Inventory Control

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New Millennium Truck and Tire Repairs

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Abstract

This project addresses the challenge of implementing an effective inventory management system for New Millennium Truck and Tire Repairs, which currently lacks a dedicated inventory control system. This has led to issues such as stockouts and excessive costs. The primary objective is to minimize stockouts, reduce ordering expenses and optimize revenue. To achieve this we utilized various demand forecasting trend models, including seasonality trend models, exponential smoothing, and moving averages. Through a careful evaluation of these models we identified the one with the smallest errors, enhancing the accuracy of our predictions. Additionally, we decided to opt for a continuous review model to optimize the placement of inventory.

We also used the Normal Distribution Method to determine safety stock and reorder points, crucial elements for implementing the Stock In, Out, Balance, and Procurement System. The purpose of this Inventory Control model, such as the Stock in, Out, Balance and Procurement model, is to help the business track and manage their inventory. To do so, the Stock in, Out, Balance and Procurement model will be adopted to track all inventory received and sold daily. In order to be further cost-effective when placing orders for our inventory we applied the total sost's function using the Managerial Reorder Point model. This approach minimizes expenses when ordering various types of tires. The results of this project provide a comprehensive inventory management solution, minimizing stockouts and costs while maximizing revenue.

Executive Summary

New Millennium Truck and Tire Repairs is a family owned business located in Vaudreuil-Dorion. It is a semi-truck and trailer repair company that provides various maintenance services such as towing, on-site road service, preventive maintenance, and fault-code diagnostics. Although they offer various services, we will be focusing on the purchases of their ten most demanded tires that are being imported from the United States and China.

The company expressed that they have been facing issues managing their inventory and forecasting. Currently, the owner Darshan Jawandha is updating the inventory by generally projecting how many tires they will need for a specific season. However, this approach is inefficient and inaccurate as it leads to inventory shortages, over stock and human errors due to not having a proper inventory and forecasting system.

In order to improve their current approach we created brand new models through Excel to showcase their inventory and forecasting. By doing so, we built the Stock In, Out, Balance and Procurement system and Demand Forecasting model that will allow New Millennium Truck and Tire Repairs for a continuous monitoring of the inventory flow of both the ins and outs of their business. We implemented two different Demand Forecasting methods since the company imports tires from different countries and their lead times vary. Therefore, we implemented the Moving Average trend for the Chinese tires and Seasonality trend for the American tires. As for inventory, we implemented the use of the R,Q model to calculate the quantity as well as the reorder point (ROP) and safety stock model which indicates the company to place an order for that specific tire. By doing so it will avoid any shortages and overstock.

Finally, after many weeks of trial and error carried out by the team, we have figured out a way to integrate their inventory and forecasting by the use of the Stock In, Out, Balance and Procurement Model and Demand Forecasting Model through Excel. This will help New Millenium Truck and Tire Repair to track and manage their inventory and forecast an accurate amount of tires while avoiding shortages, overstock and saving money in the later future.

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List of Tables

Item	Quantity On Hand
BF GOODRICH 11R22.5 DR44	11.00
CONTINENTAL 11R22.5 HS3+	14.00
FIRESTONE 11R22.5 FS591	9.00
KPATOS 11R22.5 FS591	37.00
LANDY DS969 11R22.5	39.00
MICHELIN 11R22.5 XDN2	11.00
MICHELIN XLEZ 11R22.5 LRH	13.00
SIERRA 11R22.5 SR256	32.00
SURETRAC 11R22.5 RT256	36.00
SURETRAC 11R22.5 RT 369	39.00

Table 1: Top 10 Tires with Current Quantity on Hand

Type	Date	Num	Memo	Name	Qty	Sales Price	Amount	Balance
Invoice	2/20/23	29521	23-10800-075	6917780 CANADA INC GURVINDER S	1.00	1.95	1.95	1.95
					1.00		1.95	1.95
Invoice	10/7/21	25883		CAN TRUCK INC	4.00	4.50	18.00	18.00
Invoice	9/2/23	31319	AIR FITTING	SGB FREIGHT SYSTEM	1.00	12.00	12.00	30.00
Invoice	9/26/23	31563		LIGHT SPEED LOGISTICS INC.	1.00	4.50	4.50	34.50
					6.00		34.50	34.50
Invoice	12/1/21	26159	WIRE PER FEET	GURSHAN LOGITICS.	10.00	4.12	41.20	41.20
					10.00		41.20	41.20
Invoice	3/9/23	29701	MICHELIN 11R24.5 XLEZ	BNS TRUCKING INC	2.00	900.99	1,801.98	1,801.98
					2.00		1,801.98	1,801.98
Invoice	8/15/22	28047	11R22.5 MICHELIN XLEZ LRG LOW COAST	9209-9050 QUEBEC INC	2.00	798.00	1,596.00	1,596.00
Invoice	10/3/22	28438	11R22.5 MICHELIN XLEZ LRG LOW COAST	9383-1394 QUEBEC INC	2.00	800.00	1,600.00	3,196.00
Invoice	5/4/23	30227	11R22.5 MICHELIN XLEZ LRG LOW COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	3,196.00
Invoice	5/31/23	30428	11R22.5 MICHELIN XLEZ LRG LOW COAST	PRIDE MICHELIN ACCOUNT	2.00	0.00	0.00	3,196.00
					8.00		3,196.00	3,196.00
Invoice	1/4/22	26317	11R22.5 MICHELIN XLEZ LRH 6697	LIGHT SPEED LOGISTICS INC.	1.00	0.00	0.00	0.00
Invoice	2/9/22	26525	11R22.5 MICHELIN XLEZ LRH HIGH COAST	7133651 CANADA INC BHUPINDER S	1.00	780.00	780.00	780.00
Invoice	2/22/22	26614	11R22.5 MICHELIN XLEZ LRH HIGH COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	780.00
Invoice	2/23/22	26624	11R22.5 MICHELIN XLEZ LRH HIGH COAST	P T I	1.00	710.00	710.00	1,490.00
Invoice	3/17/22	26779	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	3,047.60
Invoice	3/17/22	26780	11R22.5 MICHELIN XLEZ LRH HIGH COAST	T&S TRANSPORT SYSTEM INC	2.00	780.00	1,560.00	4,607.60
Invoice	3/18/22	26789	11R22.5 MICHELIN XLEZ LRH HIGH COAST	KHASRIA TRANSPORT	2.00	750.00	1,500.00	6,107.60
Invoice	3/21/22	26807	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	7,665.20
Invoice	3/23/22	26827	11R22.5 MICHELIN XLEZ LRH HIGH COAST	GREENWAY CARRIER	1.00	780.14	780.14	8,445.34
Invoice	3/30/22	26871	11R22.5 MICHELIN XLEZ LRH HIGH COAST	MITISON CARIER	2.00	780.00	1,560.00	10,005.34
Invoice	4/11/22	26968	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	11,562.94
Invoice	4/13/22	26995	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	13,120.54
Invoice	4/14/22	27001	11R22.5 MICHELIN XLEZ LRH HIGH COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	13,120.54
Invoice	4/27/22	27070	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	14,678.14
Invoice	5/7/22	27157	11R22.5 MICHELIN XLEZ LRH HIGH COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	14,678.14
Invoice	5/23/22	27303	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	0.00	0.00	14,678.14
Invoice	6/17/22	27522	11R22.5 MICHELIN XLEZ LRH HIGH COAST	4494911 CANADA INC. PARGAT SINGH	1.00	770.00	770.00	15,448.14
Invoice	6/29/22	27630	11R22.5 MICHELIN XLEZ LRH HIGH COAST	Contrans Tank Group	1.00	850.00	850.00	16,298.14
Invoice	7/29/22	27920	11R22.5 MICHELIN XLEZ LRH HIGH COAST PRODUI	PRIDE MICHELIN ACCOUNT	2.00	0.00	0.00	16,298.14

Table 2: Initial Data Set Provided from New Millenium Truck and Tire Repairs

AMERICAN TIRES		
Year	Date	Sum of quantity
2021		
SEP	SEP	54
OCT	OCT	66
NOV	NOV	78
DEC	DEC	71
2022		
JAN	JAN	52
FEB	FEB	47
MAR	MAR	41
APR	APR	56
MAY	MAY	58
JUN	JUN	67
JUL	JUL	66
AUG	AUG	51
SEP	SEP	43
OCT	OCT	61
NOV	NOV	77
DEC	DEC	63
2023		
JAN	JAN	58
FEB	FEB	41
MAR	MAR	57
APR	APR	52
MAY	MAY	59
JUNE	JUNE	62
JULY	JULY	64
AUGUST	AUGUST	50

CHINESE TIRES		
Year	Date	Sum of quantity
2021		
SEP	SEP	16
OCT	OCT	21
NOV	NOV	26
DEC	DEC	25
2022		
JAN	JAN	21
FEB	FEB	18
MAR	MAR	23
APR	APR	25
MAY	MAY	34
JUN	JUN	39
JUL	JUL	35
AUG	AUG	36
SEP	SEP	34
OCT	OCT	38
NOV	NOV	42
DEC	DEC	36
2023		
JAN	JAN	31
FEB	FEB	36
MAR	MAR	34
APR	APR	39
MAY	MAY	37
JUNE	JUNE	32
JULY	JULY	37
AUGUST	AUGUST	33

Table 3: Clean Data (Sales/Demand) of American and Chinese Tires

Normal Distribution	
Service Rate	Z =Coeff service
99,9%	3,09
99%	2,33
98%	2,05
97%	1,88
96%	1,75
95%	1,64
94%	1,55
93%	1,48
92%	1,41
91%	1,34
90%	1,28
89%	1,23
88%	1,17
87%	1,13
86%	1,08
85%	1,04
84%	0,99
83%	0,95
82%	0,92
81%	0,88
80%	0,84
79%	0,81
78%	0,77

Table 4: Representation of the Normal Distribution Z-Table

	American Tires			Chinese Tires		
	Seasonality Trend Forecasting	Exponential Smoothing	Moving Average	Seasonality Trend Forecasting	Exponential Smoothing	Moving Average
MAD	2.531	8.929	11.302	3.956	4.910	3.857
MSE	11.888	118.858	177.333	27.387	38.495	25.730
MAPE	4.828	16.078	21.338	12.401	15.437	12.482

Table 5: Comparison of Errors per Model for American and Chinese Tires

Year	Month	Demand Forecast
2024	JAN	52
	FEB	42
	MAR	46
	APR	51
	MAY	55
	JUN	60
	JUL	60
	AUG	47
	SEP	45
	OCT	58
	NOV	71
	DEC	61
2025	JAN	50
	FEB	40
	MAR	44
	APR	48
	MAY	52
	JUN	58
	JUL	58
	AUG	45

Table 6: Seasonal Forecast with Trend for American Tires for January 2024 to August 2025

Year	**Month**	**Forecast**
2023	September	34

Table 7: Moving-Average Forecast for Chinese Tires for September 2023

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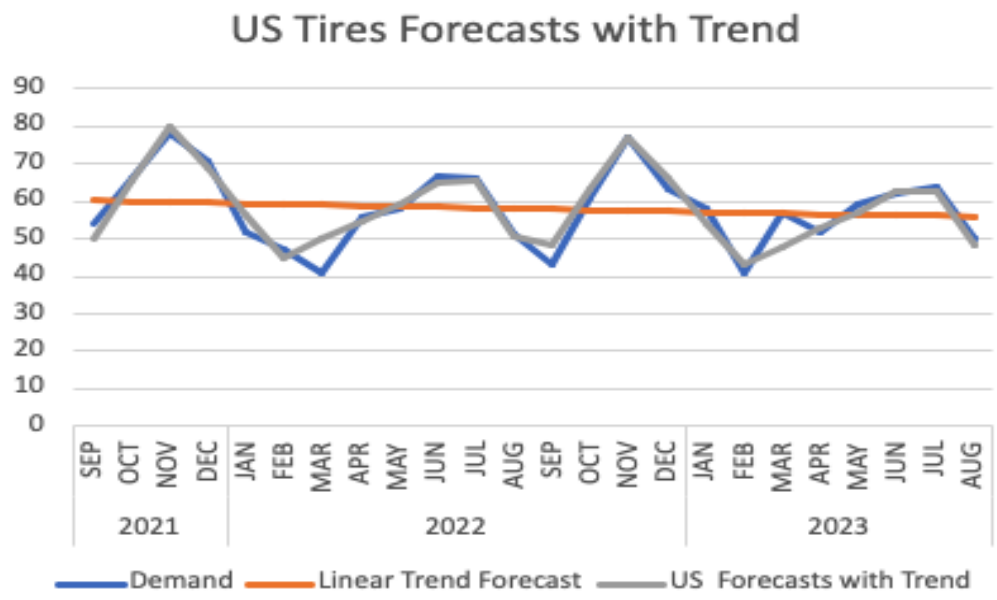

