Smart Windshield

General Motors

GM Analyst Group 3/TIM Group 3

Executive Summary:

Project Proposal: This project aims to efficiently manage the supply chain for General Motors' Smart Windshield. The overall objectives include:

- **Efficient Supply Chain Strategy**: Streamlining the supply chain to minimize costs and risks, focusing on sourcing critical components like AR displays and sensors, ensuring competitive pricing and smooth market entry.
- **Technological Integration**: The Smart Windshield incorporates advanced features such as AR-guided navigation, hazard detection, and localized dimming to enhance driver safety and experience.
- **Sustainability and Scalability**: The project emphasizes eco-friendly logistics and responsible sourcing to align with GM's sustainability goals. It also plans for scalable operations to accommodate future demand increases.

Phase 1:

Product Life Cycle	Intro.	Intro.	Growth	Growth	Growth	Growth	Maturity	Maturity
Units Sold	8,257	108,250	365,309	470,983	578,983	680,232	702,340	709,298
Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Estimated Smart Windshield Units Sold	98,257	108,250	365,309	470,983	578,983	680,232	702,340	709,298

The provided table summarizes the sales trajectory of General Motors' Smart Windshield across its lifecycle from introduction to maturity over the years 2022 and 2023. Initially launched in Q1 2022 with sales of 98,257 units, the Smart Windshield experienced a steady rise in demand, reaching a peak of 709,298 units by Q4 2023. This pattern showcases the successful market adoption and growth of the Smart Windshield.

Phase 2:

Demand Forecasting Results

Method	Average MSE	Average MAD	Average MAPE	Average bias	TS
Static	7,788,813,719	73,516	5	-58,097	-3.70 to 2.00
Moving Average	58,249,571,022	443,398	35	-657,319	-2.02 to -1.22
Simple Exponential Smoothing	77,594,236,160	246,938	199.25	-31,864	-1.00 to 3.00
Holt's	4,262,725,368	56,283	40.375	1,602,321.75	-3.76 to 2.00
Winter's	4,156,365,730	50,615	24	-59,336	-3.76 to 2.00

Phase 3:

Financial Modeling: In the third phase of the General Motors Smart Windshield project, the team significantly improved demand forecasting and inventory management, applying refined methods that incorporate seasonal variations and competitor data. Financial models were enhanced to include detailed NPV and sensitivity analyses, reflecting the project's sensitivity to changes in development costs and sales volumes. These advancements underscore the project's commitment to delivering a cutting-edge product efficiently and effectively.Below are our results:

Base Sales Volume, Qty	Change in Sales Volume, %	Sales Volume, Qty	Change in Sales Volume, Qty	Change in NPV, %	NPV, $ Thousands	Change in NPV, $ Thousands
224,091	30%	224,763	672	1.03	171,411	86,919
224,091	20%	224,539	448	0.69	142,438	57,946
224,091	10%	224,315	224	0.34	113,465	28,973
224,091	0	224,091	0	0.00	84,492	0
224,091	-10%	223,867	-224	-0.34	55,520	-28,972
224,091	-20%	223,643	-448	-0.69	26,547	-57,945
224,091	-30%	223,418	-672	-0.97	2,426	-82,066

Project Proposal:

1. Project Goals

Our goal for this project is to design and manage the supply chain for General Motors' Smart Windshield to deliver an innovative, high-tech product efficiently and effectively. To deliver on this goal we aim to complete the following objectives:

A. Develop a Supply Chain Strategy:

a. Identify sourcing strategies for key components (e.g., AR displays, advanced sensors).

b. Prioritize efficiency to minimize costs and risks during the initial rollout.

B. Design the Supply Chain:

a. Establish key supply chain stages: suppliers → manufacturing → distribution → customers.

b. Create a stage representation tailored to the Smart Windshield's requirements.

c. Create a representation of the cycles involved in the supply chain for the Smart Windshield.

d. Determine the flow of information and capital between different cycles of the supply chain.

C. Model and Forecast:

a. Use static and adaptive forecasting methods to predict demand and identify trends.

b. Account for seasonal variations and uncertainties to maintain inventory stability.

c. Use historical data and regression analysis to establish initial demand baselines

D. Optimize Supply Chain Operations:

a. Define and manage supply chain cycles (procurement, manufacturing, distribution).

b. Design transportation networks and select optimal facility locations to reduce lead times.

2. Project Plan

Phase	Tasks	Meeting Times
Project Proposal	- Propose new products designed in previous phases. - Create a preliminary Supply Chain strategy and Design.	Meeting 1: 1/8/2025 3-5pm Meeting 2: 1/15/2025 4:30-5:30pm Meeting 3: 1/20/2025 3-4:30pm
Phase 1	- Create a business model for the product's supply chain. - Develop an overall supply chain strategy. - Attempt to forecast Demand for the first 8 quarters.	Meeting 1: 1/22/2025 3-5pm Meeting 2: 1/29/2025 4:30-5:30pm Meeting 3: 2/3/2025 3-4:30pm
Phase 2	- Plan and model the product's supply chain. - Forecast Demand for future quarters.	Meeting 1: 2/5/2025 3-5pm Meeting 2: 2/12/2025 4:30-5:30pm Meeting 3: 2/17/2025 3-4:30pm
Phase 3	- Create a supply chain cycle. - Determine a safety inventory management plan.	Meeting 1: 2/19/2025 3-5pm Meeting 2: 2/26/2025 4:30-5:30pm Meeting 3: 3/3/2025 3-4:30pm
Phase 4	- Determine supply chain facilities. - Design transportation networks.	Meeting 1: 3/5/2025 3-5pm Meeting 2: 3/12/2025 4:30-5:30pm Meeting 3: 3/17/2025 3-4:30pm

3. Final Conceptual Design

Our final concept, originally concept 5 in our conceptual design process, features a series of technologies that enable the Smart Windshield to provide navigation, hazard detection and prevention, weather detection, customizability, and reliability. Here is all of the subsystems that define our product, organized by the function that they provide for the product:

Function 1: Navigation:

- Real Time Traffic Data Integration: Using live data from connected services, the Smart Windshield will suggest optimal routes to the driver to avoid traffic congestion according to current conditions.
- AR Guidance: The AR guidance will provide a highly intuitive and immersive navigation experience by overlaying directional cues and visual pathways directly onto the windshield.
- Real Time Navigation integration: The Smart Windshield will integrate with real-time navigation systems to provide turn-by-turn directions, live traffic updates, and route adjustments. This ensures the driver receives the most efficient and accurate navigation guidance directly on the windshield.
- Visual AR Cues: Augmented reality will project visual cues onto the windshield, such as lane markings, hazard indicators, and navigation directions.

Function 2: Hazard detection and Prevention:

- GPS Based Assistance: Using advanced GPS technology, the Smart Windshield will notify drivers when straying from their lane through warnings on the Smart Windshield.
- Camera Based Recognition: The smart windshield will use advanced technology in its cameras in order to detect potential hazards such as roadkill, pedestrians, and other objects in the way of the driver. It will then take that data and provide timely alerts to drivers in order to ensure safety.
- Corrective Steering System: This feature works in conjunction with lane monitoring systems to assist drivers in maintaining proper lane alignment. If the vehicle drifts out of its lane, the system provides gentle steering corrections while displaying alerts on the windshield to inform the driver.

- Cameras: Integrated cameras will capture a comprehensive view of the surroundings, feeding data to the system for hazard detection, AR guidance, and blind spot monitoring. These cameras enhance overall safety by providing a continuous and detailed visual analysis.

Function 3: Weather Detection and Protection:

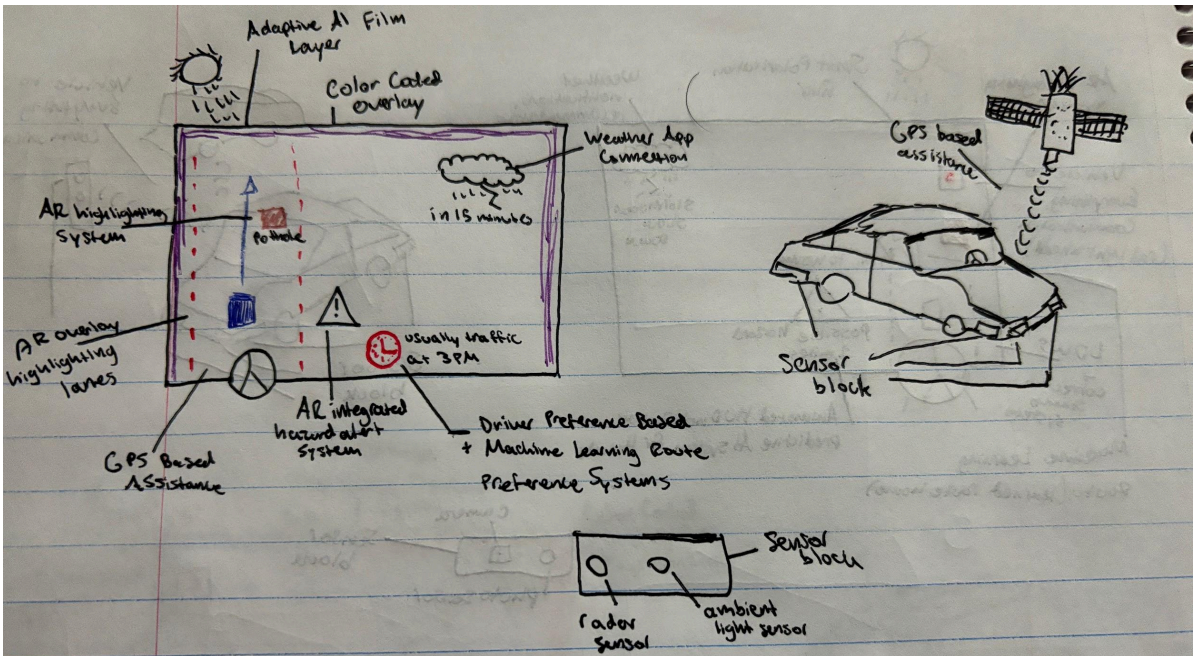
- Localized AR Dimming System: The Smart Windshield will dim selected parts of the windshield to prevent glare from affecting the driver and improving visibility.
- Real Time Weather Data Integration: The Smart Windshield will connect to external weather services to provide real-time updates on weather conditions, such as rain, fog, or snow. This information will be displayed on the windshield, enabling drivers to make informed decisions and stay safe during adverse weather.
- Leak-Proof Design: The windshield will have a seamless and leak-proof design to ensure water, dust, or other contaminants cannot enter the vehicle, keeping the interior clean and dry in all weather conditions.

Function 4: Customizability and Reliability:

- Photosensors: Photosensors will measure light intensity and adjust the display's brightness and contrast accordingly. This ensures the AR overlays remain clear and visible in varying lighting conditions, such as direct sunlight or at night.
- Solar Adaptive Power Integration: The system will include solar power integration to harness energy from sunlight, reducing dependency on the vehicle's battery.
- Voice-Driven Interface: Drivers can control settings and access information using voice commands, eliminating the need for manual adjustments.
- Secure Transmission Protocols: The Smart Windshield will use encrypted and secure communication channels to exchange data between vehicle systems and external networks, ensuring data privacy and reliability in all interactions.

Conceptual Drawing

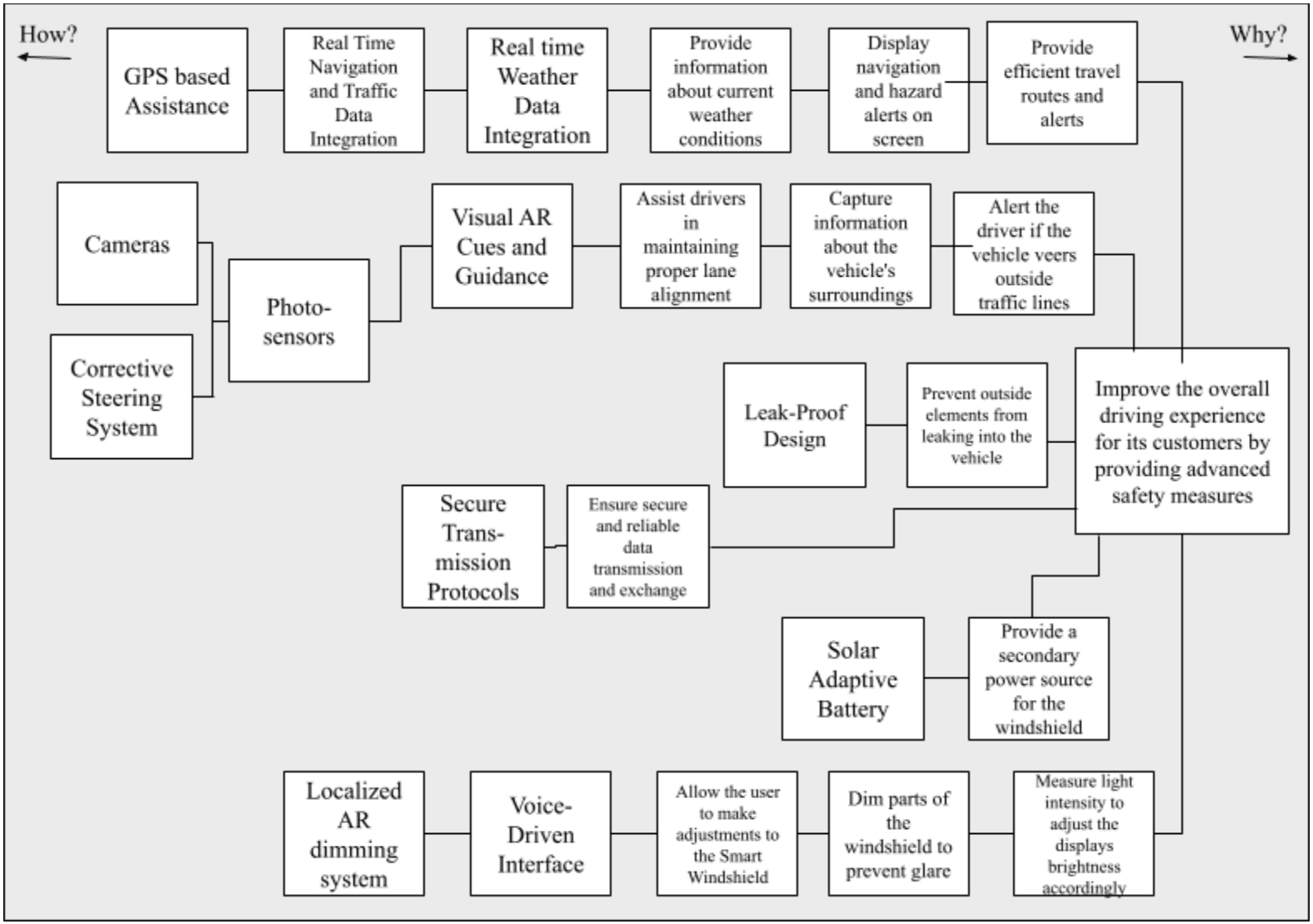
This drawing maps out some of the key technologies used in the Smart Windshield, showing how they would be implemented and how they might interact with one another.



FAST Process:

1) Extract & make a list of all the important subsystems that are relevant for your FAST diagram
2) Extract and make a list of the main or primary function, & the key subfunctions of the key subsystems (from Step 2) of the system
3) Write down the primary function at the extreme right of the FAST diagram
4) Organize the FAST diagram with the “WHYs?” to the right & the “HOWs?” to the left

FAST Diagram:



Key Subsystems and Their Functions

- Given the subsystems that we derived from the FAST di

Subsystem	Subfunction
Real-Time Navigation and Traffic Data Integration	Provide efficient travel routes and alerts
Visual AR Cues and Guidance	Display navigation and hazard alerts on screen
GPS based Assistance	Alert the driver if the vehicle veers outside traffic lines
Cameras	Capture information about the vehicle's surroundings, recognizing hazards and blind spots.
Corrective Steering System	Assist drivers in maintaining proper lane alignment
Localized AR dimming system	Dim parts of the windshield to prevent glare
Real-time Weather Data Integration	Provide information about current weather conditions
Leak-Proof Design	Prevent outside elements from leaking into the vehicle
Photosensors	Measure light intensity to adjust the displays brightness accordingly
Solar Adaptive Battery	Provide a secondary power source for the windshield
Voice-Driven Interface	Allow the user to make adjustments to the Smart Windshield
Secure Transmission Protocols	Ensure secure and reliable data transmission and exchange

4. Preliminary Supply Chain Infrastructure

Stage View Representation of the Supply Chain

1. Component Sourcing:
    a. Core Components:
        - Sensors:
            - Photosensors: light detection
            - Cameras: Visual Input
        - Materials for leak-proof design
        - AR lenses for the localized AR dimming system
    b. Energy Solutions:
        - Solar panels and adaptive battery components
2. Component Manufacturing:
    a. Integration of hardware components:
        - GPS module: more precise and accurate location tracking
        - Cameras: High-quality camera imagery for capturing details
        - Solar adaptive batteries
        - Steering and navigation hardware: guide the device's movement and directions
3. Software Development:
    a. Algorithms for:
        - Real-time traffic and weather data integration
        - Navigation integration
        - Visual AR cues and guidance
        - Corrective steering systems
        - Secure transmission protocols
        - Development of the voice-driven interface.
4. System Integration:
    - Hardware-software interfacing, such as connecting sensors, AR systems, GPS modules, and corrective steering mechanisms.
    - Testing localized AR dimming and solar battery performance under real-world conditions.

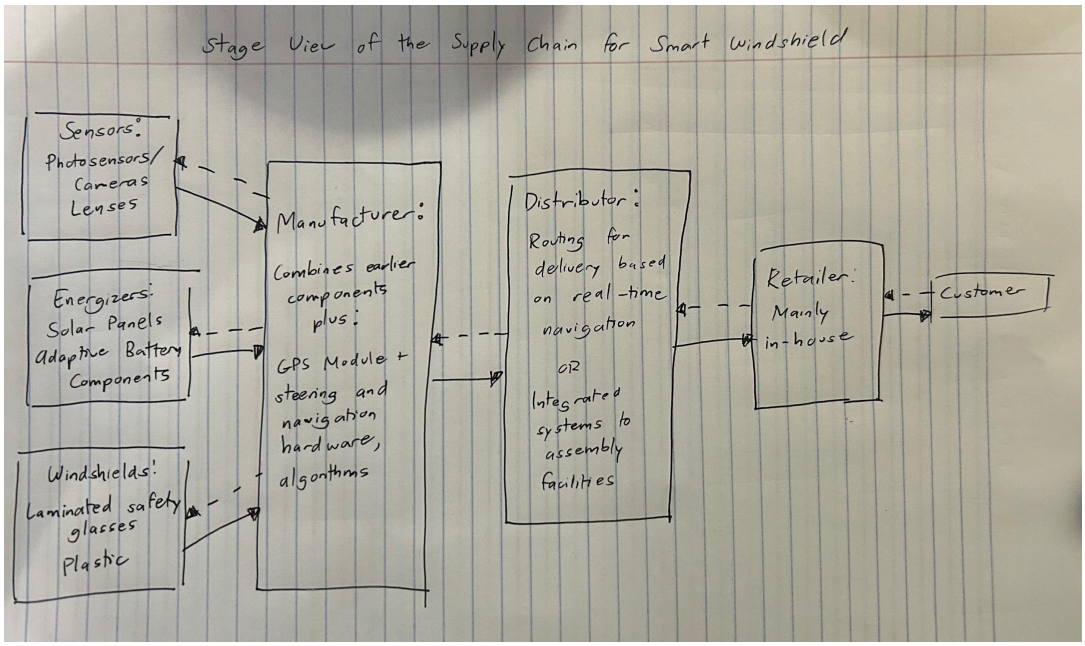
5. Distribution and Logistics:
    - Transportation of integrated systems to assembly facilities.
    - Efficient routing for delivery based on real-time navigation and traffic data.
6. Final Assembly and Quality Testing:
    - Integration of all components into the final product.
    - Testing for leak-proof performance, AR guidance accuracy, GPS reliability, and secure communication protocols.
7. Customer Delivery:
    - Warehousing and distribution to end customers.
    - Working with delivery companies
    - Post-delivery help/support:
        - Help with customer needs after the product is delivered including questions about usage or damage
        - Encourage customer feedback after delivery to ensure a well-kept product and increase customer loyalty

Stage View of the Supply Chain for Smart Windshield

Stage View Supply Chain Process:

- Supplier: Provides raw materials or other components needed for manufacturing
- Manufacturer: Uses raw materials to manufacture finished products
- Distributor: Holds and stores products before they are sent to a retailer or to the consumer directly
- Retailer: Handles the customer service and sales phases by selling finished products to consumers
- Customer: Consumers who place the order and purchase products

Stage View Diagram for Smart Windshield:



- The stage view representation demonstrates the various stages of our supply chain design, each representing a sequential phase or function in the flow of supply and information. Through the use of the FAST technique performed on our Smart Window, we were able to extract a set of subsystems for our product and applied this information to our supply chain design in order to determine where each subsystem falls within the manufacturer, distributor, retailer and customer stages of the supply chain. Now, we are able to see the different interactions of flows of information exchanged between each phase and can use this representation to develop a network representation of our supply chain design.

Processes in the Supply Chain

Cycle Process	Process Analysis
Customer Order Cycle **(PULL)**	- The customer places an order for vehicles with a smart windshield installed in it. - The dealership receives an order for the vehicle with a smart windshield installed.
Replenishment Cycle **(PUSH)**	- The dealership requests that the manufacturer produce and allocate more vehicles with smart windshields to their inventory. - The manufacturer assembles and allocates more vehicles with smart windshields installed and sends them to the dealership.
Manufacturing Cycle **(PULL)**	- An increase in demand for vehicles with smart windshields occurs, prompting manufacturers to increase production and call for more raw materials for their smart windshield from suppliers.. - With the additional resources, more vehicles with smart windshields are produced and sent to the dealership.
Procurement Cycle **(PULL)**	- Customers begin to purchase vehicles with smart windshields more often from the dealership. - Customers receive their orders and are able to return or request services on their orders should something go awry.

