GEBZE TECHNICAL UNIVERSITY

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SUPPLY CHAIN AND MANAGEMENT

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CONTENTS

ABSTRACT

Ford Otosan is an automotive manufacturing company based in Turkey that Ford Motor Company and Koç Holding equally own. The company was established in its current form in 1977, with original relations dating back to 1928. We decided to get the data we used to prepare the study from Ford Otosan.

While researching the supply chain in the study, the transportation methods used, the place where the inventories were kept, the total annual cost and eoqs were determined. After performing various analyzes with safety and cycle inventories, a three echelon supply chain network installation was prepared. capacitated plant location model was prepared and solved mathematically. The main purpose of this study is to examine Ford Otosan's supply chain process from supplier to customer in detail and analyze it with data.

KEY WORDS

Ford Otosan, Supply Chain Management, Intermodal Transportation, Automotive Industry. Commercial Vehicle

2.Introduction of the firm

Ford Otosan is an automotive manufacturing company based in Turkey that is equally owned by Ford Motor Company and **Koç Holding**. The company was established in its current form in 1977, with original relations dating back to 1928. Ford Otosan (Ford Otomotiv Sanayi A.Ş.), is a publicly traded (18%) company, where Ford Motor Company* (41%) and Koç Holding A.Ş.(41%) have equal shares. Ford Otosan, one of the top three exporting companies in Turkey since 2004, has achieved 12 consecutive years of automotive industry championship and is Turkiye goods product export champion for 8 years in a row. Ford Europe's largest commercial vehicle production center, with a production capacity of 721,700 vehicles, 436,500 engines, and 140,000 powertrains by 2022.

In 2022, the export of vehicles and spare parts from Turkiye continued with 94 countries in 5 continents worth 6,2 billion USD. Ford Otosan operates in 4 main centers with its Gölcük and Yeniköy Plants in Kocaeli, Eskişehir Plant in Eskişehir, Sancaktepe R&D Center and Spare Parts Warehouse in İstanbul and Craiova Plant in Romania employs more than 20,000 people. Ford Otosan is the most valuable automotive company in Borsa İstanbul. With 1688 R&D employees, Ford Otosan has the largest R&D organization in the Turkish industry and is exporting engineering. It serves as the global engineering center for Ford's heavy commercial vehicles, related diesel engines, and engine systems and the support center for Ford's light commercial vehicle design and engineering. Ford Otosan has all the necessary know-how, and ability to design, develop and test a complete vehicle from paper to product, including its engine.

In addition to contributing to the economic development of the country and increasing its global competitiveness, Ford Otosan, standing out with its sensitivity regarding social responsibilities, also carries out several social responsibility projects in many fields including education, healthcare, culture, arts, and sports on the path to achieving the Sustainable Development Goals in line with its corporate citizenship approach and “Future. Now” vision.

This vision they had increased our interest in this company and we decided to choose **Ford Otosan** as the company we will conduct detailed research on in the project.

3. Information about the selected products or parts or operations

What is the selected product family?

The product family that are chosen from FORD OTOSAN for this project is:

- **Commercial Vehicles**

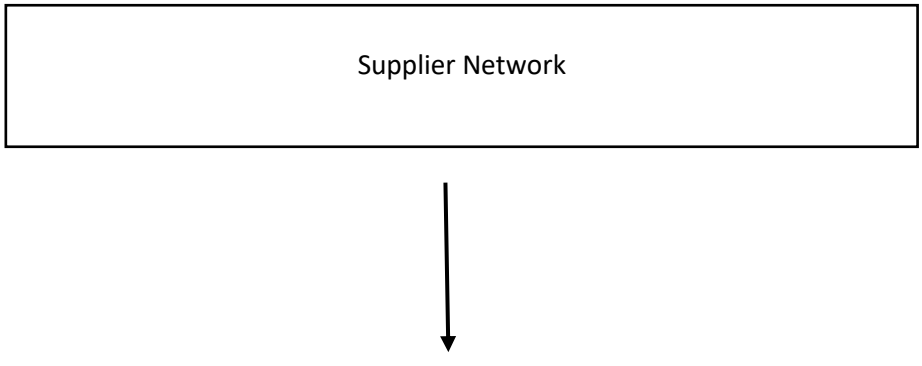
What are three different products belonging to this product family?

- **Tourneo Courier**
- **Transit Pickup**
- **Transit Van**

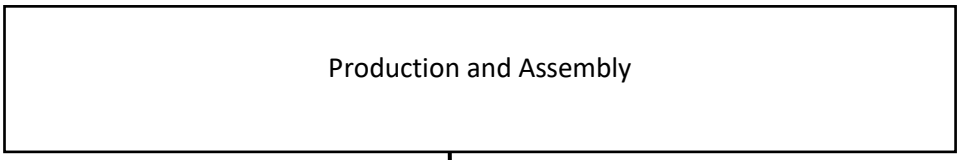
How is the process of the products from the supplier to the customer?

Although Ford Otosan applies different supply methods for many parts it produces, the methods followed are generally similar. We can briefly explain the process from supplier to customer as follows.

The Tourneo Courier is a model within the Ford Tourneo family, designed for passenger transportation. As an example for other products, let's examine the supply process of the Tourneo Courier until it reaches the customer.