Figure 1: US Tires Forecasts with Trend

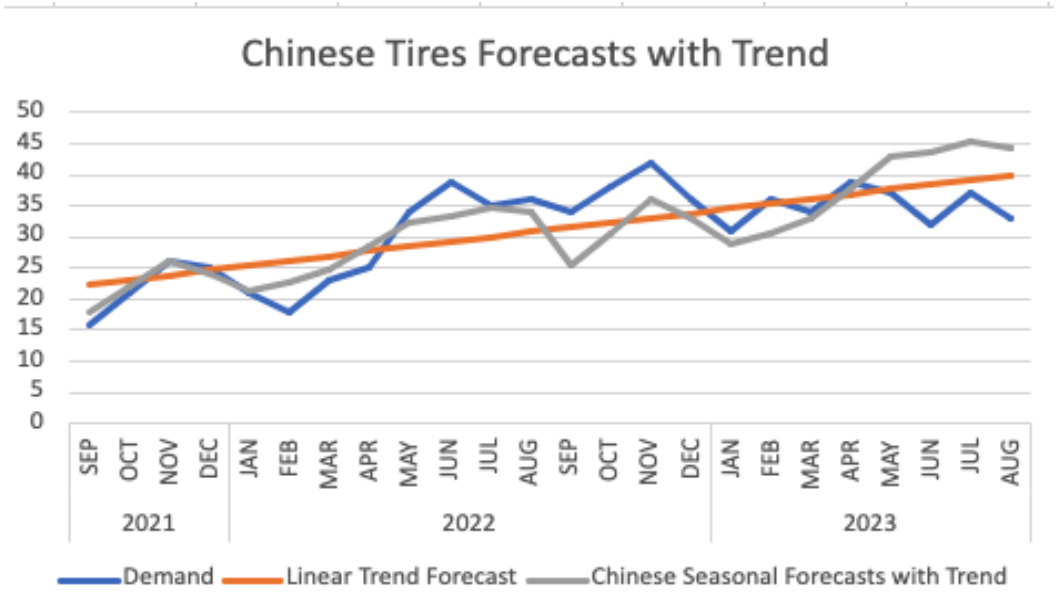

Figure 2: Chinese Tires Forecasts with Trend

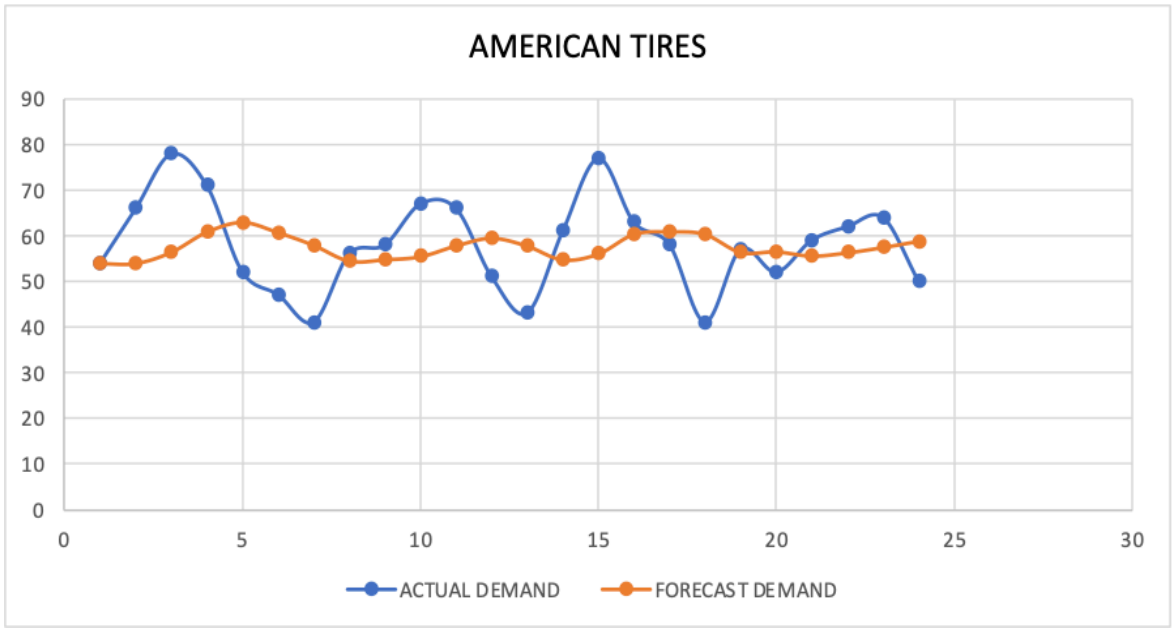

Figure 3: American Tires Forecasts Exponential Smoothing with alpha 0.2

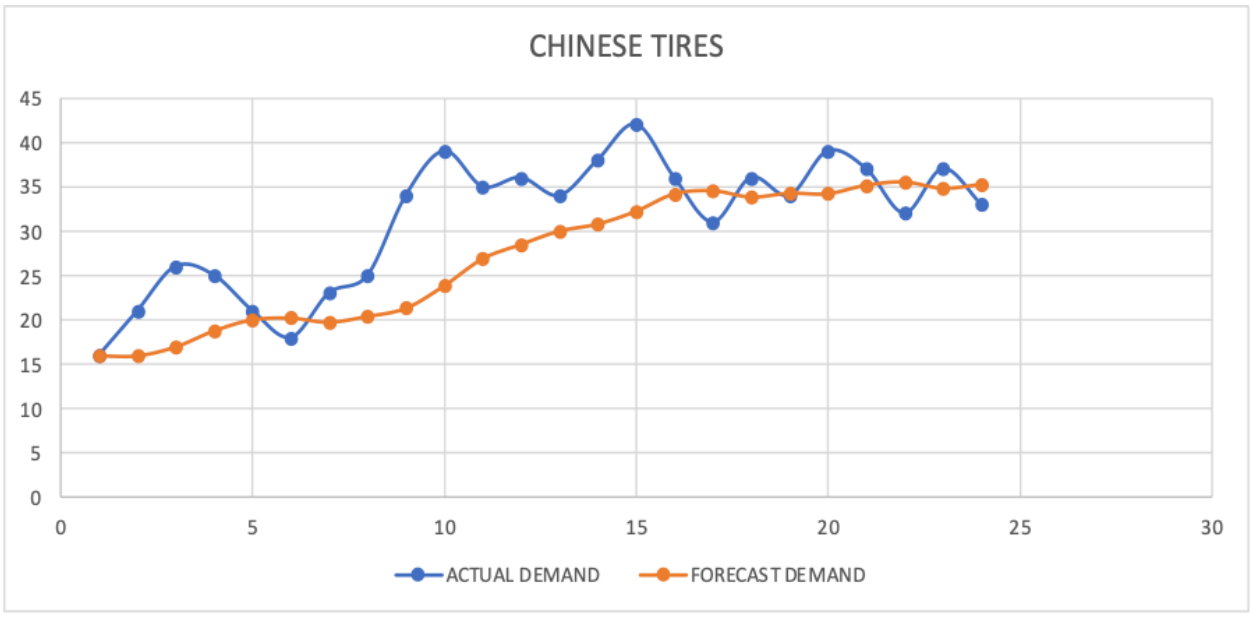

Figure 4: Chinese Tires Exponential Smoothing with alpha 0.2

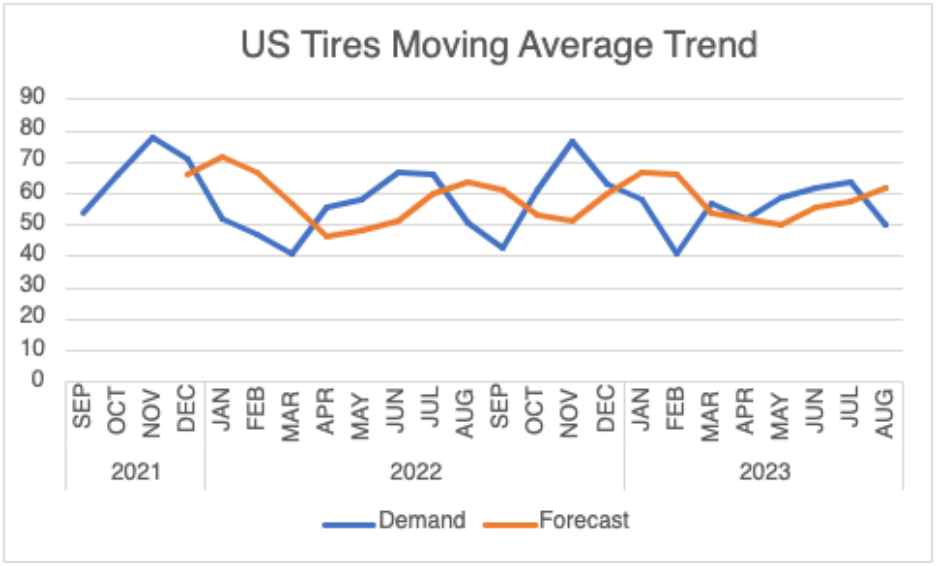

Figure 5: US Tires Moving Average Trend

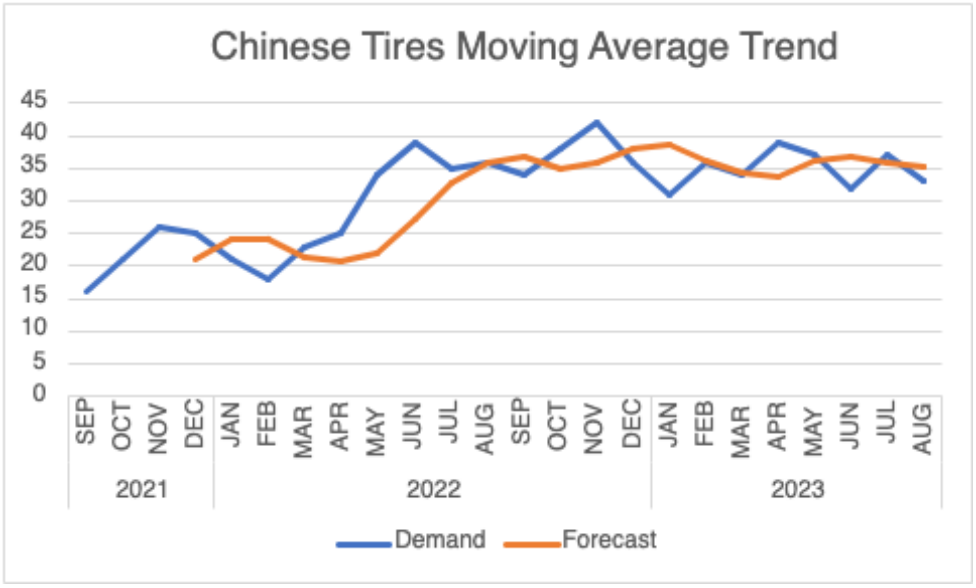

Figure 6: Chinese Tires Moving Average Trend

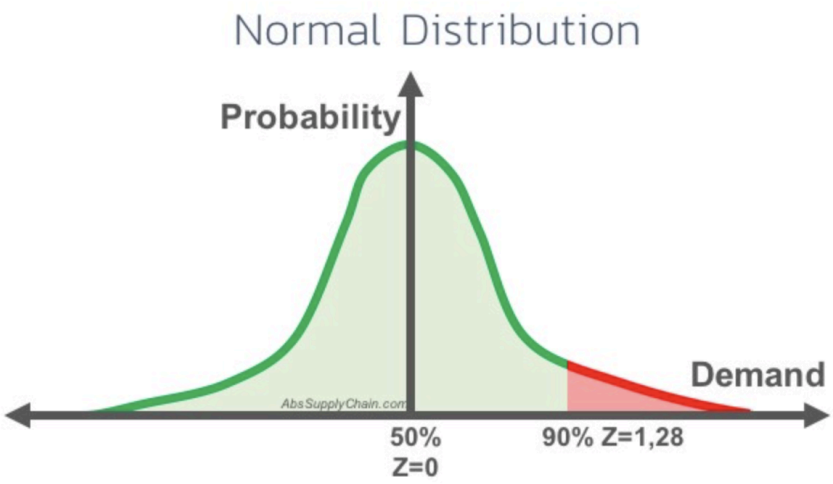

Figure 7: Safety Stock Measure using the Normal Distribution Method

METHOD 5
Uncertainty on demand and Lead Time independent
Z * sqrt((Average LT * (Demand Standard Deviation)² + (Average Sale *Lead Time Standard Deviation)²)

Figure 8: Safety Stock Formula

1. Background Information

New Millennium Truck and Tire Repairs is a company specializing in the repair of semi-trucks and trailers offering a range of maintenance services such as towing, on-site road service, preventive maintenance, and fault-code diagnostics. Established in 2007 and headquartered in Quebec, specifically Vaudreuil-Dorion, the company has a workforce of around 10 individuals, comprising mechanics, office personnel, and accountants [4](Jawandha, 2023). Their primary revenue stems from tire sales and replacement services. Annually, they move approximately 1000 brand new heavy-duty tires, procuring Chinese tires directly from suppliers in China and obtaining premium American tires from Quebec-based distributors as per demand [4](Jawandha, 2023). This facet of their business proves to be highly lucrative due to the potential resale value of replaced tires at a premium or their refurbishment through a rubber retreading factory for resale as new products. Despite their economic success, the company has encountered challenges in inventory management. Due to an inefficient ordering system [4](Jawandha, 2023).

To address the current challenge, New Millennium Truck and Tire Repairs has identified a crucial set of tires integral to their operations. These tires fall into two main categories: American and Chinese [4](Jawandha, 2023). The significance of each is explained, highlighting the need to track the top five best-selling tires in each group and analyze them collectively. In the realm of semi-trucks, functionality relies on ten tires, with two serving as steer tires at the front and eight at the rear [4](Jawandha, 2023). Steer tires, positioned at the front, experience faster wear due to the engine's weight and pose a higher risk of severe damage in case of a blowout. Unlike the rear tires, there's no secondary tire support, making the choice of front tires critical.

For the front steer tires, American options are preferred due to their superior quality, reduced wear, and significantly lower risk of blowouts. In contrast, the rear tires, typically Chinese, are chosen for their cost-effectiveness when replaced as a bundle and their lower risk profile during a blowout scenario. The decision to group the top five tires within each category stems from the uniformity in demand and sales across different brands [4](Jawandha, 2023).

In the case of American tires, their quality and pricing exhibit remarkable similarity, leading to consistent demand and sales patterns across various brands. The same holds true for Chinese brands, where variations in quality and pricing are minimal, originating from different

factories across the country [4](Jawandha, 2023). This rationale underscores the decision to collectively analyze the top five tires within each group throughout this project.

2. Introduction and Project Description

The goal of the Inventory Control project is to allow New Millenium Truck and Tire Repairs to manage their inventory in an efficient way with the use of a model. Despite their success, New Millenium Truck and Tire Repairs do not order their inventory in an optimal manner. This is why Darshan Jawandha gave us the task to find a solution to deliver an effective model that could help him have greater visibility and insights on his inventory levels.

The current way the business operates is by ordering a random number of tires on the top of their heads when they notice that their stock is running low. Typically, when inventory is running low, they will place an order of 40-75 of Chinese tires and 6-18 American tires, without taking into consideration demand forecasting, holding costs and ordering costs [4](Jawandha, 2023). Moreover, the number of orders per month for Chinese tires range from 1 to 3 and for American tires from 5 to 7 [4](Jawandha, 2023). Operating this way is not efficient because it can lead to inventory shortages or over stock, which leads to monetary losses. With overstock, the company is paying in holding costs and with shortages, the company may lose clientele to competitors, which is why it is important to find an effective solution to minimize these risks.

Currently, New Millenium Truck and Tire Repairs operates by using Quickbooks Intuit [4](Jawandha, 2023). Quickbooks focuses on the accounting aspect for businesses and can help the company keep track of certain things such as their invoicing. Unfortunately, it is not tailored to the company's inventory. Quickbooks offers various packages to all companies. Additionally, they do not provide insight regarding inventory management. Although Quickbooks may be helpful for their accounting [4](Jawandha, 2023), New Millenium Truck and Tire Repairs should begin to use an inventory model that can help them in the operations aspect as well.

The purpose of the Inventory Control project is to help the business track and manage their inventory. To do so, the Stock In, Out, Balance and Procurement model will be adopted to track all inventory received and sold on a daily basis. The model will also advise the company when to place an order according to the part’s lead-time and reorder point. Furthermore, to avoid shortages and overstock, an optimal order quantity and safety stock will be determined using previous data provided by the company.

3. Project Objectives

As mentioned above, the goal of the project is to provide an Inventory Model that New Millenium Truck and Tire Repairs can use in order to have visibility over their stock levels. The specific project objectives are to create a user friendly model that is easy to understand and can be used daily. Moreover, the model must show the current stock level depending on what comes in and out, this way it is easier to determine when to place an order or not and whether the part is in stock or not to sell to a customer.

The model must also include a reorder point and safety stock to determine when to place an order and to minimize the risk of shortages and monetary losses. To offer a target service level of 90% for American and Chinese tires, the standard deviation of previous sales will be used to help with the calculations of reorder point and safety stock. Once a quantity reaches the reorder point or below, then the inventory model will also show a message indicating that it is time to place an order. The model will also include a page to allow the company to see their orders placed and to determine when a part will be received. Having everything in one place will make it a lot easier for New Millenium Truck and Tire Repairs to be up to date with the inventory.

To create an effective model, further objectives will need to be attained. First, it is important to determine which type of model should be used (i.e., continuous review model, periodic review model, etc.,). Moreover, to determine demand in the total cost function, various forecasting methods should be computed to determine which one is the most efficient for this model based on their errors.

Furthermore, the order quantity should be established. To do so, an efficient model must be used to provide accurate information. In this case, the R,Q model will be used. To do so, holding costs must be determined as well as order costs and demand.

4. Data Collection

The data required to conduct the entirety of the project was provided by the owner, Darshan Jawandha. Any data that was required was provided to us via email on an Excel document or over a zoom meeting. The first information required from the owner was the top five American tires and the top five Chinese tires.

Table 1: Quantity on Hand for top 10 Tires

Item	Quantity On Hand
BF GOODRICH 11R22.5 DR44	11.00
CONTINENTAL 11R22.5 HS3+	14.00
FIRESTONE 11R22.5 FS591	9.00
KPATOS 11R22.5 FS591	37.00
LANDY DS969 11R22.5	39.00
MICHELIN 11R22.5 XDN2	11.00
MICHELIN XLEZ 11R22.5 LRH	13.00
SIERRA 11R22.5 SR256	32.00
SURETRAC 11R22.5 RT256	36.00
SURETRAC 11R22.5 RT 369	39.00

Secondly, the sum of the monthly sales for the five American tires combined and the sum of the monthly sales for the five Chinese tires from 2021-2023 was provided (Appendix A). The data sheet below was provided to us from Quickbooks, a software that is primarily used for accounting purposes.

