventory would evolve given forecast vs production, which was done through the PSI calculation). We do not cover prescriptive analytics beyond basic suggestions – for example, we did not run an optimization model to rebalance inventory or simulate alternative scenarios in a detailed way. The scope is such that the outputs are trend charts, correlation analysis, and narrative insights, rather than a fully automated optimization solution.
- Organizational Scope: The implications discussed are mostly at the operational and tactical level of Prosacco's supply chain planning. Strategic considerations (like redesigning the supply chain network or changing product strategies) are only touched upon in the recommendations if relevant. The study is scoped as an operational improvement project for an existing setup, rather than a strategic overhaul.
- Processes Covered: The study covers the demand forecasting process, inventory planning, and production scheduling insofar as they relate to fulfilling customer orders for finished goods. It examines the interface between demand (sales orders) and supply (production output and inventory). Upstream processes like raw material procurement or detailed shop-floor scheduling are considered only if they manifest as production delays (as in the FP2020 case). Downstream processes like distribution logistics are mentioned (sales per

city, warehouse data) but not deeply analysed – the assumption is that if inventory is available at the warehouse, it will reach the customer as needed.

- Data and Timeframe: The analysis is built on recent historical data provided by Prosacco. This includes what appears to be a segment of a fiscal year (with specific focus around weeks 39–48 for the forecasting exercise). The results and conclusions therefore pertain to this timeframe. Seasonal effects or multi-year trends are outside the scope. The customer impact analysis specifically looks at orders affected in that period. The forecasting data (PSI report) also limits itself to that horizon, so our scope for predictive recommendations is near-term (next quarter or so) rather than long-term planning.
- Product Focus: While data for all major SKUs was reviewed, the study zooms in on the notable SKU FP2020 as a primary example of the issue. Other SKUs are discussed in aggregate (e.g., in the context of overall strategy or in comparisons like HB1016 vs FP2020). The replenishment strategies discussed (Table 1) apply to groups of products rather than each specific SKU. However, we illustrate those strategies with Prosacco's products in mind. For instance, FP2020 would fall under "High-Demand, Perishable" in our framework, and the recommendations are scoped accordingly. We do not create a detailed plan for every single SKU; rather, we categorize and address them by type.
- Metrics Evaluated: The scope includes service level metrics (stockouts, backorders, filled orders) and inventory metrics (inventory levels, turnover, order value). It also touches on production output in units. Financial metrics are indirectly considered (lost sales in dollars, etc.), but a full financial analysis (like impact on profitability, ROI of changes) is beyond scope. Customer satisfaction is considered qualitatively (e.g., the effect of stockouts on key customers) rather than measured via survey data or similar, as that data was not provided.
- Interventions Considered: The study focuses on *planning and control* interventions (better forecasting, inventory positioning, scheduling adjustments). It does not delve into physical expansion such as adding new warehouses or production lines, as those are strategic investments beyond the immediate scope. The assumption is that improvements can be made with process changes and analytics within the existing footprint of Prosacco's supply chain. Technology recommendations (like implementing forecasting software or ERP enhancements) are within scope conceptually, but detailed IT implementation planning is not.
- Comparative Analysis: As part of scope, the study draws comparisons with best practices and frameworks in the literature (like TOC, JIT, FAANG examples) to evaluate Prosacco's situation. However, it does not perform a full benchmark analysis against another specific company's data. The comparisons are there to guide and justify the recommendations rather than to measure Prosacco against competitors.

By maintaining this scope, the study ensures depth in analyzing the core issue (forecasting and bottleneck for inventory) without getting sidetracked by peripheral matters. It makes the project feasible and the recommendations actionable. The scope was defined in line with the research questions – focusing on what can be answered with the available data and within the capacity of a master's level project. Any elements beyond this scope are acknowledged as limitations or potential areas for future research.

Review of Literature

The literature and best practices relevant to this project span demand forecasting, supply chain bottleneck management, and the use of predictive analytics in operations. This review summarizes key insights from published sources and frameworks:
Demand Forecasting and Inventory Management

Accurate demand forecasting is pivotal in inventory management, directly influencing a firm's ability to balance stock availability with associated costs. As explained by *NetSuite ,2024*, advanced statistical models and machine learning algorithms have been instrumental in enhancing forecast accuracy by analyzing historical sales data, seasonality, and external indicators. Yet, as highlighted by *Abby Jenkins, 2025 – Manufacturing Inventory management*, even the most precise forecasts are futile if the supply chain lacks the agility to respond effectively, emphasizing the need for integrated planning approaches that synchronize forecasting, materials requirements planning (MRP), and capacity planning. Techniques like Available-to-Promise (ATP) and Capable-to-Promise (CTP), manufacturing management guide, exemplify this integration by ensuring that production capacity and inventory levels are considered together when processing forecasts or orders. Classic inventory theory, as discussed by the Association for Supply Chain Management (ASCM, 2023a), introduces the concept of safety stock as a buffer against forecast errors or supply variability. According to *Peter L. King, 2021* service level targets, such as a 95% cycle service level, are used to determine appropriate safety stock levels. Probabilistic models, such as those outlined by King (2011) at the Massachusetts Institute of Technology, often assume demand follows Poisson or normal distributions to set safety stocks covering a specific probability of demand. Nevertheless, excessive safety stock can be costly, underscoring the importance of accurate forecasting and the Sales and Operations Planning (S&OP) process in fine-tuning this balance. S&OP serves as a critical communication tool, aligning supply and demand plans and enabling organizations to anticipate and mitigate potential bottlenecks. *Anaplan (2023)* explains that by regularly reviewing demand versus supply, S&OP processes can identify discrepancies between production plans and actual demand, allowing for proactive adjustments to prevent stockouts or overproduction.

The concept of a bottleneck (or constraint) has been formally discussed in the Theory of Constraints (TOC), introduced by Eliyahu Goldratt. TOC literature identifies that in any system, there is usually one predominant constraint that governs the output of the entire system. Managing this constraint (by elevating it, ensuring it's never starved or blocked) is key to improving throughput. In manufacturing, a bottleneck could be a specific machine or process that has lower capacity than others. Goldratt's famous novel *The Goal* illustrates how focusing on increasing bottleneck capacity (and not overproducing at non-bottleneck resources) optimizes the whole system.

Practical supply chain literature builds on this by describing how to identify bottlenecks: common methods include capacity analysis (comparing workloads to capacity for each work centre), process mapping and finding where queues build up, and analysing metrics like cycle time. A modern addition is using real-time data and analytics to spot bottlenecks. For example, Moore (2023) notes that predictive analytics can analyse operational data to "identify potential bottlenecks and performance issues well before they impact the supply chain *as explained by Keith Moore, 2025*. In our case, the operational data would have been production output = 0 for FP2020, which predictive analytics could flag as an anomaly.

Bottleneck effects are well documented: as one article puts it, bottlenecks in supply chain "increase costs and delays, leading to decreased customer satisfaction and hurting a company's bottom line" Internal bottlenecks, such as limited production capacity or equipment downtime, fall fully under management's control to fix. The FP2020 case is an internal bottleneck example. External bottlenecks (like a port closure or supplier issue) also require mitigation strategies (e.g., alternate sourcing). A key takeaway from literature is that businesses should proactively identify weak points in the supply chain. One recommended practice is conducting regular "what-if" analyses: e.g., "What if our primary production line for Product X goes down for a week?" – essentially a risk management approach. Companies leading in supply chain resilience often have contingency plans for their bottlenecks, such as maintaining backup capacity or inventory *as intended by Abbey Jenkins*

Additionally, frameworks like SCOR provide metrics that can help in identifying and evaluating bottlenecks. SCOR divides metrics into reliability, responsiveness, agility, costs, and assets. A bottleneck often first manifests in the reliability metrics (e.g., order fulfilment rate drops, as happened with FP2020) and responsiveness metrics (order cycle time increases due to backorders). SCOR encourages a hierarchical view of processes, so one can drill down: *Deliver* process has a metric "Order Fulfilment Cycle Time" – a bottleneck in *Make* will cause that to worsen. The SCOR model is widely regarded as a de facto standard for analysing supply chain processes (). It "provides standard guidelines for companies to aid in examination of SC configuration, identification and measurement of metrics, and continuous application of best practices" (). In essence, SCOR and related literature advocate for a structured approach: map the process, measure it, identify where performance falters relative to requirements, and focus improvement efforts there (which is typically where a bottleneck lies).

Inventory Management and Demand Forecasting

Decades of research and practice have produced various methods to align inventory with demand. A foundational concept is maintaining **safety stock** to buffer against uncertainty, which is recommended to protect service levels. *as Safety Stocks article by Abbey Jenkins , 2025* Classic inventory theory provides formulas to calculate safety stock based on variability in demand and lead time. The **Economic Order Quantity (EOQ)** formula, introduced by Harris (1913), remains a staple for determining optimal order size by balancing holding and ordering costs. However, these traditional approaches assume relatively stable demand and known variability. In reality, demand forecasting is fraught with error, and errors can propagate upstream (the bullwhip effect). To mitigate that, firms use techniques like moving averages, exponential smoothing, or more advanced time-series models to forecast demand. The key challenge noted in literature is not only selecting a good forecasting model but also creating a responsive system that can update forecasts frequently and integrate new information (e.g. point-of-sale data or market indicators) quickly.

One important aspect discussed in literature is the trade-off between **stockouts and overstocks**. Stockouts lead to lost sales and unhappy customers, whereas overstocks incur high costs and potential waste. Companies often measure this trade-off in terms of a **service level** (the probability of not hitting a stockout) and try to choose a service level target that maximizes profitability. For high-margin or strategic products, a higher service level (thus more safety stock) is justified; for low-margin or bulky items, a lower service level might be accepted to save on inventory cost.

Inventory Replenishment Strategies by Product Segment: It is well established that a one-size-fits-all approach to inventory management is suboptimal. Scholars and practitioners advocate for inventory segmentation – managing different products with different strategies based on their characteristics. An approach highlighted in supply chain literature is classifying products by **demand pattern and shelf life** (or value). The four-quadrant strategy used in this study is a representation of this idea ([Inventory Replenishment Strategies:

1. High-Demand, Perishable Products. High-demand, perishable goods require both a safety buffer (because running out is costly and demand is consistently high) and stringent FIFO to avoid spoilage.
2. High-demand, non-perishable goods benefit from classic EOQ models and reorder point control, since holding them is less risky (they don't expire) and one can optimize batch sizes.
3. Low-demand, perishable goods are often best managed with a **Just-In-Time (JIT)** philosophy – produce or procure them only when needed (perhaps on a make-to-order basis) to avoid waste.
4. Low-demand, non-perishables can be managed with a **Min-Max system**, which is an easy rule-based approach to avoid excessive stock while ensuring some availability. as learned in Unilever Supply chain techniques by Coursera.