- This cycle can be classified as a “PULL” cycle as it begins with customers ordering vehicles with smart windshields installed from dealerships, causing vehicles with the feature to be produced and sent to dealerships, hence a “reactive” response.

Design and Understand Flows in the SC

Where Flow is Between	Flow of Information and Cash
Customer to Retailer:	- Information flows in both directions - Cash flows from customer to retailer - Product flows from the retailer to the customer
Retailer to Manufacturer:	- Information flows in both directions - Cash flows from retailer to manufacturer - Product flows from manufacturer to retailer
Manufacturer to Supplier:	- Information flows from manufacturer to supplier - Cash flows from manufacturer to supplier - Raw material flows from supplier to manufacturer

Supply Chain Strategy Overview:

1. **Customer Driven Demand:**
    a. The start of the supply chain is when a customer places an order for a car with the Smart Windshield.
    b. This is the trigger that starts the supply chain processes.
2. **Car Dealer Partnership and Management:**
    a. Car dealerships need also to keep track of inventory of smart windshields to meet customer needs.
    b. The dealerships need to forecast demand to have available products for the customers.
3. **Manufacturing:**

a. Manufacturers change how many cars they make based on what dealerships need.
b. This helps them use resources wisely and ensure cars with Smart Windshield are available when needed.

4. **Acquiring Windshields:**
    a. Manufacturers work with suppliers to ensure a steady supply of windshields.
    b. Strong supplier relationships, contract negotiations, and quality control are essential.
5. **Logistics and Distribution:**
    a. Windshields are transported efficiently to manufacturing plants to minimize delays.
    b. Logistics teams optimize shipping routes and costs.
6. **Quality Control and Installation:**
    a. Smart Windshields undergo rigorous quality checks before installation.
    b. The installation process is streamlined to prevent production bottlenecks.
7. **Delivery to Dealerships:**
    a. Manufactured cars with Smart Windshields are distributed based on dealership demand forecasts.
    b. Efficient supply chain planning ensures the right quantity is available at the right locations.
8. **After-Sales and Support Maintenance:**
    a. Dealerships and manufacturers collaborate on windshield replacements, repairs, and software updates.
    b. It provides strong after-sales support and enhances customer trust and loyalty.

Network Representation of the Supply Chain:

1. Inventory:
    a. Main Components:
        i. Photosensors, cameras, AR lenses, solar cells, materials for a leak-proof design
        ii. Stores at supplier facilities or nearby warehouses to reduce lead times
    b. Work-In-Progress:
        i. Semi-assembled hardware components like GPS modules, corrective steering mechanisms, AR dimming systems
        ii. Held at integration centers for further assembly and testing
    c. Finished Goods:
        i. Fully integrated and tested products stored at regional distribution centers
    d. Buffer Stock:
        i. Critical components like batteries, photosensors, and GPS modules are maintained to prevent disruptions form supply chain volatility
2. Facilities:
    a. Suppliers:
        i. Component suppliers (photosensors, AR lenses, GPS modules)
        ii. Located globally but clustered for reduced transportation cost
    b. Manufacturing Plants:
        i. Facilities dedicated to hardware assembly (corrective steering mechanisms, AR hardware)
        ii. Software development hubs for AI, navigation, and weather integration
    c. Integration and Testing Centers:
        i. Combine hardware and software, ensuring all components work seamlessly
        ii. Test systems under real-world conditions (weather, navigation accuracy)
    d. Distribution Warehouses:
        i. Store finished goods regionally, ensuring proximity to customer markets
3. Transportation:
    a. Inbound Logistics:

i. Raw materials are transported from supplier to manufacturing facilities
ii. Modes of transportation: road, air, sea

b. Intra-Supply Chain Logistics:
i. WIP components move between manufacturing plants and integration centers
ii. Transportation is optimized using real-time navigation and traffic data

c. Outbound Logistics:
i. Finished goods are shipped from integration centers to distribution warehouses
ii. Last-mile delivery to customers is supported by real-time routing to minimize delays

4. Information:
a. Real-time Traffic and Navigation Data:
i. Enables dynamic route optimization for transportation

b. Demand Forecasting and Inventory Tracking:
i. Uses real-time sales data to predict future inventory needs
ii. Integrates with AR cues to monitor stock levels at distribution centers

c. Weather Data Integration:
i. Adjusts transportation schedules and routes to account for adverse conditions

d. Secure Communication Protocols:
i. Ensures data integrity and privacy during the exchange of information between suppliers, manufacturers, and distributors

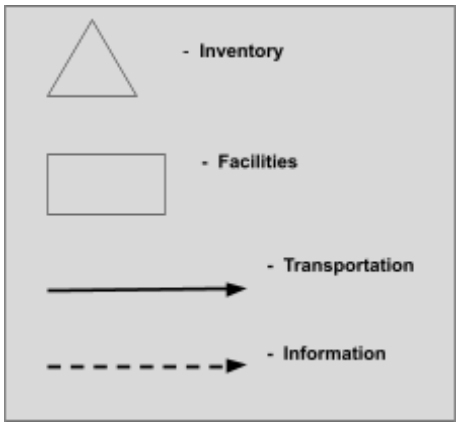
e. IoT and Sensors:
i. Cameras, GPS, and photosensors provide real-time tracking of goods in transit

Smart Window Supply Chain Network

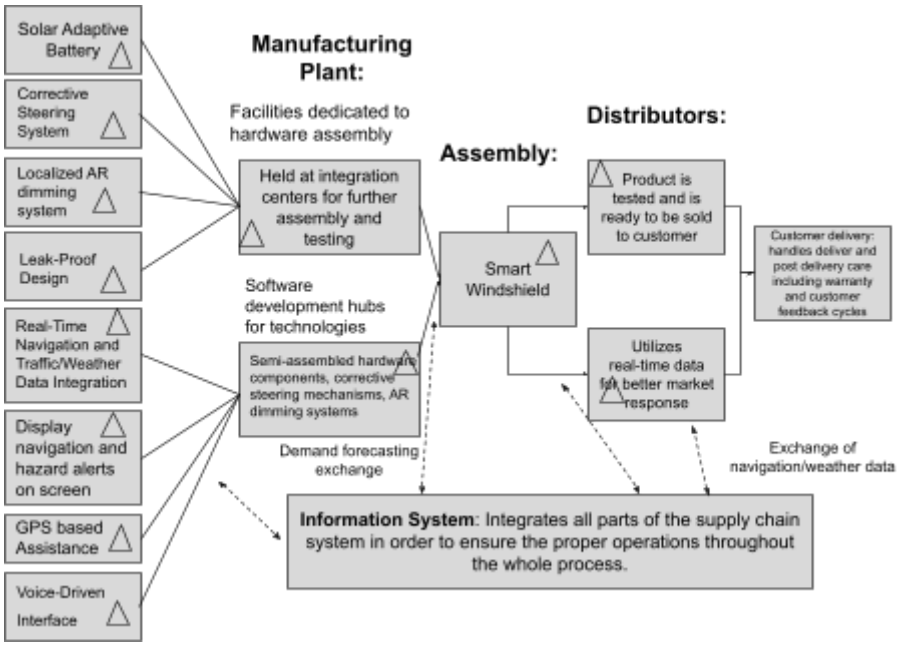
Supply Chain Network Process:

- There are 4 primary drivers in a SC:
    1) **Inventory**: Raw materials, work in progress, finished goods
    2) **Facilities**: Places where inventory is stored, or manufactured
    3) **Transportation**: Movement of inventory from one facility to another
    4) **Information**: Data or analysis regarding inventory facilities and transportation and the management of the information

Diagram Key:



Supply Chain Network Diagram :



The supply chain network demonstrates the various interconnections and multidirectional flows of information between each of the 4 drivers needed to create a supply chain infrastructure. This approach to supply chain design can help us understand the exchange of different flows of information amongst all the different phases, which differs from the stage view representation that demonstrates the supply chain in a linear and sequential approach. By understanding the multi directional flows of goods and information, we will be able to enhance our supply chain efficiency by optimizing resources like warehouses, manufacturing plants and fulfillment centers.

Project Phase	Items to fix and improve
Project Proposal	Correct the project plan to more closely follow the phases described in the syllabus.
	Fix the SC network, aligning the subsystems with the ones previously described and showing them more explicitly.
	Improve the set up and explanations of the steps taken throughout the report.

Phase I: Supply Chain Strategy & Design

1. Business Model for Supply Chain:

1. Objective:

- Develop an appropriate business model for the Smart Windshield.

2. Plan:

a. Determine the key partners in our business and supply chain.
b. Determine the key activities in the development and production of our product.
c. Explain the values that are held most importantly in our product.
d. Describe our relationship with our customers.
e. Determine the different customer segments our product will compete in.
f. Explain the key resources needed to produce our product.
g. Describe the different channels of distribution for our product.
h. Explain the details of the costs of each part of development and production.
i. Explain the different revenue streams for our product.
j. Determine our business model based on the details explained above.

3. Execution:

a. Key Partners:

- Technology Suppliers: Companies providing AR systems, GPS modules, cameras, photosensors, and voice-recognition software.
- Automotive Manufacturers: OEMs integrating the Smart Windshield into their vehicle models.
- Cloud & Data Service Providers: Partners offering real-time traffic, weather, and navigation data.
- Logistics & Distribution Partners: Ensuring efficient transport of components and finished windshields to manufacturers.
- Cybersecurity Firms: Providing secure transmission protocols to protect driver data.

b. Key Activities:

- R&D and Innovation: Continuous improvement of AR guidance, hazard detection, and weather adaptation features.
- Supply Chain Management: Sourcing high-quality materials, ensuring just-in-time delivery to assembly plants.
- Manufacturing & Quality Assurance: Producing and assembling windshields with strict quality control.

- Partnership Management: Establishing and maintaining strategic relationships with suppliers and distributors.
- Customer Support & Updates: Offering software updates and customer assistance for system optimization.

c. Value Propositions:

- Enhanced Safety: Real-time hazard detection, lane departure alerts, and corrective steering.
- Intelligent Navigation: Integrated AR-based route guidance and real-time traffic adjustments.
- Weather Adaptability: Real-time weather updates, glare reduction, and leak-proof design.
- Energy Efficiency: Solar-powered system to reduce vehicle battery consumption.
- Customization & Accessibility: Voice-driven controls and adjustable display settings.
- Data Security: Encrypted communication ensuring user privacy and secure operation.

d. Customer Relationships:

- Direct Sales & Support: Collaboration with vehicle manufacturers for direct integration and support.
- Subscription-Based Updates: Continuous software improvements through paid service models.
- Warranty & Maintenance: Providing long-term customer assurance and repairs.
- User Feedback Integration: Utilizing data analytics and customer input to refine functionality.

e. Customer Segments:

- Automotive OEMs: Companies integrating smart windshields into new vehicle models.
- Fleet Management Companies: Businesses managing transportation and logistics services.
- Luxury & High-Tech Vehicles: Premium car brands aiming for cutting-edge driver assistance features.
- Aftermarket Consumers: Individuals upgrading their vehicles with Smart Windshield technology.

f. Key Resources:

- Advanced Materials & Components: High-quality glass, AR projection systems, sensors, and cameras.
- Software Development Team: Engineers creating navigation, hazard detection, and security protocols.

- Data Infrastructure: Cloud-based networks for real-time traffic and weather updates.
- Manufacturing Facilities: High-tech plants for windshield production and integration.
- Intellectual Property: Patents on Smart Windshield features and AI-driven technology.

g. Channels:

- OEM Partnerships: Direct collaboration with automakers for factory installation.
- Aftermarket Distributors: Selling Smart Windshields through certified automotive retailers.
- Online Sales Platform: Direct-to-consumer sales for retrofit and upgrade options.
- Technology Exhibitions & Trade Shows: Showcasing innovations to attract industry adoption.

h. Cost Structure:

- R&D Costs: Investment in AI, AR, and sensor technologies.
- Manufacturing Expenses: Costs of production, quality control, and material sourcing.
- Logistics & Distribution: Costs of transportation and warehousing.
- Software Maintenance & Updates: Continuous software enhancements and cybersecurity measures.
- Customer Support Services: Technical assistance and warranty support.

i. Revenue Streams:

- OEM Sales Contracts: Revenue from automakers integrating Smart Windshields in new models.
- Aftermarket Sales: Direct sales to consumers for vehicle upgrades.
- Subscription-Based Services: Continuous software enhancements, AR navigation updates, and premium safety features.
- Partnership Licensing: Collaborations with automotive firms for proprietary technology use.
- Data Monetization: Aggregated, anonymized data sales to urban planners and transportation networks.

2. Overall Supply Chain Strategy:

Objective:

- Develop an overall supply chain for the Smart Windshield from GM.

Plan:

1. Choose a supply chain strategy and explain the reasoning behind it.
    - Align with competitive strategy
2. Explain each of the cycles in the supply chain and how the supply chain strategy affects it.
3. Explain the flow of cash and information in the supply chain given the supply chain strategy.
4. Explain the key drivers of the supply chain and how they follow the supply chain strategy.
    - Using responsiveness/efficiency assessment made above, propagate the SC strategy to the design of each driver
5. Determine where the Smart Windshield falls on the implied demand uncertainty spectrum.
6. Find where the Smart Windshield falls in the zone of strategic fit.

Execution:

I. Competitive Strategy Analysis:

- **Differentiated**:
    - Aims to produce distinctive products that make a difference in the marketplace.
    - The smart windshield includes technologies that provide a very powerful product.
    - Business has an advantage over rivals as a result of being able to raise prices and cultivate a good customer base.
        - A smart windshield differentiates itself from standard windshields and enhances the brand's reputation by appealing to safety-conscious drivers with features like real-time hazard identification will perform better on the market.

II. PERFORMANCE

Decision: The supply chain for the Smart Windshield will prioritize responsiveness over efficiency during the initial launch phase.

- **Reasoning:**
    - As a new product we must prioritize providing consumers with a user experience that is responsive and straightforward for users to interact with.
    - Because one of our products main goals is to prevent accidents, it is important that we create and develop a quick, responsive product that is able to detect any sort of potential collisions or accidents.

Why Focus on Responsiveness?

1. **User Experience:**
    a. A positive and responsive user experience with the Smart Windshield will help create a good first impression amongst consumers which will ultimately help enable the product to be viewed as reliable and high quality within the I/M landscape.
    b. Place the safety of our customer first by creating a product that accurately detects collisions and any other dangerous road conditions.
2. **Unpredictable Demand Growth:**
    a. New products often face slower market adoption. Focusing on responsiveness allows us to make adjustments to our supply to better fit customers demand and needs.
    b. Helps enable reliability amongst customers by effectively fulfilling the level of demand that the product is being currently met with.
3. **Innovation:**
    a. A responsive strategy allows us to continue to innovate and change our product to keep up with the rapidly changing technology and vehicle industry.
    b. This strategy gives us more room to make adjustments and updates to our product models, to better fit changing customer needs.

Scalability for Long-Term Growth

- Build supply chain flexibility to handle increasing demand:
    - Efficient processes and operations will help enable scalability without increasing costs
    - Scale supplier contracts for larger order volumes as needed.
    - Modularize transportation and distribution networks for expansion into new regions.
- Expand warehouse and production capacity:
    - By adding additional warehouses in the area, the demand for windshields increases and we are able to properly predict that to keep inventory levels in stock. Expanding production capacity allows for production to increase, and to grow long-term.

Sustainability

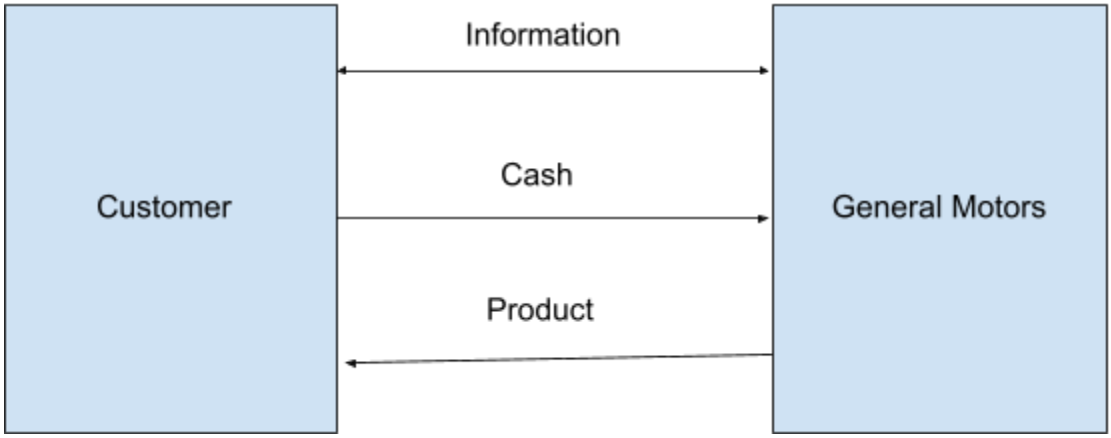
- Align with GM's broader goals of sustainability:
    - Use eco-friendly logistics methods and reduce emissions in transportation.
    - Source materials responsibly wherever feasible.

CYCLES

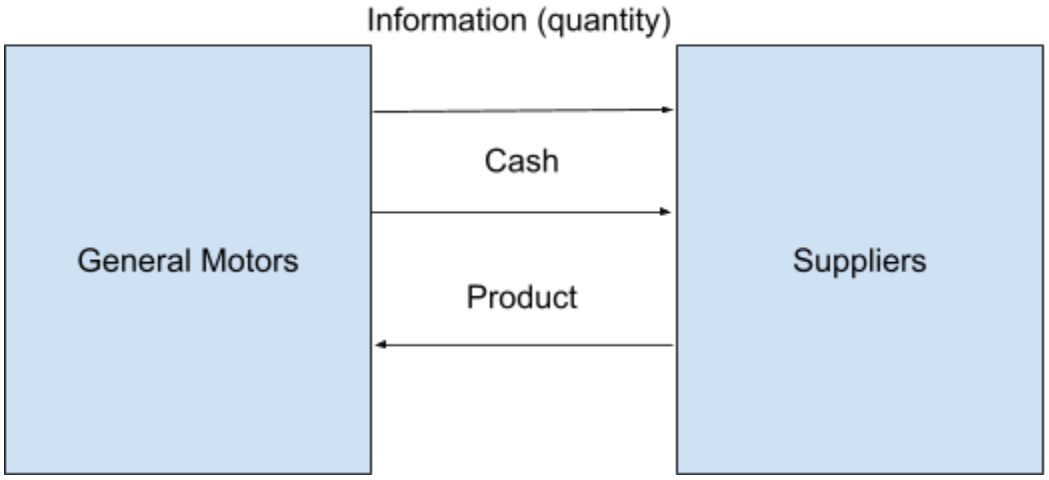
Customer Order Cycle **(PULL)**	- Customer submits an order for windshield - Components for windshield is ordered from suppliers for General Motors to create the product
Replenishment Cycle **(PUSH)**	- Based on all of the confirmed orders placed, inventory is stocked only for those orders to not have excess waste
Manufacturing Cycle **(PULL)**	- The software updates, navigation guidance, real-time hazard detection, and weather adaptation are driven by customer usage and demand. These services are updated dynamically based on real-time data and user needs.
Procurement Cycle **(PUSH)**	- The manufacturing of windshields, integration of sensors, and AR technology are done in anticipation of demand. This ensures that the product is ready for installation in vehicles, whether for OEMs or aftermarket consumers.

CASH AND INFO FLOW

1. Purchasing Smart Windshield



2. Inventory Purchase

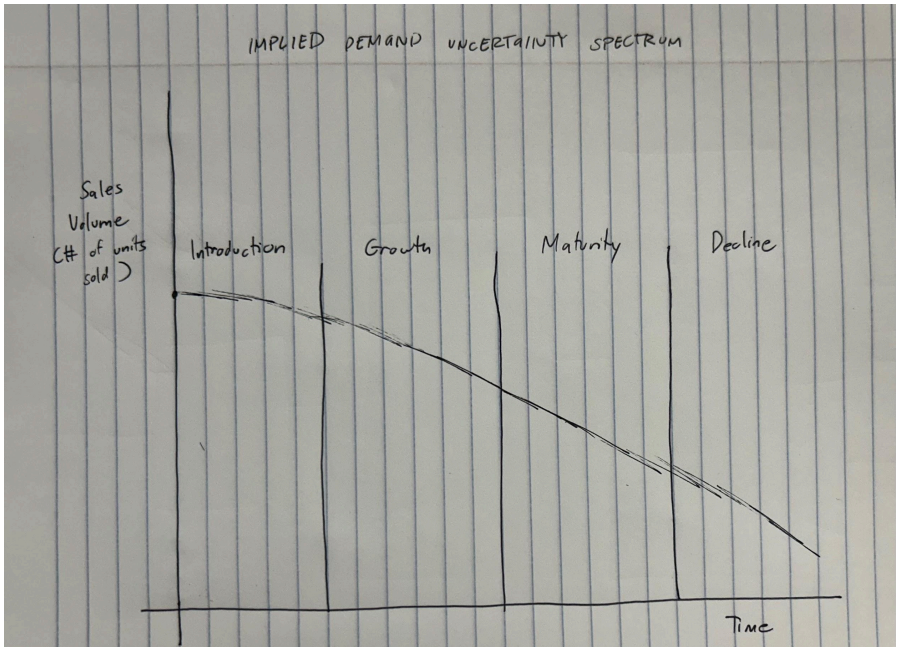


KEY DRIVERS

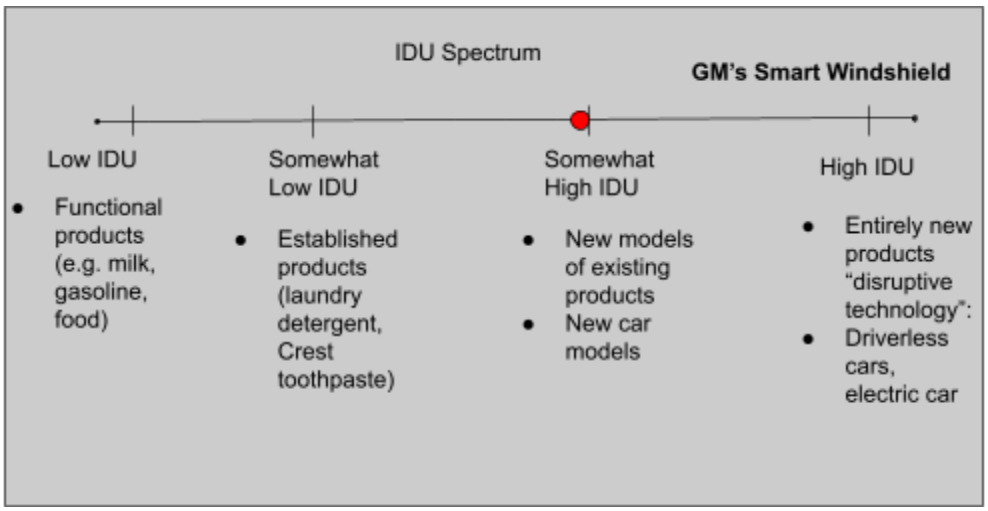
Based on our supply chain strategy that emphasizes responsiveness over efficiency our key drivers will follow similarly. All of the key drivers will focus on responsiveness with inventory taking a slightly more efficient approach when it comes to product range, as our focus is only our one product, the Smart Windshield.