The dataset comprising over 500 rows contained a mix of information including: memos, notes, quantities sold for each tire type, prices, balances, and supplier names.

Here is the original data sample – provided as a snippet due to the extensive nature of the dataset which includes over 500 rows:

Table 2: Original sample sheet provided by New Millenium Tires

Type	Date	Num	Memo	Name	Qty	Sales Price	Amount	Balance
Invoice	2/20/23	29521	23-10800-075	6917780 CANADA INC GURVINDER S	1.00	1.95	1.95	1.95
					1.00		1.95	1.95
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Invoice	2/9/22	26525	11R22.5 MICHELIN XLEZ LRH HIGH COAST	7133651 CANADA INC BHUPINDER S	1.00	780.00	780.00	780.00
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Invoice	4/13/22	26995	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	13,120.54
Invoice	4/14/22	27001	11R22.5 MICHELIN XLEZ LRH HIGH COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	13,120.54
Invoice	4/27/22	27070	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	778.80	1,557.60	14,678.14
Invoice	5/7/22	27157	11R22.5 MICHELIN XLEZ LRH HIGH COAST	LIGHT SPEED LOGISTICS INC.	2.00	0.00	0.00	14,678.14
Invoice	5/23/22	27303	11R22.5 MICHELIN XLEZ LRH HIGH COAST	PRIDE FLEET SOLUTIONS	2.00	0.00	0.00	14,678.14
Invoice	6/17/22	27522	11R22.5 MICHELIN XLEZ LRH HIGH COAST	4494911 CANADA INC. PARGAT SINGH	1.00	770.00	770.00	15,448.14
Invoice	6/29/22	27630	11R22.5 MICHELIN XLEZ LRH HIGH COAST	Contrans Tank Group	1.00	850.00	850.00	16,298.14
Invoice	7/29/22	27920	11R22.5 MICHELIN XLEZ LRH HIGH COAST PRODU	PRIDE MICHELIN ACCOUNT	2.00	0.00	0.00	16,298.14

The original data was unorganized with tires intermingled with other products. To make sense of it we created pivot tables by focusing on the top five American and Chinese tires. We refined the data by filtering out irrelevant details and organized it to reveal the essential information: types of tires and their actual demands per month over roughly the past two years. The cleaned data is presented below:

Table 3: Clean Data of American and Chinese tires

AMERICAN TIRES		
Year	Date	Sum of quantity
2021		
SEP	SEP	54
OCT	OCT	66
NOV	NOV	78
DEC	DEC	71
2022		
JAN	JAN	52
FEB	FEB	47
MAR	MAR	41
APR	APR	56
MAY	MAY	58
JUN	JUN	67
JUL	JUL	66
AUG	AUG	51
SEP	SEP	43
OCT	OCT	61
NOV	NOV	77
DEC	DEC	63
2023		
JAN	JAN	58
FEB	FEB	41
MAR	MAR	57
APR	APR	52
MAY	MAY	59
JUNE	JUNE	62
JULY	JULY	64
AUGUST	AUGUST	50

CHINESE TIRES		
Year	Date	Sum of quantity
2021		
SEP	SEP	16
OCT	OCT	21
NOV	NOV	26
DEC	DEC	25
2022		
JAN	JAN	21
FEB	FEB	18
MAR	MAR	23
APR	APR	25
MAY	MAY	34
JUN	JUN	39
JUL	JUL	35
AUG	AUG	36
SEP	SEP	34
OCT	OCT	38
NOV	NOV	42
DEC	DEC	36
2023		
JAN	JAN	31
FEB	FEB	36
MAR	MAR	34
APR	APR	39
MAY	MAY	37
JUNE	JUNE	32
JULY	JULY	37
AUGUST	AUGUST	33

This dataset served as the foundation for the entire project, utilized in the diverse forecasting models being Seasonality Forecasting with Trend, Exponential Smoothing, and Moving Averages. It played a crucial role in determining safety stock and reorder points through the normal distribution method. As it is depicted in the image above the data illustrates the quantities sold or demand for the months spanning September 2021 to August 2023 for the two categories of tires, American and Chinese.

For cost benefit analysis we needed a previous order cycle to compare it with our RQ model and discuss the gains and losses behind it. During a meeting with the owner on October 18, the requirements to conduct the analysis were mentioned to the owner. He provided a comprehensive overview of the sales, demand, and orders specifically concerning the month of June 2019 [4](Jawandha, 2023). Emphasis was placed on the suitability of this particular time frame due to it coinciding with his vacation. It was during this period that the company encountered significant challenges pertaining to quantity management.

5. Methodology

5.1. Meetings & Model Choice

To create an effective inventory model, it was important to first meet with the owner, Darshan Jawandha, to discuss his business's discrepancies and to find a project that we could work on to improve this aspect. After several discussions with him and with the course's guidelines, he determined that it would be beneficial to optimize his inventory management.

Once this aspect was determined, research was conducted by the team to determine which model would be the best for this business, all the while remaining user-friendly to allow the staff to manage the inventory adequately and track their incoming purchases. In this case, the continuous review model was deemed to be the most efficient. This model tracks inventory in real-time and allows them to update it every day. It was deemed that the total cost be calculated, the safety stock as well as the ROP, demand forecasting and order quantity be calculated.

5.2. Total Cost Function

Many factors were required to obtain the total cost (Appendix B). To do so, a breakdown of data requirements were made and presented to the owner so he could provide required numbers.

5.2.1. Holding Cost.

New Millennium Truck and Tire Repairs is located at 2550 Chemin de la Petite in Vaudreuil-Dorion. The property, spanning 1.5 acres and encompassing both the building and the surrounding land, is appraised at $2,434,233 according to Remax [1](Cajolais, 2023). They arrived at this valuation by considering recent local property sales. Within the building's 4,866 square footage, the tire inventory takes up 1,530 square feet. The building itself holds a value of $439,000 [1](Cajolais, 2023). An assessment suggests that renting out the entire property could yield around $15,000 monthly.

The building represents 18% of the total property value, with tires occupying 31.4% of the building's area [4](Jawandha, 2023). Based on this assessment, tire storage costs are estimated at $847.80 monthly or $10,173 annually. Considering a capacity of 1000 tires, the storage cost per tire amounts to $0.8478 per month or $10.17 per year. Insurance expenses for the entire inventory, wherein tires account for 35% of the value, total about $500 per month or $6,000 annually [4](Jawandha, 2023). This equates to $0.175 per tire per month or $4.2 per year.

Taking these factors into account, the overall holding cost for each tire comes to $1.03 per month or $12.36 per year.

5.2.2. Ordering Costs for Chinese Tires (Cycle Per Month)

Ordering expenses encompass all costs associated with receiving a product. This cost is calculated by dividing demand with quantity and multiplying it with the order cost per tire. In the case of procuring tires from China, three main costs need consideration: shipping the goods from China to Canada, handling customs clearance fees, and transporting the goods from the rail site to the final destination. New Millennium Truck and Tire Repairs regularly orders tires from Staridge Inc, based in Beijing.

The shipping rates for overseas freight have varied over the past decade. Taking the median rate over this period—accounting for anomalies caused by significant spikes due to COVID-19—the approximate cost stands at $3,500 USD or $4,792.46 CAD [4](Jawandha, 2023).

For customs clearance, New Millennium Truck and Tire Repairs engages Manitoulin, a brokerage firm, which charges an average of approximately $5,579.97 CAD per container or per order, based on data from the past decade [4](Jawandha, 2023).

Lastly, the expense involved in transporting the tire container from the CN railway in Lachine to NMTC's location in Vaudreuil incurs a flat fee of $600 [4](Jawandha, 2023). Combining these expenses results in a total ordering cost of $10,972.43 per month for a quantity of 272 tires, which breaks down to approximately $40.34 per tire.

5.2.3 Ordering Costs for American Tires (Cycle Per Month)

When procuring American tires, New Millennium Truck and Tire Repairs opts to order them through a distributor rather than directly from the manufacturer. This choice exempts them from incurring a transportation fee when placing orders through the distributor. Instead, the sole charge they encounter pertains to a membership fee with the distributor, amounting to $29.75 per tire [4](Jawandha, 2023).

5.3.4. Backorder Costs

According to representatives from New Millennium Truck and Tire Repairs, when a tire is out of stock, customers tend to take two paths: 50% of the time, they seek the tire elsewhere, while the remaining 50% wait for restocking.

In cases where customers choose to go elsewhere, the company faces a loss of $25 in labor profit, given that the installation of a tire costs $30. This calculation is based on the fact that an average technician, earning $25 per hour, can replace 8 tires within an hour, amounting to $3.13 of labor per tire. When factoring in equipment expenses, NMTTR estimates an average cost of approximately $5 for a single tire installation.

Moreover, the company incurs a $50 profit margin loss on the actual sale of the tire, resulting in a total opportunity cost of $75. Since half of backorders are lost, total backorder cost per tire equates to 37.5$. Representatives from New Millennium note that a back-order situation arises approximately 10% of the time.

5.3.5. Demand

To determine the demand in the Total Cost Function, three demand forecasting models were compared. The models used were Seasonal Forecasting with Trend, Exponential Smoothing and the Moving Average model. Their errors, MAD, MSE and MAPE, were then calculated to determine which forecasting model would be the best to use in terms of accuracy for the inventory model.

The first method used to determine the demand forecast found in the total cost function formula, is the **Seasonal Forecast with Trend** with the help of Dr. Canbolat's video [7](Canbolat, 2017). For the seasonal forecasting with trend, sales for the past two years were used. The data provided was from September 2021 to September 2023 and combined the sales for the top 5 American tires and the sales for the top 5 Chinese tires separately. To begin, the slope and the intercept of past American sales were calculated. The slope obtained was approximately -0.187 and the intercept was approximately 60.431. The linear trend forecast was then obtained by adding the slope and intercept and multiplying them by the demand for each and every period as well as the following 24 periods to represent the next two years.

The seasonality index was calculated by calculating the average US sales per month, which repeated once as each month was represented twice in the data (Appendix C). For

example, the American tires seasonality index for September was calculated by adding sales of September 2021 and 2022 and dividing by two which gave a value of 48.5. This number was then divided by the total average of US sales which gave an index of approximately 0.835. The same steps were followed for the remaining months and for Chinese tires (Appendix D).

Finally, the seasonal forecasts with trends were calculated by multiplying the linear trend forecast with each month's respective seasonality index (Appendix E). For instance, the seasonal forecast with trend for September 2021 was determined by multiplying its linear trend forecast of approximately 60.243 and multiplying it by September's seasonality index of 0.835, which gave a seasonal forecast with trend of 50.303. This was then calculated for all periods until August 2025. The same steps were then followed for the Chinese tires (Appendix F).

When putting the seasonality trend forecasts, it is clear that the model for American tires was effective and had low errors because of how close the demand and the forecast with trend are.

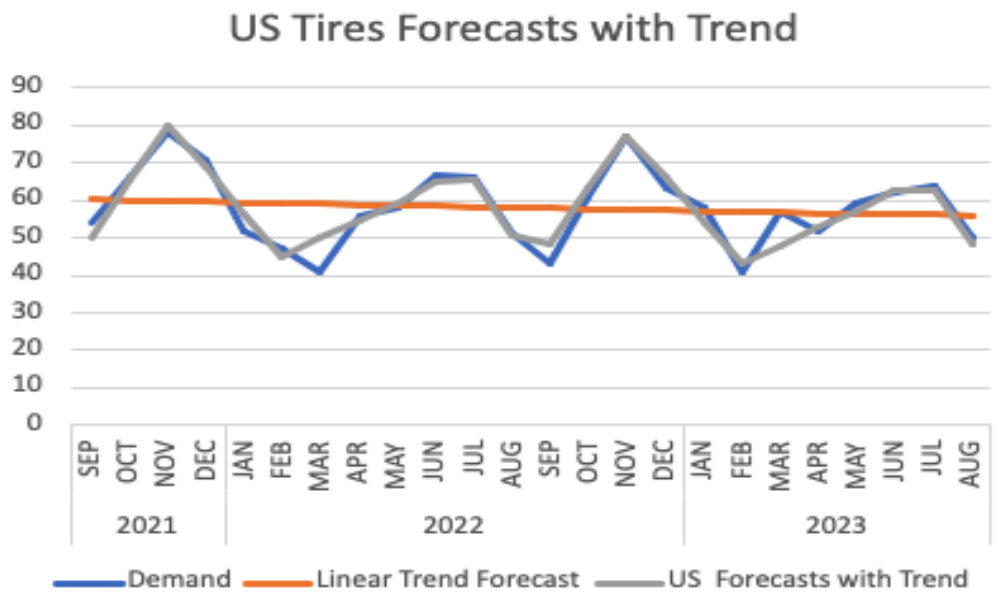

Figure 1: US Tires Forecasts with Trend

For the Chinese model on the other hand, these lines were not as close. As seen below, one can visibly see the variance between the demand and seasonal forecast with trend.

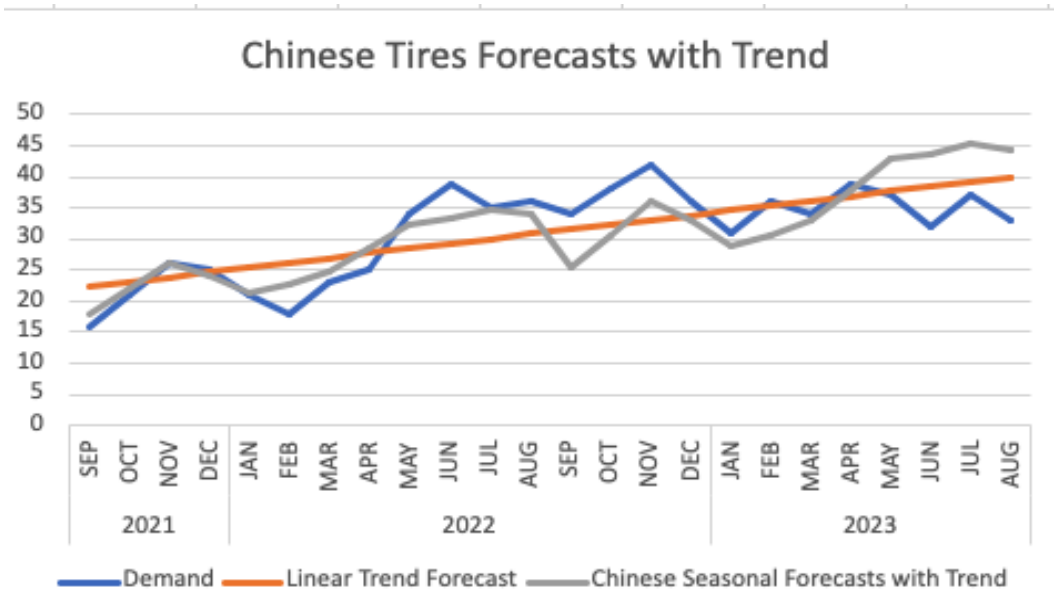

Figure 2: Chinese Tires Forecasts with Trend

The second method that was used was the **Exponential Smoothing Forecasting** with the help of *The Open Educator* on Youtube [9](The Open Educator, 2021). It is a method in time series analysis where future data points are predicted by emphasizing recent observations more than the older ones. By assigning decreasing weights to past data, it captures trends and patterns by giving a greater importance to recent information [10] (B2Bwhiteboard, 2012).