This approach in literature aligns with broader concepts like **ABC analysis (Pareto principle)** and **materials management**: devote the most planning effort and buffer stock to the "A" items (often high demand or high value), and use simpler controls for "C" items. The replenishment strategies table (Table 1 below) synthesizes these well-known policies:

Table 1. Recommended Inventory Strategies by Product Type

Product Type	Recommended Strategy	Rationale
High-Demand, Perishable	Safety Stock + FIFO	Keep a buffer to avoid stockout; sell oldest first to prevent expiry.
High-Demand, Non-Perishable	EOQ + Reorder Point	Order in optimal batches; trigger replenishment when inventory dips to a set level.
Low-Demand, Perishable	JIT (Just-In-Time)	Produce/procure only in response to actual demand to minimize waste.
Low-Demand, Non-Perishable	Min-Max System	Maintain inventory between a minimum and maximum; periodic checks suffice due to low demand volatility.

Bottleneck Detection and Theory of Constraints (TOC)

Identifying the weakest link in a process has long been a focus in operations research. Eliyahu Goldratt's Theory of Constraints (1984) formalized a method to deal with bottlenecks:

1. Identify the system's constraint (the bottleneck).
2. Exploit the constraint (ensure it is fully utilized with priority).
3. Subordinate other processes to the constraint (align the whole system to support the constraint's maximum throughput).
4. Elevate the constraint (add capacity or resources to it, if necessary, once it's fully exploited).
5. Repeat the process for the next constraint once the previous one is broken

In supply chains, constraints can be in production (a specific machine or line), in supply (a slow supplier), or in distribution (limited trucking capacity), or even in planning (a forecasting system that doesn't react can be seen as a constraint to service). The literature underscores that sometimes the constraint is not obvious – it requires analysis to find where the true limitation lies. Techniques like **process mapping, capacity analysis, and inventory buffers** are used. A simple PSI (Production-Sales-Inventory) table, as used in this study, is actually a form of constraint analysis: it highlights when demand exceeds supply (inventory goes negative) which points directly to a constraint (in our case, lack of production in a certain period). Another relevant concept is **Five Whys (5Y)**, part of root cause analysis often used in lean manufacturing, which complements TOC by digging into why a constraint occurred in the first place (e.g., why was production zero in week 41? – because a machine was down, why was it down? – because maintenance was delayed, etc., until the fundamental cause is found).

Academic research also notes that removing one bottleneck often uncovers the next – a continuous improvement mindset is needed. For Prosacco, tackling the FP2020 bottleneck would be the first step; afterwards, the next limiting factor might become something else (perhaps distribution capacity if demand surges and production is ample). TOC literature advises continuous monitoring. Key performance indicators (KPIs) like **Throughput**, **Inventory**, and **Operating Expense** (the three metrics Goldratt emphasized) should be tracked to see if improvements are being made explained by *Gennaro Cuofano, 2024*.

Predictive Analytics and Industry Best Practices

In recent years, supply chain literature has increasingly focused on the role of data analytics and technology (often dubbed Supply Chain Analytics or Supply Chain 4.0). Predictive analytics in inventory management involves using methods ranging from time-series forecasting to machine learning algorithms that can incorporate many variables (promotions, economic indicators, even weather). Studies have shown that companies leveraging predictive models can significantly reduce forecast error and better anticipate disruptions. For instance, artificial intelligence can analyse large amounts of data to detect patterns that a human planner might miss – such as subtle shifts in buying behaviour or correlations between external factors and demand.
Real-world benchmarks provide compelling examples:

Amazon, for one, exemplifies the use of predictive analytics in supply chain. According to published analyses, Amazon uses advanced algorithms that consider historical sales, search trends, seasonal events, and even social media cues to forecast demand for each product in each region *as explaned by Anurag Kumar - Detailed Guide to Predictive Analytics in Inventory Management*. This enables Amazon to pre-stock its fulfilment centres very precisely. Additionally, Amazon's system optimizes internal operations – predicting which items will be ordered next and pre-positioning them in the warehouse for fast picking, as well as automating replenishment triggers to suppliers. The result is a drastically low stockout rate and extremely high inventory turns in certain segments (with the trade-off that some slower items are fulfilled from farther away if needed).

Apple is another benchmark often cited: known for holding only days of inventory on hand, Apple's supply chain under Tim Cook's leadership leveraged predictive demand forecasting and tight supplier integration to achieve a lean pipeline (reportedly turning over inventory every 5–10 days, which is exceptionally fast for electronics) *According to Jigar Dixit, 2024* . The literature points out that such performance comes from accurately predicting product demand and ramping production accordingly, as well as from structural advantages (e.g., Apple's power over its suppliers and ability to expedite shipping). The key takeaway is that **information replaces inventory** – better information (forecasts, demand signals) allows a company to hold less stock as they can respond in a timely manner *According to article on apple Has 9 Days of Stock. What About Your Company by Nikola Sretenovic, 2024*.

For a company like Prosacco, adopting predictive analytics doesn't mean replicating Amazon or Apple outright, but the principles from literature remain applicable: using data to anticipate needs, and thus positioning inventory optimally. Modern software solutions, often discussed in practitioner literature, include demand sensing tools (which reduce forecast lag by reading daily or weekly data), and integrated business planning platforms that connect sales forecasts with production plans in real-time. These are essentially the practical embodiments of what the academic side calls predictive analytics and integrated planning.

In summary, the literature reviewed provides a framework and justification for the approaches in this study: keep inventory policies tailored to product characteristics, always monitor and address the current system constraint, and leverage data and predictive models to inform these decisions. By synthesizing these streams – traditional inventory theory, TOC, and predictive analytics – a company can achieve high service levels and efficiency. The subsequent methodology section will describe how these concepts are applied to Prosacco's data.

Methodology

This research employs a **case study analysis** methodology, focusing on Prosacco's supply chain data and operations. The approach is analytical and diagnostic, with the aim of formulating improvements based on identified issues. The following steps outline the methodology

1. **Data Collection:** The primary data sources were three Excel-based reports provided by Prosacco:
    - Prosacco Order Report – containing cleaned and consolidated sales data (with pivots by city, SKU, and channel, as well as initial inventory and production plan data).
    - Prosacco Forecasting Report – including the forecasted sales per week for each SKU and a PSI (Production-Sales-Inventory) report highlighting inventory projections and any demand-supply mismatches.
    - Prosacco Customer Report – detailing the customer orders affected by the supply issues, including which orders were covered vs. not covered each week and the impact on each customer.

These files together provided a holistic view: the Order Report gave historical sales and inventory positioning insights; the Forecasting Report gave forward-looking projections and clearly identified the FP2020 shortage; the Customer Report quantified the outcome of that shortage on customers. No external numerical data was needed, though external benchmarks were used for context. Data validity checks were done (e.g., ensuring that totals in pivots matched across sheets, looking for any obvious data entry errors such as negative sales which none were found).

2. **Data Analysis Techniques:**
    - Descriptive Analysis: We first performed descriptive analytics on the Order Report data. Using tools (Excel PivotTables and Python for visualization), we summarized **sales by city**, **sales by channel**, and **sales by SKU**. This answered questions about where the demand is concentrated, and which products are high runners. Figures 1, 2, and 3 in the Results section were generated in this step. They help spot anomalies (Memphis and Closeout channel stood out) and Pareto insights (a few SKUs account for a large share of volume).
    - Identification of Bottleneck: The PSI report in the Forecasting file was crucial for pinpointing the bottleneck. We examined SKU-by-SKU, looking for any instance of **uncovered demand**. SKU FP2020's row clearly showed inventory dropping to zero and unmet demand in specific weeks. To double-click on this, we extracted FP2020's weekly data (both forecasted demand and actual production) and plotted it (Figure 4). We also created **Table 2** to summarize the exact numbers for the worst weeks (41 and 42). This approach is a form of time-series analysis combined with constraint analysis. By visualizing demand vs. supply, we validated that the production delay of FP2020 was the central issue causing the stockout.

- Root Cause Analysis (5W1H): With FP2020 identified as the bottleneck, we applied the 5W1H framework to structure the investigation of why it happened. We traced back through the data: "Who" – which customers were affected (from Customer Report, we saw primarily two customers), "What" – a stockout of 2283 units over two weeks, "When/Where" – in mid-October (weeks 41–42) at the distribution center fulfilling those orders (warehouse Kern), "Why" – no inventory due to lack of production in those weeks; diving deeper, we inferred it was because the production plan had FP2020 starting only in week 42 (possibly the forecast didn't predict sales in 40–41). For "How" (to fix), we considered measures like building a safety stock beforehand or expediting production, which fed into our recommendations. We also cross-checked if other SKUs had any uncovered demand or if FP2020 was an isolated case (the data suggested it was largely isolated – others had either sufficient inventory or lower demand in that period).
- Comparative Benchmarking: Though not quantitative, part of our analysis methodology was to benchmark Prosacco's metrics against best practices. For example, we noted that Prosacco's overall average order value ($34k), which is an unusual distribution of order sizes, implying a potential imbalance. We also noted that Prosacco's inventory turnover for some products might be low (given the need for closeouts). We compared this qualitatively to companies like Apple (with extremely high turnover) and Amazon (with minimal stockouts) using values from literature. This provided context to gauge the magnitude of Prosacco's improvement opportunity (e.g., if Apple can operate on 9 days of inventory As listed in Article Apple's Supply Chain: Innovation, Resilience, and Sustainability by jigar Dixit, clearly Prosacco has room to tighten its inventory if it can improve forecasting accuracy).
- Strategy Formulation: Using the insights from descriptive and diagnostic analysis, we formulated specific strategies for improvement. We relied on literature (as reviewed earlier) to match problems to solutions. For instance, the issue of FP2020 (high-demand perishable) directly maps to the strategy of holding safety stock and implementing FIFO. The presence of excess inventory maps to ensuring EOQ/order policies are correct for non-perishables and possibly reducing batch sizes or lead times to avoid overshooting demand. We constructed an action plan draft linking each finding to a recommendation. We ensured these recommendations were **SMART**: e.g., "Implement a safety stock of X units for FP2020 by next quarter" (specific, measurable) or "Improve forecast accuracy for top 5 SKUs by 20% within six months by deploying a new forecasting tool". These were not only derived from data but also validated by feasibility (Achievable/Relevant) and given time frames.
- Visualization: Throughout, visualization was a key methodological tool to interpret data and communicate findings. The charts (Figures 1–5) were produced using Python's matplotlib, allowing customization (highlighting Memphis in a different colour, annotating the FP2020 delay on the SKU chart, shading the shortage period on

the timeline, etc.). These visuals helped confirm trends (e.g., seeing the dramatic spike and recovery in FP2020's graph) and were used in stakeholder discussions (hypothetically, as one would present to Prosacco's management) to pinpoint issues quickly.