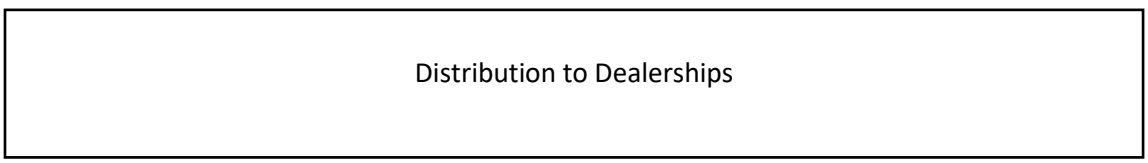


Ford Otosan sources components and parts from a network of suppliers. These suppliers provide various automotive components such as engines, transmissions, electronics, body

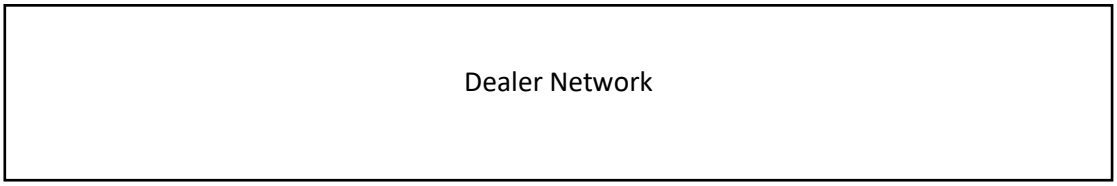


The manufacturing process begins with the assembly of components into vehicles at Ford Otosan's production facilities. The Tourneo Courier is likely to go through a series of assembly stages, with a focus on quality control to ensure that the vehicles meet safety and performance standards.

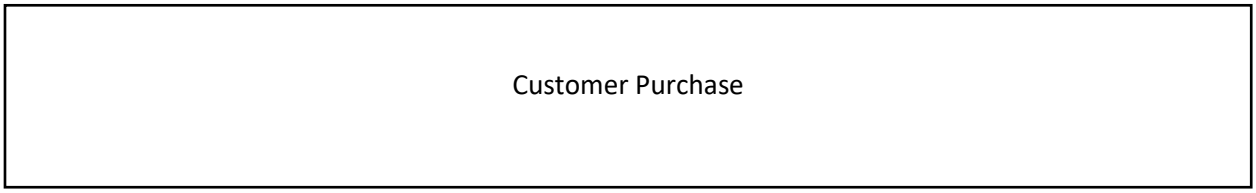
Rigorous quality control checks are conducted at various stages of production to identify and rectify any defects. This ensures that the final Tourneo Courier vehicles meet the required standards.



Once the Tourneo Courier vehicles are assembled and pass quality control, they are transported to distribution centers. From there, they are shipped to authorized Ford dealerships both domestically and internationally. Distribution may involve various modes of transportation, including trucks and ships.



Authorized Ford dealerships receive the Tourneo Courier vehicles and act as intermediaries between Ford Otosan and the end customers. Dealers provide information, facilitate test drives, and assist customers in selecting the right model and configuration.



Customers interested in the Tourneo Courier visit Ford Otosan's authorized dealerships to explore and purchase the vehicle. Dealerships assist customers with the purchasing process, including financing options and paperwork.

Once the purchase process is complete, the Tourneo Courier is delivered to the customer. The dealership may provide additional services, such as vehicle orientation and explaining features, to ensure customer satisfaction.

Tourneo Courier

Transit Pickup

Transit Van

What are the transportation methods and production types?

Ford Otosan manufactures commercial vehicles using various transportation methods and production types. The specific methods and types can vary based on the model and the manufacturing facility.

Transportation Methods

- **Truck Transport**

Completed vehicles or vehicle components may be transported using trucks. This is a common method for moving vehicles from manufacturing facilities to distribution centers or from suppliers to the assembly plant.

- **Rail Transport**

Rail transport might be utilized for long-distance movement of vehicles between different regions or countries. Rail can be an efficient mode for bulk transportation.

- **Shipping (Water)**

For international distribution, vehicles can be shipped by sea. Finished vehicles are loaded onto ships and transported to various global markets.

- **Air Transport**

While less common for bulk transportation of vehicles, air transport may be used for urgent deliveries or for transporting specific components quickly.

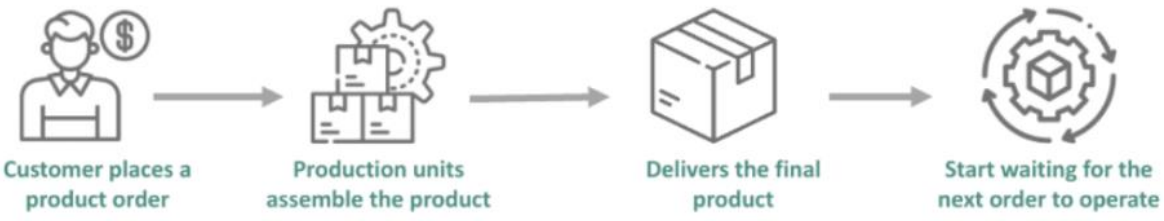
Production Types

- **Assemble to Order**

  Assemble to Order" (ATO) is a production strategy that falls under the broader umbrella of make-to-order manufacturing. In an Assemble to Order system, the manufacturer produces and stocks standard components and sub-assemblies in advance, and the final product is assembled or configured based on customer specifications or orders. This strategy aims to balance the advantages of mass production with the flexibility to accommodate customer preferences.