The previous demand data was used in forecasting the demand. The formula that was used to calculate the forecast is shown in (Appendix G). To calculate the forecast for a specific period such as October 2021 which is period 2, we assumed that the smoothing constant, alpha, was 0.2 or 20% as it can be chosen anywhere between 0 and 1. We then used the demand of the previous period September 2021 which was 54 and multiplied it by the smoothing constant of 0.20 plus 1 minus the alpha of 0.20 and finally multiplied it by the forecast demand of the previous period September 2021 which was initially 0 (Appendix H).

Since the company did not provide us with the initial forecast for September 2021 (Period 1) it was initially calculated as 0 which predicted lower values (Appendix I). The rule in exponential smoothing is if the initial forecast is not given then the actual demand for period 1 can be used as the forecasted demand for period 1 (Demand=Forecast). By doing so, this replaced the Forecast in September 2021 (Period 1) to 54 which gave a better prediction.

Excluding the initial period, this was then repeated for all following periods up until August 2023 (Appendix J) and the same procedure was repeated for Chinese tires (Appendix K).

Alternatively, we noticed that using higher alpha's ranging from 0.5 to 0.9 resulted in reducing the smoothness and demonstrated a high volatility in the forecast for both American and Chinese tires (Appendix L). Therefore, we opted to use a lower alpha anywhere between 0.2 and 0.3 to create a smooth representation of the data.

The exponential smoothing was then graphed to display a visual and it can be seen that the model for American tires has high errors:

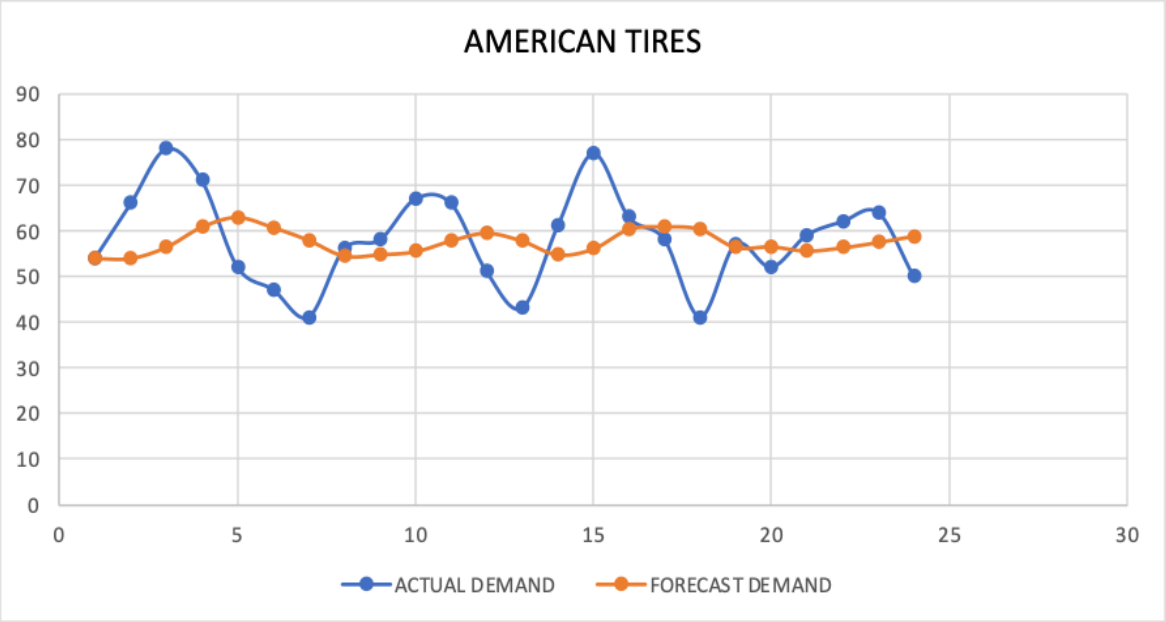

Figure 3: American Tires Forecasts Exponential Smoothing with Alpha 0.2

Alternatively, it can be seen that the Chinese Tires had lower errors compared to American:

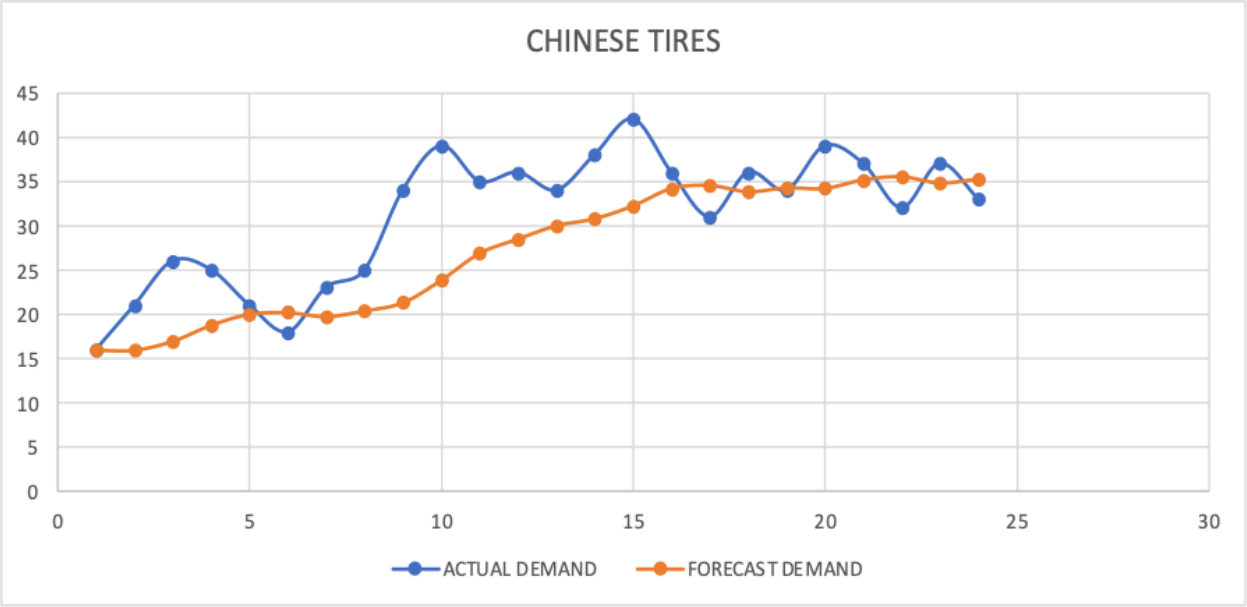

Figure 4: Chinese Tires Exponential Smoothing with Alpha 0.2

For the Moving Average Forecasting with Trend the decision to use it was driven by its suitability for scenarios with closely spaced and minimally variable demand observations. This method involves calculating the average of demand over a set number of adjacent periods to smooth out short-term fluctuations, providing a more stable trend for predictions.

To conduct this model, the data sample with demand for the two previous years was used. Since the two categories of tires that were used (American and Chinese) exhibited similarities in demand within their respective groups, the moving average method was deemed appropriate. The decision to use a 3-month moving average period aimed to strike a balance between capturing trends and avoiding undue sensitivity to short term variations.

To calculate the forecast for a specific period, such as December 2021, the demand values for the preceding three months were added (September, October, November 2021) and then divided by the sum by three (Appendix M). This averaging process eliminated potential biases from individual months, contributing to a more representative forecast. This approach was then iteratively applied to subsequent periods, starting from December 2021 and extending through August 2023.

By excluding the initial three periods without relevant data, the forecast effectively began with December 2021, aligning with the available dataset. This method facilitated accurate

predictions, contributing to effective demand forecasting for the entire period from September 2021 to August 2023 [5] (Macarty, 2018).

When putting the seasonality trend forecasts, it is clear that the model for American tires was not as effective as the Chinese forecast because the demand and forecast are more sparse.

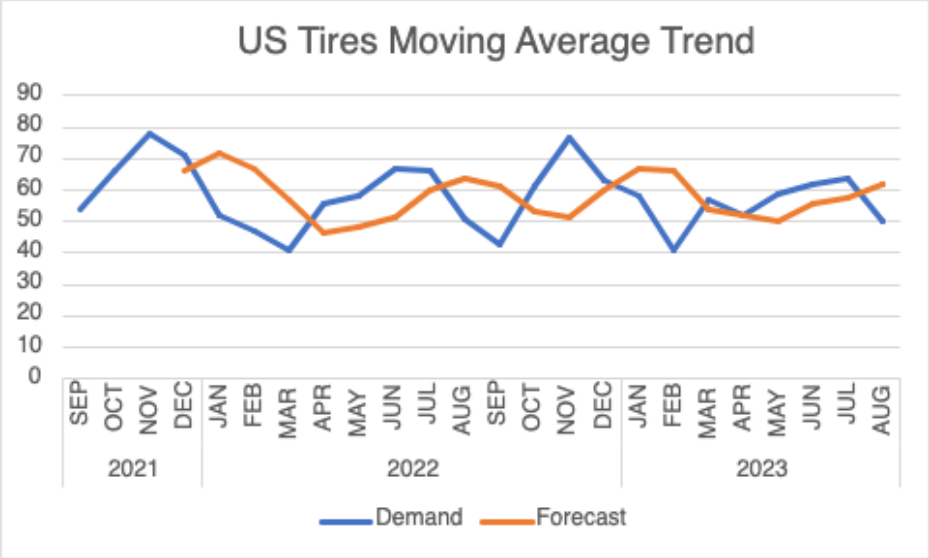

Figure 5: US Tires Moving Average Trend

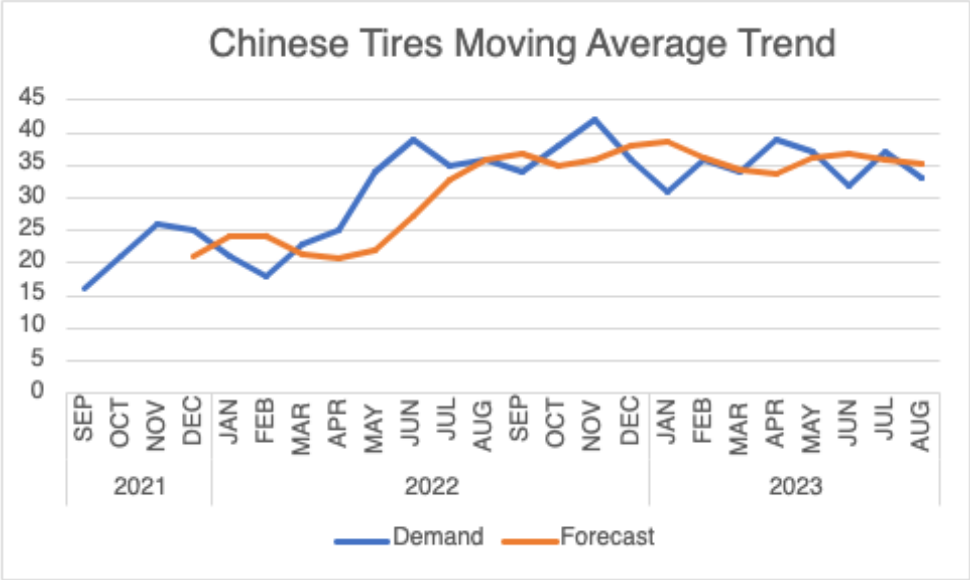

Figure 6: Chinese Tired Moving Average Trend

Notably, the Chinese tires forecasts exhibited the lowest errors when compared to other forecasting models used in this project. The forecasted trend for Chinese tires closely aligns with the actual demand, showcasing a reliable model. In contrast, the American tires displayed larger errors, which we then chose to forecast more precisely using the Seasonal Forecasting with trend.

For all three demand forecasts uses, the errors that were calculated were the mean absolute deviation (MAD), the mean squared error (MSE) and the mean absolute percentage error (MAPE) (Appendix N). To calculate the errors, the demand for the past two years was compared with the forecasts for the past two years as well to determine the forecast's accuracy. The MAD was calculated by using the sum of the absolute values of demand minus forecast, divided by the number of periods, which was 24 in this case. For the MSE, the sum of the squared MAD for each period was calculated and divided by 24 as well. Finally, for MAPE the absolute value of the demand minus the forecast, divided by the demand was obtained. This number was then divided by 24 as well. For the moving average only 21 periods were considered in these calculations because no forecasts could be obtained for the first three months.

5.3.6. Order Quantity

Determining quantity for our reorder point requires the demand, order costs, holding cost for the respective tire groups and the following formula, $\sqrt{\frac{2 \cdot D \cdot S}{H}}$ **.** Computing with the order cycle of one month for each tire group gives us order quantities of 56 for American tires and 63 for Chinese tires.

5.3.7. Total Cost Function

With the use of all the mentioned parameters, the total cost function equates to $288.93 for Chinese Tires and $265.59 for American Tires. It is easy to see and interpret the cost of tires directly off the rack from the factory or distributor, however, this function helps to visualize all other important costs such as shipping, opportunity cost, insurance and many others in one singular formula [3](Hofer, 2023). These numbers will help the company understand the true cost of their products along with perfecting inventory management [3](Hofer, 2023).

5.4. Safety Stock and Reorder Point

We used the safety stock method with normal distribution to determine a safety stock and reorder point. For example, we calculated a safety stock of 6 tires for the American tire group. This approach prioritizes a higher probability for needing exactly 6 tires, since it follows a normal distribution curve which reduces the likelihood of quantities below or above this threshold.

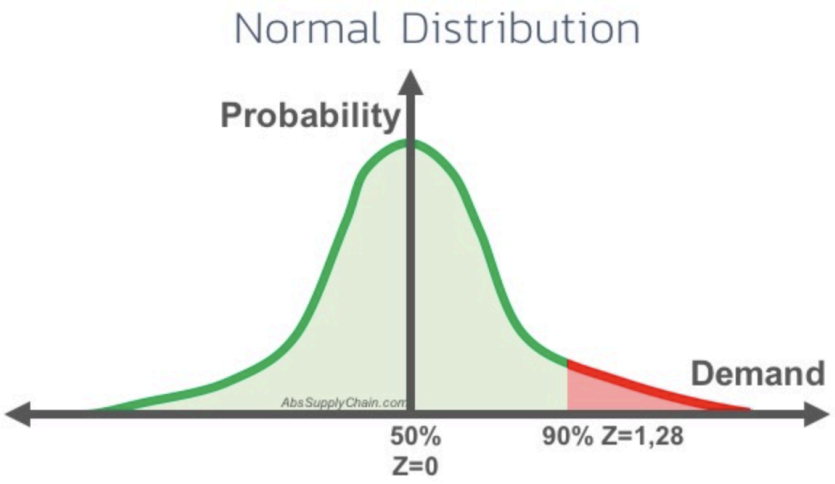

Figure 7: Safety Stock Measure using the Normal Distribution Method

The service level, shown on the Y-axis, indicates an acceptable shortage level. For both the American and Chinese tire groups, we opted for a 90% target service rate since they were equally profitable. On the X-axis, we consider the coefficient Z, also called the service factor Z.

Table 4: Representation of the normal distribution Z table

Normal Distribution	
Service Rate	Z =Coeff service
99,9%	3,09
99%	2,33
98%	2,05
97%	1,88
96%	1,75
95%	1,64
94%	1,55
93%	1,48
92%	1,41
91%	1,34
90%	1,28
89%	1,23
88%	1,17
87%	1,13
86%	1,08
85%	1,04
84%	0,99
83%	0,95
82%	0,92
81%	0,88
80%	0,84
79%	0,81
78%	0,77

The Z-coefficient shows how much values deviate from the average. Picking a 90% service level means aiming to minimize stock shortages, needing extra safety stock and a higher reorder point. A strong reordering process is crucial in preventing shortages, cutting holding costs and avoiding having too much stock.