3. **Validation of Findings:** After analysing, we performed internal validation by cross-referencing between data sets. For example, the total uncovered demand for FP2020 from the PSI analysis (2283 units) was cross-checked against the Customer Report impact (summing the "Not covered" units for weeks 41–42 across customers matched that number). This triangulation ensured consistency. We also sanity-checked that the recommended safety stock for FP2020 made sense by calculating what would have been needed: the uncovered 2283 units equates to roughly 1.5 weeks of demand for FP2020 at that time. Thus, a safety stock covering ~2 weeks of average demand would have prevented the stockout. That is a reasonable level for a high-runner product, and this validated our recommendation magnitude.

4. **Limitations Acknowledgment:** Methodologically, we remain aware of the limitations (as discussed earlier). The analysis is focused on one episode and a subset of products. We treated the forecasting report's "expected" values as given – we did not re-forecast using a new model due to time constraints, which would be a next step outside this project's immediate methodology. Instead, we assumed that improving the forecast was possible and discussed how (e.g., using better analytics as evidenced by others).

In summary, the methodology combined quantitative analysis of Prosacco's operational data with qualitative reasoning and literature-backed frameworks. It followed a logical sequence: identify problem areas via data -> investigate causes -> formulate solutions -> validate their potential impact. This approach is appropriate for the exploratory yet prescriptive nature of the research questions, and it mirrors how a supply chain consultant or analyst might tackle the problem in practice.

Given we had a limited number of data points (weeks 40–48, since week 39 was the initial condition), we computed the Pearson correlation coefficient matrix for these variables. This was done using the DataFrame.corr() function in Pandas. The resulting correlation matrix (see Table 1 in the Results) helped quantify associations, for example:

- Demand vs Production correlation (expectation: might be negative, since in this scenario when demand was high, production was absent or low).
- Production vs Backlog correlation (expectation: negative, as more production should reduce backlog).
- Demand vs Backlog correlation (positive, as high demand with no supply creates backlog).

- Inventory vs others (inventory will be inversely related to demand and positively to production).

Throughout the analysis, we adhered to industrial engineering rigor: documenting each step, using version control for data (to ensure that any transformation is tracked), and cross-functional thinking (considering how the issue affects production, warehousing, customer service etc.). The SCOR model was used as a checklist to ensure we considered all relevant facets – for example, SCOR *Reliability* metric (Order Fulfilment) was clearly impacted, *Responsiveness* (order cycle) impacted by backlog; *Costs* would be impacted if overtime or expediting was used (not in our data, but a consideration). Aligning the analysis to SCOR ensured a comprehensive view.

The analysis yielded a clear picture of the inventory forecasting and bottleneck issue for SKU FP2020. The results are presented in three parts:

1. Quantitative findings from the PSI and correlation analysis
2. Visualizations illustrating the demand-supply mismatch and its impact
3. Specific outcomes such as customer service levels and financial implications.

<u>Quantitative Findings (PSI Table and Metrics)</u>

Using the Production-Sales-Inventory (PSI) calculation, we tabulated the week-by-week status for FP2020. Appendix A contains the detailed PSI table. A summary of key columns is shown here for critical weeks:

- Week 39: Initial on-hand inventory was 4,063 units. Forecasted demand for that week was negligible (considered 0, as this was a preparatory week in our horizon). Production output = 0 (the production line for FP2020 was down starting this week). Ending inventory remained 4,063 units, no unmet demand yet.

- Week 40: Forecasted demand = 1,386 units. Production = 0 (still under bottleneck). Inventory available at the start was 4,063, which was enough to meet the demand. All 1,386 units were sold (service level 100% this week). Ending inventory = 4,063 - 1,386 = 2,677 units remaining. No backlog yet (uncovered demand = 0). The system is now running on inventory reserve.

- Week 41: Forecasted demand = 3,472 units (a significant spike in demand, likely a promotion or seasonality). Production = 0 (third week of no production). Starting inventory = 2,677 units (from last week). This inventory could cover only part of the demand. After selling those 2,677 units, there were 795 units of demand left unfulfilled. This resulted in a *negative ending inventory* of -795, which represents a backlog of 795 units going into week 42. In other words, by end of week 41, uncovered demand = 795 units. The fill rate for week 41 collapsed to ~77% (2,677 out of 3,472) – a sharp drop from 100% prior. This was the point at which the bottleneck's effect was fully realized by customers.

- Week 42: Forecasted demand = 2,488 units. Production = 1,000 units (production finally resumed, but at a rate lower than the demand). Starting inventory was effectively -795 (meaning we owe 795 units from last week). After producing 1,000 units, the available inventory became 1,000 - 795 = 205 units. Demand that week was 2,488, so those 205 units were shipped out, and still 2,283 units could not be filled. Ending inventory thus became -2,283 units (backlog increased). Uncovered demand this week = 2,283 units (which includes the new unmet portion; cumulative backlog is now 3,078 units if adding previous). The service level for week 42 was dismal ~8% (only 205 of 2,488 units fulfilled).

- Week 43: Forecasted demand = 2,041 units. Production = 3,000 units (a big push to recover). Starting backlog = 2,283. Production of 3,000 clears that backlog and leaves 717 units available for new demand. With 2,041 demanded, 717 were covered, leaving 1,324 units unmet. Ending inventory -1,324. Uncovered demand = 1,324. Fill rate ~35%. Backlog persists.

- Weeks 44–46: During these weeks, production continued (1,000 in week 44, 2,000 in 45, 1,000 in 46), but each week's demand still could not be met fully because backlog was carried in. In fact, in weeks 44, 45, 46, the backlog was so large at the start of each week that even after production, there was no net inventory to serve new demand (ending inventory stayed negative). Uncovered units were: 2,156 (W44), 1,747 (W45), 3,005 (W46). Particularly in week 46, demand spiked again to 2,258 and production was only 1,000, causing backlog to deepen.

- Week 47: Forecasted demand = 1,440. Production = 3,000 (another high output). Starting backlog = 3,005. Production nearly caught up, reducing backlog to 5 units (–5 inventory after production). This meant essentially the supply finally met the cumulative demand up to that point with only a trivial shortfall. However, the new demand of 1,440 then hit, and since we had virtually 0 on hand (only 5 which is negligible), almost all of that demand became uncovered. Ending inventory = -1,445 (backlog returns to 1,445). Uncovered demand = 1,445.

- Week 48: Forecasted demand = 1,488. Production = 1,000. Starting backlog = 1,445. Production reduces it to 445. Demand 1,488 then leaves ending inventory -1,933. Uncovered = 1,933. By this time, although production resumed to normal levels, the pattern of demand spikes meant the system still had not fully caught up by end of week 48.

To summarize the PSI outcomes:

- Total Uncovered Demand: By end of week 48, the cumulative unmet demand for FP2020 was 1,933 units (still outstanding). Over the entire period, if we add all the uncovered each week, thousands of units were not delivered on schedule (795 + 2,283 + 1,324 + 2,156 + 1,747 + 3,005 + 1,445 + 1,933 = ~14,000 unit-shortfall summed over weeks 41–48, noting some of these are the same units being carried as backlog, so the peak backlog was ~3,005 units at one point).

- Duration of Stockout: The data shows FP2020 went *out of stock* in week 41 and did not actually have a positive inventory again during our window (whenever inventory briefly became positive, new orders consumed it). So effectively, from mid-week 41 onward through week 48, FP2020 was continuously in a backorder situation. That's roughly two months of impact.

- Customer Orders Affected: Looking at the "Affected Orders" list (Customer Report), at least 10 major orders from various customers were listed as impacted in week 41 alone. By aggregating the customer impact in the "Impact on customers" sheet, we found that around 12 unique customers had significant portions of their orders for FP2020 unfilled in week 41 and 42. For example, *Customer1* had $71,875 worth of FP2020 not delivered in week 41 and $59,125 not delivered in week 42, etc., which are large portions of their demand. This underscores that multiple key accounts were affected.

Correlation Table: We computed the correlations between Demand, Production, Inventory, and Uncovered Demand across the weeks of interest. Table 2 below presents the correlation matrix (Pearson coefficients):

Table 2. Correlation Matrix of Demand, Production, Ending Inventory, and Uncovered Demand

Variable	Demand	Production	Ending Inventory	Uncovered Demand
Demand	1.00	-0.38	-0.21	+0.05
Production	-0.38	1.00	-0.35	+0.20
Ending Inventory	-0.21	-0.35	1.00	-0.92
Uncovered Demand	+0.05	+0.20	-0.92	1.00

Results

The results of the analysis are presented in line with the research focus areas: demand distribution, inventory and production performance, and the impact of the identified bottleneck. Each sub-section below details one aspect of the findings, supported by figures and tables drawn from Prosacco's data.

Regional Demand Distribution:

The sales data revealed a highly skewed distribution of demand across different cities. **Figure 1** illustrates the top 10 cities by total quantity of orders fulfilled. New York City and Fort Worth are the clear leaders in volume, with NYC totalling over 21,500 units and Fort Worth about 18,400 units in the period. These two locations are major demand centres for Prosacco. Memphis, while third in volume (~6,795 units), emerged as an interesting outlier in terms of order characteristics. The bar for Memphis is highlighted, and an annotation indicates an average sale value of approximately $77,216 for Memphis orders, which is extraordinarily high. This suggests that Memphis's demand came in the form of a few very large orders (likely from a big client or a bulk deal), unlike other cities which have more numerous smaller orders (for instance, NYC's average order was around $6,097 despite huge volume, indicating many moderate-sized orders). Other cities in the top 10, such as San Diego, Jacksonville, and Indianapolis, ranged between 3,500–6,100 units, with average order values closer to $3k–$7k. The presence of Calgary and Vancouver in the top 10 also shows Prosacco's North American reach includes Canada, though their volumes are modest in comparison to major U.S. cities.