Driver	Supply Chain Strategy
Inventory	Efficient & Responsive - Our inventory will consist of only a small range of products, our windshields produced for a small number of vehicle models, to help us be efficient in our production of the new product with unknown demand. - We will keep high inventory levels of our product and directly work with vehicle manufacturers to produce the optimal amounts of product for growing demand.
Facilities	Responsive - Our manufacturing facilities will be spread out across the United States with centralized locations that service a wide array of customer locations. - Completed goods will be stored regionally through distributors, closer to customers than the manufacturing facilities.
Transportation	Responsive - With the growing and variable demand products will be shipped frequently to distributors and customers. - The primary method of transportation for our product will be by long-haul trucks, which allow us to make frequent shipments to distributors and customers - Implement better tools to make the most out of the planning and delivery in order to ensure that customers are being communicated to about where their product is. This helps with the market presence of the windshield.
Information	Responsive - Information and data about sales, inventory, and manufacturing metrics will be collected and shared efficiently throughout the supply chain. - Having effective communication across all General Motors will help with the overall supply chain management. This will help the customer's needs.

IMPLIED DEMAND UNCERTAINTY SPECTRUM:



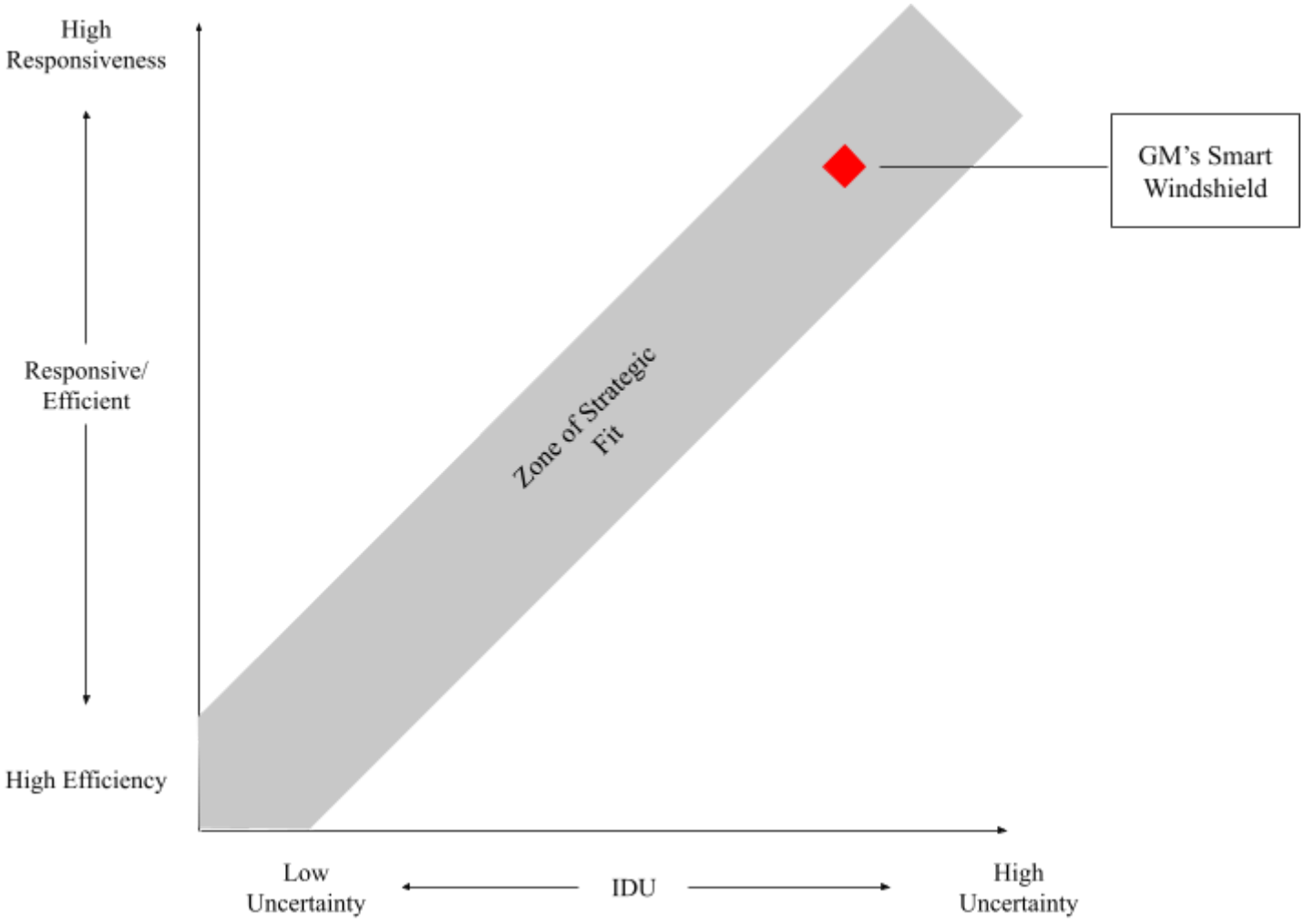
Description: Demand + projected sales gradually decreases as time progresses for the product. Our Smart Windshield is generally disruptive and a new concept, beginning in the introduction phase of the product life cycle, so it starts off with a High IDU and grows smaller as people grow more familiar with the product. As the implied demand uncertainty decreases over time sales gradually decrease into the maturity and decline phases of the product life cycle.



Description: Our Smart Windshield on the moderately High IDU phase of the implied demand uncertainty spectrum. Because this product utilizes advanced and innovative technologies, we are characterizing it as a "disruptive technology" where demand isn't as certain as existing and established products.

SC STRATEGY (ZONE OF STRATEGIC FIT)

Given the emphasis on high responsiveness in the supply chain strategy and the moderately high implied uncertainty of demand, the Smart Windshield fits into the zone of strategic fit, balancing the supply chain's strengths with customer demands.



3. Demand Estimation

Objective:

- Attempt to estimate the demand that our product, the Smart Windshield, might face in its first 8 quarters, then forecast the demand for the next 8 quarters.

Plan:

1. Estimate the possible demand for years 1-2 by using the demand data from a related product.
2. Forecast the demand for years 3-4 using the estimated demand data from the previous step.

Execution:

1. Estimate the First 8 Quarters:
    - Corning Incorporated is a leading competitor in materials science, particularly in advanced glass and windshield technologies such as Gorilla Glass. Understanding an estimate of their windshield demand is crucial in forecasting for the Smart Windshield as it provides insights into market trends and fluctuations and helps ensure accurate predictions for planning the product timeline.

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
GAAP Net Sales($ in millions)	3,680	3,615	3,488	3,406	3,178	3,243	3,173	2,994

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

- Corning Incorporated segments its net sales into 6 parts:

Optical Communications	- Products involve optical fibers, cables and connectivity. Products provide solutions for optical based communication infrastructures for services such as voice and video.
Display Technologies	- Products involve glass panels and substrates that may be used to create the screens in computers, monitors, and related technologies.
Speciality Materials	- Products involve glass made for a wide variety of markets including **windshields**, mobile phones, and other glass screens. Its biggest selling product in this segment is Gorilla Glass for windshields.
Environmental Technologies	- Segment of products focuses on creating ceramic glass products and

	filters to control emissions.
Life Sciences	- Provides products such as plastic vessels, labware, and other related equipment.
Other(Emerging Technology and Businesses)	- This group consists of various new emerging technologies in which the company is involved throughout many industries, and emerging businesses into which they've invested.

- In order to understand Corning Incorporated's units sold per quarter it is only necessary to focus on Specialty Materials for a general estimate.

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Specialty Materials GAAP Net Sales($ in millions)	493	485	519	520	406	423	563	473

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

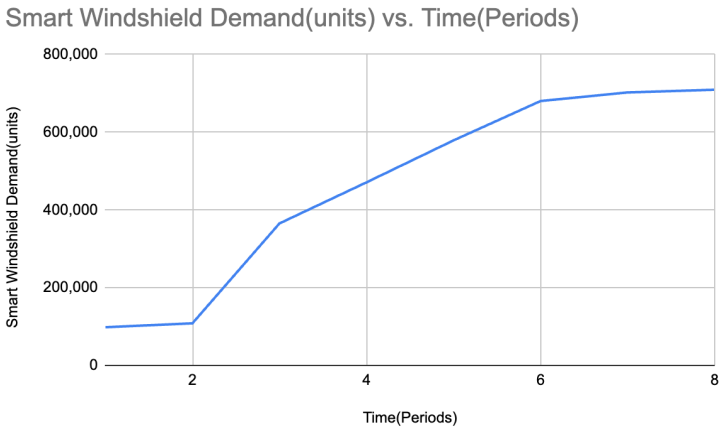
- Averaging the GAAP Net Sales for the segment Specialty Materials data from Q1 2022-Q4 2023, data indicates that Specialty Materials accounts for approximately 14.47% of Corning Incorporated's total GAAP Net Sales.
- Gorilla Glass windshields cost significantly more than their competitors products which often cost around $100-$200 for a basic windshield, compared to $700+ for a 2018 Jeep Wrangler, $900 for a 2019 Ford F150, and for newer Jeep Wranglers the cost has fallen to roughly $500. Assuming that each unit was sold for about $550/unit on average, they sold these estimated numbers of windshield units per quarter:
- This estimate will be broad, as Gorilla Glass is not the only product sold under this segment of the company.

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023

Estimated Windshield Units Sold	896,363	881,818	943,636	945,454	738,181	769,090	1,023,636	860,000

- We must understand the scale of the number of windshields sold by Corning Incorporated to GMC to account for the difference in sales, as GMC provides many more windshields per year.
- Sing Corning Incorporated produces around 3.39 million windshields, Corning Incorporated has the capability resources to meet the demand which is forecasted GM assuming that the Smart Windshield will be delivered to customers effectively. This is a key factor in their differentiated strategy because this will allow them to keep inventory levels high while also fulfilling customer needs.
- While at maturity Corning Incorporated sold around 800-900,000 units per quarter, totaling around 3.39 million windshields, GM sold 6.186 million vehicles in 2023.
- Assuming that for GM the Smart Windshield:
    a. The product costs around $500 in comparison to the standard $100-200 windshield installed in most models,
    b. GM continues to sell its vehicles on a cost leadership basis
    c. On average 30-45% of customers are willing to pay for premium options in their vehicles(actual statistic).
- We can assume that only about 35% of GM customers will opt for the premium Smart Windshield option to be installed into their vehicles.
- If 35% of GM vehicles are equipped with the Smart Windshield approximately 2,165,100 or more vehicles will be installed with Smart Windshields in them per year at maturity.

Product Life Cycle	Intro.	Intro.	Growth	Growth	Growth	Growth	Maturity	Maturity
Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Estimated Smart Windshield Units Sold	98,257	108,250	365,309	470,983	578,983	680,232	702,340	709,298



- This estimate of the first eight quarters of demand for the GM Smart Windshield aligns with the product life cycle we expect the product to follow, and in the year it reaches maturity we estimate that 2,165,100 units will be sold.
- While this is less than the total number of estimated units sold by Corning Incorporated, we must remember that GM is a cost leadership based company and many customers may not be willing to pay the premium despite GM selling many more vehicles overall, as well as that the estimate for Corning Incorporated's windshields sold is likely high due to other products being sold under the Specialty Materials sector.

Project Phase	Items to fix and improve
Phase 1	Improve the overall structure of the report.
	Correct the IDU graph.
	The estimation of demand has to be converted into an explicit mathematical process to obtain the data.
	Make the business model more specific with an explicit step-by-step process.
	Fix the competitive strategy

Phase II: Supply Chain modeling & planning

1: Revised Estimate Demand Data

STEP 1: DEFINE

Objective:

Attempt to estimate the demand that our product, the Smart Windshield, might face in its first 8 quarters.

STEP 2: PLAN

Stepwise Plan:

1. Find an existing competitor producing a product similar to the Smart Windshield that we can base our possible demand data on.
2. Analyze the company's (Corning) net sales and determine the portion of those sales that come from products similar to the Smart Windshield.
3. Using the data from the previous step, adjust the expected sales based on differences in our product and company that might change sales volume, price, and product life cycle.
4. Present the predicted demand data for the first 8 quarters.

STEP 3: EXECUTE

1. Existing Competitor Demand

Corning Incorporated

Corning Incorporated is a leading competitor in materials science, particularly in advanced glass and windshield technologies such as Gorilla Glass. Understanding an estimate of their windshield demand is crucial in forecasting for the Smart Windshield as it provides insights into market trends and fluctuations and helps ensure accurate predictions for planning the product timeline.

Corning segments their net sales into 6 key parts, which can be seen in the table below:

Optical Communications	- Products involve optical fibers, cables and connectivity. Products provide solutions for optical based communication infrastructures for services such as voice and video.
Display Technologies	- Products involve glass panels and substrates that may be used to create the screens in computers, monitors, and related technologies.
Speciality Materials	- Products involve glass made for a wide variety of markets including **windshields**, mobile phones, and other glass screens. Its biggest selling product in this segment is Gorilla Glass for windshields.
Environmental Technologies	- Segment of products focuses on creating ceramic glass products and filters to control emissions.
Life Sciences	- Provides products such as plastic vessels, labware, and other related equipment.

Other(Emerging Technology and Businesses)	- This group consists of various new emerging technologies in which the company is involved throughout many industries, and emerging businesses into which they've invested.

2. Corning Incorporated Net Sales

For the 8 quarters through 2022 and 2023 Corning Incorporated had the following net sales:

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
GAAP Net Sales ($ in millions)	3,680	3,615	3,488	3,406	3,178	3,243	3,173	2,994

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

This data represents the entirety of Corning's sales, including products that are not similar to our own. To adjust the data for our product we need to choose the segment of Corning that most closely relates to our product.

The Smart Windshield most closely matches Corning's Specialty Materials segment, with the segment mainly focusing on windshields. That means to get a general estimate we only need to look at their specialty materials net sales, which is shown below:

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Specialty Materials Net Sales ($ in millions)	493	485	519	520	406	423	563	473

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

3. Adjusted Expected Demand

Using the net sales for Specialty Materials we found above can estimate Corning's units sold. We do this by Analyzing Corning's portion of sales that are from windshields, in which we find the following:

- Averaging the GAAP Net Sales for the segment Specialty Materials data from Q1 2022-Q4 2023, data indicates that Specialty Materials accounts for approximately 14.47% of Corning Incorporated's total GAAP Net Sales.

- Gorilla Glass windshields cost significantly more than their competitors products which often cost around $100-$200 for a basic windshield, compared to $700+ for a 2018 Jeep Wrangler, $900 for a 2019 Ford F150, and for newer Jeep Wranglers the cost has fallen to roughly $500.

- Assuming that each unit was sold for **$550/unit**, they sold these estimated numbers of windshield units per quarter, seen in the table below.

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Estimated Windshield Units Sold	896,363	881,818	943,636	945,454	738,181	769,090	1,023,636	860,000

Now using this estimation of Corning's Windshield sales we can make an estimation of the Smart Windshield's possible demand by adjusting the data to the Smart windshields specific traits. We take into account the following information to make our estimation:

- Account for the scale of the number of windshields sold by Corning Incorporated to GMC to account for the difference in sales, as GMC provides less windshields

- Corning Incorporated produces around 800-900,000 units per quarter at most during 2022-2023, totaling around 3.39 million windshields a year

- GM sold 6.186 million new vehicles total in 2023.

- Therefore, assuming that for GM the Smart Windshield:
    - The product costs around $500 in comparison to the standard $100-200 windshield installed in most models,

- GM continues to sell its vehicles using a differentiated strategy
- On average 25-45% of customers are willing to pay for premium options in their vehicles(actual statistics according to Cox Auto Inc. and McKinsey and Company).

- We can assume that only about 37.5% of GM customers will opt for the premium Smart Windshield option to be installed into their vehicles.

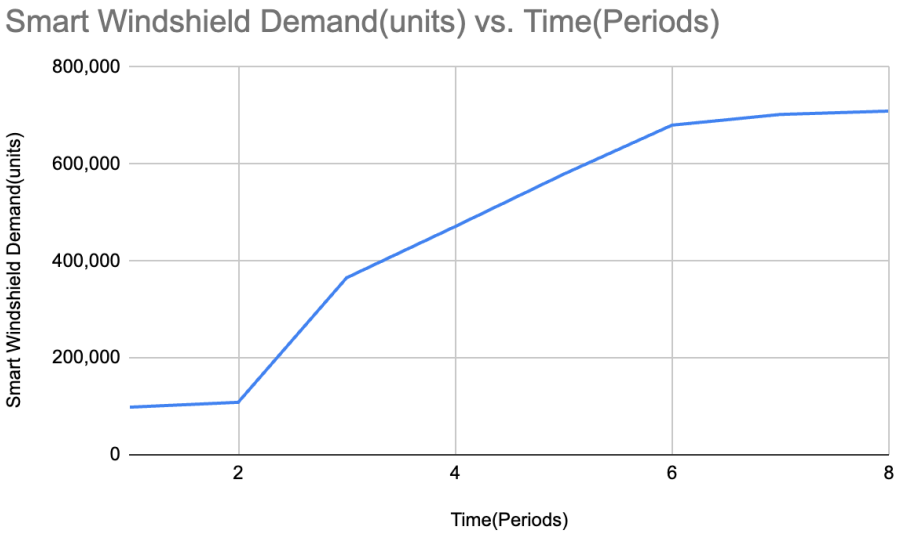
- If 35% of GM vehicles are equipped with the Smart Windshield approximately 2,165,100 or more vehicles will be installed with Smart Windshields in them per year at maturity.

4. Predicted Demand for the first 8 Quarters

Taking all of these details of GM and Corning's sales into account we can now determine our estimated demand for the Smart Windshield:

Product Life Cycle	Intro	Intro	Growth	Growth	Growth	Growth	Maturity	Maturity
Quarter, Year	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026	Q3 2026	Q4 2026
Estimated Smart Windshield Units Sold	98,257	108,250	365,309	470,983	578,983	680,232	702,340	709,298

We can see this predicted change of demand over the product life cycle more clearly in this graph:



This predicted demand was calculated with the following details in mind:

- This estimate of the first eight quarters of demand for the GM Smart Windshield aligns with the product life cycle we expect the product to follow, and in the year it reaches maturity we estimate that 2,165,100 units will be sold.

- While this is less than the total number of estimated units sold by Corning Incorporated, we must remember that, while we have a differentiated business strategy, many customers may not be willing to pay the premium for a new product, despite GM selling many more vehicles overall, as well as that the estimate for Corning Incorporated's windshields sold is likely high due to other products being sold under the Specialty Materials sector.

STEP 4: CHECK

- Numbers provided was based on existing company and examination
- Although numbers are not definite, they are calculated based on real life products and are completely hypothetical

STEP 5: LEARN

- Through this first part of the deliverable, we are able to find a projected demand for our product based on real historical demand data of a similar one. Within our team, there was lots of discussion regarding what differentiated our Smart Windshield from the Corning Product, borrowing heavily from Specialty Material's demand and adjusting based on taking GMC sales history of total products into account as well as portion of sales in ratio of all products Corning and GMC sell.

2:Demand Forecasting:

STEP 1: DEFINE

- Use all five forecasting methods on forecasted demand above to forecast data for the next following years along with error analysis.
    - Static
    - Moving Average
    - Simple Exponential
    - Holt's
    - Winter's
- Determine the most accurate forecast for Smart Windshield.

STEP 2: PLAN

Now that we have historical demand data we can now forecast the future demand for the Smart Windshield, so that we can calculate important information for our supply chain. To do this we will forecast the demand using both the static and adaptive methods, which we will compare to find the most accurate forecast for our product.