In an ATO workflow, the manufacturer forecasts orders for the goods based on historical data, current trends, and the prevailing market conditions. Based on the forecasts, the manufacturer orders several sub-assembly parts for the goods.

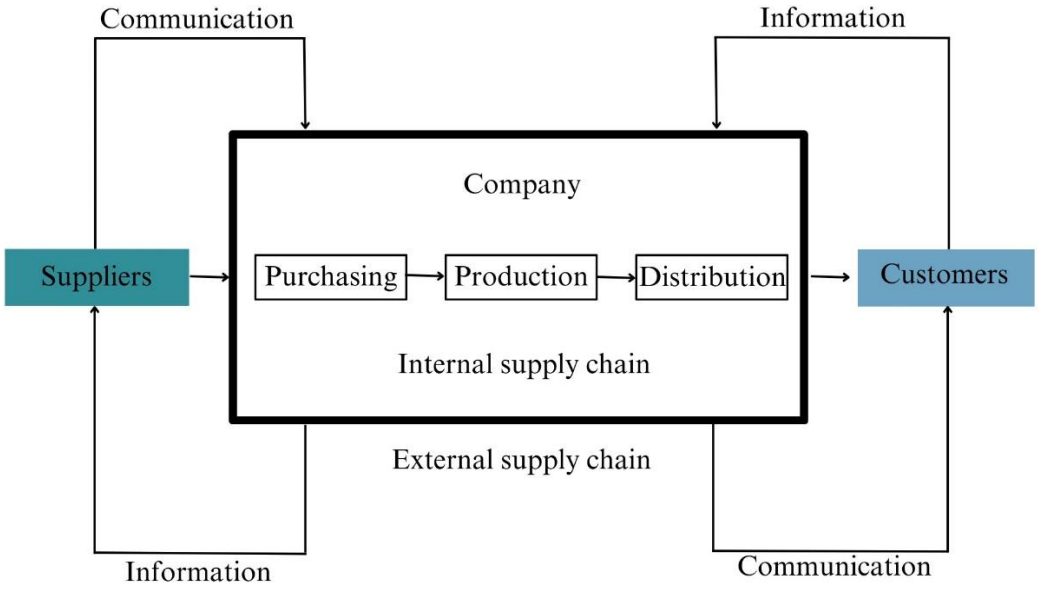
A customer then places an order and gives instructions on how they want the product customized. Based on the order instructions, the manufacturer assembles the components into a finished product that’s then delivered to the customer.



- **Just-In-Time (JIT) Manufacturing**

  Also we can say that FORD OTOSAN may implement a just-in-time manufacturing approach, where components and materials are delivered to the production line precisely when they are needed. This helps minimize inventory costs and improve efficiency.

Draw the supply chain. Show internal and external costs.

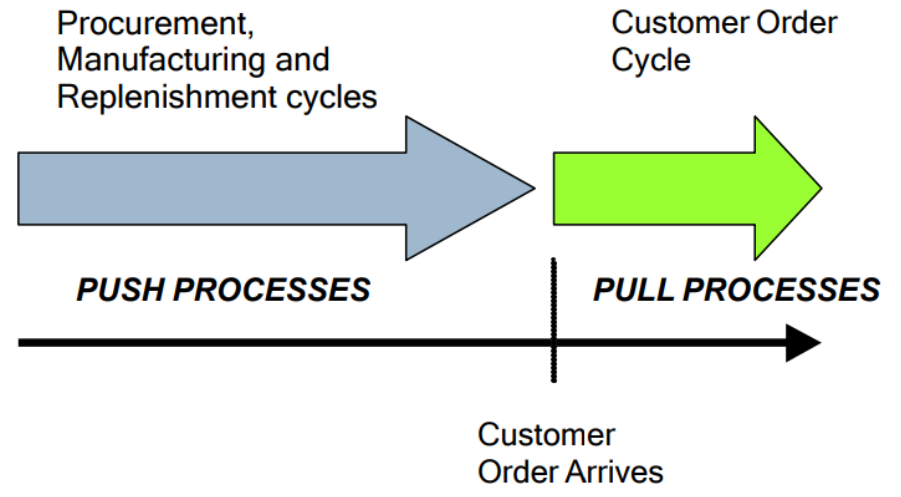


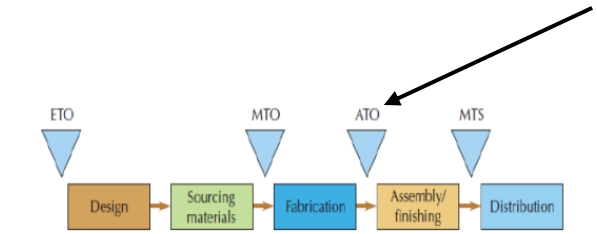
Internal and External Costs

Internal costs pertain to expenses directly associated with a company's operations, such as production costs, labor, and administrative expenses. External costs, on the other hand, are incurred outside the company and may include environmental impacts or societal costs not reflected in the company's financial statements. For Ford Otosan, internal costs could include expenses related to manufacturing processes, employee salaries, and administrative overhead. External costs might encompass environmental impacts arising from the production process, such as emissions or waste disposal, and societal costs related to factors like traffic congestion or road infrastructure strain caused by the use of their vehicles.