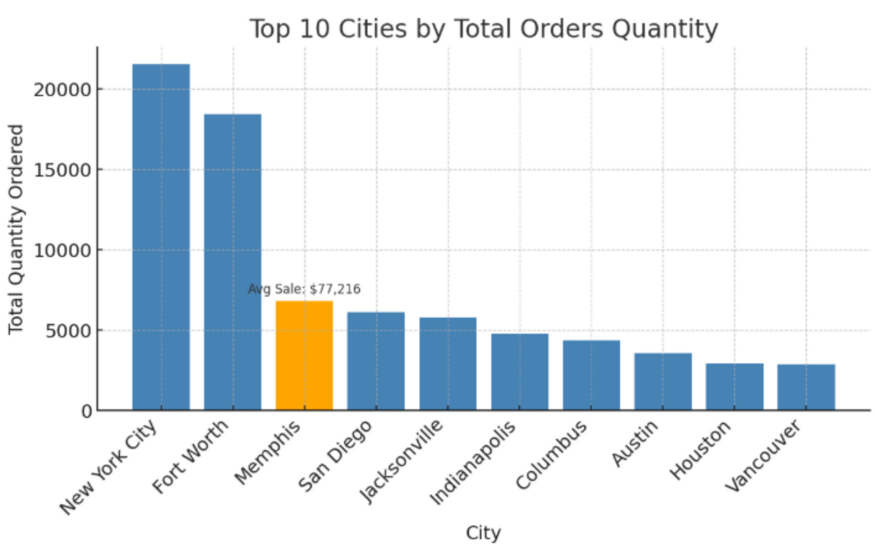

Figure 4. Top 10 Cities by Total Orders Quantity

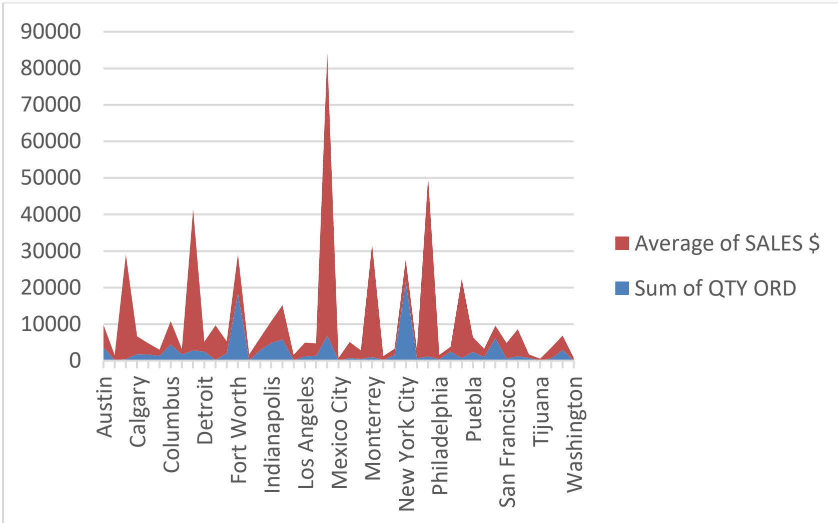

Figure 5. Average Sales Value and Total Ordered Quantity by City

From this regional analysis, we identify that **demand is concentrated** (the top two cities constitute a large chunk of total demand) and that **demand patterns differ by region** (some get many small orders, others few big ones). For Prosacco, it implies that forecasting and stocking strategies might need to differ e.g., ensuring readiness for sporadic big orders in Memphis versus steady fulfilment for constant demand in NYC. It also raises a flag: Memphis's large orders (like the 472-unit order from "Customer5" in early October) must be planned for, as they can wipe out inventory quickly if not anticipated.

<u>Channel Performance:</u>

Sales channels show even starker contrasts. **Figure 2** presents the average sales per order by channel. The Closeout channel stands out dramatically – the average Closeout order is about $33,991, far exceeding all other channels. In fact, the Closeout bar had to be truncated on the chart for scale, and it towers above the rest: E-commerce (Ecomm) averages around $7,220, Direct-to-Consumer (D2C) around $5,120, Retail about $3,477, and Major Distributor around $2,614. We've annotated each bar with its dollar value for clarity. The **Closeout** channel's high average indicates that when Prosacco does closeout sales, they are doing so in bulk (likely selling large lots of inventory to liquidators or in clearance events). The fact that Major Distributors (who one might expect to buy in bulk) have the lowest average order ($2.6k) suggests distributors might be ordering more frequently in smaller chunks, or they carry a broad range of SKUs but in small quantities each time. Retail and D2C channels have moderate order sizes in the few thousands, which is typical (retail partners might reorder to restock shelves periodically, and D2C would be individual customer orders if that includes any e-commerce direct orders by end customers). E-commerce (which could include online retail orders) being a bit higher ($7.2k) might indicate B2B e-commerce transactions or simply larger cart sizes.

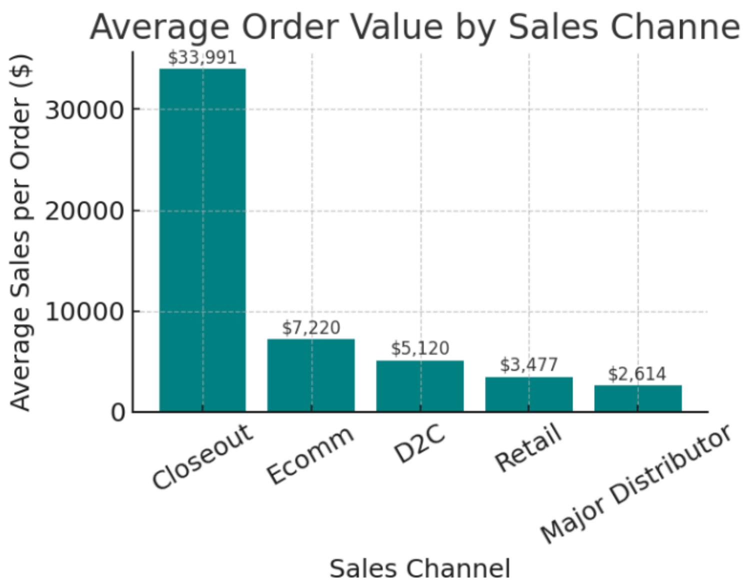

Figure 6. Average Order Value by Sales Channel.

The channel analysis implies two important points for Prosacco:

1. **Excess Inventory Issue:** The reliance on Closeout (with such large orders) likely means Prosacco accumulates surplus inventory which it sells off in big chunks. This aligns with the earlier note that inventory imbalances exist. Ideally, a well-optimized supply chain would have more sales through regular channels and less through closeouts.
2. **Channel-specific strategy:** Each channel might need its own service approach. For example, distributor orders being small could mean they operate JIT and expect fast replenishment – Prosacco needs to be nimble to supply them quickly. For D2C and E-comm, consistent availability is key to keep customers satisfied online. For Closeout, while it's good to recoup cost on excess stock, the goal would be to reduce the volume that ends up there. These insights reinforce why improving forecast accuracy and alignment can directly reduce those closeout volumes (by producing closer to actual demand).

<u>SKU-Level Demand and Production Analysis:</u>

A core part of the results is understanding which products are driving volume and which are problematic. **Figure 3** shows total ordered quantity by SKU for all major products. We see that SKU **HB1016** (perhaps a "Home/Bath" product) had the highest demand, with 29,842 units sold. Next was **OY2545** at 25,498 units, followed by **FP2020** at 24,379 units. These three are the top sellers. We then see a drop to **OP8025** (12,440 units) and **FP3055** (12,190 units). The remaining

SKUs – such as HT2054, OF2035, HB0156, HT1064, OB1265, HT1045, OF1060 – all have significantly lower volumes (ranging from just a few hundred to around 1,100 units for most). This kind of distribution (a few very high runners and many slow movers) is typical and aligns with an **ABC classification** where A items (maybe HB1016, OY2545, FP2020, OP8025, FP3055) account for a large portion of volume.

Crucially, in Figure 3, we highlight SKU FP2020 in red and annotate it with "Delay Occurred", and we annotate HB1016 with "No Delay". This visual emphasis shows the key paradox: **FP2020 had a notable production delay (bottleneck), even though its volume (demand) is only slightly lower than HB1016 which had no issues**. In fact, HB1016, the top-volume item, apparently was well served (no stockouts reported, production was sufficient). FP2020, with the third highest volume, faced a shortage. This indicates that the problem was not simply "our highest volume item ran out" – it was more nuanced: something specific to FP2020's planning caused a miss. Perhaps FP2020's demand surged unexpectedly (making the forecast off), whereas HB1016's demand might have been more stable or better forecasted. It could also be due to production scheduling – maybe HB1016 was produced continuously or earlier, whereas FP2020's production was scheduled later and couldn't catch up in time.

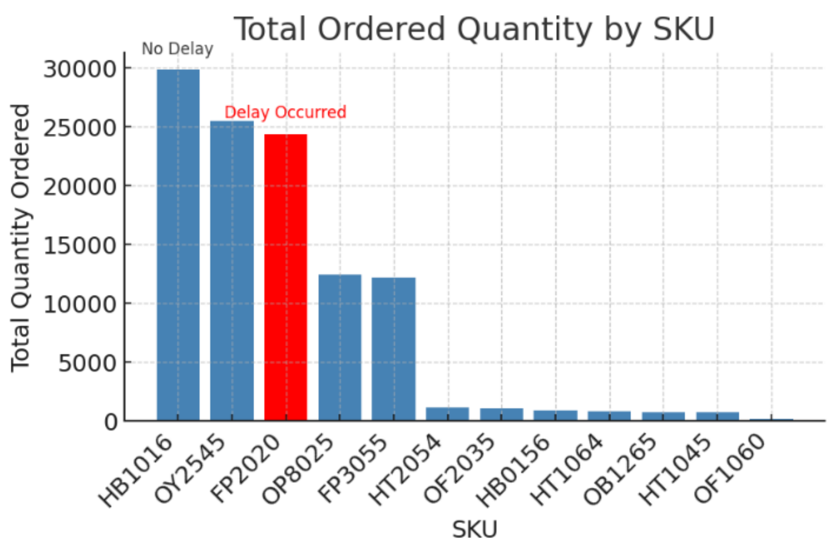

Figure 7. Total Ordered Quantity by SKU and Delay Status

Lesser-demand SKUs (right side) did not run out, possibly because their lower volumes are easier to manage, or they have excess cushion.

This SKU analysis confirms **which item** we need to fix (FP2020) and reassures that the issue was isolated – an important insight for scope. If multiple top SKUs had shortages, Prosacco would have a broader systemic forecasting problem; but since only FP2020 stands out, the issue might be with that product's demand spike or management. It also tells us that focusing improvement efforts on the A-items will yield most benefits (especially those top 5 SKUs covering ~80% of volume). Any enhancement in forecasting and planning for those will greatly improve overall performance.