All of the demand forecasting excel documents can be found here: Smart Windshield Demand Forecasting

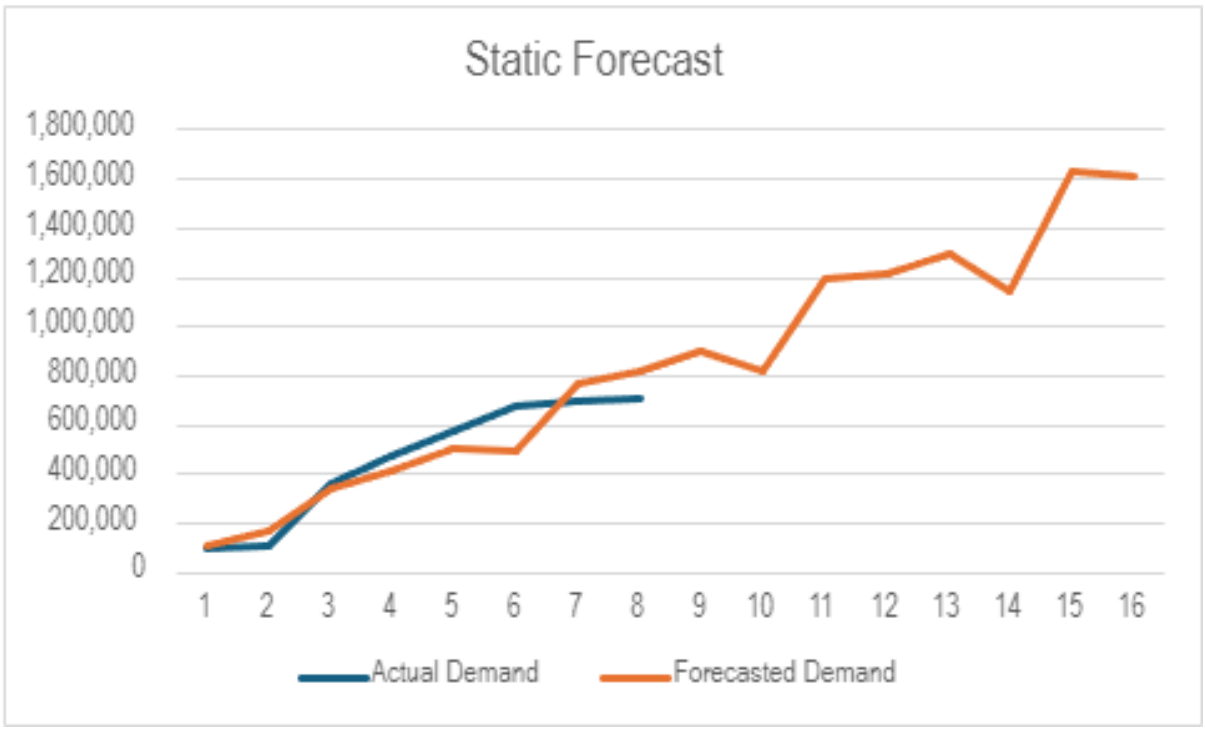
- Reference textbook for help with Excel
- Reference Notes for formulas regarding each forecasting method

STEP 3: EXECUTE

Static Forecasting:

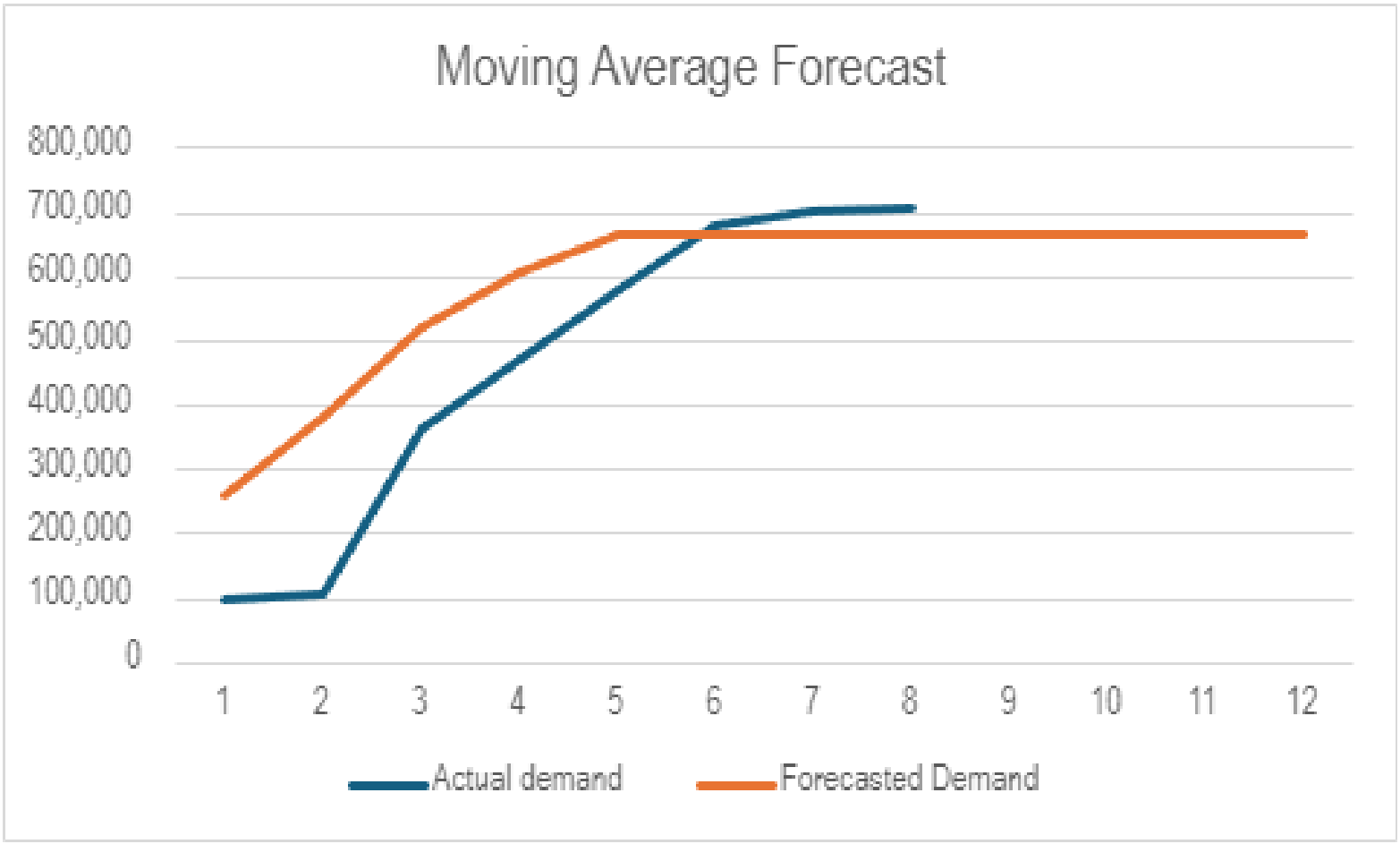
	B	C	D	E	F
1	Demand Dt	Deseasonalized Demand	Seasonal Factor	Average Seasonal Factor	Predicted Demand for next periods
2	1	80438	81517	0.986763497	1.39142557	113424.8382
3	2	140400	88544	1.585652331	1.293113509	114497.4425
4	3	114075	95571	1.193615218	1.199880887	114673.8163
5	4	184275	102598	1.796087643	1.804371764	185124.9342
6	5	109688	109625	1.000574686		152535.0281
7	6	187200	116652	1.604773171		150844.277
8	7	149175	123679	1.206146557		148400.0683
9	8	236925	130706	1.812655884		235842.2157
10	9					191645.218
11	10					187191.1115
12	11					182126.3203
13	12					286559.4973
14	13					230755.408
15	14					223537.946
16	15					215852.5722
17	16					337276.7788

Year	Quarter	Period t	Demand Dt	Deseasonalized Demand	Regression	Seasonal Factors	Avg Seasonal Factors	Quarterly Forecast	Error Et	Absolute Error At	Squared Error MSEt	MADt	% Error	APE	MAPEt	bias	TSt
2025	1	1	98,257		121,515	0.81	0.93	113,009	14,752	14,752	217,631,279	14,752	15	15	15	14,752	1.00
	2	2	108,250		228,018	0.47	0.76	173,294	65,044	65,044	2,224,161,231	39,898	60	60	38	79,796	2.00
	3	3	365,309	320,791	334,521	1.09	1.01	337,866	-27,443	27,443	1,733,813,239	35,746	-8	8	23	52,353	1.46
	4	4	470,983	452,379	441,024	1.07	0.94	414,562	-56,421	56,421	2,096,189,436	40,915	-12	12	14	-4,068	-0.10
2026	1	5	578,983	566,006	547,526	1.06	0.93	509,199	-69,784	69,784	2,650,902,404	46,689	-12	12	9	-73,851	-1.58
	2	6	680,232	637,924	654,029	1.04	0.76	497,062	-183,170	183,170	7,800,961,887	69,436	-27	27	3	-257,021	-3.70
	3	7	702,340		760,532	0.92	1.01	768,137	65,797	65,797	5,411,499,255	68,916	9	9	4	-191,225	-2.77
	4	8	709,298		867,034	0.82	0.94	815,012	105,714	105,714	7,788,813,719	73,516	15	15	5	-85,510	-1.16
2027	1	9						905,389									
	2	10						820,830									
	3	11						1,198,408									
	4	12						1,215,462									
2028	1	13						1,301,579									
	2	14						1,144,598									
	3	15						1,628,679									
	4	16						1,615,913									


Static Forecast
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Actual Demand
Forecasted Demand

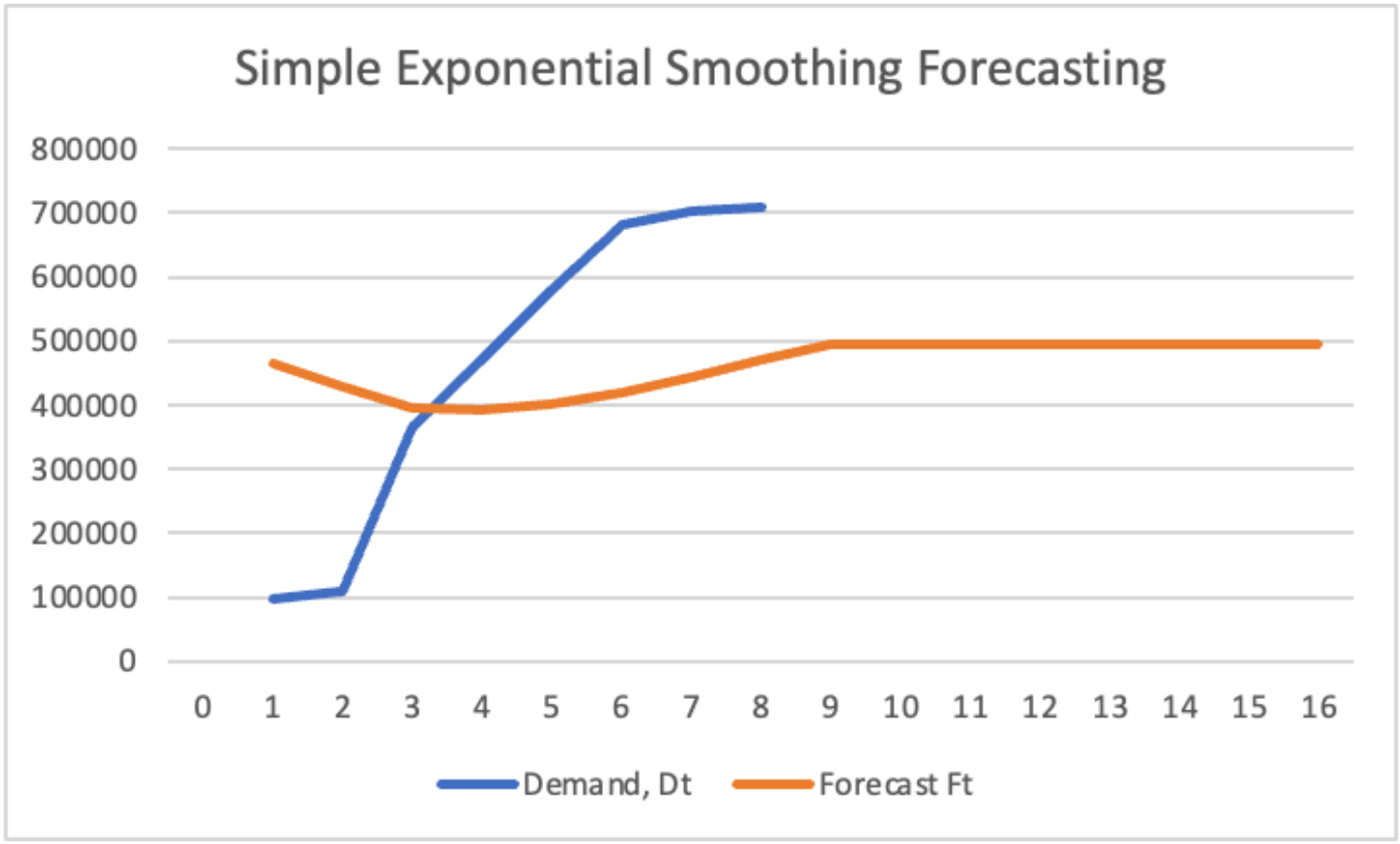
Moving Average:

Year	Quarter	Period t	Demand, D_t	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	bias	TS_t
2025	1	1	98,257											
	2	2	108,250											
	3	3	365,309											
	4	4	470,983	260,700										
2026	1	5	578,983	380,881	260,700	-318,283	318,283	101,304,227,231	260,700	-55	55	-55	-318,283	-1.22
	2	6	680,232	523,877	380,881	-299,351	299,351	95,457,549,378	320,791	-44	44	-49	-617,634	-1.93
	3	7	702,340	608,135	523,877	-178,463	178,463	74,254,743,452	388,486	-25	25	-41	-796,097	-2.05
	4	8	709,298	667,713	608,135	-101,164	101,164	58,249,571,022	443,398	-14	14	-35	-897,261	-2.02
2027	1	9			667,713									
	2	10			667,713									
	3	11			667,713									
	4	12			667,713									
2028	1	13			667,713									
	2	14			667,713									
	3	15			667,713									
	4	16			667,713									


Moving Average Forecast
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1
2
3
4
5
6
7
8
9
10
11
12
Actual demand
Forecasted Demand

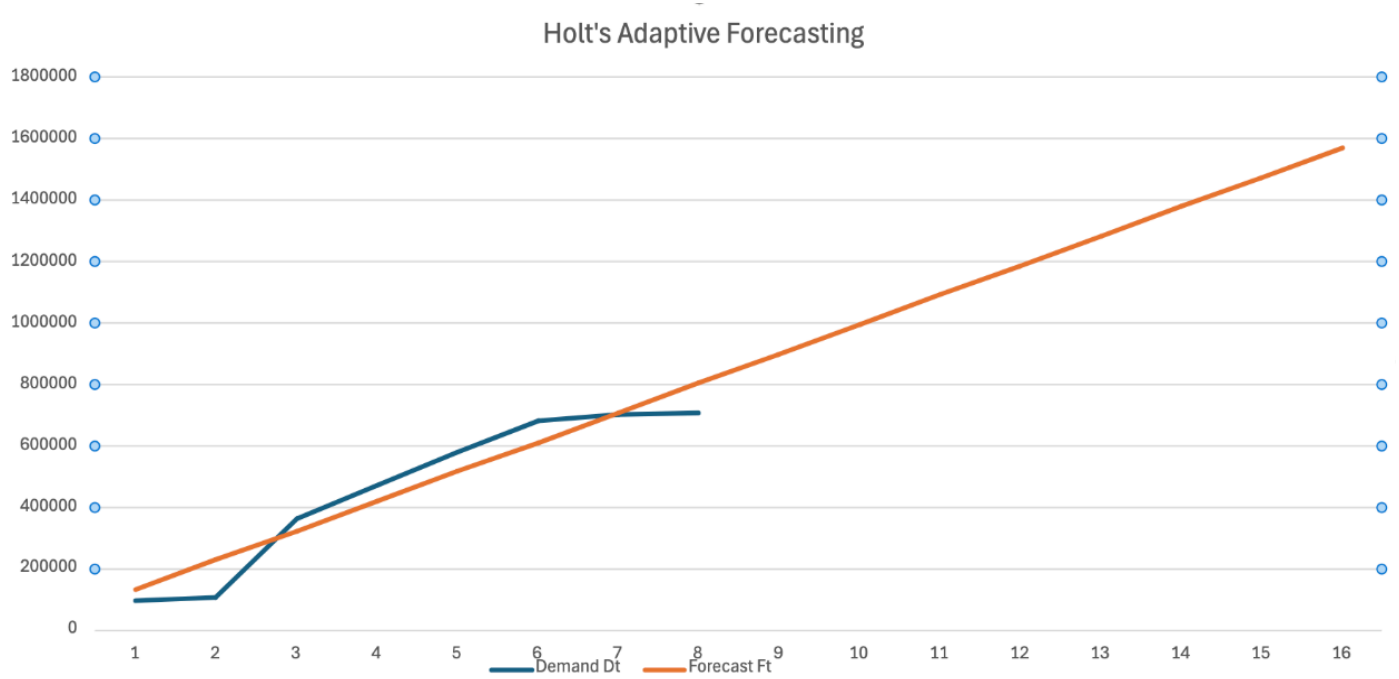
Simple Exponential Smoothing:

Period t	Demand, D_t	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	Bias	TS_t
0		464,207										
1	98,257	427,612	464,207	365,950	365,950	133,919,036,550	365,950	372	372	372	365,950	1
2	108,250	395,675	427,612	319,362	319,362	117,955,418,084	342,656	295	295	334	319,362	2
3	365,309	392,639	395,675	30,366	30,366	78,994,318,038	238,559	8	8	225	30,366	3
4	470,983	400,473	392,639	-78,344	78,344	60,742,693,690	198,505	17	17	173	-78,344	3
5	578,983	418,324	400,473	-178,510	178,510	54,967,306,123	194,506	31	31	145	-178,510	2
6	680,232	444,515	418,324	-216,908	216,908	57,238,707,707	205,740	39	39	127	-216,908	1
7	702,340	470,297	444,515	-257,825	257,825	58,558,000,691	213,181	37	37	114	-257,825	0
8	709,298	494,198	470,297	-239,001	239,001	58,378,408,397	216,408	34	34	104	-239,001	-1
9			494,198									
10			494,198									
11			494,198									
12			494,198									
13			494,198									
14			494,198									
15			494,198									
16			494,198									


Simple Exponential Smoothing Forecasting
800000
700000
600000
500000
400000
300000
200000
100000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Demand, Dt
Forecast Ft

Holts Method:

Period t	Demand Dt	Level Lt	Trend Tt	Forecast Ft	Error Et	Absolute Error At	MSEt	MADt	% Error	MAPEt	Biast	TSt
0		36,761	95,945									
1	98,257	132,362	95,942	132,706	34,449	34,449	1,186,733,601	34,449	35	35	365,950	1
2	108,250	227,103	95,930	228,303	120,053	120,053	7,799,736,020	77,251	111	73	685,311	2
3	365,309	323,455	95,934	323,032	-42,277	42,277	5,795,603,216	65,593	12	53	715,677	1.71
4	470,983	419,905	95,939	419,389	-51,594	51,594	5,012,197,143	62,093	11	42	637,333	0.98
5	578,983	516,475	95,945	515,844	-63,139	63,139	4,807,076,716	62,303	11	36	458,823	-0.04
6	680,232	613,098	95,952	612,420	-67,812	67,812	4,772,304,933	63,221	10	32	196,916	-1.11
7	702,340	708,983	95,951	709,050	6,710	6,710	4,096,979,689	55,148	1	27	-60,910	-1.15
8	709,298	803,978	95,942	804,935	95,637	95,637	4,728,151,315	60,209	13	25	-299,910	0.53
9				899,920								
10				995,862								
11				1,091,804								
12				1,187,745								
13				1,283,687								
14				1,379,629								
15				1,475,571								
16				1,571,513								


Holt's Adaptive Forecasting
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1
2
3
4
5
6
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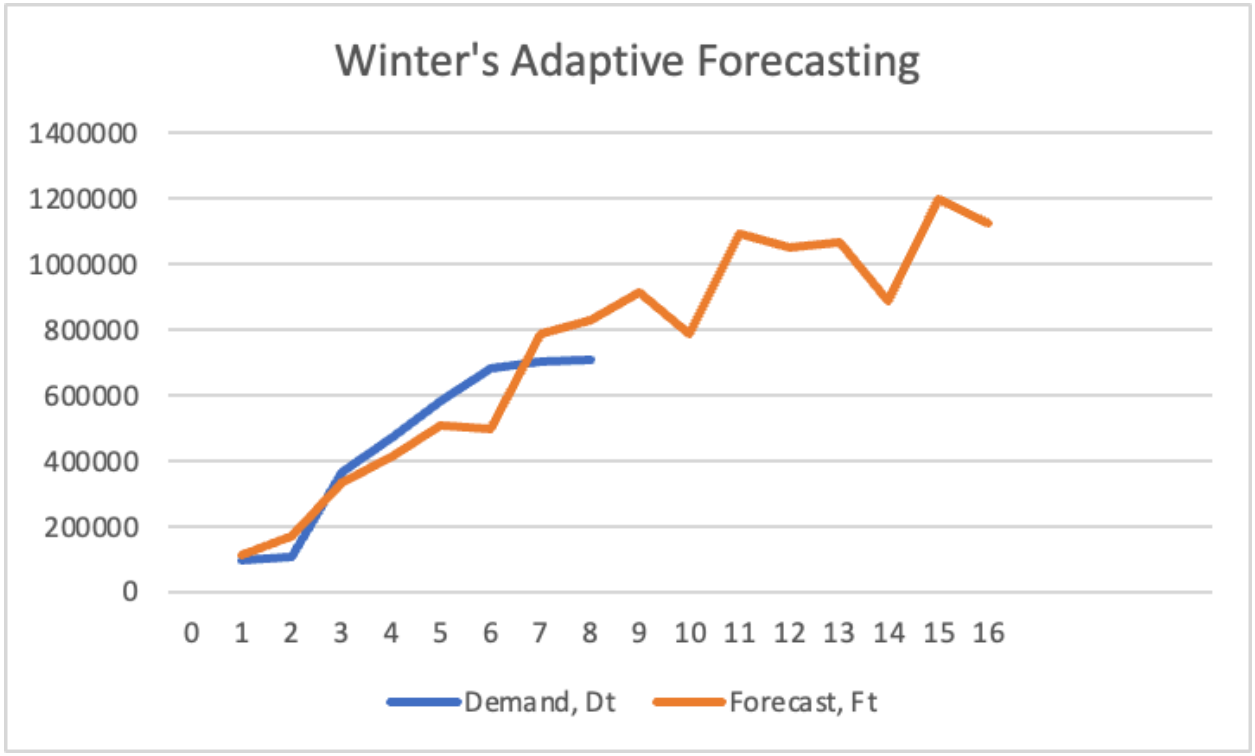
11
12
13
14
15
16
Demand Dt
Forecast Ft

Winter's Method:

Year	Quarter	Period t	Demand, Dt	Level, Lt	Trend, Tt	Average Seasonal Factor	Forecast, Ft	Error, Et	Absolute Error Et	MSEt	MADt	% Error	MAPEt	TSt	Bias
	0	0		15,013	106,503										
2025	1	1	98,257	120,723	106,424	0.93	113,009	14,753	14,753	217,647,468	14,752	15.01	15.015	1	14,753
	2	2	108,250	222,911	106,000	0.76	172,631	64,381	64,381	2,181,303,078	39,567	59.47	37.24	2	79,134
	3	3	365,309	330,550	106,164	1.01	332,200	-33,109	33,109	1,819,601,040	37,414	9.06	27.85	1.23	46,025
	4	4	470,983	439,931	106,486	0.94	410,511	-60,472	60,472	2,278,908,674	43,178	12.84	24.10	-0.33	-14,446
2026	1	5	578,983	550,224	106,866	0.93	508,167	-70,816	70,816	2,826,101,718	48,706	12.23	21.72	-1.75	-85,262
	2	6	680,232	668,988	108,056	0.76	499,388	-180,844	180,844	7,805,815,400	70,729	26.59	22.53	-3.76	-266,106
	3	7	702,340	772,961	107,648	1.01	784,814	82,474	82,474	7,662,414,693	72,406	11.74	20.99	-2.54	-183,631
	4	8	709,298	874,307	107,018	0.94	827,772	118,474	118,474	8,459,133,771	78,165	16.70	20.46	-0.83	-65,157
2027	1	9		932,259	102,111	0.93	912,632								
	2	10		982,651	96,939	0.76	786,120								
	3	11		1,025,611	91,541	1.01	1,090,386								
	4	12		1,061,294	85,956	0.94	1,050,123								
2028	1	13		1,089,887	80,219	0.93	1,066,943								
	2	14		1,111,601	74,369	0.76	889,281								
	3	15		1,126,672	68,439	1.01	1,197,830								
	4	16		1,135,355	62,463	0.94	1,123,404								


Winter's Adaptive Forecasting
1400000
1200000
1000000
800000
600000
400000
200000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Demand, Dt
Forecast, Ft

Error Analysis:

STEP 1: DEFINE

- Conduct cycle inventory analysis on Smart Windshield Product.