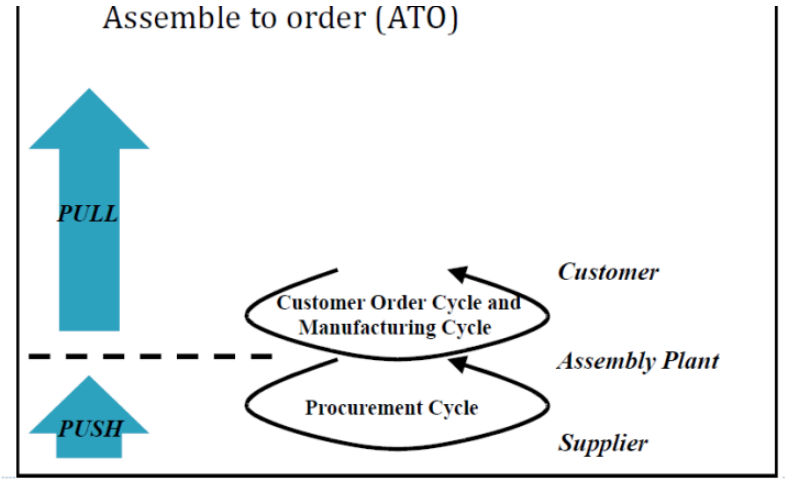
How is the push pull view of supply chain?

In a push system, production is driven by long-term forecasts and predetermined production schedules. Products are manufactured and pushed into the supply chain based on anticipated demand. In a pull system, production is driven by actual customer demand. Products are not produced until an order is received, and the production process is initiated by customer orders.





ASSEMBLE TO ORDER



Assemble-to-Order (ATO) is a production strategy where products are partially assembled in advance, but the final assembly is not completed until a customer order is received. This approach is often used in the automotive industry to

balance the need for mass production efficiency with the desire to offer customization to customers.

Providing information about the transportation modes in the supply chain. What kind of transportation units and loading units are used?

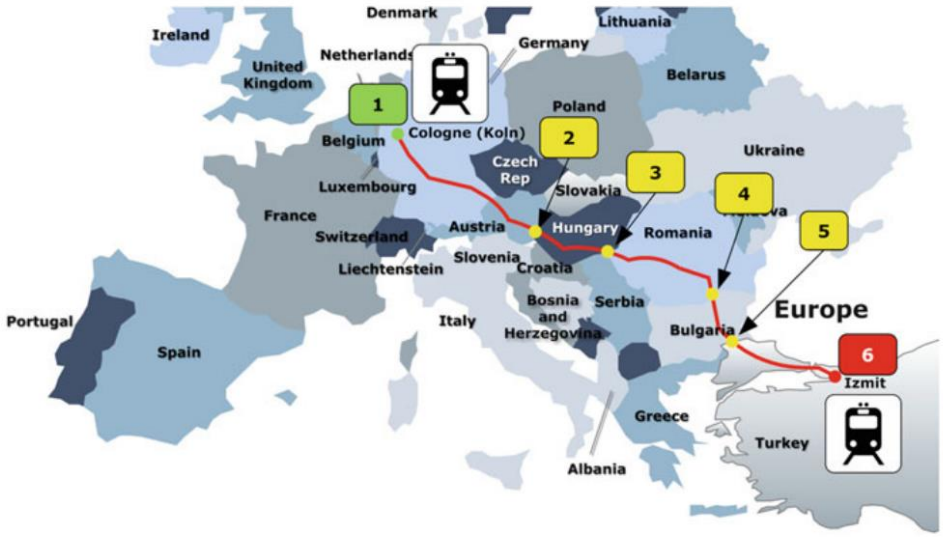
Lo-Lo (lift-on-lift-off)

Shipping (Water) + Truck

Swap Body

Ro-Ro (Roll-on-roll-off)

Ro-La (Rolling Road)



The current map of intermodal transport corridor of Ford Otosan.

Ford Otosan has developed its intermodal system mainly on the railway transportation mode. However, sea transportation and road transportation are also used in the system. Swap bodies are loaded directly onto the wagons and transferred to the intermodal terminal. The system depends on swap bodies instead of using shipping containers as the protective package instrument. Swap bodies often have the same external width of corner fittings as shipping containers, so that they can be placed on the same kinds of **trucks, trailers and railroad cars** designed for shipping containers.

High cube swap-bodies being the means for door-to-door transport, are handled by mobile or gantry cranes from road to rail and vice versa in the terminals at both ends of the intermodal train route. For road transport, the swap bodies are put on skeletal trailers (chassis) being towed by tractor units. For rail transport, special double-platform wagons are used.

4. The existing production system in the firm

(Stock / order-based production, etc.)