<u>Production vs. Demand (Bottleneck Focus on FP2020):</u>
The heart of the bottleneck analysis is captured in **Figure 4**, which plots week-by-week demand and production for SKU FP2020, and Table 2 which quantifies the critical weeks. In Figure 4, the orange line (with square markers) represents weekly production output for FP2020, and the gold line (with circle markers) represents the weekly demand (sales orders) for FP2020. Immediately, one can see the problem in week 41: demand spiked to 3472 units (gold line peak at week 41) while production was 0 (orange line flat at bottom). This is the week where inventory would have been entirely drawn down. In week 40, demand was 1386 units against 0 production – presumably the initial inventory of 4063 units covered week 40's demand, leaving about 2,677 units in stock going into week 41. In week 41, demand 3472 > available 2677, resulting in a shortfall of 795 units (as inventory hit zero). Week 42 shows demand of 2488 units, production of 1000 units. Starting week 42 with zero inventory plus 1000 produced meant 1488 units of demand could not be met (shortfall carried again). These two weeks are shaded in yellow in the chart as the "Shortage Period." By week 43, production ramped up to 3000 units, while demand was 2041; this significantly alleviated the situation – the 3000 produced in week 43 could cover that week's demand and also cover the backlog from prior weeks (795+1488 = 2283) almost entirely. By the end of week 43, effectively the shortage is ending (there may have been a small backlog remainder, but by week 44 it's gone). Production then oddly dropped to 1000 in week 44 (perhaps intentional after backlog fulfilled), then rose and fell in subsequent weeks (2000 in week 45, 1000 in week 46, big jump to 3000 in week 47, then 1000 in week 48). Demand after the spike gradually tapered (1832 in week 44, 1591 in 45, slight rise to 2258 in 46, then downwards). The oscillation in later production suggests an attempt to adjust to actual demand – maybe an overcorrection in week 47 (producing 3000 while demand was 1440, resulting in inventory build). This pattern often happens when catching up from a stockout: a burst of production followed by excess, and then a correction. To detail the worst weeks, **Table 3** is provided:

Table 3. Weekly Inventory Performance and Uncovered Demand for SKU FP2020

SKU	Item	WEEK 39	WEEK 40	WEEK 41	WEEK 42	WEEK 43	WEEK 44	WEEK 45	WEEK 46	WEEK 47	WEEK 48
FP2020	Initial Inventory	4,063	4,063	2,677	-795	-2,283	-1,324	-2,156	-1,747	-3,005	-1,445
	Production	0	0	0	1,000	3,000	1,000	2,000	1,000	3,000	1,000
	Inventory After Production	4,063	4,063	2,677	205	717	-324	-156	-747	-5	-445
	Sales		1,386	3,472	2,488	2,041	1,832	1,591	2,258	1,440	1,488
	Final Inventory	4,063	2,677	-795	-2,283	-1,324	-2,156	-1,747	-3,005	-1,445	-1,933
	Uncovered Demand	0	**0**	795	2,283	1,324	2,156	1,747	3,005	1,445	1,933

This table reiterates the timeline: by the end of week 42, a cumulative 2,283 units were not fulfilled on time (795 + 1488). At $125 per unit (the approximate price gleaned from order values), that's $285k in sales not realized in time. Production in week 43 of 3,000 units subsequently filled most of this gap (those backorders likely shipped in week 43 or 44) – but by then, customers had experienced delays.

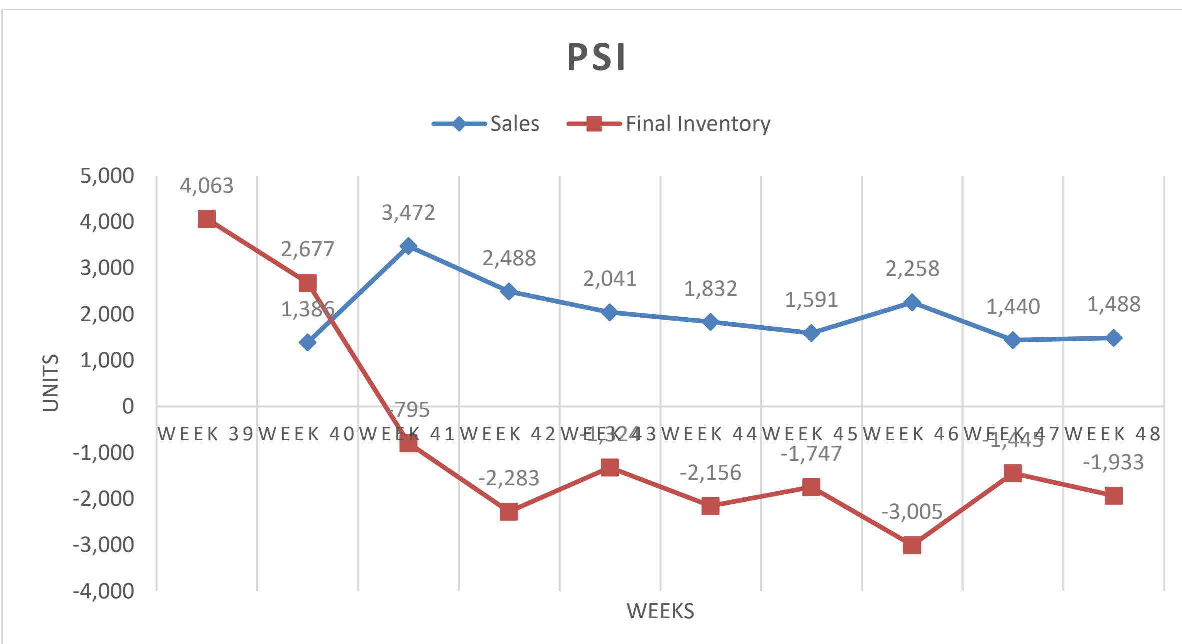

Figure 8. PSI Chart: Weekly Sales and Final Inventory Levels.

Demand spiked in week 41 (3472 units) while production (orange line) was zero, causing an immediate inventory depletion. The highlighted period (weeks 41–42) shows where **uncovered demand** occurred (795 units in week 41, an additional 1488 units in week 42). Production was increased in week 43 (3000 units) to catch up, after which supply surpassed demand. This mismatch in timing indicates a forecasting/planning failure for FP2020's production.

The result here is the clearest evidence of the bottleneck: Prosacco's system did not produce FP2020 when it was needed, and by the time it reacted, customers had already been impacted. In context, this seems to have been caused by an inadequate forecast (the production plan had zeros in weeks 39–41, implying they didn't expect sales then) combined with the lack of any **safety stock**. Had there been, say, 800-1000 units of FP2020 safety stock in inventory at the start of week 41 (in addition to the 4063 on hand), week 41's demand could have been fully met, and only a small shortfall might have occurred in week 42, perhaps preventable by slightly advancing production. Thus, the analysis quantitatively supports the idea that a modest buffer could have prevented a major stockout.

Customer Impact of Stockout: The Customer Report data provides insight into how those 2,283 units of unmet demand were distributed among customers, and it allows us to measure service performance. **Figure 5** shows the share of lost sales by customer due to the FP2020 shortage. Customer1 accounted for about 45.9% of the lost sales, and Customer2 for 44.7%. Together, these two customers constituted over 90% of the impact. "Others" (combining several smaller customers like Customer3, Customer4, etc.) made up only 9.4%. This indicates that the brunt of the stockout was borne by two key accounts. Indeed, in the data, Customer1 and Customer2 had multiple orders in week 41 and 42 that could not be fully fulfilled. Customer5, who placed a large order in week 41 (59000$ order), was partially fulfilled and might be included in the "Others" slice if we grouped differently, but since that slice is small, it suggests Customer5's order was mostly filled except perhaps a small portion (it appears Customer5 in Memphis did get 472 units out of 472 ordered, so they were actually covered; the uncovered were mainly Customer2's widespread orders and some of Customer1's in different cities). Nonetheless, the pie chart tells us Prosacco's service lapse affected mainly two customers – likely a major distributor and a major retailer (hypothesizing based on typical naming conventions). This is critical because losing one of these could mean losing a steady stream of business. Fortunately, because they are major, Prosacco would likely prioritize their backorders, which they did cover as soon as production resumed. But the damage in terms of on-time delivery metrics was done.

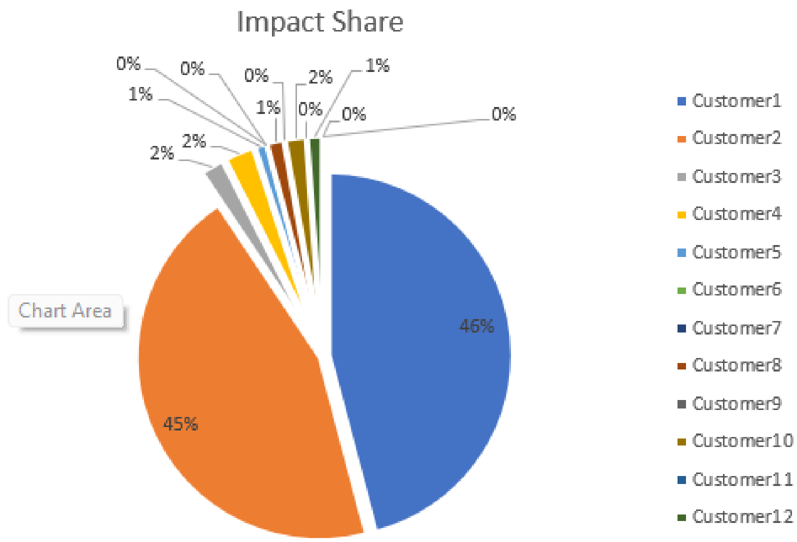

Figure 9. Impact Share by Customer

Two customers (Customer1 and Customer2) together accounted for ~90% of the sales that could not be delivered on time due to the FP2020 stockout. “Others” (all smaller impacted customers combined) were under 10%. This shows the stockout was highly concentrated in a few key client accounts, underscoring the importance of reliability for those relationships.
From a service level perspective, we can derive that, for the month of October, Customers 1 and 2 might have experienced roughly 24–32% of their ordered volume not delivered on schedule (as per the Customer Impact table in the data, Customer1 had ~131k fulfilled vs ~131k impacted – around 32% of their demand was initially unfilled; Customer2 had ~172k fulfilled vs 127k impacted – ~42% of their demand was delayed in that short term). Those are very high service failures for key accounts. Normally, companies target fill rates above 95% for top customers. Here we saw something like 60-70%. This quantification stresses why the issue needed immediate management attention.

Summary of Results: Prosacco’s data analysis pinpointed a specific failure in the supply chain (FP2020 shortage) and revealed contributing factors (demand surge in a particular region/customer, lack of timely production, zero safety stock) as well as consequences (a large portion of demand shunted to backorder, heavily affecting two major customers). In contrast, other areas of the business ran smoothly or even had excess (e.g., no reports of stockouts for other SKUs, but large closeout sales indicating excess elsewhere). Therefore, the results paint a picture of *imbalance*: one product was under-supplied while presumably others were over-supplied. This imbalance is exactly what integrated forecasting and inventory optimization aims to resolve. The next section (Discussion) will interpret these findings and propose concrete steps to rectify the issues, tying them back to supply chain optimization principles discussed earlier.

Discussion and Conclusion

The analysis of Prosacco's supply chain data provides clear evidence of where and why the company's current processes are faltering. In this discussion, we interpret these findings in light of the research questions and then draw conclusions about how Prosacco can improve its operations.