To compute the safety stock for the American tires, we summed the forecasted demand from September 2022 to August 2023, resulting in 684 tires. We then derived the monthly average by dividing 684 by 12, yielding an approximate value of 106 tires. The daily average was determined by dividing the total of 365 days, resulting in 2 tires per day. Given a 90% target service rate, the Z-coefficient value of 1.28 was used from the table above. Simultaneously, we calculated the demand standard deviation for the forecasted months. This involved subtracting the mean (106 tires) from each forecasted demand, squaring the differences, summing the squares, and dividing by 12 periods minus 1.

To calculate the safety stock, we considered the lead time for the next 10 deliveries, set at 7 days. We calculated the average and maximum lead times, finding no variability with a

standard deviation of 0. Using these values, we applied a straight forward formula to determine the safety stock accurately.

METHOD 5
Uncertainty on demand and Lead Time independent
Z * sqrt((Average LT * (Demand Standard Deviation)² + (Average Sale *Lead Time Standard Deviation)²)

Figure 8: Safety Stock Formula

We calculated the reorder point for the American tires by multiplying the average daily forecasted demand by the average lead time and adding the safety stock obtained by the formula above (Appendix O). The same steps were repeated for the Chinese group of tires to determine their safety stock and reorder point [6](Thieuleux, 2023).

5.5. R, Q Model

The reorder point model provides the company with a designated quantity to be ordered at a certain reorder level while assuring safety stock. To get such a model, we calculated ROP and the safety stock with the use of forecasted demand. The quantity was calculated using the holding costs, ordering costs and demand.

5.6. Inventory Model Creation

To present this model, the Stock In, Out, Balance and Procurement System inspired by Smart Office [8](Smart Office, 2020) was selected by the team. This video allowed us to have a proper layout to present to the company.

Following the creation of the layout, the team met to discuss what data would be essential from the owner to conduct the inventory model. During the discussion with the owner, he explained that the most popular types of tires were American and Chinese. He provided the top 5 selling American tires which are the BF Goodrich 11R22.5 DR444, Continental 11R22.5 HS3+, Michelin 11R22.5 XDN2, Michelin XLEZ 11R22.5 and Firestone 11R22.5 FS591 and top 5 Chinese tires which are KPATOS 11R22.5 KTD88, Landy DS969 11R22.5, Sierra 11R22,5 SR256, SURETRAC 11R22.5RT369 and SURETRAC 11R22.5 RT256. After determining the

top 5 sellers for each type, their monthly sales for the past two years were provided as well as their current inventory levels.

Once these tires were added to the template alphabetically, to calculate the quantity in stock and to make it update every time there is a change, a formula was applied to every cell in that column which takes the opening stock, adds inventory that has been delivered and subtracts what has been sold. For the procurement suggestion to appear automatically an *IF* formula on Excel was applied on all cells in that column saying *IF* quantity in stock is less than the ROP, then show Place Order. The formulas were input into Excel before the data, this way when the data was added it would update automatically.

For the moment, the quantity in stock is the same as the opening stock because no orders have been entered into the model. The ROP for all American tires was 19.076, which provided an ROP of 3.8, rounded to 4 per tire. The ROP for all Chinese tires was 86.118, which provided a value of 17.22, rounded to 18 per tire. Finally, the safety stock of all American tires was 5.958, which gave a rounded value of 2 per tire. The safety stock for all Chinese tires was 14.940 which gave a rounded value of 3 per tire.

6. Analysis of Results

6.1. Cost Benefit Analysis

By using previous orders and comparing their lead times and order costs to our RQ model, we can create a cost benefit analysis and justify our findings.We will be using the month of June 2019 as an example for this analysis and the data provided for this month comes directly from the representatives of the company.

As stated previously, *New Millenium Truck and Tire Repairs* current way of ordering tires was based on intuition and visualizing how many tires were left. During the month of June 2019, the company had an opening stock of 10 Chinese tires, throughout the month there were 72 of these tires demanded however only one order of 40 was made for a restock during the first week [4](Jawandha, 2023). This was due to the owner going on vacation and not being able to oversee the stock and demand in real time and since he is the only figure authorized to place orders, the company faced issues. The order was received June 22nd and 28 tires were installed to fulfill the backlog. The 38 tires sold with profits of 75$/each raised revenue of 2850$ [4](Jawandha, 2023).

With ordering costs of $40.34 and 40 tires ordered, expenses for tires on this month totalled to $1613.60 equating to a profit of 1236.40. If our model was active with the business during this time, the situation would have played out as follows. The opening inventory would not have been 10 tires as the ROP of our model for chinese tires is 86 and the order quantity is 63. Ordering costs would consist of $2541.42 as Chinese tires cost $40.34 to order however all demand would have been fulfilled and 72 tires would have been sold with revenues of $5400 as each tire profits $75 with labor and resell margins.

With the Stock In, Out Balance and Procurement system, profits total $2858.58 whereas without the model profits equate to 1236.40. When comparing intangible factors, our model is superior as well. Since our model does not fall into backorders and all demand is fed, we do not lose any goodwill to lost customers. It can also be argued that because the stockout issue arose due to the owner being on vacation, the inventory model also implements a method that removes stress and the inefficiency of intuition from the process.

6.2. Demand Forecasting Using Errors

To determine which model to rely on for the demand found in the total cost function the errors for the three models were compared. Shown in the table below, for the American tires, the Seasonality Trend Forecasting model was the one with the lowest errors and for the Chinese tires it was the Moving Average model. Therefore these models were used to calculate the demand in the *Total Cost Function.* No trends were seen while comparing the demand and forecasts for American and Chinese tires, therefore, these models were only deemed better in terms of errors.

Table 5: Comparison of Errors per Model for American and Chinese Tires

	American Tires			Chinese Tires		
	Seasonality Trend Forecasting	Exponential Smoothing	Moving Average	Seasonality Trend Forecasting	Exponential Smoothing	Moving Average
MAD	2.531	8.929	11.302	3.956	4.910	3.857
MSE	11.888	118.858	177.333	27.387	38.495	25.730
MAPE	4.828	16.078	21.338	12.401	15.437	12.482

6.3. Safety Stock and Reorder point using the Normal Distribution Method

Using the normal distribution method, we calculated for example a safety stock of 6 tires and a reorder point of 20 tires for the American group of tires. The safety stock in this case acts as a

buffer to handle uncertainties, such as unexpected demand fluctuations or delays in supply chain processes. In this situation if the inventory level drops to 6 tires, it triggers a reorder point, prompting the company to place a new order to replenish stock. This approach helps prevent stockouts, ensuring that the company maintains enough tires to meet customer demand. It also considers the variability in demand and lead times, aligning with a chosen service level goal, which, in this case, is set at 90%. In practical terms, the company should place orders for the American group of tires when the inventory reaches the safety stock level (6 tires), ensuring a continuous supply and minimizing the risk of running out of stock during unforeseen circumstances or increased demand [2](Ellison, 2023).

Similarly, for the Chinese group of tires, the process remains the same. When the inventory level reaches 15 tires (safety stock), it's time to reorder. The reorder point is set at 87 tires, so once they hit 15 tires, it's a signal to place a new order and maintain a healthy stock level.

6.4. Total Cost Function

With the use of all the mentioned parameters, the total cost function equates to $288.93 for Chinese Tires and $265.59 for American Tires. It is easy to see and interpret the cost of tires directly off the rack from the factory or distributor, however, this function helps to visualize all other important costs such as shipping, opportunity cost, insurance and many others in one singular formula [3](Hofer, 2023). These numbers will help the company understand the true cost of their products along with perfecting inventory management [3](Hofer, 2023).

7. Deliverable

7.1. Demand Forecasting

7.1.1. Seasonal Demand Forecasting

To apply the seasonal forecasting model to American tires, the company can use the Excel template used to create the Inventory Control Model. In this case, they would extend the periods, the years, the months and add all previous monthly demand for American tires combined. Once this is done, they can simply drag down the formula for “Linear Trend Forecast" for the last

value calculated, until the very last period that they added. They can then do the same for "Forecasts with Trend".

Using the same template would make it a lot easier because when adding new data, the slope, the intercept and the seasonality index will adjust automatically with new data. The demand forecasted for the next 12 month period would be from September 2024 to August 2025 and it would be as follows:

Table 6: Seasonal Forecast with Trend for American Tires for January 2024 to August 2025

Year	Month	Demand Forecast
2024	JAN	52
	FEB	42
	MAR	46
	APR	51
	MAY	55
	JUN	60
	JUL	60
	AUG	47
	SEP	45
	OCT	58
	NOV	71
	DEC	61
2025	JAN	50
	FEB	40
	MAR	44
	APR	48
	MAY	52
	JUN	58
	JUL	58
	AUG	45

This deliverable comes with the Inventory Model and should be used by the company because it gives a better idea for what is to come. The models chosen for demand forecasting were used to determine the optimal order quantity per type of tire. Using a forecasting model to do so will prevent the business from ordering random quantities and it will allow them to have more control over their stock. In the long term this may reduce overall costs.

7.1.2. Moving Average Trend Model for Chinese Tires Forecast

To implement the 3-month moving average forecasting model, the company can use an Excel template. Enter the desired forecast months for the upcoming year, utilizing the historical actual demand data. Use an Excel function like =AVERAGE, selecting the last three historical actual periods, starting from the fourth period. Once the value for the fourth period is generated, extend the data to the required month and year for the forecast. Note that, when starting, please block the first three months as they have no relevant values, and the first value should begin with the fourth period [5](Macarty, 2018).

Regarding the moving average trend model, forecasting is currently limited to September 2023 due to the absence of historical demand data beyond August 2023.

Table 7: Moving-Average Forecast for Chinese Tires for September 2023

Year	**Month**	**Forecast**
2023	September	34

However, moving forward, the company can manually input the actual demand for the current month to generate forecasts for the subsequent month. This process allows for ongoing monthly predictions on a per-period basis, ensuring adaptability as new data becomes available.

7.2. R, Q Model

The Reorder Point Model is one of the most important and useful deliverables we will be presenting to the company. New Millenium Truck and Tire Repairs previous order format involved various inefficiencies and created issues. Operations without such models created unnecessary backorders, excess holding costs and was dependent on one person. Being dependent on a single individual results in problems for the entire company when communication is lacking and also biases the owner's thought process and reasoning rather than always being backed by statistics and data analytics.

Investing into a reorder point model removes all these problems and implements ideal and beneficial performance. This new deliverable uses all costs, lead times and other variables into account which is something a human brain cannot consistently always put together and analyze especially when numbers vary throughout the year. The figures created using the model

minimize costs and maximize revenue which is the whole basis of running a business. Using the data of their current tire costs and forecasted demand models, *New Millenium Truck and Tire Repairs* will be able to hold a safety stock of inventory, order the most efficient number of american and chinese tires at a statistically significant reorder point.

In the short-term, the number of backorders will decrease, optimizing revenue and the unideal form of ordering based on intuition will be removed giving way to a more disciplined form of business rather than depending on and having pressure on a single individual. In the long-term, with an improved goodwill on the company name due to the decreased number of backorders, *New Millenium Truck and Tire Repairs* will see a general increase in customers and thus a general increase in revenue.

7.3. Stock In, Out Balance and Procurement System

The Stock In, Out, Balance and Procurement system includes two pages with the first one being *In-Out Orders* and the second one being *Placed Orders*. The In-Out Orders page serves to show what stock is coming in and out, what quantity of each tire is currently in stock, what the ROP and safety stock is and finally it provides a procurement suggestion that tells you to place an order when stock is below the ROP. The *Placed Orders* page shows the date orders are placed, with their quantity and an indication to show what is in transit and what has been received.

The Stock In, Out, Balance and Procurement System (Appendix P) includes opening stock, product name, quantity in stock, ROP and safety stock already have values. Moreover, to place an order, or a sale a drop down list is offered to select the appropriate inventory, this way mistakes are to be avoided (Appendix Q). The Placed Orders layout is relatively simple and serves to demonstrate which orders are in transit and which orders have been received (Appendix R). It also allows the company to input the orders they have just placed.

The model's functionality will be demonstrated through the company's sales for the first two weeks of November 2023 provided by the owner (Appendix S). Looking at the data for November 1st to November 14th, the FIRESTONE 11R22.5 tire was ordered six times, making the quantity in stock go from 9 to 3, which is below the ROP of 4. When looking at the "Procurement Suggestion" column it shows "Place Order" which confirms that an order does need to be placed.

The FIRESTONE 11R22.5 FS591 is an American tire, therefore its lead time is 1-2 days. According to the R,Q model described earlier, the order quantity would be 56 for all American tires, thus approximately 12 per type of American tire. After placing the order, in the *Placing Orders* page, the date should be input in the first row. In the second row, the letter "T" or "R" should be indicated to demonstrate whether the order is in transit or received. In this case, when ordering the letter "T" would be put and the quantity ordered would be added in the appropriate tire's row (Appendix T). By doing so, the "Place Order" under the procurement suggestion will disappear because the order has been placed. When the order is received, it is important to change "T" to an "R" because it is important to keep track of what has been received. Finally, the quantity received must be input in the "Stock In" section of the model for the quantity to readjust (Appendix U).

In this demonstration, an order of 10 FIRESTONE 11R22.5 was placed when there were only 3 left in stock. When the 12 were received, they were input into the model, thus changing the "Quantity in stock" to 13. A high quantity is not required to be kept in stock for American tires because their lead time is short and low ordering fees are charged per order.

The company should invest in this deliverable because firstly, it is affordable. The model is made from Microsoft Excel, where all of the formulas have already been inputted as well as the company's data. A page with the same interface is provided for the twelve months of the year where the quantity in stock will carry over to opening stock for the following month. Moreover, over time when data needs to be updated, it can be done so easily. The company already has access to Excel on their computers, therefore, no additional costs will be incurred for the use of Excel.

This model, as demonstrated above, will allow the company to track all incoming inventory as well as existing inventory. They will have a clear view of what is in stock. As mentioned previously, the company currently solely relies on Quickbooks Intuit, which serves as an accounting software and helps them keep track of their invoicing. With the addition of the inventory model, this will allow the company to have a global view of their administration as well as their operation. They will have a clear view of what is currently in stock, what has been ordered and what has been received.

A long term impact this model will bring to the company is that they will most likely decrease the number of orders they place yearly, thus reducing overall costs. This model will

allow them to order an accurate amount of inventory with the help of the R,Q quantity model, which helped obtain an optimal order quantity for American and Chinese tires. Additionally, with an ROP and safety stock, orders will be placed on time. By placing orders on time, having an optimal order quantity, using a ROP and safety stock, risks of shortages or overstock will be reduced, thus reducing holding costs and ordering costs.

8. Conclusions and Recommendations

8.1. Conclusions

This conclusion highlights the significant outcomes achieved through the Inventory Control project for New Millennium Truck and Tire Repairs. It ties these achievements directly to the project objectives:

- Seasonal Demand Forecasting:
    - Forecasting models extended through Excel templates facilitate informed decision-making for American tires, enhancing inventory management.
    - These models present a potential solution for cost reduction and improved operational efficiency over the long term.
- Moving Average Trend Model for Chinese Tires Forecast:
    - Implementing the 3-month moving average forecasting model in Excel aids in analyzing historical demand, providing a methodical approach to monthly predictions.
    - Despite initial data limitations, ongoing manual input ensures adaptability and alignment with evolving data trends.
- R, Q Model (Reorder Point Model):
    - The implementation of the reorder point model signifies a shift towards data-driven, cost-effective practices, reducing backorders and optimizing revenue.
    - Short-term improvements include minimized backorders, while long-term benefits encompass enhanced goodwill, increased customer satisfaction, and revenue growth.
- Cost Benefit Analysis
    - Proves the effectiveness and benefits of using a reorder model to order tires and fulfill demand.

    - Calculating revenues and expenses during an order cycle without the model highlights the presence of backorder costs which have an opportunity cost of $75 per tire and result in a loss of goodwill.
- Stock In, Out, Balance, and Procurement System:
    - The comprehensive tracking system for inventory movements offers real-time visibility into stock levels and incoming inventory, enabling informed procurement decisions.
    - Its affordability, user-friendliness in Excel, and adaptability for updates make it a sustainable solution for enhanced administrative and operational control.