STEP 2: PLAN

- Reference Notes for Equations to perform given base stats
- Set up context for performing cycle inventory analysis

STEP 3: EXECUTE

To determine which of the 5 forecasting methods is the most accurate and fits our estimated demand the best we must compare their calculated errors. All of the method's various error analysis can be seen and compared in the table below:

Method	Average MSE	Average MAD	Average MAPE	Average bias	TS
Static	7,788,813,719	73,516	5	-58,097	-3.70 to 2.00
Moving Average	58,249,571,022	443,398	35	-657,319	-2.02 to -1.22
Simple Exponential Smoothing	77,594,236,160	246,938	199.25	-31,864	-1.00 to 3.00
Holt's	4,262,725,368	56,283	40.375	1,602,321.75	-3.76 to 2.00
Winter's	4,156,365,730	50,615	24	-59,336	-3.76 to 2.00

- The smallest average MSE: Winter's Method
- The smallest average MAD: Winter's Method
- The smallest MAPE: Static
- Closest to Zero Average Bias: Simple Exponential Smoothing
- All Tracking Signals are within reasonable ranges.

Based on all average error metrics calculated, **Winter's Method** fits the most criteria over the most selectable methods making it the most accurate forecast out of all five methods.

STEP 4: CHECK

- Forecasting methods were done with the same starting date as calculated in Task 1
- Forecasting methods were divided with different members using different methods for task delegation
- Formulas were derived from textbooks and notes

STEP 5: LEARN

- Lots of the forecasting methods were done in class. We learned that even with the differing final results when comparing error analysis, Winter's Method was the most versatile in terms of having a smaller Mean Squared Error and Mean Average Deviation. Static had the smallest Mean Absolute Percentage Error, however, which is also important. Taking all consideration from all team members, we decided Winter's Method was the most applicable to our product's demand.

3: Cycle Inventory Management:

Cycle Inventory in GMC's Supply Chain:

- **Raw Material Procurement:** GMC sources specialized materials such as glass, embedded sensors, and connectivity chips. These components are ordered in bulk to optimize cost savings and ensure availability.
- **Production Scheduling:** The manufacturing process aligns with demand forecasts, balancing production rates and inventory levels to minimize holding costs while avoiding shortages.
- **Just-in-Time (JIT) and Lean Practices:** GMC incorporates lean manufacturing principles, reducing excess inventory and improving efficiency in the supply chain.
- **Supplier Relationships:** Strong partnerships with Tier 1 and Tier 2 suppliers ensure a steady flow of materials while minimizing overstocking.
- **Distribution & Inventory Management:** Finished smart windshields are distributed based on dealership and service center demand, ensuring optimal stock levels without excessive storage costs.

Smart Windshield Data:

1. GMC buys products to create these windshields from corning and gorilla glass.
2. The price of a smart windshield is $650 after being compared to a basic windshield and considering its material costs.
    a. **P = 650**
3. Material Cost:
    a. C = 500
4. Percent Holding Cost:
    a. **H = 15%**
5. Fixed Shipping Cost per Order:
    a. **S = $300**
6. Annual Demand Data: based on static forecasted demand:
    a. **D = 896,363**

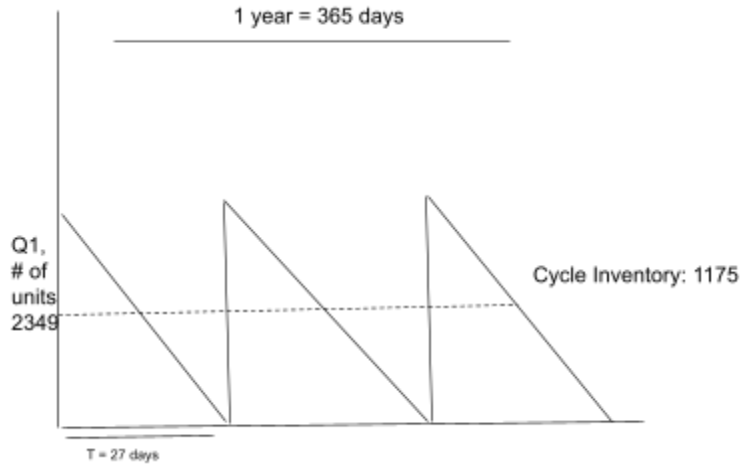
- **Lot size per shipment to minimize total cost:**
    - $Q_L^* = \sqrt{(2DS/hC)}$
        - $= \sqrt{(2\ (896{,}363)\ (300)\ /\ (0.15)\ (650))} = 2349$
    - The optimal lot size per shipment is **2349 units of the smart windshield.**
- **Economic Order of Quantity:**
    - $EOQ = Q_L^*$
    - EOQ is **2349 units of the smart windshield.**
- **Number of shipments per year to meet the forecasted demand:**
    - $n^* = D/Q_L^* = \sqrt{(\ DhC\ /\ 2S\ )}$

    - (896,363) / (2349) = 381.593
    - The number of shipments needed per year to meet the forecasted demand is **382 shipments.**

****since 382 shipments doesn't make sense, we recommend 191 shipments a year with about 4698 units to meet the demand*****

- **Cycle Inventory:**
    - CI = EOQ/2
    - 2349/2 = 1174.5
    - The cycle inventory is **1175 units**.
- **Cycle Inventory Holding Cost:**
    - h * C * (EOQ/2)
    - 0.15 * 650 * 1175 = 114562.5
    - The cycle inventory holding cost is **114,563**.
- **Replenishment Cycle Time:**
    - (EOQ/D) * 365
    - (2349/896,363) * 365 = 0.957
    - The replenishment cycle is about **1** day.
- **Average Flow Time:**
    - T = CI/D
    - 1175/896,363 * 365 = 0.4784
    - The average flow time is about **0.48** days.

Diagram to represent the above data as a function of time:



- 1
- Equations were calculated from equations from notes

STEP 5: LEARN

- When drawing conclusions, we learned with our cycle inventory that it refreshes quite often as the replenishment cycle time is 1 day. We learned our cycle inventory can store up to around 1175 units. Annually, this would cost around $114,563. We would want to ship around 382 orders per year to reach forecasted demand. We did a lot of number crunching from our basic stats and this is how we interpret the main results that we can use to find total revenue and total cost in the later/last task.

4: Base Case Profit

STEP 1: DEFINE

- Calculate the base case profit

STEP 2: PLAN

The excel sheet containing the calculations for the NPV analysis can be found here:
Smart Windshield GM NPV Analysis.xlsx

1. Determine the following parameters of the Smart Windshield product using data from previous project calculations and outside research:
    a. Sales and Production Volume
    b. Development Cost
    c. Unit Price
    d. Unit Production Cost
    e. Ramp-up Cost
    f. Marketing and Support Cost
    g. Annual Discount Factor %

2. Use the established parameters from the previous step to calculate the base-case NPV.

3. Perform a sensitivity analysis of the base-case NPV with respect to Development cost, Sales volume, and Unit production cost, to identify critical variables and assess possible risk.

STEP 3: EXECUTE

To calculate the possible base case profit for the Smart Windshield we have to establish several parameters using data that was calculated previously in this report along with other data estimated from research.

Sales and Production Volume:

The Sales volume of the product is set equal to the demand data previously determined in task 2 of this report. This was calculated using existing data from Corning inc. and adjusted and forecasted for the Smart Windshield.

Sales Volume = **896,363** units/year

Development Cost:

To estimate the development cost of our product we took into consideration the different material components that have to be developed along with the possible labor costs of these developments. Most of our components are heavily software based, which means that development cost will be mostly in software development. Here are the systems that have to be developed:

Software development	***Material Development***
- AR system	- Cameras
- Real time data integration	- leak-proof windshields
- GPS	- Photosensors
- Corrective steering system	- Solar Powered back-up battery
- Voice based User Interface	
- Information Security	

We expect that many of the software development costs will be higher than the material development costs due to complex innovative and AI-driven software. This is our estimation for each system:

Software development	***Material Development***
- AR system = $55M	- Cameras = $10M
- Real time data integration = $20M	- leak-proof windshields = $5M
- GPS = $15M	- Photosensors = $10M
- Corrective steering system = $20M	- Solar Powered battery = $15M
- Voice based User Interface = $15M	
- Information Security = $25M	

Total Development Cost = **$190 million**

Unit Price:

We determined the unit price for our product in the previous tasks in this report. When taking into account existing windshield costs and factoring in material costs we came to the decision of this unit price:

Unit Price = **$650** per unit

Unit Production Cost:
The unit production cost was similarly determined in the previous sections of this project phase. This cost was calculated based off of similar existing products, giving us this production price:

Unit Production Price = **$500** per unit

Ramp-up Cost:
To calculate the ramp-up cost we estimated it to be around 10% of development costs which gives us the following:

Total Ramp-up Cost = **$23 million**

Marketing and Support Cost:
To calculate the annual marketing and support cost we estimated it to be around 5% of our total estimated revenue, which is $582,635,950. This gives us the following:

Annual Marketing and Support Costs = **$29,131,797** per year

Annual Discount Factor:
We chose an annual discount factor of **10%** based on similar factors in the industry.

Now that we have determined all of the relevant factors we can calculate the base case NPV. Here are the input scenario parameters again:

SCENARIO INPUT PARAMETERS

Development Cost (total $)	190,000,000
Unit price	650
Unit Productions Cost ($/unit)	500
Ramp-up cost (total $)	23,000,000
Marketing & support cost ($/year)	29,131,797
Annual Discount Factor (%)	10

The base case calculation sheet is shown on the next page

	Year 1				Year 2				Year 3				Year 4			
period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
($ values in thousands)	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Development Cost	-47,500	-47,500	-47,500	-47,500												
Ramp-up cost				-11,500	-11,500											
Marketing & support cost					-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283	-7,283
Production cost						-112,045	-112,045	-112,045	-112,045	-112,045	-112,045	-112,045	-112,045	-112,045	-112,045	-112,045
Production volume						224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091
Unit production cost						-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50
Sales Revenue						145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659
Sales volume						224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091
Unit price						0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Period Case Flow	(47,500)	(47,500)	(47,500)	(59,000)	(18,783)	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331
PV Year 1, r=10%	(47,500)	(46,341)	(45,211)	(54,787)	(17,016)	23,272	22,705	22,151	21,611	21,084	20,569	20,068	19,578	19,101	18,635	18,180

Project NPV, $	16,098															

all units in thousands,

Using our estimated values we were able to calculate this project's base case profit is projected to be **$16,098,000**.

Project Phase	Items to fix and improve
Phase 2	The estimation of demand has to be converted into an explicit mathematical process to obtain the data.
	Provide the chosen values for alpha, beta, and gamma for the Winter's method
	Provide set up and explanations for all the demand forecasting methods
	Re-Examine and fix the demand forecasting methods, some of the error results are too high and the best method should be an adaptive model, not a static one.
	Add a SC network to the Cycle Inventory Management section. We also need to explicitly show how we derived two subsystems from it.
	NPV analysis needs to be improved, removing "Sales & Production Volume" from Scenario Parameters table, correcting the sales volume, including sensitivity analyses, and analyzing 5 years.

Phase III: Supply Chain cycle & safety inventory management

For the next phase we are going back and revising our previous demand estimations and forecasts to ensure that we are getting an accurate prediction of the demand our product will face. This will also entail us revising pur cycle and safety inventory costs as well as our 5-year financial model.

1. Revised Estimated Demand for Quarters 1-8

1. Choose a Competitor and Examine their Demand

Corning Incorporated

- Corning Incorporated is a leading competitor in materials science, particularly in advanced glass and windshield technologies such as Gorilla Glass

- Understanding an estimate of their windshield demand is crucial in forecasting for the Smart Windshield as it provides insights into market trends and fluctuations and helps ensure accurate predictions for planning the product timeline

- It its important to understand how Corning Incorporated divides its sales into the segments of the company shown in the table below in order to pay attention to the segment most similar to our product:

Optical Communications	- Products involve optical fibers, cables and connectivity - Products provide solutions for optical based communication infrastructures for services such as voice and video.
Display Technologies	- Products involve glass panels and substrates that may be used to create the screens in computers, monitors, and related technologies
Speciality Materials	- Products involve glass made for a wide variety of markets including **windshields**, mobile phones, and other glass screens. - Its biggest selling product in this segment is Gorilla Glass for windshields.
Environmental Technologies	- Products focused on creating ceramic glass products and filters to control emissions
Life Sciences	- Provides products such as plastic vessels, labware, and other related equipment
Other(Emerging Technology and Businesses)	- This group consists of various new emerging technologies in which the company is involved throughout many industries, and emerging businesses into which they've invested.

2. Corning Incorporated Net Sales

For the 8 quarters through 2022 and 2023 Corning Incorporated had the following net sales:

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
GAAP Net Sales ($ in millions)	3,680	3,615	3,488	3,406	3,178	3,243	3,173	2,994

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

- This data represents the entirety of Corning's sales, including products that are not similar to our own

- To adjust the data for our product we need to look at how Corning segments their net sales using the table from Step 1

- **The Smart Windshield most closely matches Corning's Specialty Materials segment, with the segment mainly focusing on windshields**

- That means to get a general estimate we only need to look at their specialty materials net sales, which is shown below:

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Specialty Materials Net Sales ($ in millions)	493	485	519	520	406	423	563	473

Sources:(CorningQ1Q2, CorningQ3Q4, CorningQ5Q6, CorningQ7Q8)

3. Adjusted Expected Demand

- By finding the Specialty Materials Net Sales and dividing it by the average cost of a Gorilla Glass Windshield, an estimation of the number of windshield sold per quarter can be made

- Gorilla Glass windshields cost significantly more than their competitors products which often cost around $100-$200 for a basic windshield, compared to $700+ for a 2018 Jeep Wrangler, $900 for a 2019 Ford F150, and for newer Jeep Wranglers the cost has fallen to roughly $500

- This estimate may be be broad, as Gorilla Glass is not the only product sold under this segment of the company, but it is the primary source of sales

- Assuming that each unit was sold for **$550/unit,** Corning sold the following amount of Gorilla Glass Windshield per quarter:

Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Estimated Windshield Units Sold	896,363	881,818	943,636	945,454	738,181	769,090	1,023,636	860,000

- Now using this estimation of Corning's Gorilla Glass Windshield sales we can make an estimation of the Smart Windshield's estimated demand for the first 8 quarters, adjusting demand to fit our product lifecycle and comparing to Corning to see if our estimates are reasonable

- While at maturity Corning Incorporated sold around 800-900,000 units per quarter, totaling around 3.39 million windshields, GM sold 2.6 million vehicles in 2023

- Assuming that for GM the Smart Windshield:
    a. The product costs around $500 in comparison to the standard $100-200 windshield installed in most models they produce
    b. GM continues to sell its vehicles using a differentiated strategy
    c. On average 25-45% of customers are willing to pay for premium options in their vehicles(actual statistic according to McKinsey and Company, Cox Automotive)
    d. An average of 2.6 million vehicles are sold per year

- We can assume that only about 37.5% of GM customers will opt for the premium Smart Windshield option to be installed into their vehicles.

- If 37.5% of GM vehicles are equipped with the Smart Windshield approximately 975,000 will be installed with Smart Windshields in them per year at maturity

- Assuming that in the first 8 quarters of the GM Smart Windshield Launch, the product begins with only 15% of customers opting to install the premium option, and that each quarter the demand increases by about 1.5% of customers opting in for it the following equation may be used:
    a. D = demand in period t
    b. Q = units sold per quarter
    c. A = proportion of vehicles initially opting for GM Smart Windshield

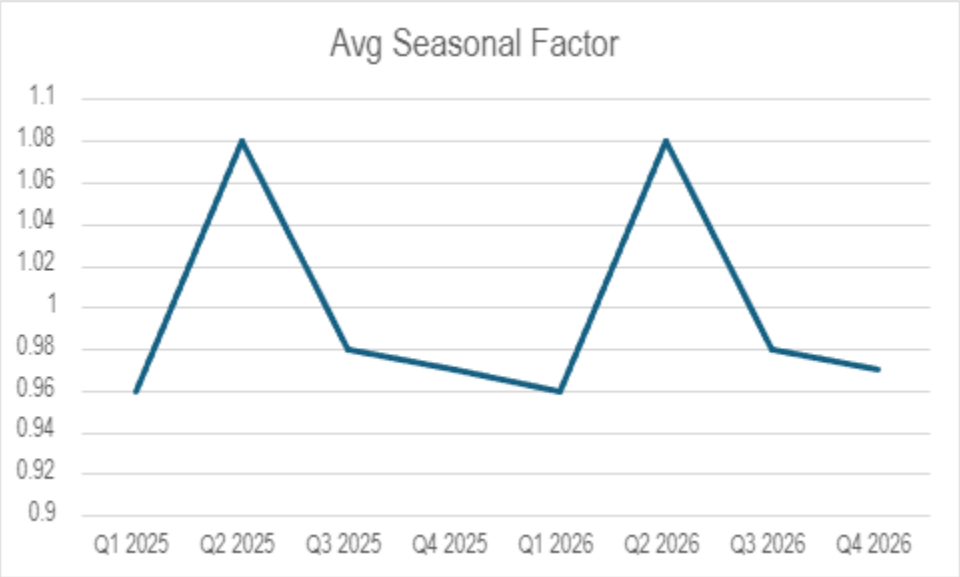
d. a = additional proportion of vehicles opting in for GM Smart Windshield per quarter
e. t = time in periods
f. S = average seasonality determined based on vehicle sales market research
g. D = (Q * (A + (a * t))) * S

- Q = 650,000 units, A = 0.15, a = .015, t = period t, S = (0.96, 1.08, 0.98, 0.97)

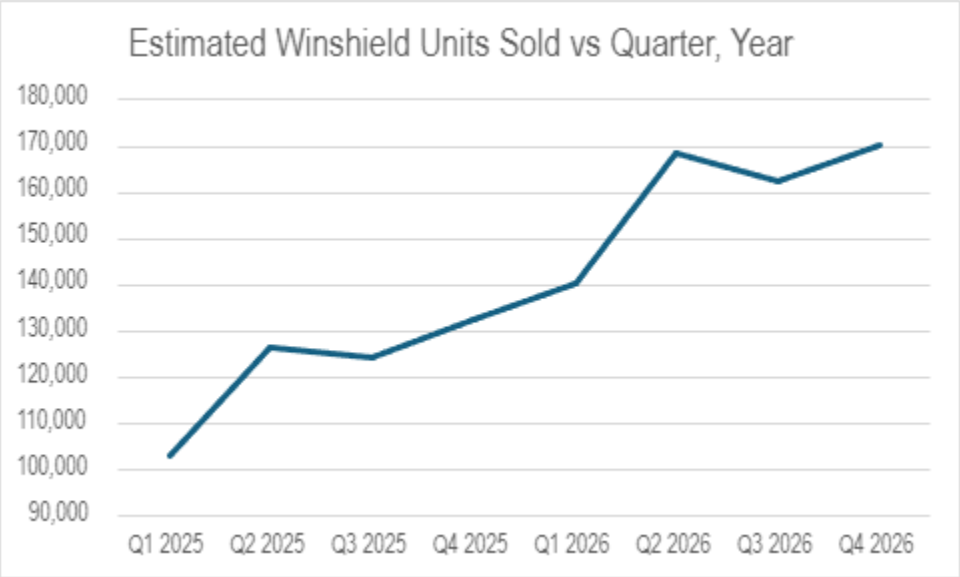
4. Determine the Seasonal Factors

- Average Seasonality for the four quarters was determined using data from the Federal Reserve (Which can be found here: Federal Reserve Seasonal Factors for Motor Vehicle Sales).
- To calculate the seasonal factors of domestic autos for each quarter we took the average of the seasonal factors of the months in the quarter providing the following average seasonal factors:

Quarter, Year	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026	Q3 2026	Q4 2026
Months	Jan-Mar	April-June	July-Sept	Oct-Dec	Jan-Mar	April-June	July-Sept	Oct-Dec
Avg Seasonal Factor	0.96	1.08	0.98	0.97	0.96	1.08	0.98	0.97



Quarter, Year	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026	Q3 2026	Q4 2026
Estimated Smart Windshield Units Sold	102,960	126,360	124,215	132,405	140,400	168,480	162,435	170,235



2. Revised Forecasted Demand

STEP 1: DEFINE

- Use all five forecasting methods on forecasted demand above to forecast data for the next following years along with error analysis.
    - Static
    - Moving Average
    - Simple Exponential
    - Holt's
    - Winter's
- Determine the most accurate forecast for Smart Windshield.