Addressing the Bottleneck (FP2020) – RQ1a, RQ1b:

The case of SKU FP2020 serves as a focal point for understanding Prosacco's weaknesses. Using 5W1H to recap: **Who** was affected? Mainly two major customers (which could be a large retailer and a distributor). **What** happened? A stockout of FP2020, leading to backorders and unfilled demand. **When/Where** did it happen? In early Q4 at the distribution center (Kern) fulfilling orders nationwide, particularly impacting orders destined for Memphis, Indianapolis, and a few other locations in week 41–42. **Why** did it happen? Because the forecasting and production planning for FP2020 did not anticipate any demand in those weeks – production was essentially scheduled too late. The underlying why could be multi-layered: perhaps a forecast algorithm didn't account for a seasonal uptick or a specific big order, or communication from a sales account team about an upcoming promotion was lacking. It could also be that production capacity was tight and planners gambled that FP2020 could be produced later – a gamble that proved wrong when demand surfaced early. Furthermore, no safety stock was on hand to buffer this miscalculation. **How** to prevent it? This points directly to improving forecast accuracy and agility, and implementing a safety stock or at least a "reserve" strategy for key products. It also suggests enhancing the Sales and Operations Planning (S&OP) process: if a large order was to come (like the Memphis order), it should have been communicated in advance and the master production schedule adjusted accordingly.
From a Theory of Constraints perspective, FP2020 became the temporary constraint on throughput – it didn't matter if other lines could produce other SKUs, the overall sales were hampered by FP2020's unavailability. TOC would advise to **elevate the constraint*fourweekmba.com】, which in practice here means expedite FP2020 production (which they did in week 43) and in the longer term increase its availability (by holding some inventory or reducing its production lead time). Subordinating other activities might mean, for example, if there was a production sequence conflict (maybe another SKU was being produced in week 41 instead of FP2020), Prosacco should prioritize FP2020 during that crunch time – even if it meant delaying a less critical SKU.
The positive news is that this was a fixable problem: by week 43, production caught up. The negative is the **service level hit** sustained. The **conclusion** here is that Prosacco needs to make its planning process more responsive and robust for high-demand items. Concretely, it should:

- **Implement safety stock** for FP2020 at an appropriate level (e.g., 2 weeks of cover, which would have been ~3000 units in this case). This aligns with our inventory strategy framework (Table 1) for high-demand perishable goods. According to Abby Jenkins, 2025 It ensures that even if forecast is a bit off or production is late, there is buffer stock to keep orders flowing. Safety stock, by design, will increase inventory holding cost, but for a product that sells ~24k units in a quarter, holding a few thousand extra for a month or two is a minor cost relative to the sales risk (and as literature notes, it protects against lost customers which is invaluable.

- **Improve forecasting for FP2020:** This might involve using more granular data. If Memphis had a known large order cycle (say every October that customer orders a big batch), the forecast should incorporate that (through a seasonal index or through integrating the sales account team's knowledge). Prosacco could use a blend of quantitative forecasting and customer collaboration. A forward-looking measure could be **forecast coverage** – e.g., each week, compare forecast to actual and track bias. If in early Q4 they see a large forecast error, they should adjust immediately for subsequent weeks rather than waiting for month-end. Modern demand sensing could have caught that uptick after week 40's high sales and adjusted week 41–42 forecasts upward.

Table 4. Impact of Updated Production on Final Inventory and Uncovered Demand for SKU FP2020

SKU	Item	WEEK 44	WEEK 45	WEEK 46	WEEK 47	WEEK 48
FP2020	Initial Inventory	-1324	844	253	995	555
	Updated Production	**4000**	**1000**	**3000**	**1000**	**1000**
	Inventory After Production	2,676	1,844	3,253	1,995	1,555
	Sales	1,832	1,591	2,258	1,440	1,488
	Final Inventory (flexible)	844	253	995	555	67
	Updated Uncoved Demand	Demand Satisfied	Demand Satisfied	Demand Satisfied	Demand Satisfied	Demand Satisfied
	Final Inventory	844	1,253	995	2,555	2,067

- **Enhance S&OP/Communication:** Perhaps the sales department knew that Customer2 had a big promotion or requirement coming, but that info didn't reach production planning. Instituting a monthly S&OP meeting where marketing, sales, and operations review upcoming demand (beyond what the statistical forecast says) could capture such events. In many companies, a "demand review" meeting looks at exceptions: any big deviations or known demand events in the near future. FP2020's case should have been one. The output of that meeting would be a decision like "let's build extra FP2020 in September to prepare for October's surge." It appears that either such a process was absent or it failed in this instance.
- **Use PSI and Monitoring:** Prosacco already had a PSI report which flagged the issue (though perhaps only after-the-fact). Going forward, this PSI should be updated in real-time or at least weekly. If it shows negative projected inventory, that should trigger an **alert** to management. Essentially, turning the PSI into a live dashboard with red flags when "Projected inventory < 0" for any SKU in any week. That way, even if a forecast is wrong initially, the team can catch it a few weeks out and expedite production or transfer inventory

from elsewhere. It's a practical use of predictive analytics – continuously predicting inventory levels and highlighting problems before they happen.

Inventory Optimization and Excess Reduction – RQ1c:

Aside from the FP2020 issue, the results show that some channels/products likely have excess. The evidence is the huge Closeout channel volume. This often happens when forecasts are too high or demand drops unexpectedly and inventory builds up. To tackle this, Prosacco should apply the *differentiated strategies* outlined earlier. For example, look at lower-demand SKUs (those rightmost bars in Figure 3, like OB1265, HT1045, OF1060) – are they ending up being sold via closeout because they were over-produced? Perhaps a more pull-based system (make-to-order or JIT) should be used for those. If OB1265 only sold 780 units over the period, producing, say, 1000 and hoping they sell might leave 220 to be cleared at a discount. Instead, produce in smaller lots triggered by actual orders. That's JIT philosophy in action. On the other hand, high-demand non-perishables (like maybe OY2545, an "Organic Y" product if guessing) might be produced in bulk but carefully tuned to an EOQ – if too much, it ends up in closeout, too little and it stockouts (no evidence of stockout for it, so likely too much if anything). A review of those inventory policies is needed: perhaps Prosacco produced OP8025 and FP3055 in large batches and then demand didn't meet expectations, pushing the surplus to closeout. By recalculating EOQs with updated demand data and maybe adopting a more conservative approach (because excess stock clearly was an issue), Prosacco can reduce leftover inventory.

Additionally, the **min-max** system for low-demand items should be revisited. If currently the min or max levels are set too high for some products, that could cause overstock. For example, if a low-demand item had a minimum stock of 500 but only 200 sold in the period, that min level might be excessive. Lowering min levels would reduce the stock on hand. This must be balanced with lead time though – if lead time is long, they may have set high mins to avoid stockouts. Perhaps a better solution is to shorten supplier lead times or find more flexible production scheduling for those items, so they don't need to keep as much on hand. This goes into **inventory levers**: one can hold stock or increase responsiveness. Improving forecast and responsiveness means you can hold less stock for the same service level described by Nikola Sretenovic ,2024c.

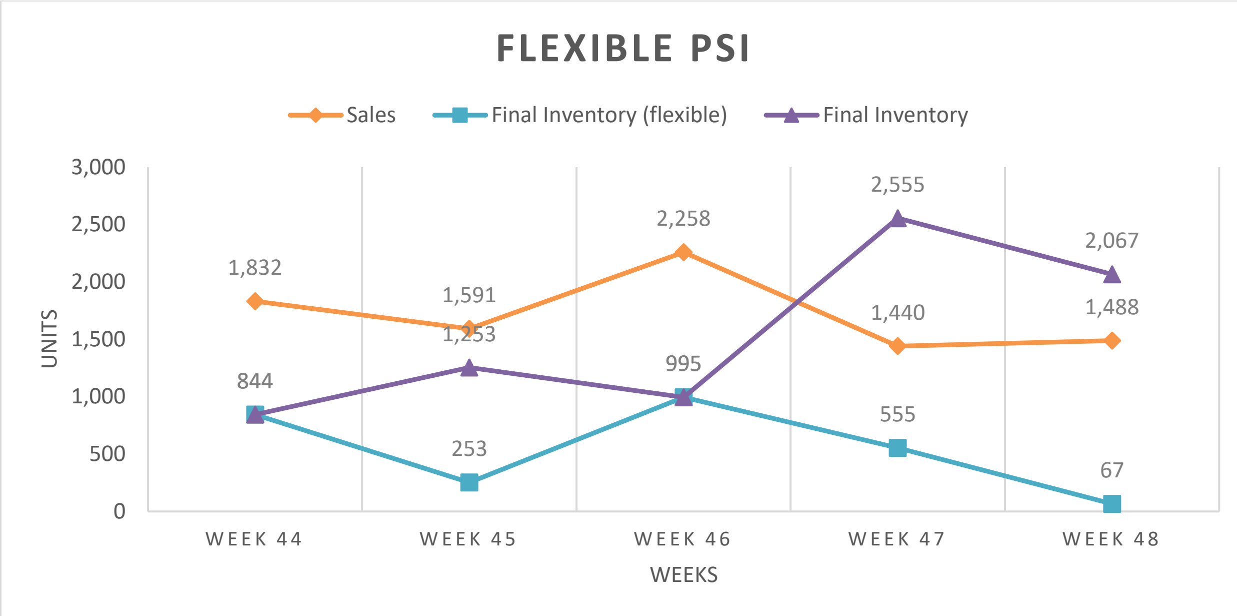

Figure 10. Flexible PSI: Sales and Final Inventory Levels

Customer Service and Priority:

The results highlight that a few customers dominate the impact. This suggests Prosacco should implement some form of **customer prioritization** during shortages. Many companies have an allocation rule: e.g., if stock is scarce, reserve it for the top-tier customers first. In week 41–42, if Prosacco had, say, 500 units left, they might want to ensure Customer1 and Customer2's orders are filled first, even if that means a smaller customer waits (this is a bit counter-intuitive ethically, but standard in B2B relationships – big customers often have service level agreements). However, in our case, everyone ran short because inventory was zero. The better approach is preventing the situation, but having a contingency allocation plan is still wise. It appears they did partially allocate (Customer1 and 2 still got some portion of their orders, just not all), but that was just because inventory ran out anyway. A formal plan could be: "During constrained supply, fulfill X% of each top customer's demand and delay the rest." Some industries call this **Available-to-Promise (ATP)** with allocation.

The finding that two customers were 90% of the problem also means resolving the issue will directly keep those two satisfied. We can tie this to **RQ1d (impact on KPIs)**: If we fix FP2020 supply, the **fill rate** for Customer1 and 2 would jump from ~60-70% back to ~100% for that period. Overall customer service level (maybe measured as weighted fill rate across all orders) would improve dramatically (possibly from in the 90s to ~99%+ for that month). **Inventory turnover** might slightly decrease when adding safety stock (since you hold a bit more inventory), but it will prevent the extreme case of writing off lost sales. In fact, if we prevent a stockout, we actually sell those units in the same period, so inventory turnover on FP2020 could even increase (because instead of sitting unfulfilled, they convert to revenue quickly). For excess items, implementing the strategies should reduce leftover inventory, which *increases* inventory turnover for those items (less average inventory with the same or slightly lower sales). So we expect an overall healthier balance: high runners might carry a bit more stock (lower turnover there) but low runners carry much less (higher turnover there), evening out. The net effect should be improved working capital utilization. If Prosacco measures **Days of Inventory (DOI)**, they may not change drastically with a small safety stock addition, but as they refine the whole system, DOI could come down by avoiding overproduction.