These conclusions directly align with the project's objectives, showcasing the efficacy of the implemented models and systems in revolutionizing inventory management for New Millennium Truck and Tire Repairs.

8.2. Recommendations

0-6 Months

Short-term recommendations for the project to be successful would be to meet with the team and do an in depth explanation of how the model works to ensure that they use it adequately. Moreover, a small training guide can be created to allow them to have a guide afterwards. Lastly, doing a test run for the first month or few months can be beneficial to see if anything needs to be tweaked on the model or if it is working successfully. Weekly meetings can be scheduled to go over questions and to see whether this model is efficient or not.

6 Months to 1 Year

Medium term recommendations are to schedule monthly meetings rather than weekly meetings because at this point, they will most likely be comfortable using this model. Additionally, updating forecasting is essential to ensure that the most accurate data is being used. All three forecasting models can be conducted once again to ensure that the company is using the one with the least errors.

More than 1 Year

Long-term recommendations are to compare costs before the implementation of the Inventory Control Model with costs incurred after its implementation to see if it made a significant difference. It is also to compare the amount of overstock and shortages before using the model and while using it. Lastly, if it is determined that the model does indeed make a significant difference, then all of their inventory can be added to this model.

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Appendix A

Appendix A: Demand/Sales from September 2021 to August 2023

AMERICAN TIRES					CHINIESE TIRES				
Year	Date	Sum of quantity			Year	Date	Sum of quantity		
2021					2021				
SEP	SEP	54			SEP	SEP	16		
OCT	OCT	66			OCT	OCT	21		
NOV	NOV	78			NOV	NOV	26		
DEC	DEC	71			DEC	DEC	25		
2022					2022				
JAN	JAN	52			JAN	JAN	21		
FEB	FEB	47			FEB	FEB	18		
MAR	MAR	41			MAR	MAR	23		
APR	APR	56			APR	APR	25		
MAY	MAY	58			MAY	MAY	34		
JUN	JUN	67			JUN	JUN	39		
JUL	JUL	66			JUL	JUL	35		
AUG	AUG	51			AUG	AUG	36		
SEP	SEP	43			SEP	SEP	34		
OCT	OCT	61			OCT	OCT	38		
NOV	NOV	77			NOV	NOV	42		
DEC	DEC	63			DEC	DEC	36		
2023					2023				
JAN	JAN	58			JAN	JAN	31		
FEB	FEB	41			FEB	FEB	36		
MAR	MAR	57			MAR	MAR	34		
APR	APR	52			APR	APR	39		
MAY	MAY	59			MAY	MAY	37		
JUNE	JUNE	62			JUNE	JUNE	32		
JULY	JULY	64			JULY	JULY	37		
AUGUST	AUGUST	50	TOTAL	1276	AUGUST	AUGUST	33	TOTAL	748

Appendix B: Total Cost Function Formula, Data and Calculation

$$Total\ Cost\ Function\ =\ H\ \cdot\ (\frac{Q}{2}+\ R\ -\ \overline{DL})\ +\ (N\cdot S)\ +\ (P\ \cdot\ n\,(R)\ \cdot\ N)$$

$H\ =\ Holding\ Cost\ per\ month$

$Q\ =\ Order\ Quantity$

$R\ -\ \overline{DL} = Safety\ Stock\ per\ cycle$

$S\ =\ Order\ placement\ cost\ per\ tire$

$P\ =\ Backorder\ Cost\ per\ tire$

$n(R)\ =\ Number\ of\ units\ out\ of\ stock\ per\ cycle$

N= Number of order cycles

For American Tires per month

D = 53.60 demand of american tires/month

S = 29.75$ cost order per american tire

H = 1.03$ per tire per month

$R - \overline{DL} =$ 6 tires for safety stock per month

P = 37.50$ per backorder per tire

$n(R)$ = 53.60 units x 10% = 5.36 units backordered per month

Q= $\sqrt{\frac{2 \cdot D \cdot S}{H}} = \sqrt{\frac{2 \cdot 53.60 \cdot 29.75}{1.03}} = 55.65$

N= 1 per month

$$Total\ Cost\ Function = 1.03\$ \cdot (\frac{55.65}{2} + 6) + (1 \cdot 29.75\$) + (37.50\$ \cdot 5.36\$ \cdot 1)$$

= 265.59$

For Chinese Tires per month

D = 49.71 demand of chinese tires/month

S= 40.34$ cost order per chinese tire

H = 1.02$ holding cost per tire per month

$R - \overline{DL} =$ 15 tires for safety stock per month

P = 37.50$ per backorder per tire

$n(R)$ = 49.71 units x 10% = 5.36 units backordered per month

N= 1 per month

Q= $\sqrt{\frac{2 \cdot D \cdot S}{H}} = \sqrt{\frac{2 \cdot 53.60 \cdot 25.63}{1.02}} = 62.40$

$$Total\ Cost\ Function = 1.03\$ \cdot (\frac{62.40}{2} + 15) + (1 \cdot 40.34\$) + (37.50\$ \cdot 5.36 \cdot 1)$$

= 288.93$

Appendix C: Slope & Seasonal Index for American Tires

US Slope	-0.187826087
US Intercept	60.43115942
US Month	US Seasonality Index
SEP	0.835007174
OCT	1.093256815
NOV	1.334289813
DEC	1.153515065
JAN	0.946915352
FEB	0.757532281
MAR	0.843615495
APR	0.929698709
MAY	1.007173601
JUN	1.110473458
JUL	1.119081779
AUG	0.869440459

Appendix D: Slope & Seasonal Index for Chinese Tires

Chinese Intercept	21.62318841
Chinese Slope	0.763478261
Month	Seasonality Index
SEP	0.802139037
OCT	0.946524064
NOV	1.090909091
DEC	0.978609626
JAN	0.834224599
FEB	0.86631016
MAR	0.914438503
APR	1.026737968
MAY	1.139037433
JUN	1.139037433
JUL	1.155080214
AUG	1.106951872

Appendix E: Seasonality Trend Forecasting for American Tires with Errors

American Tires					
Period	Year	Month	Demand	Linear Trend Forecast	US Forecasts with Trend
1	2021	SEP	54	60.24333333	50.30361549
2		OCT	66	60.05550725	65.65609257
3		NOV	78	59.86768116	79.88083713
4		DEC	71	59.67985507	68.84161188
5	2022	JAN	52	59.49202899	56.33391554
6		FEB	47	59.3042029	44.92484811
7		MAR	41	59.11637681	49.87149149
8		APR	56	58.92855072	54.78579752
9		MAY	58	58.74072464	59.16210717
10		JUN	67	58.55289855	65.02143971
11		JUL	66	58.36507246	65.31528913
12		AUG	51	58.17724638	50.5816518
13		SEP	43	57.98942029	48.42158194
14		OCT	61	57.8015942	63.19198678
15		NOV	77	57.61376812	76.87346391
16		DEC	63	57.42594203	66.24168923
17	2023	JAN	58	57.23811594	54.19965068
18		FEB	41	57.05028986	43.21743622
19		MAR	57	56.86246377	47.97005552
20		APR	52	56.67463768	52.69033747
21		MAY	59	56.48681159	56.89202545
22		JUN	62	56.29898551	62.5185291
23		JUL	64	56.11115942	62.79297611
24		AUG	50	55.92333333	48.62200861
25		SEP		55.73550725	46.53954838
26		OCT		55.54768116	60.72788098
27		NOV		55.35985507	73.8660907
28		DEC		55.17202899	63.64176658
29	2024	JAN		54.9842029	52.06538581
30		FEB		54.79637681	41.51002433
31		MAR		54.60855072	46.06861955
32		APR		54.42072464	50.59487742
33		MAY		54.23289855	54.62194373
34		JUN		54.04507246	60.01561849
35		JUL		53.85724638	60.27066309
36		AUG		53.66942029	46.66236542
37		SEP		53.4815942	44.65751482
38		OCT		53.29376812	58.26377519
39		NOV		53.10594203	70.85871748
40		DEC		52.91811594	61.04184393
41	2025	JAN		52.73028986	49.93112095
42		FEB		52.54246377	39.80261244
43		MAR		52.35463768	44.16718358
44		APR		52.16681159	48.49941738
45		MAY		51.97898551	52.35186202
46		JUN		51.79115942	57.51270788
47		JUL		51.60333333	57.74835007
47		AUG		51.60333333	44.86602582

Appendix F: Seasonality Trend Forecasting for Chinese Tires with Errors

Chinese Tires						I
Period	Year	Month	Demand	Linear Trend Forecast	Chinese Seasonal Forecasts with	S
1	2021	SEP	16	22.38666667	17.95721925	M
2		OCT	21	23.15014493	21.91216926	S
3		NOV	26	23.91362319	26.08758893	C
4		DEC	25	24.67710145	24.14924901	N
5	2022	JAN	21	25.44057971	21.22315741	D
6		FEB	18	26.20405797	22.70084166	J.
7		MAR	23	26.96753623	24.66015345	F
8		APR	25	27.73101449	28.47248547	M
9		MAY	34	28.49449275	32.45629389	A
10		JUN	39	29.25797101	33.3259242	M
11		JUL	35	30.02144928	34.67718205	J
12		AUG	36	30.78492754	34.07743316	J
13		SEP	34	31.5484058	25.30620786	A
14		OCT	38	32.31188406	30.58397582	
15		NOV	42	33.07536232	36.08221344	
16		DEC	36	33.83884058	33.11501511	
17	2023	JAN	31	34.60231884	28.86610556	
18		FEB	36	35.3657971	30.63774936	
19		MAR	34	36.12927536	33.03800047	
20		APR	39	36.89275362	37.87919089	
21		MAY	37	37.65623188	42.89185771	
22		JUN	32	38.41971014	43.76148803	
23		JUL	37	39.18318841	45.25972565	
24		AUG	33	39.94666667	44.21903743	
25		SEP		40.71014493	32.65519647	
26		OCT		41.47362319	39.25578238	
27		NOV		42.23710145	46.07683794	
28		DEC		43.00057971	42.08078121	
29	2024	JAN		43.76405797	36.50905371	
30		FEB		44.52753623	38.57465706	
31		MAR		45.29101449	41.41584748	
32		APR		46.05449275	47.2858963	
33		MAY		46.81797101	53.32742153	
34		JUN		47.58144928	54.19705185	
35		JUL		48.34492754	55.84226924	
36		AUG		49.1084058	54.36064171	
37		SEP		49.87188406	40.00418507	
38		OCT		50.63536232	47.92758893	
39		NOV		51.39884058	56.07146245	
40		DEC		52.16231884	51.04654731	
41	2025	JAN		52.9257971	44.15200186	
42		FEB		53.68927536	46.51156475	
43		MAR		54.45275362	49.79369449	
44		APR		55.21623188	56.69260172	
45		MAY		55.97971014	63.76298535	
46		JUN		56.74318841	64.63261567	
47		JUL		57.50666667	66.42481283	
48		AUG		58.27014493	64.50224599	

Appendix G: Formula used to Calculate Forecast Demand for Exponential Smoothing

Exponential Smoothing Formula:

$$F_t = \alpha A_{t-1} + (1 - \alpha)F_{t-1}$$

Where:

- F_t is the forecast demand for week t
- α is the smoothing constant
- A_{t-1} is the previous period's actual demand
- F_{t-1} is the previous period's forecast demand

Appendix H : Exponential Smoothing Forecast

Figure H.1 Exponential Smoothing Forecast for American Tires with Errors

AMERICAN TIRES			ERRORS		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND	MAD	MSE	MAPE
1	54	54			
2	66	54.00	12.00	144.00	18.18
3	78	56.40	21.60	466.56	27.69
4	71	60.72	10.28	105.68	14.48
5	52	62.78	10.78	116.12	20.72
6	47	60.62	13.62	185.53	28.98
7	41	57.90	16.90	285.50	41.21
8	56	54.52	1.48	2.20	2.65
9	58	54.81	3.19	10.15	5.49
10	67	55.45	11.55	133.38	17.24
11	66	57.76	8.24	67.88	12.48
12	51	59.41	8.41	70.71	16.49
13	43	57.73	14.73	216.88	34.25
14	61	54.78	6.22	38.67	10.19
15	77	56.03	20.97	439.94	27.24
16	63	60.22	2.78	7.73	4.41
17	58	60.78	2.78	7.71	4.79
18	41	60.22	19.22	369.44	46.88
19	57	56.38	0.62	0.39	1.09
20	52	56.50	4.50	20.26	8.66
21	59	55.60	3.40	11.55	5.76
22	62	56.28	5.72	32.71	9.22
23	64	57.42	6.58	43.23	10.27
24	50	58.74	8.74	76.38	17.48
		TOTAL	**8.93**	**118.86**	**16.08**

Figure H.2 Exponential Smoothing Forecast for Chinese Tires with Errors

CHINESE TIRES			ERRORS		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND	MAD	MSE	MAPE
1	16	16			
2	21	16.00	5.00	25.00	23.81
3	26	17.00	9.00	81.00	34.62
4	25	18.80	6.20	38.44	24.80
5	21	20.04	0.96	0.92	4.57
6	18	20.23	2.23	4.98	12.40
7	23	19.79	3.21	10.33	13.98
8	25	20.43	4.57	20.90	18.29
9	34	21.34	12.66	160.21	37.23
10	39	23.87	15.13	228.79	38.78
11	35	26.90	8.10	65.62	23.14
12	36	28.52	7.48	55.96	20.78
13	34	30.02	3.98	15.88	11.72
14	38	30.81	7.19	51.66	18.91
15	42	32.25	9.75	95.06	23.21
16	36	34.20	1.80	3.24	5.00
17	31	34.56	3.56	12.67	11.48
18	36	33.85	2.15	4.63	5.98
19	34	34.28	0.28	0.08	0.82
20	39	34.22	4.78	22.82	12.25
21	37	35.18	1.82	3.32	4.92
22	32	35.54	3.54	12.55	11.07
23	37	34.83	2.17	4.69	5.85
24	33	35.27	2.27	5.14	6.87
		TOTAL	**4.910**	**38.495**	**15.437**

Appendix I: Representation of Forecast Demand as 0 in Exponential Smoothing

Figure I. 1 Representation of Forecast Demand as 0 in Exponential Smoothing American Tires

AMERICAN TIRES		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND
1	54	0
2	66	10.80
3	78	21.84
4	71	33.07
5	52	40.66
6	47	42.93
7	41	43.74
8	56	43.19
9	58	45.75
10	67	48.20
11	66	51.96
12	51	54.77
13	43	54.02
14	61	51.81
15	77	53.65
16	63	58.32
17	58	59.26
18	41	59.00
19	57	55.40
20	52	55.72
21	59	54.98
22	62	55.78
23	64	57.03
24	50	58.42

Figure I. 2 Representation of Forecast Demand as 0 in Exponential Smoothing American Tires

CHINESE TIRES		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND
1	16	0.00
2	21	3.20
3	26	6.76
4	25	10.61
5	21	13.49
6	18	14.99
7	23	15.59
8	25	17.07
9	34	18.66
10	39	21.73
11	35	25.18
12	36	27.15
13	34	28.92
14	38	29.93
15	42	31.55
16	36	33.64
17	31	34.11
18	36	33.49
19	34	33.99
20	39	33.99
21	37	34.99
22	32	35.39
23	37	34.72
24	33	35.17

Appendix J: Representation of Exponential Smoothing when Actual Demand = Forecast Demand for American Tires