Once Ford has all the parts, bring them together at manufacturing plants. This is where the magic happens. Workers and robots work side by side to assemble the cars. It's like putting together a giant jigsaw puzzle on a massive scale. Therefore, it is clear that Ford uses an assemble-to-order strategy.

Just-In-Time: Ford often uses a "just-in-time" inventory system. This means Ford get parts from suppliers exactly when they need them. It helps reduce storage costs and ensures fresh components for assembly.

Minimizing Waste: By managing inventory carefully, Ford can minimize waste. Too much inventory can lead to unused parts, while too little can halt production. So, it's like a delicate balancing act.

Regular Updates: Ford maintains close relationships with its suppliers and communicates regularly. Thus, Ford and suppliers can understand each other's needs and plan for any changes in demand. Also when issues arise, like delays or quality concerns, open communication allows Ford and its suppliers to work together to find solutions. This helps prevent disruptions in production.

5.Application and Answer of Questions

5.1. EOQ Calculations

Where is inventory kept? Determine EOQ and total annual cost for each three product.

Consider two situations for one product

1. **Lots are ordered and delivered independently for each product.**
2. **Aggregation: Order All Products Jointly**

For finished vehicles stocks are kept in vehicle fields within the factory area and at **Ford Otosan** dealers.

This is an important point that should not be overlooked. When calculating EOQ, it is assumed that all Ford Otosan dealership demands are consolidated in a single Ford Otosan dealership, and calculations are made based on this single dealership.

Annual demands, fixed transportation costs, fixed receiving costs, inventory holding rates and unit costs for each three products are given. Accordingly, EOQ (Q*) values are determined and total annual costs are calculated for two situations.

1) Lots are Ordered and Delivered Independently for Each Product

D: Annual Demand

S: Fixed Transportation Cost + Fixed Receiving Cost

h: Inventory Holding Rate

C: Unit Cost

Q*: Optimal Lot Size

Q* = Sqrt(2DS/hC)

Total Annual Cost = Annual Purchase Cost + Annual Order Cost + Annual Holding Cost

TAC = D×C + (D/Q*)×S + (Q*/2)×h×C

Parameters and calculations according to these formulas for this situation are given below.

TOURNEO COURIER				
ANNUAL DEMAND	**FIXED TRANSPORT. COST**	**FIXED RECEIVING COST**	**INV. HOLDING RATE**	**UNIT COST**
32472	8.000.000 TRY	1.000.000 TRY	0,45	640.000 TRY
EOQ =	**1.424,61**	**Annual Purchase Cost=**	20.782.080.000 TRY	
		Annual Order Cost=	205.143.150 TRY	
		Annual Holding Cost=	205.143.150 TRY	
		Total Annual Cost=	**21.192.366.300 TRY**	

TRANSIT PICKUP				
ANNUAL DEMAND	**FIXED TRANSPORT. COST**	**FIXED RECEIVING COST**	**INV. HOLDING RATE**	**UNIT COST**
11870	8.000.000 TRY	1.000.000 TRY	0,45	775.000 TRY
EOQ=	**782,7165268**	**Annual Purchase Cost=**	9.199.250.000 TRY	
		Annual Order Cost=	136.486.194 TRY	
		Annual Holding Cost=	136.486.194 TRY	
		Total Annual Cost=	**9.472.222.389 TRY**	

TRANSIT VAN				
ANNUAL DEMAND	**FIXED TRANSPORT. COST**	**FIXED RECEIVING COST**	**INV. HOLDING RATE**	**UNIT COST**
8130	8.000.000 TRY	1.000.000 TRY	0,45	790.000 TRY
EOQ=	**641,596111**	**Annual Purchase Cost=**	6.422.700.000 TRY	
		Annual Order Cost=	114.043.709 TRY	
		Annual Holding Cost=	114.043.709 TRY	
		Total Annual Cost=	**6.650.787.417 TRY**	

Total annual cost for this situation is the sum of each product's total annual costs which is given below.

TOTAL ANNUAL COST FOR ALL =	**37.315.376.106 TRY**

2) **Aggregation: Ordering All Products Jointly**

D: Annual Demand

$S_{agg.}$: Fixed Transportation Cost + Receiving Cost of Tourneo Custom + Receiving Cost of Transit Pickup

+ Receiving Cost of Transit Van

h: Inventory Holding Rate

C: Unit Cost

Q: Lot Size , Q*: Optimal Lot Size

n*: Optimal Order Frequency

$n^* = \text{Sqrt}[(D_1 \times h \times C_1 + D_2 \times h \times C_2 + D_3 \times h \times C_3)/2 \times S_{agg.})]$

Firstly, optimal order frequency is found with the given formula.

OPTIMAL # OF ORDERS=	**27,28787068**

Then, each product's annual demand is divided by this value to find the lot size of each product in each order.

Q (Tourneo Courier) Demand/# of orders	1189,979254
Q (Transit Pickup) Demand/# of orders	434,9918005
Q (Transit Van) Demand/# of orders	297,9345693

Finally, ordering cost is calculated with multiplying aggregate fixed cost and number of orders given ($n^* \times S_{agg.}$), holding costs are calculated with the $(Q/2) \times h \times C$ formula and purchasing costs are calculated with the $D \times C$ formula for each three products. Sum of these calculations give the total annual cost.