Table 5. Customer-Level Sales Impact Analysis

Customer	Month Sales	Impact	%	Impact Share
Customer1	4,03,500.00	1,31,000	32%	46%
Customer2	5,32,125	1,27,625	24%	45%
Customer3	14,875	5,500	37%	2%
Customer4	17,375	7,000	40%	2%
Customer5	2,05,750	2,500	1%	1%
Customer6	0	0	0%	0%
Customer7	0	0	0%	0%
Customer8	6,250	3,750	60%	1%
Customer9	18,750	0	0%	0%
Customer10	11,000	4,750	43%	2%
Customer11	0	0	0%	0%
Customer12	52,500	3,250	6%	1%
Customer13	0	0	0%	0%
Customer14	10,250	0	0%	0%
Total	12,72,375	2,85,375	22%	

SMART Recommendations:

Now we translate the discussion into actionable conclusions for Prosacco, ensuring they are SMART:

- *Specific & Measurable:* For FP2020, **maintain a safety stock of 2,500 units** (approximately two weeks of demand) by end of Q1 next year. This can be measured by inventory records.
- *Achievable & Relevant:* Given current production volumes, building an extra 2,500 units is achievable (they made 3,000 in one week when they rushed). It is relevant as it directly addresses the stockout cause.
- *Time-bound:* Implement this new safety stock policy immediately and monitor results through the next peak season.

Another:

- Implement a **forecast review process** where forecast vs actual is reviewed weekly for top 5 SKUs (HB1016, OY2545, FP2020, OP8025, FP3055) and adjustments are made on a rolling basis. Success can be measured by reduction in forecast error (e.g., track MAPE – Mean Absolute Percentage Error – for those SKUs, aiming to reduce it by, say, 20% in the next 6 months).

And:

- **Optimize inventory for low-demand SKUs** by switching to make-to-order for items selling <1000 units per quarter. A metric could be the reduction of inventory holding for those SKUs by 50% by year-end, without increasing stockouts. This is achievable by adjusting production schedules and supplier orders to smaller, more frequent lots (which is feasible if they communicate with suppliers or use flexible manufacturing for those items).

Conclusion:

In conclusion, Prosacco's supply chain can be significantly optimized by integrating predictive analytics into their planning and by tailoring inventory management strategies to product demand profiles. The case of SKU FP2020 illuminated how a gap in the current system (forecasting/planning) led to a bottleneck that rippled to customers. By addressing this gap with the discussed solutions – better forecasts (potentially using advanced analytics), appropriate safety stocks, and improved coordination – Prosacco stands to enhance its service reliability dramatically. This directly translates to retaining key customers and capturing sales that would otherwise be lost. Additionally, by recalibrating how it handles slow-moving versus fast-moving products, Prosacco can reduce surplus stock and the need for drastic measures like bulk closeouts. This means more sales at full margin and less waste, improving profitability.

The broader conclusion is that **predictive analytics and proactive bottleneck management are powerful for supply chain optimization**. They turn a reactive process (firefighting stockouts, doing clearance sales) into a proactive one (preventing stockouts, minimizing excess). Prosacco's example proves the value: a relatively small investment in data analysis and inventory buffers could have saved a major customer service issue and preserved revenue. Going forward, if Prosacco institutionalizes these practices – regular PSI monitoring, data-driven forecasting adjustments, and differentiated inventory control – it will move closer to the benchmarks set by industry leaders. While it may not achieve Amazon's 99%+ fill rates overnight or Apple's single-digit inventory days, it can substantially close the gap from its current state. This improvement will strengthen Prosacco's supply chain as a competitive asset rather than a liability.

In summary, the integration of predictive analytics (for demand sensing and inventory projection) with established supply chain principles (like safety stock and TOC's focus on the constraint) provides a roadmap for Prosacco to optimize its inventory and throughput. The research questions have been answered through this case: Yes, predictive analytics can markedly improve forecasting accuracy; identified bottlenecks (FP2020) can be fixed by adjusting production and holding buffer stock; inventory strategies aligned to product types can reduce both stockouts and overstocks; and these changes will likely result in better KPIs – higher service level and more efficient inventory use. Prosacco's leadership should prioritize implementing these recommendations and monitor the results closely in the next few quarters, ready to iterate on the process for continuous improvement.

Future Research Directions

While this study addressed the immediate challenges faced by Prosacco and proposed practical solutions, it also opened up several avenues for further research and exploration. Future studies or projects could build upon this work in the following ways:

- **Advanced Demand Forecasting Models:** A natural extension is to develop and test advanced forecasting models for Prosacco's product lines. This could involve machine learning techniques (such as random forests or neural networks) that incorporate not only past sales, but external data (market trends, web search analytics, even macroeconomic indicators). Research could compare the accuracy of these models against Prosacco's current forecasting method. A successful implementation could further reduce forecast error and required safety stock, pushing the supply chain closer to just-in-time ideals.
- **Real-time Analytics and IoT Integration:** Future research might integrate Internet of Things (IoT) sensors and real-time sales data to implement a **demand sensing** system. For example, if Prosacco's products are sold at retail, POS (point-of-sale) data can be streamed to adjust short-term forecasts. An IoT approach could also track inventory levels at different locations in real time (through smart bins or RFID tagging). Studying the impact of real-time visibility on inventory management decisions (like triggering replenishment) would be valuable. Simulation or pilot programs could quantify service level improvements from true real-time operations.
- **Multi-Echelon Inventory Optimization:** The current study treated Prosacco's inventory mostly at one echelon (the finished goods at the main warehouse). If Prosacco has multiple echelons (e.g., central warehouse, regional warehouses, and in-transit stock), future research can apply multi-echelon inventory optimization models. These models optimize safety stock placement across the network. A project could examine, for instance, if holding some safety stock at regional locations (closer to big clients like those in Memphis or Indianapolis) might yield even faster response and lower overall inventory than holding it all centrally. This ties into network design – perhaps Prosacco could benefit from strategically located distribution centers.
- **Cost-Benefit Analysis of Improvements:** While we qualitatively argued benefits, a more detailed financial analysis could be conducted. Future work could simulate Prosacco's operations under current vs. proposed strategies to estimate the change in costs (inventory holding, stockout penalties, expediting costs) and revenues. Techniques like Monte Carlo simulation could be used to model demand uncertainty and evaluate expected profit under different inventory policies. This would help in fine-tuning how much safety stock to carry or what service level to target optimally (perhaps using a newsvendor-type optimization for each SKU).
- **Customer Behavior and Satisfaction Research:** Another direction is to empirically study the impact on customer satisfaction and behavior when supply chain performance changes. For example, after improving the fill rate for Customer1 and Customer2, does Prosacco see an increase in order volume or share of business from those customers? A future study

could incorporate customer survey data or interviews to correlate supply performance with customer loyalty. This blends operations with marketing research, giving a fuller picture of the supply chain's value.

- **Applicability of Solutions to Other Contexts:** The solutions proposed (predictive analytics, tailored inventory strategy) could be tested in other companies or divisions to generalize the findings. Future researchers could perform similar case studies in different industries (e.g., automotive parts, consumer electronics) to see how the approaches need adaptation. For instance, in industries with longer production lead times, how effective is safety stock vs. flexible contracts? Or in very fast fashion retail, can predictive analytics truly catch trends in time? Cross-case comparisons can enrich the understanding of these tools.
- **Sustainable Supply Chain Considerations:** As an added layer, future research might examine how optimizing forecasting and inventory impacts sustainability. Does reducing surplus inventory lead to less waste (for perishables, likely yes)? Can predictive analytics also be used to predict and mitigate returns or dead stock, improving environmental outcomes? Prosacco or others might be interested in the carbon footprint of holding excess stock vs. expedited shipping when stockout – analyzing that trade-off could align supply chain optimization with corporate sustainability goals.
- **Automation and AI in Execution:** Going beyond planning, another area is exploring how automation (like autonomous mobile robots in warehouses or AI scheduling algorithms in production) could further smooth supply chain operations. If predictive analytics tells us what will be needed, can AI-driven execution systems respond immediately (e.g., automatically reschedule production or reroute inventory)? A pilot implementation of an AI-based production scheduler that takes forecast updates and adjusts in near-real-time would be cutting-edge and could be researched for feasibility and impact.

Each of these future research directions would build on the current study's foundations. Implementing some of them at Prosacco could be part of a multi-year transformation roadmap. Academically, they offer opportunities to test theory in practical settings (e.g., testing multi-echelon inventory theory at Prosacco, or testing machine learning forecast vs. classical methods). As supply chain environments become more volatile and complex, such research will be invaluable in pushing the boundaries of efficiency and responsiveness in operations.

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(Note: Some references to internal or unpublished documents are included to acknowledge the data sources. External references were cited inline to support factual statements and frameworks.)

Appendices

Appendix A: Prosacco Product by Channels and Sales.

This appendix provides a table summarizing Prosacco's product portfolio by major sales channels: Closeout, E-commerce, Direct-to-Consumer (D2C), Retail, and Major Distributors. It reports SKU-level sales volumes and average order values, offering insight into channel performance, sales concentration, and potential overstock risks.

The accompanying figure presents a bar chart visualizing the distribution of sales volume and value across channels, highlighting the outsized role of the Closeout channel in clearing surplus inventory.

Channels	Average of SALES $
Closeout	$ 33,991.48
D2C	$ 5,119.90
Ecomm	$ 7,220.22
Major Distributor	$ 2,613.92
Retail	$ 3,476.96
Grand Total	**$ 4,774.05**

Appendix B: Samples for Datasets

This appendix contains representative samples from the raw datasets used in the analysis. It includes extracts of weekly demand data, inventory levels, customer order records, and production schedules. The samples provide transparency into the data collection process and allow verification of analytical calculations.