AMERICAN TIRES		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND
1	54	54
2	66	54.00
3	78	56.40
4	71	60.72
5	52	62.78
6	47	60.62
7	41	57.90
8	56	54.52
9	58	54.81
10	67	55.45
11	66	57.76
12	51	59.41
13	43	57.73
14	61	54.78
15	77	56.03
16	63	60.22
17	58	60.78
18	41	60.22
19	57	56.38
20	52	56.50
21	59	55.60
22	62	56.28
23	64	57.42
24	50	58.74

Appendix K: Representation of Exponential Smoothing when Actual Demand = Forecast Demand for Chinese Tires

CHINESE TIRES		
PERIOD	ACTUAL DEMAND	FORECAST DEMAND
1	16	16
2	21	16.00
3	26	17.00
4	25	18.80
5	21	20.04
6	18	20.23
7	23	19.79
8	25	20.43
9	34	21.34
10	39	23.87
11	35	26.90
12	36	28.52
13	34	30.02
14	38	30.81
15	42	32.25
16	36	34.20
17	31	34.56
18	36	33.85
19	34	34.28
20	39	34.22
21	37	35.18
22	32	35.54
23	37	34.83
24	33	35.27

Appendix L: Trial and Error with Various Alphas

Figure L. 1: Using an alpha of 0.5 for Exponential Smoothing which demonstrates high volatility for American Tires

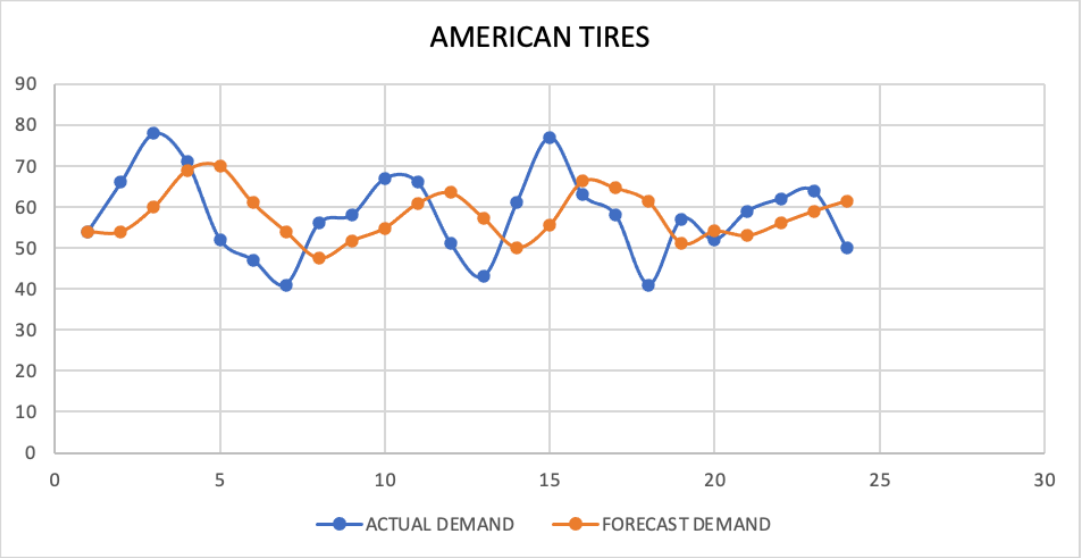


Figure L.2: Using an alpha of 0.7 for Exponential Smoothing which demonstrates high volatility for American Tires

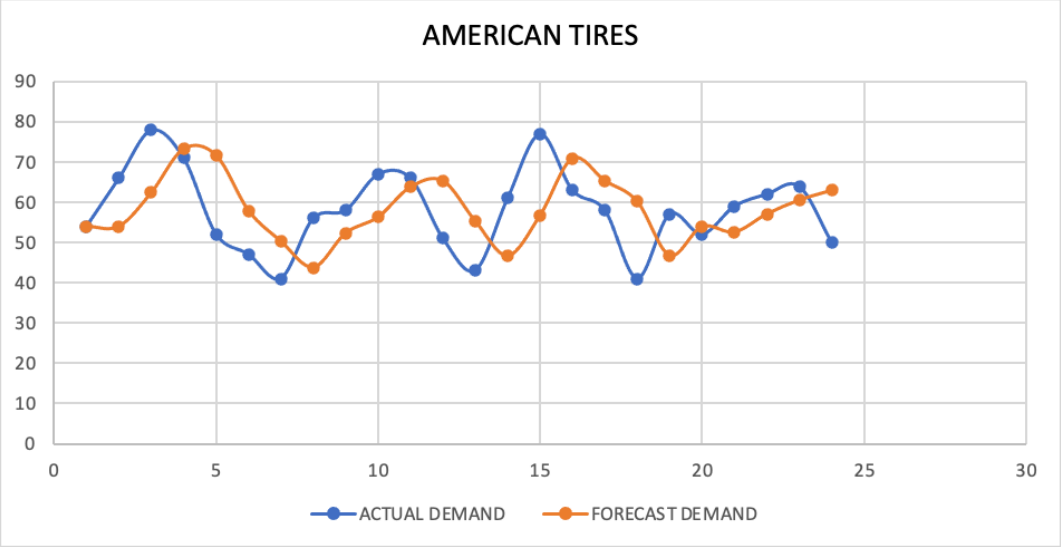


Figure L.3: Using an alpha of 0.9 for Exponential Smoothing which demonstrates high volatility for American Tires

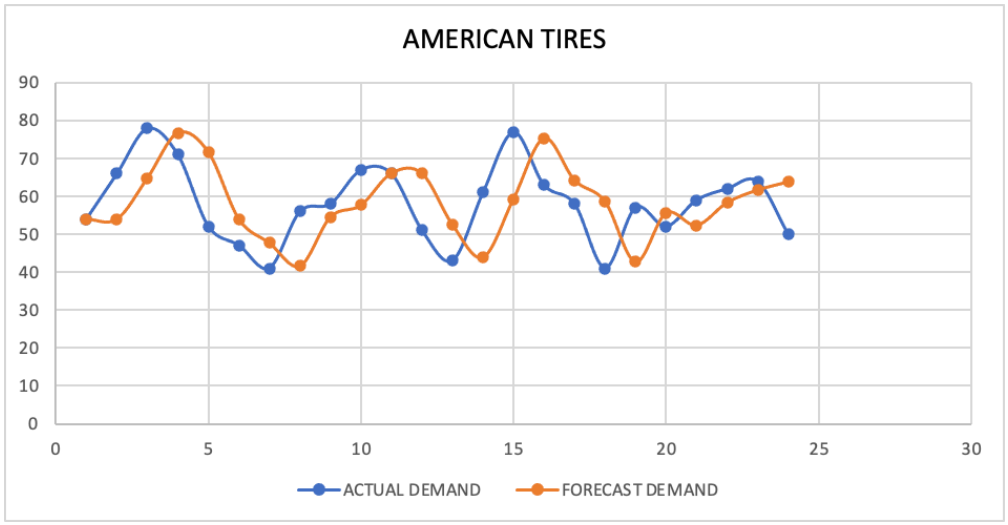


Figure L.4: Using an alpha of 0.5 for Exponential Smoothing which demonstrates high volatility for Chinese

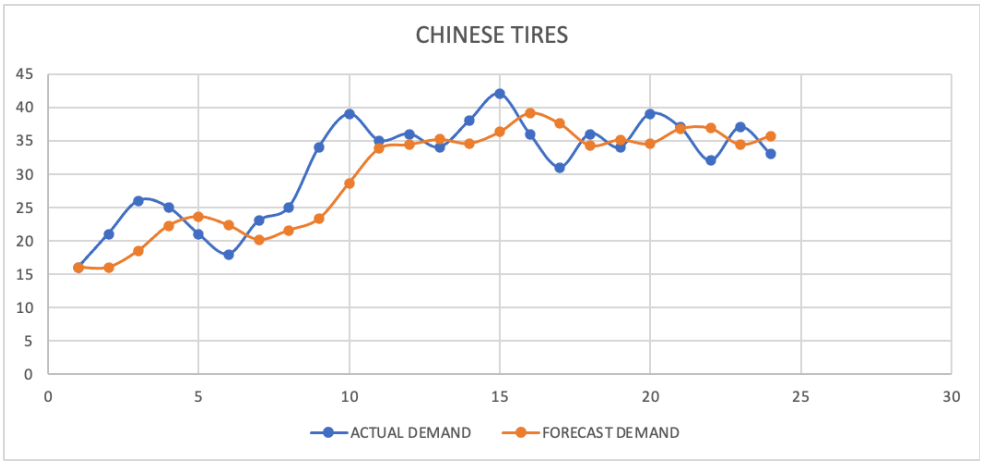


Figure L.5: Using an alpha of 0.7 for Exponential Smoothing which demonstrates high volatility for Chinese

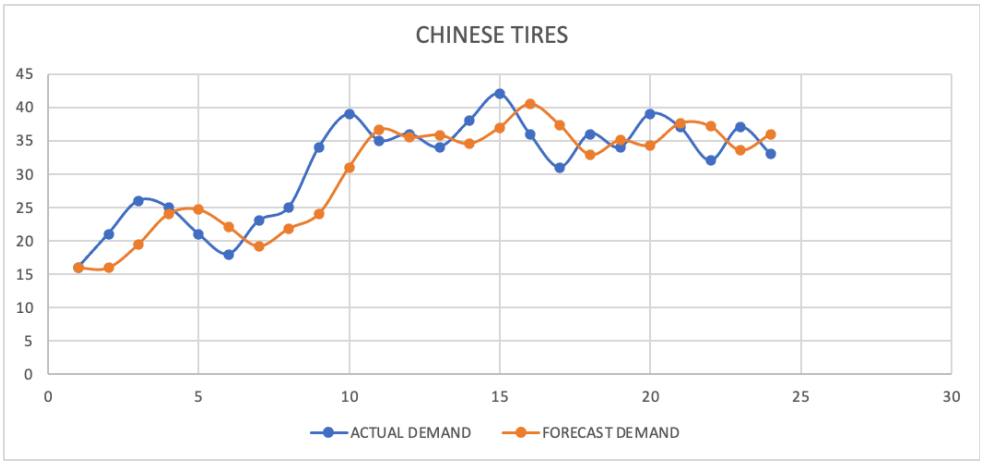
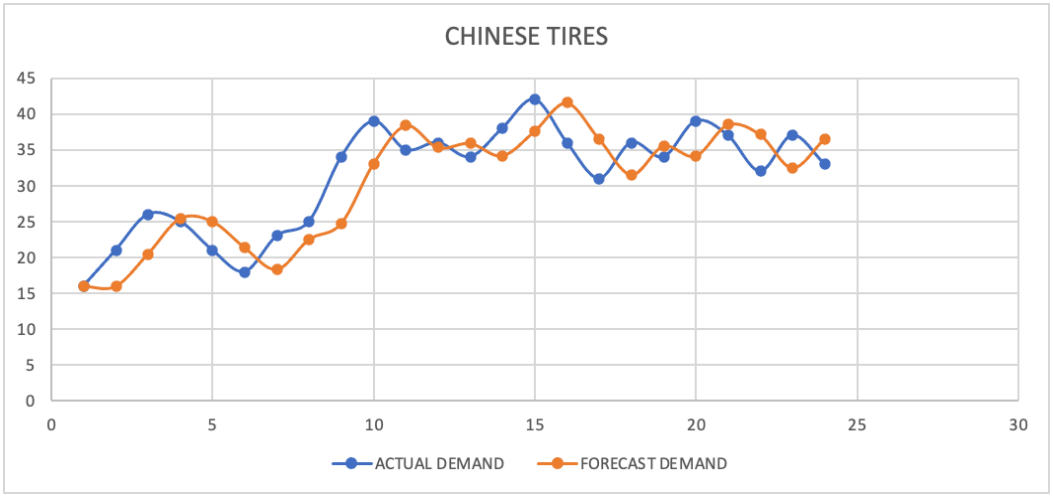


Figure L.6: Using an alpha of 0.9 for Exponential Smoothing which demonstrates high volatility for Chinese



Appendix M : Moving Average Model Trend with Demand and Forecasting for American Tires

Figure M.1: Moving Average Model Trend with Demand and Forecasting for American Tires

Period	Year	Month	Demand	Forecast
1	2021	SEP	54	3 month MA
2		OCT	66	American
3		NOV	78	
4		DEC	71	66
5	2022	JAN	52	71.67
6		FEB	47	67
7		MAR	41	57
8		APR	56	47
9		MAY	58	48
10		JUN	67	51.67
11		JUL	66	60.33
12		AUG	51	63.67
13		SEP	43	61.33
14		OCT	61	53.33
15		NOV	77	51.67
16		DEC	63	60.33
17	2023	JAN	58	67
18		FEB	41	66
19		MAR	57	54
20		APR	52	52
21		MAY	59	50
22		JUN	62	56
23		JUL	64	57.67
24		AUG	50	61.67

Figure M.2: Moving Average Model Trend with demand and forecasting for Chinese Tires

Period	Year	Month	Demand	Forecast
1	2021	SEP	16	3-month average
2		OCT	21	Chinese
3		NOV	26	
4		DEC	25	21
5	2022	JAN	21	24
6		FEB	18	24
7		MAR	23	21.33
8		APR	25	20.67
9		MAY	34	22
10		JUN	39	27.33
11		JUL	35	32.67
12		AUG	36	36
13		SEP	34	36.67
14		OCT	38	35
15		NOV	42	36
16		DEC	36	38
17	2023	JAN	31	38.67
18		FEB	36	36.33
19		MAR	34	34.33
20		APR	39	33.67
21		MAY	37	36.33
22		JUN	32	36.67
23		JUL	37	36
24		AUG	33	35.33

Appendix N: Errors Calculations per Forecasting Method

Figure N.1 Seasonality Forecasting with Trend Errors Calculation for American Tires

Error	MAD	MSE	MAPE
3.696	3.696	13.663	0.0685
0.344	0.344	0.118	0.0052
-1.881	1.881	3.538	0.0241
2.158	2.158	4.659	0.0304
-4.334	4.334	18.783	0.0833
2.075	2.075	4.306	0.0442
-8.871	8.871	78.703	0.2164
1.214	1.214	1.474	0.0217
-1.162	1.162	1.350	0.0200
1.979	1.979	3.915	0.0295
0.685	0.685	0.469	0.0104
0.418	0.418	0.175	0.0082
-5.422	5.422	29.394	0.1261
-2.192	2.192	4.805	0.0359
0.127	0.127	0.016	0.0016
-3.242	3.242	10.509	0.0515
3.800	3.800	14.443	0.0655
-2.217	2.217	4.917	0.0541
9.030	9.030	81.540	0.1584
-0.690	0.690	0.477	0.0133
2.108	2.108	4.444	0.0357
-0.519	0.519	0.269	0.0084
1.207	1.207	1.457	0.0189
1.378	1.378	1.899	0.0276
-0.310	60.749	285.321	1.159

	N=24	Formula	
	MAD	Sum of ABS/N	2.531
	MSE	Sum of square/N	11.888
	MAPE	Sum of abs value of error divded by actual/N * by 100	4.828

Figure N. 2 Seasonality Forecasting with Trend Errors Calculation for Chinese Tires

Error	MAD	MSE	MAPE
-1.957	1.957	3.831	0.122
-0.912	0.912	0.832	0.043
-0.088	0.088	0.008	0.003
0.851	0.851	0.724	0.034
-0.223	0.223	0.050	0.011
-4.701	4.701	22.098	0.261
-1.660	1.660	2.756	0.072
-3.472	3.472	12.058	0.139
1.544	1.544	2.383	0.045
5.674	5.674	32.195	0.145
0.323	0.323	0.104	0.009
1.923	1.923	3.696	0.053
8.694	8.694	75.582	0.256
7.416	7.416	54.997	0.195
5.918	5.918	35.020	0.141
2.885	2.885	8.323	0.080
2.134	2.134	4.554	0.069
5.362	5.362	28.754	0.149
0.962	0.962	0.925	0.028
1.121	1.121	1.256	0.029
-5.892	5.892	34.714	0.159
-11.761	11.761	138.333	0.368
-8.260	8.260	68.223	0.223
-11.219	11.219	125.867	0.340
-5.340	94.951	657.283	2.976