Annual Order Cost=	300.166.578 TRY
Annual Holding Cost (Tourneo Courier)	171.357.013 TRY
Annual Holding Cost (Transit Pickup)	75.851.695 TRY
Annual Holding Cost (Transit Van)	52.957.870 TRY
Annual Purchase Cost (Tourneo Courier)	20.782.080.000 TRY
Annual Purchase Cost (Transit Pickup)	9.199.250.000 TRY
Annual Purchase Cost (Transit Van)	6.422.700.000 TRY
TOTAL ANNUAL COST=	**37.004.363.155 TRY**

5.2. Safety Inventory Calculations

Calculate safety inventory and calculate cycle service level and fill rate.

Evaluate safety inventory to achive a 95% cycle service level.

The formula given below was used to calculate the safety inventory. Accordingly, in order to find weekly demand, annual demand was divided by 52 and multiplied by 5 weeks, which is the lead time, and subtracted from the reorder point to calculate safety inventory.

$$\text{Safety inventory, } ss = ROP - DL$$

The Excel formula given below was used to calculate the cycle service level. To calculate the standard deviation of demand during lead time, the root of the lead time was multiplied by the standard deviation of weekly demand and the cycle service level was calculated with the Excel formula.

$$CSL = F(ROP, D_L, \sigma_L) = NORMDIST(ROP, D_L, \sigma_L, 1)$$

The formula given below was used to calculate the fill rate. Accordingly, first of all, the expected shortages per replenishment cycle (ESC) value was found according to the Excel formula below. Afterwards, the fill rate was calculated by substituting this esc and optimal lot size in the fill rate formula.

$$fr = 1 - ESC/Q = (Q - ESC)/Q$$

$$ESC = -ss[1 - NORMDIST(ss/\sigma_L, 0, 1, 1)] + \sigma_L NORMDIST(ss/\sigma_L, 0, 1, 0)$$

For evaluating safety stock to achieve 95% cycle service level, the excel formula given below is used.

$$ss = F_s^{-1}(CSL) \times \sigma_L = NORMSINV(CSL) \times \sigma_L$$

TOURNEO COURIER				
Annual Demand (D)	**Lead Time (L)(week)**	**Reorder Point(ROP)**	**Standard deviation of weekly demand (σ_d)**	**Q***
32472	5	4000	200	1425

DDLT	3122,307692
Safety stock (ROP-DDLT)=(ROP-(D/52)*5)	877,6923077

Calculations for CSL (ROP, DDLT, σ_L 1)		Calculations for fill rate	
Standart deviation of DDLT (σ_L) (Sqrt(L)*σ_d)	447,2135955	**Expected Shortage Per Cycle (ESC)**	4,195211375
Cycle Service Level (CSL)	0,9751524822	**Fill Rate [(Q*-ESC)/Q]**	0,997055992

Evaluating Safety Stock To Achieve a 95% Service Level	
Safety Stock	735,6009038

TRANSIT PICKUP				
Annual Demand(D)	**Lead Time (L)(week)**	**Reorder Point (ROP)**	**Standard deviation of weekly demand**	**Q***
11870	5	1600	120	783

DDLT	1141,346154
Safety stock (ROP-DDLT)=(ROP-(D/52)*5)	458,6538462

Calculations for CSL (ROP, DDLT, σL, 1)		Calculations for fill rate	
Standart deviation of DDLT (σ_L) (Sqrt(L)*σ_d)	268,3281573	**Expected Shortage Per Cycle (ESC)**	4,796980781
Cycle Service Level (CSL)	0,9563024851	**Fill Rate [(Q*-ESC)/Q]**	0,9938735878

Evaluating Safety Stock To Achieve a 95% Service Level	
Safety Stock	441,3605423

TRANSIT VAN				
Annual Demand(D)	**Lead Time (L)(week)**	**Reorder Point(ROP)**	**Standard deviation of weekly demand**	**Q***
8130	5	1200	100	642

DDLT	781,7307692
Safety stock (ROP-DDLT)=(ROP-(D/52)*5)	418,2692308

Calculations for CSL (ROP, DDLT, σ_L 1)	
Standart deviation of DDLT (σ_L) (Sqrt(L)*σ_d)	223,6067977
Cycle Service Level (CSL)	0,969296736