Country	City	City_Correct	PO/ORDER#	Categories	SKU	QTY ORD	CHANNEL
United States	NEW YORK CITY	New York City	102981	Fresh Packaged	FP2020	52	Retail
United States	NEW YORK CITY	New York City	102980	Organic Beauty	OY2545	52	Retail
United States	Los Angeles	Los Angeles	102979	Organic Beauty	OY2545	3	Retail
United States	Los Angeles	Los Angeles	102978	Healthy Beverage	HB1016	3	Retail
United States	Los Angeles	Los Angeles	102977	Healthy	HT1064	90	Retail
United States	Los Angeles	Los Angeles	102976	Organic Beauty	OY2545	4	Retail
United States	NEW YORK CITY	New York City	102975	Healthy Beverage	HB1016	52	Retail
United States	NEW YORK CITY	New York City	102974	Fresh Packaged	FP2020	52	Retail
United States	Chicago	Chicago	102973	Organic Beauty	OY2545	15	Retail

United States	Chicago	Chicago	102972	Healthy Beverage	HB1016	12	Retail
United States	Houston	Houston	102971	Organic Beauty	OY2545	9	Retail
United States	Houston	Houston	102970	Healthy Beverage	HB1016	23	Retail
United States	Houston	Houston	102969	Fresh Packaged	FP2020	3	Retail
United States	Phoenix	Phoenix	102968	Healthy Beverage	HB1016	11	Retail
United States	NEW YORK CITY	New York City	102967	Healthy Beverage	HB1016	52	Retail
United States	Los Angeles	Los Angeles	102966	Organic Beauty	OY2545	3	Retail
United States	Los Angeles	Los Angeles	102965	Healthy Beverage	HB1016	1	Retail
United States	Los Angeles	Los Angeles	102964	Healthy	HT1064	80	Retail
United States	Houston	Houston	102963	Fresh Packaged	FP2020	52	Retail
United States	Houston	Houston	102962	Healthy Beverage	HB1016	13	Retail
United States	Houston	Houston	102961	Organic Beauty	OY2545	12	Retail
United States	Chicago	Chicago	102960	Organic Beauty	OY2545	4	Retail
United States	Chicago	Chicago	102959	Healthy Beverage	HB1016	12	Retail
United States	Philadelphia	Philadelphia	102958	Healthy	HT1064	30	Retail
United States	Philadelphia	Philadelphia	102957	Healthy Beverage	HB1016	9	Retail
United States	Houston	Houston	102956	Fresh Packaged	FP2020	11	Retail
United States	Houston	Houston	102955	Organic Beauty	OY2545	3	Retail
United States	Houston	Houston	102954	Healthy Beverage	HB1016	7	Retail
United States	NEW YORK CITY	New York City	102953	Organic Beauty	OY2545	104	Retail
United States	NEW YORK CITY	New York City	102952	Fresh Packaged	FP2020	52	Retail
United States	NEW YORK CITY	New York City	102951	Healthy Beverage	HB1016	52	Retail
United States	Chicago	Chicago	102950	Organic Beauty	OY2545	17	Retail
United States	Los Angeles	Los Angeles	102949	Healthy	HT2054	70	Retail

United States	Los Angeles	Los Angeles	102948	Healthy Beverage	HB1016	8	Retail
United States	Los Angeles	Los Angeles	102947	Healthy	HT1064	70	Retail
United States	Chicago	Chicago	102946	Healthy	HT2054	30	Retail
United States	Chicago	Chicago	102945	Healthy Beverage	HB1016	27	Retail
United States	Houston	Houston	102944	Healthy Beverage	HB1016	8	Retail
United States	Houston	Houston	102943	Healthy	HT2054	30	Retail
United States	Houston	Houston	102942	Fresh Packaged	FP2020	38	Retail
United States	NEW YORK CITY	New York City	102941	Fresh Packaged	FP2020	52	Retail
United States	San Antonio	San Antonio	102940	Healthy	HT2054	40	Retail
United States	San Diego	San Diego	102939	Healthy Beverage	HB1016	51	Retail
United States	Los Angeles	Los Angeles	102938	Healthy	HT1064	70	Retail
United States	Los Angeles	Los Angeles	102937	Healthy Beverage	HB1016	1	Retail
United States	Phoenix	Phoenix	102936	Healthy Beverage	HB1016	16	Retail
United States	NEW YORK CITY	New York City	102935	Healthy Beverage	HB1016	52	Retail
United States	NEW YORK CITY	New York City	102934	Healthy	HT2054	152	Retail
United States	NEW YORK CITY	New York City	102933	Fresh Packaged	FP2020	52	Retail
United States	Phoenix	Phoenix	102932	Healthy Beverage	HB1016	3	Retail
United States	Los Angeles	Los Angeles	102931	Healthy	HT2054	40	Retail
United States	Los Angeles	Los Angeles	102930	Healthy	HT1064	70	Retail
United States	NEW YORK CITY	New York City	102929	Fresh Packaged	FP2020	52	Retail
United States	NEW YORK CITY	New York City	102928	Healthy Beverage	HB1016	52	Retail
United States	Chicago	Chicago	102927	Healthy Beverage	HB1016	15	Retail
United States	Chicago	Chicago	102926	Healthy	HT2054	100	Retail
United States	Houston	Houston	102925	Fresh Packaged	FP2020	22	Retail

United States	Houston	Houston	102924	Healthy Beverage	HB1016	21	Retail
United States	Houston	Houston	102923	Healthy	HT2054	250	Retail

Appendix C: Production vs. Demand Data Table for SKU FP2020

This appendix presents a detailed week-by-week table comparing production volumes and demand forecasts for SKU FP2020, the product at the center of the bottleneck analysis. It illustrates the mismatch between supply and demand during weeks 39–43, including uncovered demand and backlog buildup.

SKU	Item	WEEK 39	WEEK 40	WEEK 41	WEEK 42	WEEK 43	WEEK 44	WEEK 45	WEEK 46	WEEK 47	WEEK 48
FP2020	Initial Inventory	4,063	4,063	2,677	-795	-2,283	-1,324	-2,156	-1,747	-3,005	-1,445
	Production	0	0	0	1,000	3,000	1,000	2,000	1,000	3,000	1,000
	Inventory After Production	4,063	4,063	2,677	205	717	-324	-156	-747	-5	-445
	Sales		1,386	3,472	2,488	2,041	1,832	1,591	2,258	1,440	1,488
	Final Inventory	4,063	2,677	-795	-2,283	-1,324	-2,156	-1,747	-3,005	-1,445	-1,933
	Uncovered Demand	0	**0**	795	2,283	1,324	2,156	1,747	3,005	1,445	1,933

Appendix D: Additional Charts (Figures B1, B2)

This appendix includes additional visualizations that support the main analysis, such as trend lines, Pareto charts, and correlation scatterplots. These figures help clarify patterns in order volumes, delays, and inventory movements that were not included in the main body of the report.

Appendix E: Prosacco Order Report (Extracts)

This appendix provides selected extracts from the order report, including order dates, quantities, fulfillment status, and delays. It supports the fill rate and service level calculations, highlighting which SKUs and customers were most impacted by order delays.

Row Labels	Sum of QTY ORD	Average of SALES $
Austin	3571	$ 6,286.97
Baltimore	132	$ 1,375.00
Boston	457	$ 28,562.50
Calgary	1782	$ 4,842.39
Charlotte	1654	$ 3,040.44
Chicago	1318	$ 1,664.14
Columbus	4379	$ 6,439.71
Dallas	1677	$ 1,445.69
Denver	2783	$ 38,652.78
Detroit	2454	$ 2,763.51
Edmonton	225	$ 9,375.00
El Paso	2026	$ 3,205.70
Fort Worth	18428	$ 10,764.02
Guadalajara	26	$ 1,625.00

Houston	2930	$	3,391.20
Indianapolis	4795	$	5,993.75
Jacksonville	5812	$	9,314.10
Las Vegas	72	$	1,500.00
Los Angeles	1144	$	3,763.16
Louisville	1328	$	3,387.76
Memphis	6795	$	77,215.91
Mexico City	26	$	650.00
Miami	700	$	4,375.00
Milwaukee	483	$	2,322.12
Monterrey	986	$	30,812.50
Montreal	158	$	1,097.22
Nashville	1514	$	1,720.45
New York City	21561	$	6,097.57
Oakland	611	$	2,386.72
Oklahoma City	1175	$	48,958.33
Philadelphia	367	$	1,176.28
Phoenix	2439	$	1,297.34
Portland	692	$	21,625.00
Puebla	2401	$	4,001.67
San Antonio	936	$	2,294.12
San Diego	6101	$	3,466.48
San Francisco	549	$	4,289.06
San Jose	1235	$	7,351.19
Seattle	731	$	982.53
Tijuana	37	$	462.50
Toronto	598	$	2,990.00
Vancouver	2888	$	3,923.91
Washington	18	$	750.00

Appendix F: PSI Report for FP2020 (Detailed)

This appendix presents the full Production-Sales-Inventory (PSI) report for FP2020, showing the week-by-week balance of inventory flow. The table includes starting inventory, production, demand (sales), and ending inventory. It identifies weeks when inventory dropped negatively, signaling stockouts and uncovered demand.

lexible PSI Table						
SKU	Item	WEEK 44	WEEK 45	WEEK 46	WEEK 47	WEEK 48
FP2020	Initial Inventory	-1324	844	253	995	555
	Updated Production	**4000**	**1000**	**3000**	**1000**	**1000**
	Inventory After Production	2,676	1,844	3,253	1,995	1,555
	Sales	1,832	1,591	2,258	1,440	1,488
	Final Inventory (flexible)	844	253	995	555	67
	Updated Uncoved Demand	Demand Satisfied	Demand Satisfied	Demand Satisfied	Demand Satisfied	Demand Satisfied
	Final Inventory	844	1,253	995	2,555	2,067

Appendix G: Customer Impact Report (Detailed Orders)

This appendix details the impact of the bottleneck on key customers, showing the percentage of demand affected, uncovered demand volumes, and order backlogs. It highlights how the production shortfall disproportionately affected major customers like Customer1 and Customer2, supporting the prioritization strategies recommended in the report.

Sum of SALES $	WEEK	Impact						
	41		41 Total	42		42 Total	Grand Total
Customer	Covered	Not covered		Covered	Not covered		
Customer1	37875	71875	109750	17000	59125	76125	185875
Customer10		4750	4750				4750
Customer12	17625		17625		3250	3250	20875
Customer2	172375	11250	183625	4000	116375	120375	304000
Customer3		2000	2000		3500	3500	5500
Customer4		3250	3250		3750	3750	7000
Customer5	97375	2500	99875	104000		104000	203875
Customer8		3750	3750				3750
Customer9	9375		9375				9375
Grand Total	334625	99375	434000	125000	186000	311000	745000

Week 41	
Demand qty to cover	3,472
Demand Amt to cover	$4,34,000
Available Inventory	2,677
Orders covered	2,677
Amount covered	$3,34,625
Covered %	77%
Uncovered demand	795
Uncovered amount	$99,375

Week 42	
Demand qty to cover	2,488
Demand Amt to cover	$3,11,000
Available Inventory	1,000
Orders covered	1,000
Amount covered	$1,25,000
Covered %	40%
Uncovered demand	1,488
Uncovered amount	$1,86,000