N=24	Formula	
MAD	Sum of ABS/N	3.956
MSE	Sum of square/N	27.387
MAPE	Sum of abs value of error divded by actual/N * by 100	12.401

Figure N.3: Exponential Smoothing Errors Calculation for American Tires

ERRORS		
MAD	MSE	MAPE
12	144	18.18
21.6	466.56	27.69
10.28	105.68	14.48
10.78	116.12	20.72
13.62	185.53	28.98
16.9	285.5	41.21
1.48	2.2	2.65
3.19	10.15	5.49
11.55	133.38	17.24
8.24	67.88	12.48
8.41	70.71	16.49
14.73	216.88	34.25
6.22	38.67	10.19
20.97	439.94	27.24
2.78	7.73	4.41
2.78	7.71	4.79
19.22	369.44	46.88
0.62	0.39	1.09
4.5	20.26	8.66
3.4	11.55	5.76
5.72	32.71	9.22
6.58	43.23	10.27
8.74	76.38	17.48
8.93	**118.86**	**16.08**

Figure N.4: Exponential Smoothing Errors Calculations for American Tires

ERRORS		
MAD	**MSE**	**MAPE**
5	25	23.81
9	81	34.62
6.2	38.44	24.8
0.96	0.92	4.57
2.23	4.98	12.4
3.21	10.33	13.98
4.57	20.9	18.29
12.66	160.21	37.23
15.13	228.79	38.78
8.1	65.62	23.14
7.48	55.96	20.78
3.98	15.88	11.72
7.19	51.66	18.91
9.75	95.06	23.21
1.8	3.24	5
3.56	12.67	11.48
2.15	4.63	5.98
0.28	0.08	0.82
4.78	22.82	12.25
1.82	3.32	4.92
3.54	12.55	11.07
2.17	4.69	5.85
2.27	5.14	6.87
4.91	**38.495**	**15.437**

Figure N.5: Moving Average Errors Calculations for American Tires

Error	Absolute value of Error	Square of Error	Abs value of error/ actual
5	5	25	0.070422535
-19.66666667	19.66666667	386.7777778	0.378205128
-20	20	400	0.425531915
-15.66666667	15.66666667	245.4444444	0.382113821
9.333333333	9.333333333	87.11111111	0.166666667
10	10	100	0.172413793
15.33333333	15.33333333	235.1111111	0.228855721
5.666666667	5.666666667	32.11111111	0.085858586
-12.66666667	12.66666667	160.4444444	0.248366013
-18.33333333	18.33333333	336.1111111	0.426356589
7.666666667	7.666666667	58.77777778	0.12568306
25.33333333	25.33333333	641.7777778	0.329004329
2.666666667	2.666666667	7.111111111	0.042328042
-9	9	81	0.155172414
-25	25	625	0.609756098
3	3	9	0.052631579
0	0	0	0
9	9	81	0.152542373
6	6	36	0.096774194
6.333333333	6.333333333	40.11111111	0.098958333
-11.66666667	11.66666667	136.1111111	0.233333333
-26.66666667	237.3333333	3724	4.480974524
N=21	**Formula**		American
MAD	Sum of ABS/N	11.302	
MSE	Sum of square/N	177.333	
MAPE	Sum of abs value of error divded by actual/N * by 100	21.338	

Figure N.6: Moving Average Errors Calculations for American Tires

Error	Absolute value of Error	Square of Error	Abs value of error/ actual
4	4	16	0.16
-3	3	9	0.142857143
-6	6	36	0.333333333
1.666666667	1.666666667	2.777777778	0.072463768
4.333333333	4.333333333	18.77777778	0.173333333
12	12	144	0.352941176
11.66666667	11.66666667	136.1111111	0.299145299
2.333333333	2.333333333	5.444444444	0.066666667
0	0	0	0
-2.666666667	2.666666667	7.111111111	0.078431373
3	3	9	0.078947368
6	6	36	0.142857143
-2	2	4	0.055555556
-7.666666667	7.666666667	58.77777778	0.247311828
-0.333333333	0.333333333	0.111111111	0.009259259
-0.333333333	0.333333333	0.111111111	0.009803922
5.333333333	5.333333333	28.44444444	0.136752137
0.666666667	0.666666667	0.444444444	0.018018018
-4.666666667	4.666666667	21.77777778	0.145833333
1	1	1	0.027027027
-2.333333333	2.333333333	5.444444444	0.070707071
23	81	540.3333333	2.621244754

N=21	Formula		Chinese
MAD	Sum of ABS/N	3.857	
MSE	Sum of square/N	25.730	
MAPE	Sum of abs value of error divded by actual/N * by 100	12.482	

Appendix O: Safety Stock and Reorder Point Normal Distribution Method

Figure O.1: Safety Stock and Reorder Point Normal Distribution Method for American Tires

American Tires	Month	Sales
2022	SEP	48
	OCT	63
	NOV	77
	DEC	66
2023	JAN	54
	FEB	43
	MAR	48
	APR	53
	MAY	57
	JUN	63
	JUL	63
	AUG	49
	Total	684
	Average/Month	105.2307692
	Average/Day	1.873972603
	Target Service Rate	90%
	Z= Coefficient of Serv	1.281551566
	Demand Standard Deviation	9.704731742

Delivery	Lead time (Days)	Lead time (Month)
1	7	0.23
2	7	0.23
3	7	0.23
4	7	0.23
5	7	0.23
6	7	0.23
7	7	0.23
8	7	0.23
9	7	0.23
10	7	0.23
Average Lead Time	7	0.23
Max Lead Time	7	0.23
Lead Time Standard Deviation	0	2.92569E-17

Safety Stock	5.95824999
Re-order Point	19.07605821

Figure O.2: Safety Stock and Reorder Point Normal Distribution Method for ChineseTires

Chinese Tires	Month	Sales
2023	SEP	37
	OCT	35
	NOV	36
	DEC	38
2024	JAN	39
	FEB	36
	MAR	34
	APR	34
	MAY	36
	JUN	37
	JUL	36
	AUG	35
	Total	433
	Average/Month	36.08333333
	Average/Day	1.18630137
	Target Service Rate	90%
	Z= Coefficient of Serv	1.281551566
	Demand Standard Deviation	1.505042031

Delivery	Lead time (Days)	Lead time (Month)
1	60	1.97
2	60	1.97
3	60	1.97
4	60	1.97
5	60	1.97
6	60	1.97
7	60	1.97
8	60	1.97
9	60	1.97
10	60	1.97
Average Lead Time	60	1.97
Max Lead Time	60	1.97
Lead Time Standard Deviation	0	0

Safety Stock	14.94033513
Re-order Point	86.11841732

Appendix P: Stock In, Out, Balance and Procurement Planning System

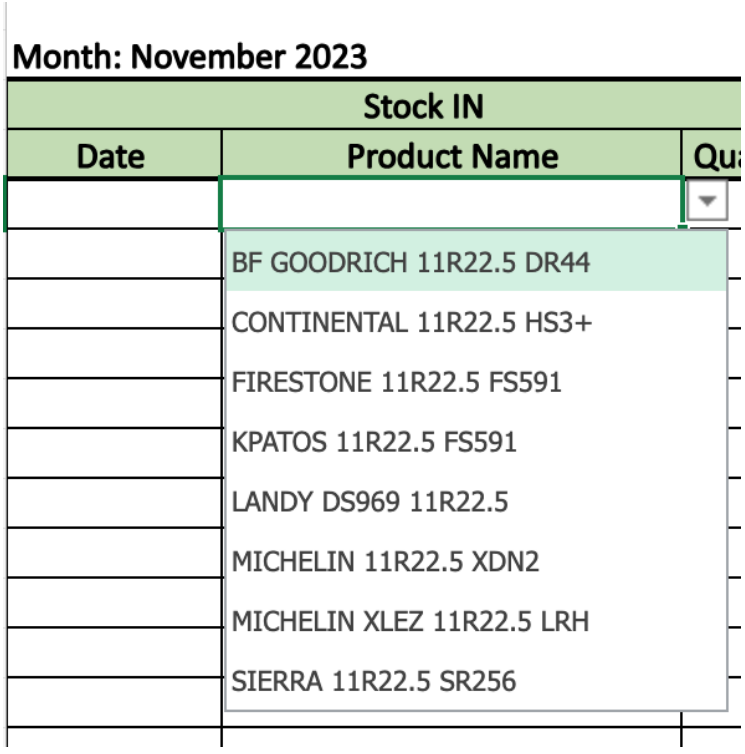
Stock IN, OUT, Balance and Procurement Planning System

Month: November 2023

Stock IN			Stock OUT		
Date	Product Name	Quantity	Date	Product Name	Quantity

Opening Stock	Balance Stock		ROP	Procurement Suggestion	Safety Stock
	Product Name	Quantity in stock			
11	BF GOODRICH 11R22.5 DR44	11	4		2
14	CONTINENTAL 11R22.5 HS3+	14	4		2
9	FIRESTONE 11R22.5 FS591	9	4		2
37	KPATOS 11R22.5 FS591	37	18		3
39	LANDY DS969 11R22.5	39	18		3
11	MICHELIN 11R22.5 XDN2	11	4		2
13	MICHELIN XLEZ 11R22.5 LRH	13	4		2
32	SIERRA 11R22.5 SR256	32	18		3
36	SURETRAC 11R22.5 RT256	36	18		3
39	SURETRAC 11R22.5 RT369	39	18		3

Appendix Q: Drop Down List of Top 10 Tires



Appendix R: Placed Orders

R/T Status	Date								
Part	Total Transit								
BF GOODRICH 11R22.5 DR44	0								
CONTINENTAL 11R22.5 HS3+	0								
FIRESTONE 11R22.5 FS591	0								
KPATOS 11R22.5 FS591	0								
LANDY DS969 11R22.5	0								
MICHELIN 11R22.5 XDN2	0								
MICHELIN XLEZ 11R22.5 LRH	0								
SIERRA 11R22.5 SR256	0								
SURETRAC 11R22.5 RT256	0								
SURETRAC 11R22.5 RT 369	0								

Appendix S: Model for First two Weeks of November 2023

Figure S.1: Stock Out from November 1st to November 14th, 2023

Month: November 2023

Stock IN			Stock OUT		
Date	Product Name	Quantity	Date	Product Name	Quantity
			1-Nov-2023	KPATOS 11R22.5 FS591	2
			1-Nov-2023	BF GOODRICH 11R22.5 DR44	3
			2-Nov-2023	SIERRA 11R22.5 SR256	2
			2-Nov-2023	MICHELIN 11R22.5 XDN2	3
			3-Nov-2023	SURETRAC 11R22.5 RT256	2
			3-Nov-2023	SURETRAC 11R22.5 RT369	2
			3-Nov-2023	FIRESTONE 11R22.5 FS591	2
			3-Nov-2023	MICHELIN 11R22.5 XDN2	1
			6-Nov-2023	CONTINENTAL 11R22.5 HS3+	4
			7-Nov-2023	SURETRAC 11R22.5 RT256	1
			7-Nov-2023	CONTINENTAL 11R22.5 HS3+	2
			8-Nov-2023	SURETRAC 11R22.5 RT256	1
			8-Nov-2023	MICHELIN XLEZ 11R22.5 LRH	5
			9-Nov-2023	KPATOS 11R22.5 FS591	1
			10-Nov-2023	FIRESTONE 11R22.5 FS591	2
			13-Nov-2023	BF GOODRICH 11R22.5 DR44	2
			13-Nov-2023	LANDY DS969 11R22.5	2
			14-Nov-2023	KPATOS 11R22.5 FS591	1
			14-Nov-2023	FIRESTONE 11R22.5 FS591	2

Figure S.2 Balance Stock on November 14, 2023

Opening Stock	Balance Stock		ROP	Procurement Suggestion	Safety Stock
	Product Name	Quantity in stock			
11	BF GOODRICH 11R22.5 DR44	6	4		2
14	CONTINENTAL 11R22.5 HS3+	8	4		2
9	FIRESTONE 11R22.5 FS591	3	4	Place Order	2
37	KPATOS 11R22.5 FS591	33	18		3
39	LANDY DS969 11R22.5	37	18		3
11	MICHELIN 11R22.5 XDN2	7	4		2
13	MICHELIN XLEZ 11R22.5 LRH	8	4		2
32	SIERRA 11R22.5 SR256	30	18		3
36	SURETRAC 11R22.5 RT256	32	18		3
39	SURETRAC 11R22.5 RT369	37	18		3

Appendix T: Order Placed and in Transit for 12 Firestone 11R22.5 FS591 Tires

R/T Status	Date	11/14/2023	
Part	Total Transit	T	
BF GOODRICH 11R22.5 DR44	0		
CONTINENTAL 11R22.5 HS3+	0		
FIRESTONE 11R22.5 FS591	12	12	
KPATOS 11R22.5 FS591	0		
LANDY DS969 11R22.5	0		
MICHELIN 11R22.5 XDN2	0		
MICHELIN XLEZ 11R22.5 LRH	0		
SIERRA 11R22.5 SR256	0		
SURETRAC 11R22.5 RT256	0		
SURETRAC 11R22.5 RT 369	0		

Appendix U: Order Received November 16, 2023

Figure U. 1: Order Received in Stock

Month: November 2023

Stock IN			Stock OUT		
Date	Product Name	Quantity	Date	Product Name	Quantity
16-Nov-2023	FIRESTONE 11R22.5 FS591	12	1-Nov-2023	KPATOS 11R22.5 FS591	2
			1-Nov-2023	BF GOODRICH 11R22.5 DR44	3
			2-Nov-2023	SIERRA 11R22.5 SR256	2
			2-Nov-2023	MICHELIN 11R22.5 XDN2	3
			3-Nov-2023	SURETRAC 11R22.5 RT256	2
			3-Nov-2023	SURETRAC 11R22.5 RT369	2
			3-Nov-2023	FIRESTONE 11R22.5 FS591	2
			3-Nov-2023	MICHELIN 11R22.5 XDN2	1
			6-Nov-2023	CONTINENTAL 11R22.5 HS3+	4
			7-Nov-2023	SURETRAC 11R22.5 RT256	1
			7-Nov-2023	CONTINENTAL 11R22.5 HS3+	2
			8-Nov-2023	SURETRAC 11R22.5 RT256	1
			8-Nov-2023	MICHELIN XLEZ 11R22.5 LRH	5
			9-Nov-2023	KPATOS 11R22.5 FS591	1
			10-Nov-2023	FIRESTONE 11R22.5 FS591	2
			13-Nov-2023	BF GOODRICH 11R22.5 DR44	2
			13-Nov-2023	LANDY DS969 11R22.5	2
			14-Nov-2023	KPATOS 11R22.5 FS591	1
			14-Nov-2023	FIRESTONE 11R22.5 FS591	2

Figure U.2: Balance Stock Update

Opening Stock	Balance Stock		ROP	Procurement Suggestion
	Product Name	Quantity in stock		
11	BF GOODRICH 11R22.5 DR44	6	4	
14	CONTINENTAL 11R22.5 HS3+	8	4	
9	FIRESTONE 11R22.5 FS591	15	4	
37	KPATOS 11R22.5 FS591	33	18	
39	LANDY DS969 11R22.5	37	18	
11	MICHELIN 11R22.5 XDN2	7	4	
13	MICHELIN XLEZ 11R22.5 LRH	8	4	
32	SIERRA 11R22.5 SR256	30	18	
36	SURETRAC 11R22.5 RT256	32	18	
39	SURETRAC 11R22.5 RT369	37	18	