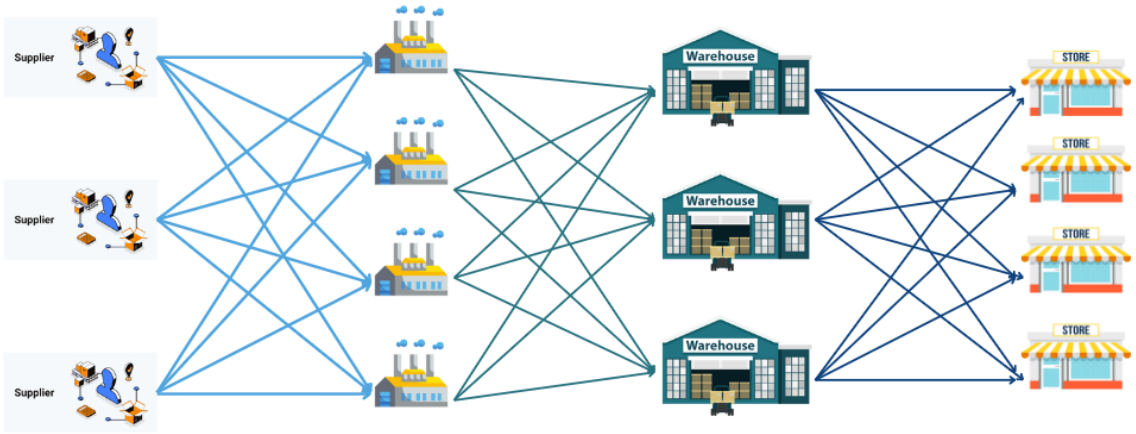
Calculations for fill rate	
Expected Shortage Per Cycle (ESC)	2,667368258
Fill Rate [(Q*-ESC)/Q]	0,9958452208

Evaluating Safety Stock To Achieve a 95% Service Level	
Safety Stock	367,8004519

5.3. Capacitated Plant Location Model

Design a three echelon supply chain network for a product that minimized total cost. Develop a capacitated plant location model and solve the mathematical model. Analyze related results.

Multi-Echelon Supply Chain System for Ford Otosan



Ford has;

- 4 plant in global
- 3 warehouses
- 70 distributors (it is assumed that there were 5 retails in this problem)

Therefore to obtain a three echelon supply chain mathematical model is as shown below:

Parameters

m = # of markets

n = # of potential factory locations

l = # of suppliers

t = # of potential warehouse locations

D_j = demand of customer j

K_i = potential capacity of factory i

S_h = supply capacity of supplier h

W_e = potential capacity of Warehouse e

F_i = fixed cost of locating a plant at site i

f_e = fixed cost of locating a Warehouse at site e

c_{hi} = cost of shipping one unit from supply source h to factory i

c_{ie} = cost of producing and shipping one unit from factory i to warehouse e

c_{ej} = cost of shipping one unit from warehouse e to customer j

Decision Variables

c_{ij} = cost of sending one unit from node i to node j

y_i = 1 if a factory located at site i, 0 otherwise

y_e = 1 if a warehouse is located at site e, 0 otherwise

x_{ej} = # of cars supplied from warehouse e to market j

x_{ie} = # of cars supplied from factory i to warehouse e

x_{hi} = # of cars supplied from supplier h to factory i

Objective is to minimize total cost, which includes both fixed and sum of unit costs.

$$\text{Min } z = \sum_i F_i y_i + \sum_e f_e y_e + \sum_h \sum_i x_{hi} c_{hi} + \sum_e \sum_j x_{ej} c_{ej} + \sum_i \sum_e x_{ie} c_{ie}$$

st:

$\sum_h x_{hi} \leq S_h$ for each $h \in \{1,\ldots,l\}$ (1)

$\sum_h x_{hi} - \sum_e x_{ie} \geq 0$ for each $i \in \{1,\ldots,n\}$ (2)

$\sum_i x_{ie} - \sum_j x_{ej} \geq 0$ for each $e \in \{1,\ldots,t\}$ (3)

$\sum_e x_{ie} \leq K_i y_i$ for each $i \in \{1,\ldots,n\}$ (4)

$\sum_j x_{ej} \leq W_e y_e$ for each $e \in \{1,\ldots,t\}$ (5)

$\sum_e x_{ej} = D_j$ for each $j \in \{1,\ldots,m\}$ (6)

$x_{ej}, x_{ie}, x_{hi} \geq 0$ (7)

$y_i, y_e \in \{1,0\}$ (8)

To obtain a reliable model total number of units supplied from a supplier can not exceed the capacity of that supplier.(1) The flow of units must be conserved. (2,3) Number of units produced and supplied can not exceed the capacity of the factory. (4) If a warehouse is opened, the total number of products can not exceed the capacity of the warehouse.(5) All the market demands should be satisfied from warehouses.(6) Number of units sent, must equal to a non-negative integer. (7) The status of a warehouse or a factory should be denoted by binary variables.(8)

Ford is a globally operating company that receives demand from five main regions, and the approximate demands for each region each year are as follows:

- North America: 140.000
- South America: 130.000
- Europe: 190.000
- Asia: 150.000
- Africa: 40.000

- The cost of a supply transaction of 1000 units from supplier of one region to a possible plant in another region is as seen in the orange box and supplier capacity is as seen in the green box.

	Variable Costs from Supplier to Possible Plant Regions					
Suppliers\Plants	N. America	S. America	Europe	Asia	Africa	Supplier Capacity
N. America	48.600,00 TRY	50.400,00 TRY	54.000,00 TRY	58.800,00 TRY	57.000,00 TRY	280
Europe	52.200,00 TRY	48.000,00 TRY	42.000,00 TRY	46.200,00 TRY	49.200,00 TRY	160
Africa	62.400,00 TRY	55.200,00 TRY	52.800,00 TRY	51.600,00 TRY	43.200,00 TRY	240

Number of units supplied from "supplier to possible plant" related decision variables and values of the optimal solution is as shown below.