STEP 2: PLAN

Now that we have historical demand data we can now forecast the future demand for the Smart Windshield, so that we can calculate important information for our supply chain. To do this we will forecast the demand using both the static and adaptive methods, which we will compare to find the most accurate forecast for our product.

All of the demand forecasting excel documents can be found here: Smart Windshield Demand Forecasting

All Demand forecasts will use these smoothing constants: $\alpha = 0.8$, $\beta = 0.1$, $y = 0.6$

STEP 3: EXECUTE

Static Method:

To perform this forecasting method we first deseasonalize the actual demand, then perform regression on it. We use this regressed data to calculate the average seasonal factors and then the forecast using these steps:

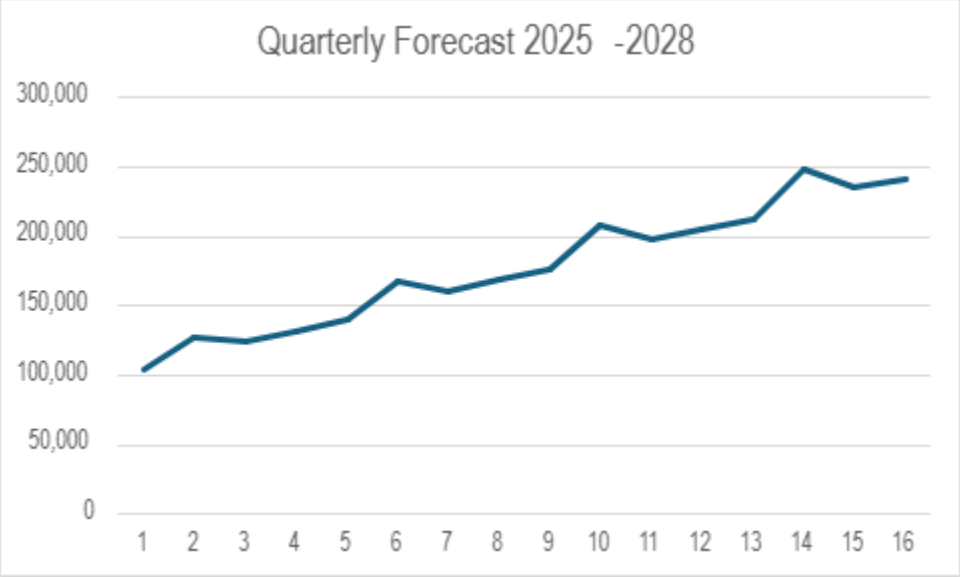
1. Deseasonalize demand and get a trendline formula based on results.
2. Find seasonal factors to account for seasonality.
3. Find the average seasonal factor (in this case, for every four periods).
4. Implement formulas on data (multiply trend by the period number) and then multiply product by corresponding average seasonal factor.

Here is the resulting forecasted demand:
(*Trendline Equation is 9852.4x +116391)*

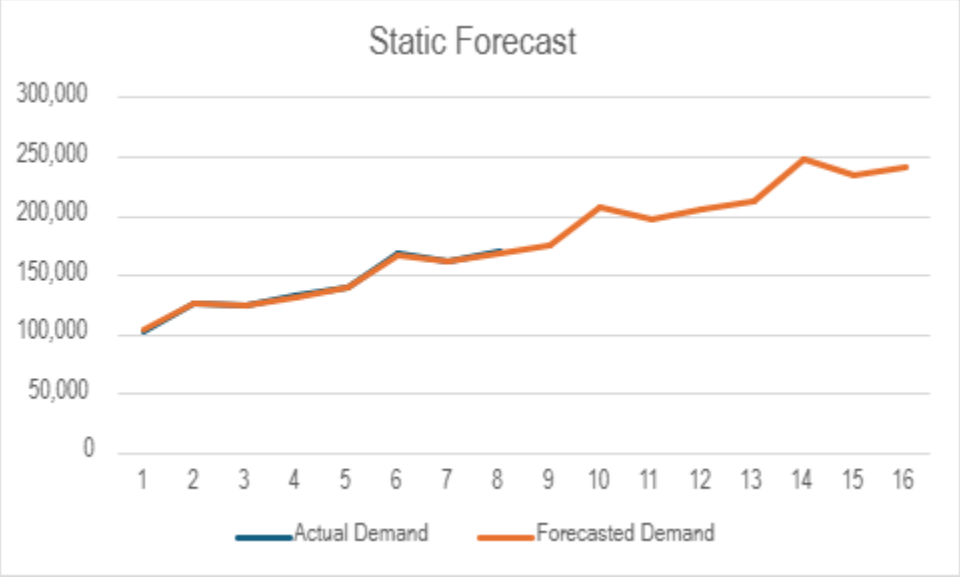
Year	Quarter	Period t	Demand, D_t	Deseasonalized Demand	Regression	Seasonal Factors	Avg Seasonal Factors	Quarterly Forecast
2025	1	1	102,960		126,243	0.96	0.96	103,615
	2	2	126,360		136,096	1.08	1.08	126,751
	3	3	124,215	126,165	145,948	0.98	0.98	124,256
	4	4	132,405	136,110	155,801	0.96	0.97	132,135
2026	1	5	140,400	146,153	165,653	0.96	0.96	139,825
	2	6	168,480	155,659	175,505	1.08	1.08	167,487
	3	7	162,435		185,358	0.98	0.98	161,220
	4	8	170,235		195,210	0.97	0.97	168,722
2027	1	9						176,035
	2	10						208,223
	3	11						198,184
	4	12						205,308
2028	1	13						212,244

	2	14		248,959
	3	15		235,148
	4	16		241,895

We can see the shape of the forecasted demand more clearly in this graph:



Here we can clearly see that the demand is following the seasonality of the actual demand. This points towards it being a possibly accurate forecast of our future demand, but we have to see it compared to the actual demand to come to a conclusion. We can see this in the graph below:



We can see in the graph that while the forecasted demand does take seasonality into account it over forecasts by a large margin. It is hundreds of thousands of units off in some places, meaning that is it probably not the best forecasting method for our project.

Static Complete Table

Year	Quarter	Period t	Demand, Dt	Deseasonalized Demand	Regression	Seasonal Factors	Avg Seasonal Factors	Quarterly Forecast	Error Et	Absolute Error At	Squared Error MSEt	MADt	% Error	APE	MAPEt	bias	TS
2025	1	1	102,960		126,243	0.96	0.96	103,615	655	655	429,413	655	0.64	0.64	0.64	655	1.00
	2	2	126,360		136,096	1.08	1.08	126,751	391	391	291,216	523	0.31	0.31	0.47	1,046	2.00
	3	3	124,215	126,165	145,948	0.98	0.98	124,256	41	41	194,703	362	0.03	0.03	0.33	1,087	3.00
	4	4	132,405	136,110	155,801	0.96	0.97	132,135	-270	270	164,285	339	-0.20	0.20	0.30	817	2.41
2026	1	5	140,400	146,153	165,653	0.96	0.96	139,825	-575	575	197,562	387	-0.41	0.41	0.32	242	0.63
	2	6	168,480	155,659	175,505	1.08	1.08	167,487	-993	993	328,961	488	-0.59	0.59	0.36	-751	-1.54
	3	7	162,435		185,358	0.98	0.98	161,220	-1,215	1,215	351,741	592	-0.75	0.75	0.42	-1,966	-3.32
	4	8	170,235		195,210	0.97	0.97	168,722	-1,513	1,513	717,545	707	-0.89	0.89	0.48	-3,479	-4.92
2027	1	9						176,035									
	2	10						208,223									
	3	11						198,184									
	4	12						205,308									
2028	1	13						212,244									
	2	14						248,959									
	3	15						235,148									
	4	16						241,895									

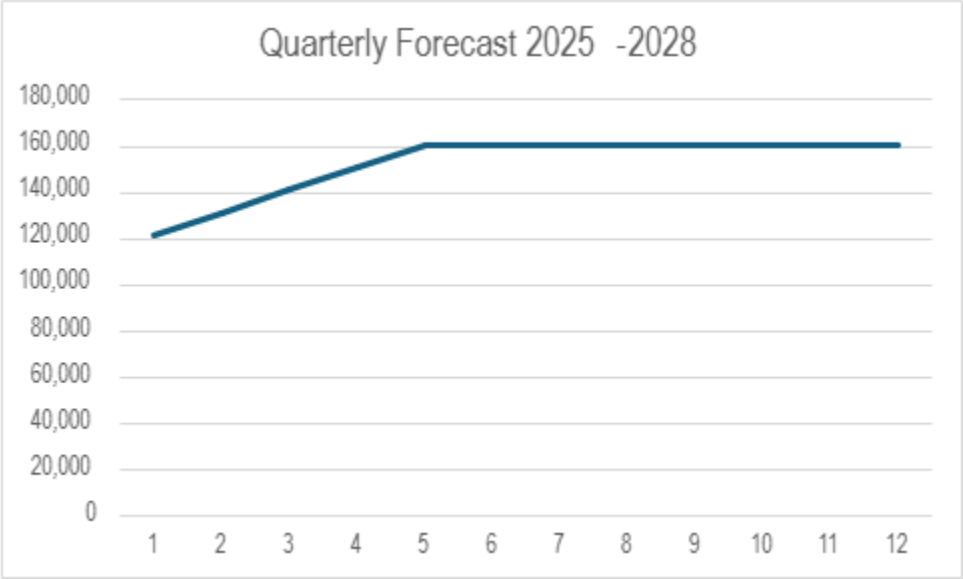
Moving Average

To perform this forecasting method we only look at the level which is calculated through a moving average of the actual demand. The forecast is then put equal to the previous period's level, with all of the forecasted quarters being set equal to the final actual demand's level.

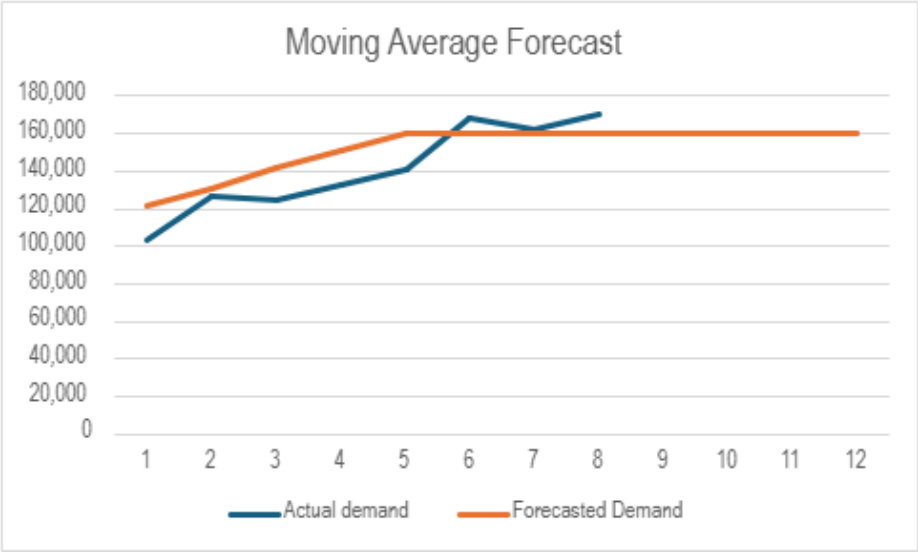
Here is the resulting forecasted demand:

Year	Quarter	Period t	Demand, D_t	Level L_t	Forecast F_t
2025	1	1	102,960		
	2	2	126,360		
	3	3	124,215		
	4	4	132,405	121,485	
2026	1	5	140,400	130,845	121,485
	2	6	168,480	141,375	130,845
	3	7	162,435	150,930	141,375
	4	8	170,235	160,388	150,930
2027	1	9			160,388
	2	10			160,388
	3	11			160,388
	4	12			160,388
2028	1	13			160,388
	2	14			160,388
	3	15			160,388
	4	16			160,388

We can see the shape of the forecasted demand more clearly in this graph:



Here we can clearly see how the demand starts off with a steady climb but levels off once we get to the forecasted unknown demand. This is because of this method having all future forecasted quarters equal to the same predicted demand. This means that it misses a lot of the different factors that may affect its accuracy. We can see this more clearly in the graph below:



Here we can see that the actual demand starts out significantly higher than the forecasted demand but starts to grow closer in later quarters. The graph still suggests that this forecasting method may not be the most accurate.

Moving Average Complete table

Year	Quarter	Period t	Demand, D_t	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	bias	TS_t
2025	1	1	102,960											
	2	2	126,360											
	3	3	124,215											
	4	4	132,405	121,485										
2026	1	5	140,400	130,845	121,485	-18,915	18,915	357,777,225	121,485	-13	13	13	-18,915	-0.16
	2	6	168,480	141,375	130,845	-37,635	37,635	887,085,225	126,165	-22	22	18	-56,550	-0.45
	3	7	162,435	150,930	141,375	-21,060	21,060	739,231,350	131,235	-13	13	16	-77,610	-0.59
	4	8	170,235	160,388	150,930	-19,305	19,305	647,594,269	136,159	-11	11	15	-96,915	-0.71
2027	1	9			160,388									
	2	10			160,388									
	3	11			160,388									
	4	12			160,388									
2028	1	13			160,388									
	2	14			160,388									
	3	15			160,388									
	4	16			160,388									

Simple Exponential Smoothing

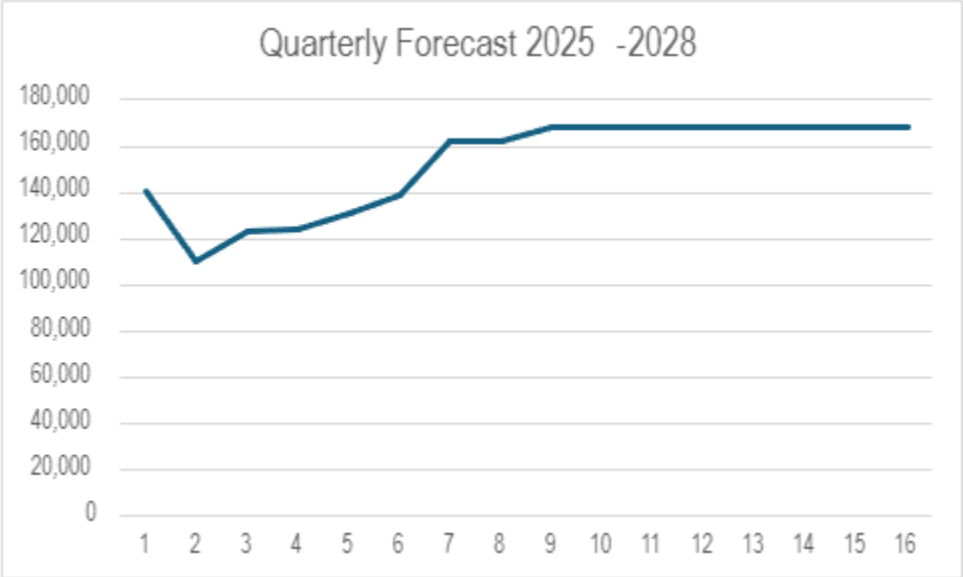
To start calculating our forecast using the simple exponential smoothing method we must calculate the level. We calculate the level for each period using a different method than what we did in the moving average method. Level 0 is calculated by taking the average of all the actual demands. Levels 1-8 are then calculated using this formula:

$$Lt = \alpha * Dt + (1 - \alpha) * Lt - 1$$

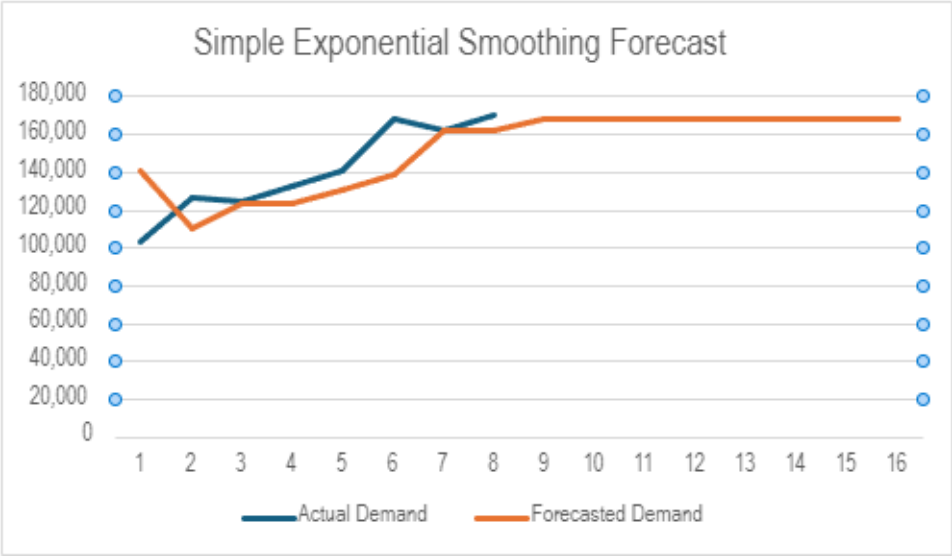
Using an α of 0.8 we get the following forecast:

Year	Quarter	Period t	Demand, D_t	Level L_t	Forecast F_t
				140,936	
2025	1	1	102,960	110,555	140,936
	2	2	126,360	123,199	110,555
	3	3	124,215	124,012	123,199
	4	4	132,405	130,726	124,012
2026	1	5	140,400	138,465	130,726
	2	6	168,480	162,477	138,465
	3	7	162,435	162,443	162,477
	4	8	170,235	168,677	162,443
2027	1	9			168,677
	2	10			168,677
	3	11			168,677
	4	12			168,677
2028	1	13			168,677
	2	14			168,677
	3	15			168,677
	4	16			168,677

We can see the shape of the forecasted demand more clearly in this graph:



We can see that the forecasted demand captures some of the movement of the actual demand starting at quarter one, but then flattens off completely once we begin forecasting with no actual demand. That's because it is simply set equal to the final Level calculated with actual data. This means that this forecasting model is probably not the most accurate for our purposes. We can see this more clearly when we compare the forecast to the actual demand:



Here we can see that the forecasted demand, when compared to the actual demand, barely follows the seasonality of the actual demand, making it a bad model for this scenario.

Simple Exponential Smoothing

Year	Quarter	Period t	Demand, Dt	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	bias	TS_t
				140,936										
2025	1	1	102,960	110,555	140,936	37,976	37,976	1,442,195,564	37,976	37	37	37	37,976	1.00
	2	2	126,360	123,199	110,555	-15,805	15,805	845,992,843	26,891	-13	13	25	22,172	0.82
	3	3	124,215	124,012	123,199	-1,016	1,016	564,339,280	18,266	-1	1	17	21,156	1.16
	4	4	132,405	130,726	124,012	-8,393	8,393	440,865,870	15,798	-6	6	14	12,762	0.81
2026	1	5	140,400	138,465	130,726	-9,674	9,674	371,408,550	14,573	-7	7	13	3,089	0.21
	2	6	168,480	162,477	138,465	-30,015	30,015	459,654,437	17,146	-18	18	14	-26,926	-1.57
	3	7	162,435	162,443	162,477	42	42	393,989,770	14,703	0	0	12	-26,884	-1.83
	4	8	170,235	168,677	162,443	-7,792	7,792	352,329,657	13,839	-5	5	11	-34,676	-2.51
2027	1	9			168,677									
	2	10			168,677									
	3	11			168,677									
	4	12			168,677									
2028	1	13			168,677									
	2	14			168,677									
	3	15			168,677									
	4	16			168,677									

Holt's Method

To create a forecast using Holt's model we first have to calculate the Level and Trend of the demand data.

1. We calculate Level and Trend of period 0 by running a regression equation on the given demand. This gives us:

   $$\mathbf{L_0} = 81{,}482.43 \text{ and } \mathbf{T_0} = 15{,}286.57$$

2. Using this preliminary Level and Trend we can now calculate the Level for the rest of the demand data using the $\alpha = 0.8$ and this formula:

   $$=\alpha*D_1+(1-\alpha)*(L_0+T_0)$$

   We calculate the Trend using $\beta = 0.1$ and this formula:

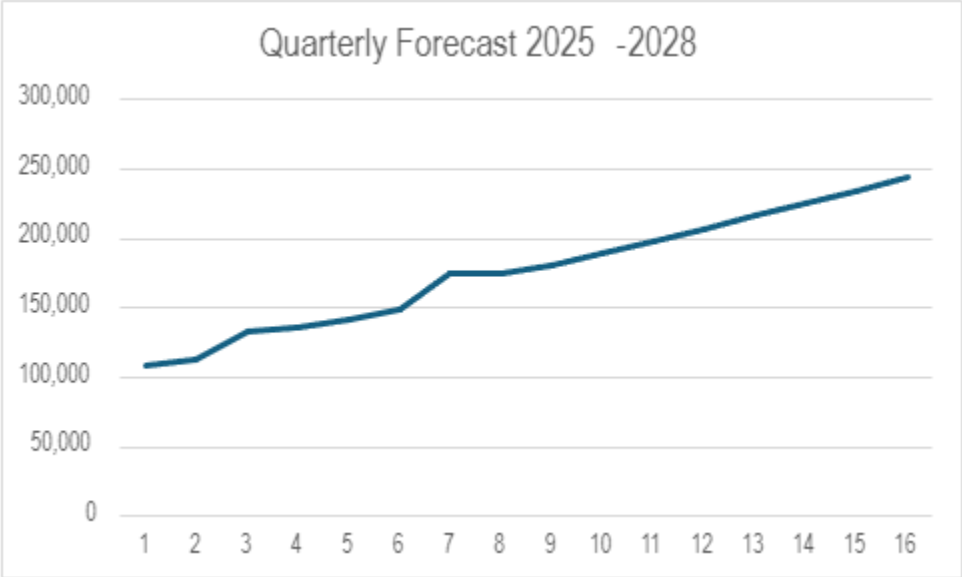
   $$=\beta*(L_1-L_0)+(1-\beta)*T_0$$

3. Now we can use each of the calculated level and trends to make a forecast of the data using this formula:

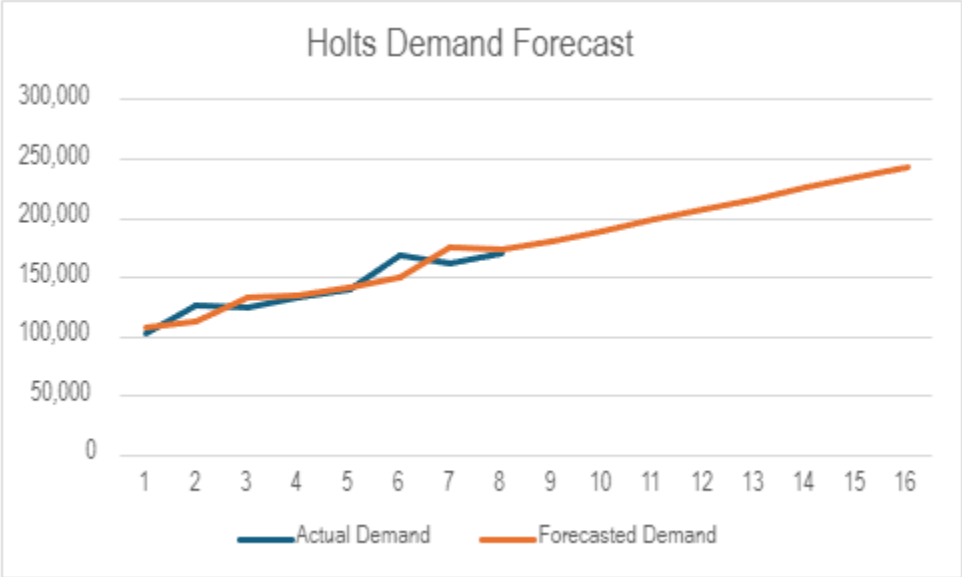
   $$=L_t+T_t$$

Year	Quarter	Period t	Demand, D_t	Level L_t	Trend T_t	Forecast F_t
				98,503	**9,430**	
2025	1	1	102,960	103,955	9,032	107,933
	2	2	126,360	123,685	10,102	112,986
	3	3	124,215	126,129	9,336	133,787
	4	4	132,405	133,017	9,091	135,465
2026	1	5	140,400	140,742	8,954	142,108
	2	6	168,480	164,723	10,457	149,696
	3	7	162,435	164,984	9,438	175,180
	4	8	170,235	171,072	9,103	174,422
2027	1	9				180,175
	2	10				189,278
	3	11				198,380
	4	12				207,483
2028	1	13				216,585
	2	14				225,688
	3	15				234,791
	4	16				243,893

We can see the shape of the forecasted demand more clearly in this graph:



The shape of the forecasted demand shows an exponential increase, with the demand rarely varying or dropping. This is very different from the shape of the actual demand data and most likely comes from the fact that seasonality wasn't taken into account. You can see the difference more clearly in the graph below:



It's clear that this forecasting method ignores an important part of the actual demand data's shape, meaning it is probably not the best forecasting method for this project.

Holt's Method

Year	Quarter	Period t	Demand, D_t	Level L_t	Trend T_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	bias	TS_t
				98,503	**9,430**										
2025	1	1	102,960	103,955	9,032	107,933	4,973	4,973	24,726,751	4,973	5	5	5	4,973	1.00
	2	2	126,360	123,685	10,102	112,986	-18,427	18,427	182,147,911	11,700	-15	15	10	-13,455	-1.15
	3	3	124,215	126,129	9,336	133,787	9,572	9,572	151,972,679	10,991	8	8	9	-3,883	-0.35
	4	4	132,405	133,017	9,091	135,465	3,060	3,060	116,320,901	9,008	2	2	7	-823	-0.09
2026	1	5	140,400	140,742	8,954	142,108	1,708	1,708	93,640,289	7,548	1	1	6	886	0.12
	2	6	168,480	164,723	10,457	149,696	-18,784	18,784	136,839,480	9,421	-11	11	7	-17,898	-1.90
	3	7	162,435	164,984	9,438	175,180	12,745	12,745	140,497,378	9,896	8	8	7	-5,153	-0.52
	4	8	170,235	171,072	9,103	174,422	4,187	4,187	125,126,169	9,182	2	2	7	-966	-0.11
2027	1	9				180,175									
	2	10				189,278									
	3	11				198,380									
	4	12				207,483									
2028	1	13				216,585									
	2	14				225,688									
	3	15				234,791									
	4	16				243,893									

Winter's Method

To create a forecast using Winter's model we first have to calculate the Level, Trend, and Seasonal Factors of the demand data.

1. To find Trend and Level of period 0 we have to run a regression on the deseasonalized demand. This gives us:

   $\mathbf{L_0}$ = 81,482.43 and $\mathbf{T_0}$ = 15,286.57

2. Next we have to calculate the beginning seasonal factors of periods 1-4. Using the deseasonalized demand from the previous part we get:

   $\mathbf{S_1}$ = 0.75, $\mathbf{S_2}$ = 1.2, $\mathbf{S_3}$ = 0.9, and $\mathbf{S_4}$ = 1.35

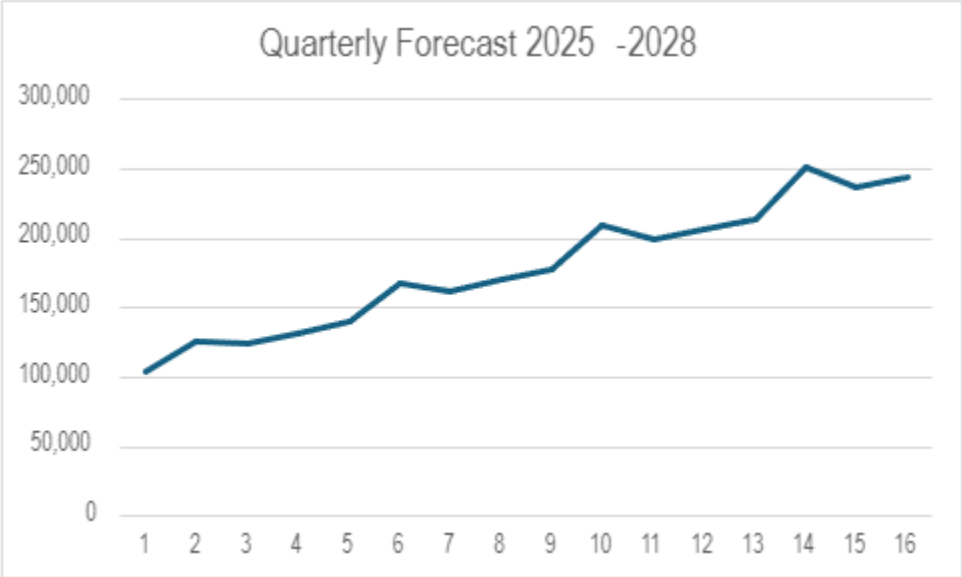
3. Using this information we can now calculate the Level and Trend of the rest of the demand data using $\alpha = 0.8$, $\beta = 0.1$, $\gamma = 0.6$ and this formula:

   $\mathbf{L_t} = \alpha(Dt/St) + (1-\alpha) * (Lt-1+Tt-1)$, $\mathbf{T_t} = \beta(Lt-Lt-1) + (1-\beta) * Tt-1$, And $\mathbf{S_t} = \gamma(Dt/Lt) + (1-\gamma) * S_{t-3}$

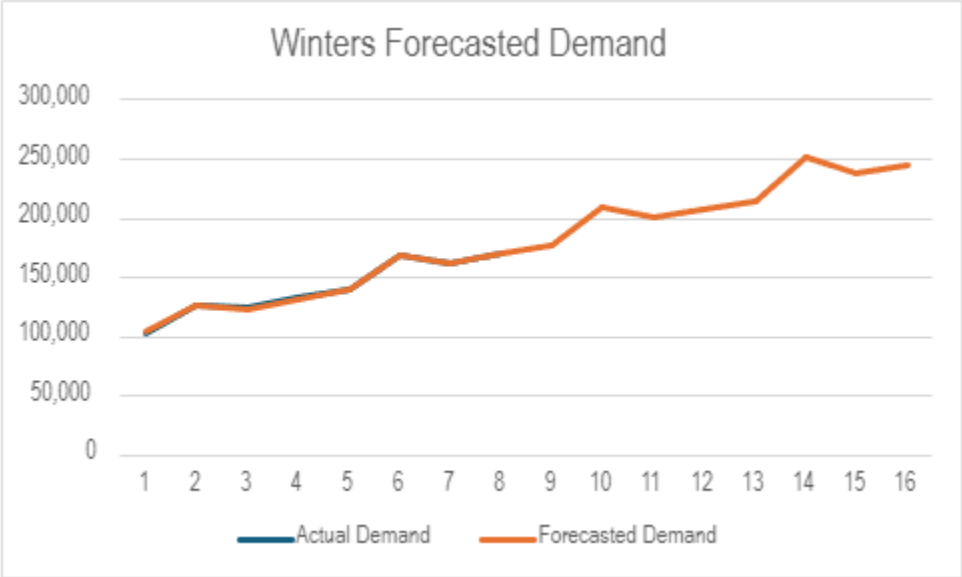
This gives us the following forecast:

Year	Quarter	Period t	Demand, Dt	Level Lt	Trend Tt	Seasonal Factor St	Forecast Ft
				98,503	**9,430**		
2025	1	1	102,960	107,387	9,375	**0.96**	103,615
	2	2	126,360	116,952	9,394	**1.08**	126,102
	3	3	124,215	126,669	9,426	**0.98**	123,819
	4	4	132,405	136,419	9,459	**0.97**	132,013
2026	1	5	140,400	146,310	9,502	0.96	139,882
	2	6	168,480	155,917	9,512	1.08	168,338
	3	7	162,435	165,610	9,530	0.98	162,213
	4	8	170,235	175,353	9,552	0.97	169,977
2027	1	9				0.96	177,423
	2	10				1.08	210,122
	3	11				0.98	200,092
	4	12				0.97	207,321
2028	1	13				0.96	214,085
	2	14				1.08	251,407
	3	15				0.98	237,566
	4	16				0.97	244,411

We can see the shape of the forecasted demand more clearly in this graph:



This forecasting method seems to correctly include the seasonality of the actual demand data, unlike other adaptive models. It also seems to forecast data more accurately past the actual demand data, which is something that previous models like moving average or simple exponential smoothing were unable to do. We can see how this method matches the actual demand in this graph:



The forecasted demand clearly follows the shape of the actual demand, and seems to accurately replicate it in its forecasts through quarters 9-16. By just looking at it this might be the best forecasting method for this project.

Winter's Method

Year	Quarter	Period t	Demand, D_t	Level L_t	Trend T_t	Seasonal Factor S_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	APE	$MAPE_t$	bias	TS_t
				98,503	**9,430**											
2025	1	1	102,960	107,387	9,375	**0.96**	103,615	655	655	429,413	655	0.64	0.64	0.64	655	1.00
	2	2	126,360	116,952	9,394	**1.08**	126,102	-258	258	247,877	456	-0.20	0.20	0.42	398	0.87
	3	3	124,215	126,669	9,426	**0.98**	123,819	-396	396	217,406	436	-0.32	0.32	0.39	2	0.00
	4	4	132,405	136,419	9,459	**0.97**	132,013	-392	392	201,516	425	-0.30	0.30	0.36	-390	-0.92
2026	1	5	140,400	146,310	9,502	0.96	139,882	-518	518	214,776	444	-0.37	0.37	0.36	-908	-2.05
	2	6	168,480	155,917	9,512	1.08	168,338	-142	142	182,333	393	-0.08	0.08	0.32	-1,049	-2.67
	3	7	162,435	165,610	9,530	0.98	162,213	-222	222	163,307	369	-0.14	0.14	0.29	-1,271	-3.45
	4	8	170,235	175,353	9,552	0.97	169,977	-258	258	151,235	355	-0.15	0.15	0.27	-1,529	-4.31
2027	1	9				0.96	177,423									
	2	10				1.08	210,122									
	3	11				0.98	200,092									
	4	12				0.97	207,321									
2028	1	13				0.96	214,085									
	2	14				1.08	251,407									
	3	15				0.98	237,566									
	4	16				0.97	244,411									

Error Analysis

To determine which of the 5 forecasting methods is the most accurate and fits our estimated demand the best we must compare their calculated errors. All of the method's various error analysis can be seen and compared in the table below:

Method	MSE	MAD	MAPE	bias	TS
Static	717,545	707	0.48	-3,479	-4.92 to 3.00
Moving Average	647,594,269	136,159	15	-96,915	-0.71 to -0.16
Simple Exponential Smoothing	352,329,657	13,839	11	-34,676	-2.51 to 1.16
Holt's	125,126,169	9,182	7	-966	-1.90 to 1.00
Winter's	151,235	355	0.27	-1,529	-4.31 to 1.00

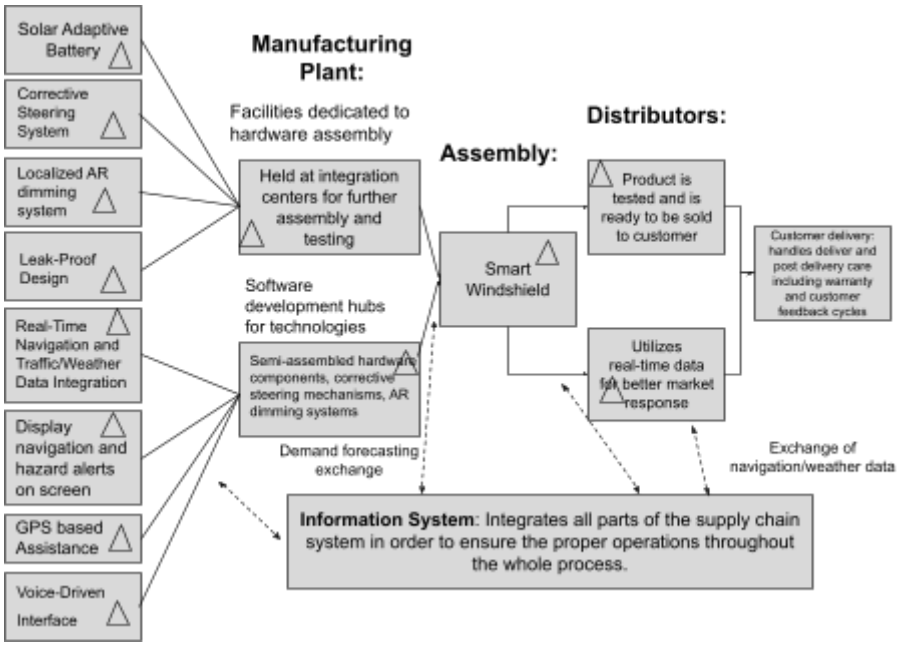
When comparing the results of the error analysis between all of the methods, as seen in the above table, we get the following:

- The lowest MSE: Winter's Method
- The lowest MAD: Winter's Method
- The lowest MAPE: Winter's Method
- Closest to Zero Average Bias: Winter's Method
- All Tracking Signals are within reasonable ranges

Looking at the error results it is clear that **Winter's Method** is the most accurate forecasting model for our project. Although Static method and Winter's Method are very close to zero, Winter's is lower and has a lower MSE and MAD. Its accuracy when compared to other models is most likely because it takes into consideration seasonal factors, level, and trend, more than any other forecasting method.

3. Revised Cycle and Safety Inventory

Step 1: Supply Chain Network Diagram :



Subsystems:

1. Localized AR Dimming System (affects visibility and display)
2. Corrective Steering System (integrates with real-time navigation)
3. Real-Time Navigation and Traffic/Weather Data Integration (affects functionality and real-time adjustments)

Step 2: Parameters + Assumptions

Inventory Parameters:

- Cycle Inventory: The average inventory held between replenishment cycles.
- Safety Inventory: The extra stock kept to protect against variability in demand or supply disruptions.
- Lead Time (L): The time taken to receive components from suppliers.
- Demand (D): The expected usage rate of each component.
- Service Level (Z-score): Desired probability of avoiding a stockout.

Assumptions:

- Each subsystem is a required component of the Smart Windshield.
- If every Smart Windshield sold requires one unit of each subsystem, then the demand (D) for each subsystem is the same as the demand for the Smart Windshield.

Step 3: Calculations for subsystems + final product

Localized AR Dimming System

C = 150
H = 15%
Holding Cost: h = 0.35
S = $300

	Year 1	**Year 2**	**Year 3**	**Year 4**
D	485940	641550	787933	938441
Q_L*	3600	4136	4584	5003
EOQ	3600	4136	4584	5003
D/QL*	1800	2068	2292	2501
EOQ/2	135	155	172	188
Fill Rate: 1 - ESQ/lot size:	99.4%	99.5%	99.6%	99.7%
h * C * (EOQ/2)	40497	46532	51568	56278
(EOQ/D) * 365	2.7	2.35	2.12	1.95
(EOQ/2)/D	1.35	1.18	1.06	0.97

Corrective Steering System

C = 200
H = 15%
Holding Cost: h = 0.35
S = $300

	Year 1	**Year 2**	**Year 3**	**Year 4**
D	485940	641550	787933	938441

Q_L*	3117	3582	3970	4332
EOQ	3117	3582	3970	4332
D/QL*	1559	1791	1985	2166
EOQ/2	156	179	198	217
Fill Rate: 1 - ESQ/lot size:	99.2%	99.3%	99.4%	99.5%
h * C * (EOQ/2)	46762	53731	59546	64984
(EOQ/D) * 365	2.34	2.04	1.84	1.69
(EOQ/2)/D	1.17	1.02	0.92	0.84

Real-Time Navigation and Traffic/Weather Data Integration

C = 150
H = 15%
Holding Cost; h = 0.35
S = $300

	Year 1	**Year 2**	**Year 3**	**Year 4**
D	485940	641550	787933	938441
Q_L*	3600	4136	4584	5003
EOQ	3600	4136	4584	5003
D/QL*	1800	2068	2292	2501
EOQ/2	135	155	172	188
Fill Rate: 1 - ESQ/lot size:	99.2%	99.3%	99.4%	99.5%
h * C * (EOQ/2)	40497	46532	51568	56278
(EOQ/D) * 365	2.70	2.35	2.12	1.95
(EOQ/2)/D	1.35	1.18	1.06	0.97

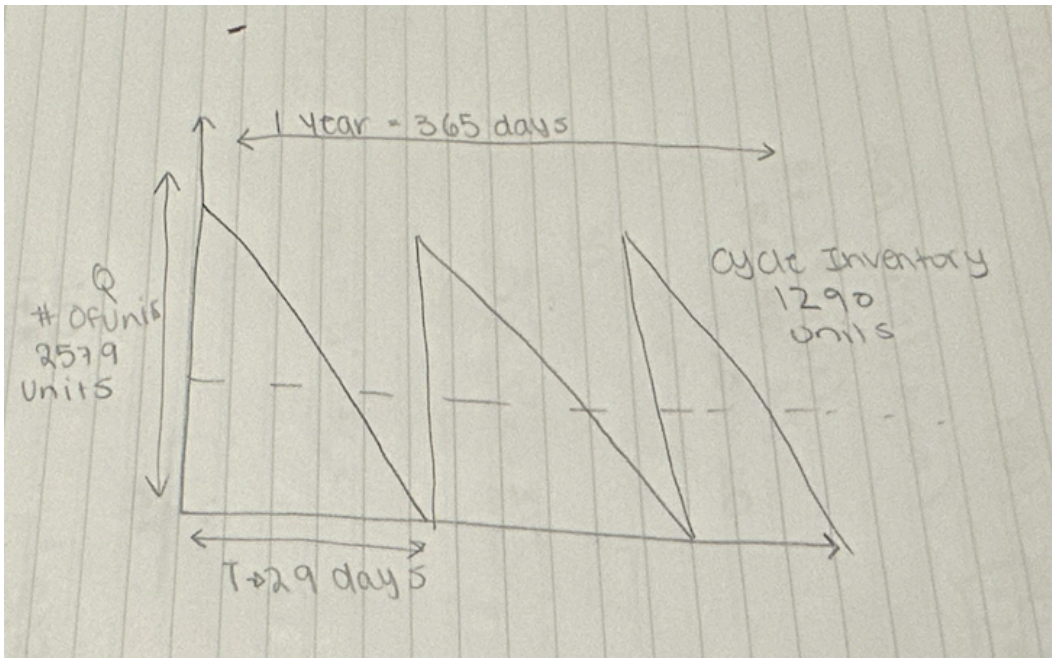
Smart Windshield (finished product) Data:

C = 500
H = 15%
Holding Cost; h = 0.35
S = $300

	Year 1	**Year 2**	**Year 3**	**Year 4**
D	485940	641550	787933	938441
√(2DS/hC)	1,972	2,265	2,511	2,740
EOQ	1,972	2,265	2,511	2,740
D/√(2DS/hC)	247	283	314	343
EOQ/2	986	1133	1255	1370
Fill Rate: 1 - ESQ/lot size:	99.4%	99.4%	99.5%	99.6%
h * C * (EOQ/2)	73938	84956	94150	102750
(EOQ/D) * 365	1.48	1.29	1.16	1.07
(EOQ/2)/D * 365	0.74	0.64	0.58	0.53

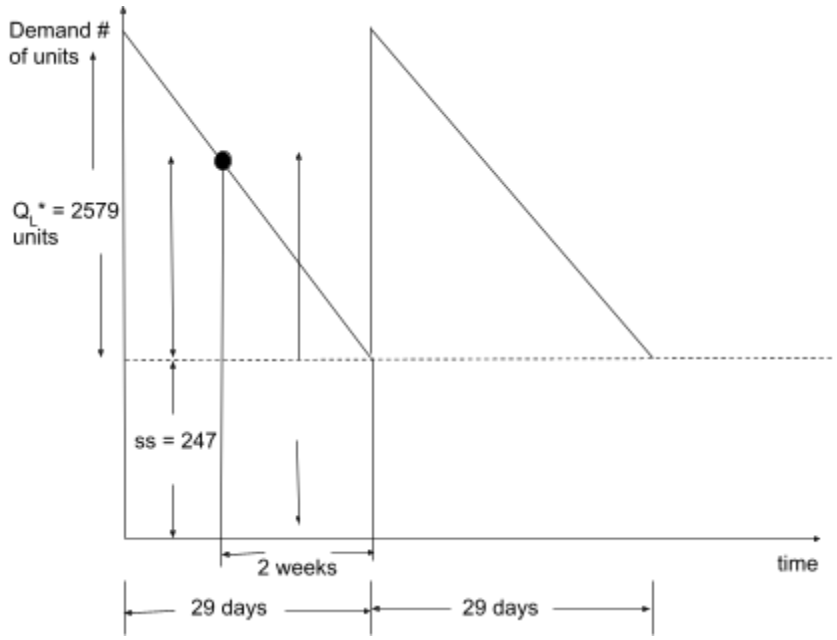
Step 4: Diagram to represent cycle and safety inventory as a function of time

Cycle Inventory Diagram:



This diagram represents the windshield inventory in a given year. It shows the initial fall from a complete inventory of **2579 units to 0 units.** This shows how the product is restocked on a nearly daily basis, with a cycle length of around **29 days.** The continuous replenishment to capacity demonstrates the frequent shipping cycle necessary to maintain the stock, with a mean holding of 1290 units depicted at the center of each cycle. This figure illustrates the dynamic nature of inventory control and the operational requirements of maintaining uniform stock levels.

Safety Inventory Diagram:



The diagram above shows the first year where the optimal safety inventory ranges from 247 units in the first year to 343 units in the fourth year.

4. Revised Financial Modeling

STEP 1: DEFINE

- Create a comprehensive financial model to determine the expected profit for our Smart Windshield based on a five-year NPV analysis

STEP 2: PLAN

The excel sheet containing the calculations for the NPV and sensitivity analysis can be found here:

Excel Financial Modeling

1. Revist and justify the inputs used in base case financial model
    a. Sales and Production Volume
    b. Development Cost
    c. Unit Price
    d. Unit Production Cost
    e. Ramp-up Cost
    f. Marketing and Support Cost
    g. Annual Discount Factor %
2. Perform a sensitivity analysis of the base-case NPV with respect to:
    - Development cost

- Sales volume

3. Use sensitivity analysis performed on base case model to understand and quantify the trade-offs between the development cost & production cost

STEP 3: EXECUTE

1. Revist and justify the inputs used in base case financial model:

a. Sales and Production Volume

- The Sales volume of the product is set equal to the demand data previously determined in task 2 of this report. This was calculated using existing data from Corning inc. and adjusted and forecasted for the Smart Windshield:
  - *Sales Volume* = **896,363** units/year

b. Development Cost

To estimate the development cost of our product we took into consideration the different material components that have to be developed along with the possible labor costs of these developments. Most of our components are heavily software based, which means that development cost will be mostly in software development. Here are the systems that have to be developed:

Software development	***Material Development***
- AR system	- Cameras
- Real time data integration	- leak-proof windshields
- GPS	- Photosensors
- Corrective steering system	- Solar Powered back-up battery
- Voice based User Interface	
- Information Security	

We expect that many of the software development costs will be higher than the material development costs due to complex innovative and AI-driven software. This is our estimation for each system:

Software development	***Material Development***
- AR system = $55M	- Cameras = $10M
- Real time data integration = $20M	- leak-proof windshields = $5M
- GPS = $15M	- Photosensors = $10M
- Corrective steering system = $20M	- Solar Powered battery = $15M
- Voice based User Interface = $15M	
- Information Security = $25M	

- *Total Development Cost* = **$190 million**

c. **Unit Price**
    - We determined the unit price for our product in the previous tasks in this report. When taking into account existing windshield costs and factoring in material costs we came to the decision of this unit price:
        - *Unit Price* = **$650** per unit

d. **Unit Production Cost**
    - The unit production cost was similarly determined in the previous sections of this project phase. This cost was calculated based off of similar existing products, giving us this production price:
        - *Unit Production Price* = **$500** per unit

e. **Ramp-up Cost**
    - To calculate the ramp-up cost we estimated it to be around 10% of development costs which gives us the following:
        - *Total Ramp-up Cost* = **$23 million**

f. **Marketing and Support Cost**
    - To calculate the annual marketing and support cost we estimated it to be around 5% of our total estimated revenue, which is $582,635,950. This gives us the following:
        - *Annual Marketing and Support Costs* = **$29,131,797** per year

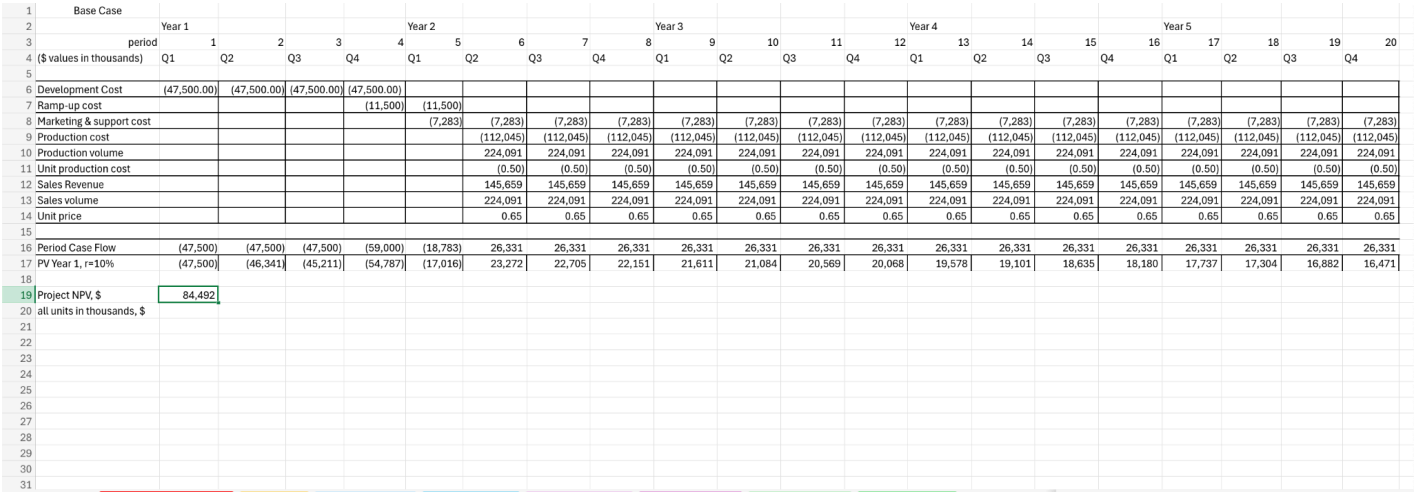
g. **Annual Discount Factor %**
    - We chose an annual discount factor of **10%** based on similar factors in the industry.
        - *Annual Discount Factor* = **10%**

Now that we have determined all of the relevant factors we can calculate the base case NPV. The input scenarios are shown below:

SCENARIO INPUT PARAMETERS

Sales & Production Volume (units/year)	896,363
Development Cost (total $)	190,000,000
Unit price	650
Unit Productions Cost ($/unit)	500
Ramp-up cost (total $)	23,000,000
Marketing & support cost ($/year)	29,131,797
Annual Discount Factor (%)	10

The base case calculation sheet is shown below:



Base Case																				
	Year 1				Year 2				Year 3				Year 4				Year 5			
period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
($ values in thousands)	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Development Cost	(47,500.00)	(47,500.00)	(47,500.00)	(47,500.00)																
Ramp-up cost				(11,500)	(11,500)															
Marketing & support cost					(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)	(7,283)
Production cost						(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)	(112,045)
Production volume						224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091
Unit production cost						(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Sales Revenue						145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659	145,659
Sales volume						224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091	224,091
Unit price						0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Period Case Flow	(47,500)	(47,500)	(47,500)	(59,000)	(18,783)	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331	26,331
PV Year 1, r=10%	(47,500)	(46,341)	(45,211)	(54,787)	(17,016)	23,272	22,705	22,151	21,611	21,084	20,569	20,068	19,578	19,101	18,635	18,180	17,737	17,304	16,882	16,471
Project NPV, $	84,492																			
all units in thousands, $																				

- Thus, given a set of input parameters varying from development costs to sales revenue and volume, we are able to determine the project NPV to be $84,492K, which indicates that it is a project that should be pursued.

2. Perform a sensitivity analysis of the base-case NPV with respect to Development Cost & Sales Volume:

In order to quantitatively understand the effect of changes on the input parameters on the expected profit we computed above, 84492K, we will now be performing a sensitivity analysis on the base case model, incrementally changing Sales Volume and Development Cost.

Development Cost Sensitivity Analysis:

Base Dev. Costs, Qty	Change in Dev. Costs , %	Dev. Costs , Qty	Change in Dev. Costs , Qty	Change in NPV, %	NPV, $ Thousands	Change in NPV, $ Thousands
190,000	30%	247000	57000	-0.65	29,544	-54,948
190,000	20%	228000	38000	-0.43	47,860	-36,632
190,000	10%	209000	19000	-0.22	66,176	-18,316
190,000	0%	190000	0	0.00	84,492	0
190,000	-10%	171000	-19000	0.22	102,809	18,317

190,000	-20%	152000	-38000	0.43	121,125	36,633
190,000	-30%	133000	-57000	0.65	139,441	54,949

- Based on the results from the sensitivity analysis on the development cost parameter in our base case model, we can conclude that there is a negative relationship between the development cost and the NPV. That is, when we incrementally increase the development costs in our Smart Windshield project, we see a decrease in the NPV. When we increase the development costs by 30%, the NPV decreases to 29,544 which is a huge decrease from our base case NPV of 84,492. However, when we decrease the development costs, the NPV increases. For instance, when we decrease the costs by 30%, we get an NPV of 139,441.

Sales Volume Sensitivity Analysis:

Base Sales Volume, Qty	Change in Sales Volume, %	Sales Volume, Qty	Change in Sales Volume, Qty	Change in NPV, %	NPV, $ Thousands	Change in NPV, $ Thousands
224,091	30%	224,763	672	1.03	171,411	86,919
224,091	20%	224,539	448	0.69	142,438	57,946
224,091	10%	224,315	224	0.34	113,465	28,973
224,091	0	224,091	0	0.00	84,492	0
224,091	-10%	223,867	-224	-0.34	55,520	-28,972
224,091	-20%	223,643	-448	-0.69	26,547	-57,945
224,091	-30%	223,418	-672	-0.97	2,426	-82,066

- Based on the sensitivity analysis performed above, we see how there is a negative change in the NPV when we decrease the sales volume such that the more we decrease down by 10%, the smaller the NPV becomes. At a 30% decrease in sales volume, the NPV goes down to 2,246. However, we also see that with a positive increase in the sales volume, the NPV becomes incrementally higher. At a 30% increase, the NPV increases to $171,411. This demonstrates a positive relationship between Sales Volume and the NPV.

3. Use sensitivity analysis performed on base case model to understand and quantify the trade-offs between the development cost and production cost

Development Cost:
After performing a sensitivity analysis on the development costs, we were able to see how different increases or decreases in development cost can impact our NPV.

- Trade-off law: For each incremental increase by 10% in the development cost, there is a $18,316 decrease in NPV.

Production Cost:
After performing a sensitivity analysis on the sales volume, we were able to see how different increases or decreases in sales volume can impact our NPV.

- Trade-off law: For each incremental increase by 10% in the sales volume, there is a $28,973 increase in NPV.

5. Project Backlog/Revisions of Each Section

Project Phase	Items to fix and improve
Phase 3	Include fill rate and inventory holding cost
	Double-check cycle time
	Modify MAPE (cannot be 0)
	Change smoothing constants (to prevent Winter and Static model results to be the same)
	Cycle Inventory: change sales volume so they are not the same for all quarters + link to demand data in earlier sections

Conclusion and Next Steps:

In this report we have continued the planning of General Motors new product, the Smart Windshield. After developing the product in the last quarter's report, this report focuses on the development of the product's supply chain. We determined the following:

a. Supply Chain Strategy:
    - We determined that a responsive supply chain strategy would be the best fit for our product as it best supports new products and complements the product's differentiated competitive strategy.
    - The push/pull boundary of the product is between its manufacturing and replenishment cycles. As it is a new product we are expecting there to be a relatively high uncertainty of demand.

b. Demand Estimation/Forecast:
    - We estimated the first 8 quarters of demand of the product by using existing demand data from Corning Inc. and tailoring it to our product's situation. We estimated the first quarter of demand to be 102,960 units and quarter 8's demand to be 170,235 units.
    - When forecasting this demand for another 8 quarters we found that Winter's method provided the most accurate results. This resulted in a demand of 244,411 units in quarter 16.

c. Cycle and Safety Inventory:
    - Using the demand that was forecasted previously we computed several important inventory parameters for the supply chain for 4 years. Most importantly we found the cycle inventory for the finished product to range from 986 units in the first year to 1,370 units in the fourth year. We also found the optimal safety inventory range from 247 units in the first year to 343 units in the fourth year.

d. Financial Model:
    - We conducted an NPV analysis using the data we collected throughout the report to find the predicted profit from the first 5 years of the project. We found the projected profit to be $84,492,000.

Next Steps:

Our team still has a several important steps before the product can be fully released, including:

- Determine Facilities and Transportation:
    - We have to determine what facilities are needed to produce our product, which manufacturers, their size, etc.. We also have to determine where these facilities should be located to be able to minimize total cost.
    - We have to determine what type of transportation for each part of our product.

- Determine Sourcing:

    - We also need to determine where we will source the subsystems that make up our product, finding a producer that is in our budget and is high quality.

- Prototyping:
    - There also has to be a prototype of our product so that we can ensure that it is ready for the market and functions as intended.

- Marketing:
    - We have to make a marketing strategy for our product, determining our target audience and gaining a better understanding of our current market.

Key Lessons from TIM 172Q:

1. **Difference between TIM172P:** The project course differed a lot in terms of subject matter.
    a. TIM172P: Prototyping and analyzing our product's functionality
    b. TIM172Q: Projecting sales and costs of production
2. Communication is important! This project was more demanding compared to last quarter, as there were more mathematical formulas and more times where we needed to check each other's work and verify all our calculations are correct.
3. Teamwork: Throughout this quarter and during our project review meetings we learned the importance of teamwork and working together in order to have a cohesive report. We were able to conduct group meetings in order to go over our work, and make decisions as a team.
4. Work Allocation: In our group, the coordinator would suggest roles for each one of us to fulfill. Each one of us would state what we are most confident doing and make our tasks explicit before starting the project so that we can finish the phase as efficiently as possible. It also ensures accountability to make sure everyone contributes to the project.
5. Openness to feedback: These courses required biweekly meetings with the professor/manager who would give us recommendations to guide us in the right direction. Lots of the meetings involved all of us being attentive and taking notes in order to recognize what we can work on and improve moving forward.
6. Time Management: For our phases, we would make sure to schedule based on the days what progress our group should be making. We would also meet at the library + Discord as a group to discuss and update what work has been done.
7. Organization of Work: With TIM172P + TIM172Q, we had to transition from essay format to an engineering writing cycle multiple times. Lots of the challenges we faced regarded having lots of "filler" words and not being as direct. We learned to organize our layout and the language we used, as well as the way the words were displayed, to switch styles.
8. Enforcement of TIM172A + TIM172B Material! - Excluding the homework assignments, this course gave us even more experience with the concepts that were taught during the courses.
    a. Here are some key differences:

TIM 172P	TIM 172Q
● More qualitative work ● More planning, and a lot of set up ● Reviewed FAST iagrams, and kept remaking them to show the components of our	● More quantitative work ● Forecasting methods + Cycle Inventory ● Demand projection with different forecasting methods ● Error/NPV analysis

products more structured. ● Conceptual Designing and concept designs ● Determining best possible solution	● Determing which annual demand would have to be transferred to the cycle inventories in order to get better results

Collaboration:

Representative Project Task: *Forecasting Methods and Cycle Inventory*

To demonstrate our group's work project, one of the main tasks highlighted is the forecasting methods + the cycle inventory. Lots of stuff within the forecasting methods were modified, including the demand as we had to revise it with including a mathematical formula from Corning's data to have as ours. Our group would check having the task completed on time and check each other's work; we would constantly review our work after the meetings and ask each other questions when we needed help. In regards to the forecasting methods specifically, a challenge for us was retrieving demand and having holding + shipping costs that are logical and can be plugged into equations to get cycle inventories and times. Numbers were moved around a lot; we would check in with every member of the group before work is turned in to make sure calculations are correct and processes are being followed correctly. Below are some strengths and weaknesses with our collaboration.

Pros **(what worked well)**	- Time Management: work was always done on time - Communication: Members were always updated with phase prompts and what needs to be done - Work Allocation: Members did not feel they were overwhelmed/underwhelmed with work
Cons **(what needs to be improved)**	- Efficiency: math must always be redone (work will not always be completed correct the first time) - Content: as we are learning material in TIM172B for first time, some processes were not always correct and inaccurate and must be redone, even with communication

Appendices:

Appendix A: Key Data Tables

This appendix includes relevant data tables used throughout the report.

Table A.1: Estimated Smart Windshield Sales Over Eight Quarters

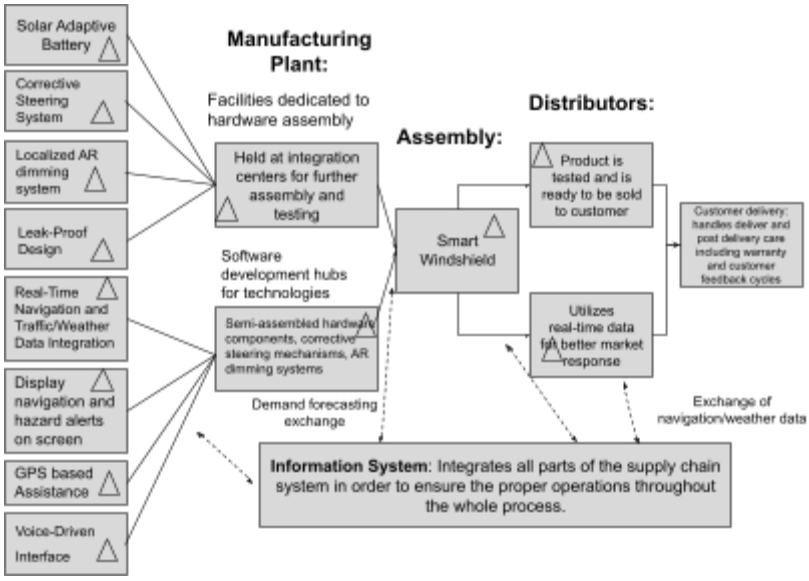
Product Life Cycle	Intro.	Intro.	Growth	Growth	Growth	Growth	Maturity	Maturity
Quarter, Year	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023
Estimated Smart Windshield Units Sold	98,257	108,250	365,309	470,983	578,983	680,232	702,340	709,298

Appendix B: Forecasting Method Comparison

This appendix provides additional analysis of the forecasting models used in the report. All of the method's various error analysis can be seen and compared in the table below:

Method	Average MSE	Average MAD	Average MAPE	Average bias	TS
Static	7,788,813,719	73,516	5	-58,097	-3.70 to 2.00
Moving Average	58,249,571,022	443,398	35	-657,319	-2.02 to -1.22
Simple Exponential Smoothing	77,594,236,160	246,938	199.25	-31,864	-1.00 to 3.00
Holt's	4,262,725,368	56,283	40.375	1,602,321.75	-3.76 to 2.00
Winter's	4,156,365,730	50,615	24	-59,336	-3.76 to 2.00

Appendix C: Supply Chain Flow Diagram



Appendix D: References & Citations

This section includes external sources, reports, and datasets referenced in the project.

1. Corning Incorporated Sales Reports (2022-2023)
2. General Motors Annual Report (2023)
3. Industry Analysis Reports on AR Windshield Market Trends