Suppliers\Plants	N. America	S. America	Europe	Asia	Africa
N. America	190	0	60	0	0
Europe	0	0	120	40	0
Africa	0	0	0	20	220

- The cost of a supply transaction of 1000 units from a possible plant of one region to a possible warehouse in another region is as seen in the orange box and plant capacity is as seen in the green box.

	Variable Costs from Possible Plant to Possible warehouse					Fixed Cost	Factory Capacity
Plants\Warehouses	N. America	S. America	Europe	Asia	Africa		
N. America	48.600,00 TRY	50.400,00 TRY	54.000,00 TRY	58.800,00 TRY	57.000,00 TRY	93.000,00 TRY	210
S. America	52.200,00 TRY	51.000,00 TRY	55.200,00 TRY	58.200,00 TRY	61.200,00 TRY	85.000,00 TRY	260
Europe	52.200,00 TRY	48.000,00 TRY	42.000,00 TRY	46.200,00 TRY	49.200,00 TRY	102.000,00 TRY	180
Asia	54.000,00 TRY	54.600,00 TRY	45.600,00 TRY	43.200,00 TRY	48.000,00 TRY	80.000,00 TRY	210
Africa	62.400,00 TRY	55.200,00 TRY	52.800,00 TRY	51.600,00 TRY	43.200,00 TRY	76.000,00 TRY	220

Number of units supplied from "possible plant to possible warehouses", and "to open a plant or not" related decision variables and values of the optimal solution is as shown below.

Plants\Warehouses	N. America	S. America	Europe	Asia	Africa	Open/Close
N. America	180	0	10	0	0	1
S. America	0	0	0	0	0	0
Europe	0	0	180	0	0	1
Asia	0	0	0	60	0	1
Africa	0	0	0	0	220	1

- The cost of a supply transaction of 1000 units from a possible warehouse of one region to a retail in another region is as seen in the orange box and plant capacity is as seen in the green box. Demands are given as in purple box.

	Variable Costs from Possible Warehouses to retails					Fixed Cost	Warehouse Capacity
Warehouses\Retails	N. America	S. America	Europe	Asia	Africa		
N. America	48.600,00 TRY	50.400,00 TRY	54.000,00 TRY	58.800,00 TRY	57.000,00 TRY	74.400,00 TRY	180
S. America	52.200,00 TRY	51.000,00 TRY	55.200,00 TRY	58.200,00 TRY	61.200,00 TRY	68.000,00 TRY	270
Europe	52.200,00 TRY	48.000,00 TRY	42.000,00 TRY	46.200,00 TRY	49.200,00 TRY	81.600,00 TRY	280
Asia	54.000,00 TRY	54.600,00 TRY	45.600,00 TRY	43.200,00 TRY	48.000,00 TRY	64.000,00 TRY	180
Africa	62.400,00 TRY	55.200,00 TRY	52.800,00 TRY	51.600,00 TRY	43.200,00 TRY	60.800,00 TRY	240
Demand(in1000 units)	140	130	190	150	40		

Number of units supplied from "possible warehouses to possible retails", and "to open a warehouse or not" related decision variables and values of the optimal solution is as shown below.

Warehouses\Retails	N. America	S. America	Europe	Asia	Africa	Open/Close
N. America	140	40	0	0	0	1
S. America	0	0	0	0	0	0
Europe	0	0	190	0	0	1
Asia	0	0	0	60	0	1
Africa	0	90	0	90	40	1

Objective:

- Objective is to minimize the total cost while meeting the demand. Since costs are in thousands it is multiplied by 1000.

$$\text{Min } z = \sum_i F_i\, y_i + \sum_e f_e\, y_e + \sum_h \sum_i x_{hi}\, c_{hi} + \sum_e \sum_j x_{ej}\, c_{ej} + \sum_i \sum_e x_{ie}\, c_{ie}$$

```
=(SUMPRODUCT(B3:F5;K3:O5)+SUMPRODUCT(B9:G13;K9:P13) + SUMPRODUCT(B17:G21;K17:P21))*1000
```

Objective	
Min Cost=	90.205.800.000,00 TRY

Constraints:

Capacity constraints are as shown below.

Supply Constraints	Amount Supplied	Supply Available
N. America	250	280
Europe	160	160
Africa	240	240

- `=H9*P9` Available capacities are multiplied by y values which denotes the status of a facility. If a facility is opened capacity is available.

Plant Capacity Cons.	Amount Manufactured	Capacity
N. America	190	210
S. America	0	0
Europe	180	180
Asia	60	210
Africa	220	220

Warehouse Capacity Cons.	Amount Stored	Capacity
N. America	180	180
S. America	0	0
Europe	190	280
Asia	60	180
Africa	220	240

Supply demand equation constraint is given below.

	N. America	S. America	Europe	Asia	Africa
Amount Supplied	140	130	190	150	40
Demand	140	130	190	150	40

Warehouses\Retails	N. America	S. America	Europe	Asia	Africa	Open/Close
N. America	140	40	0	0	0	1
S. America	0	0	0	0	0	0
Europe	0	0	190	0	0	1
Asia	0	0	0	60	0	1
Africa	0	90	0	90	40	1

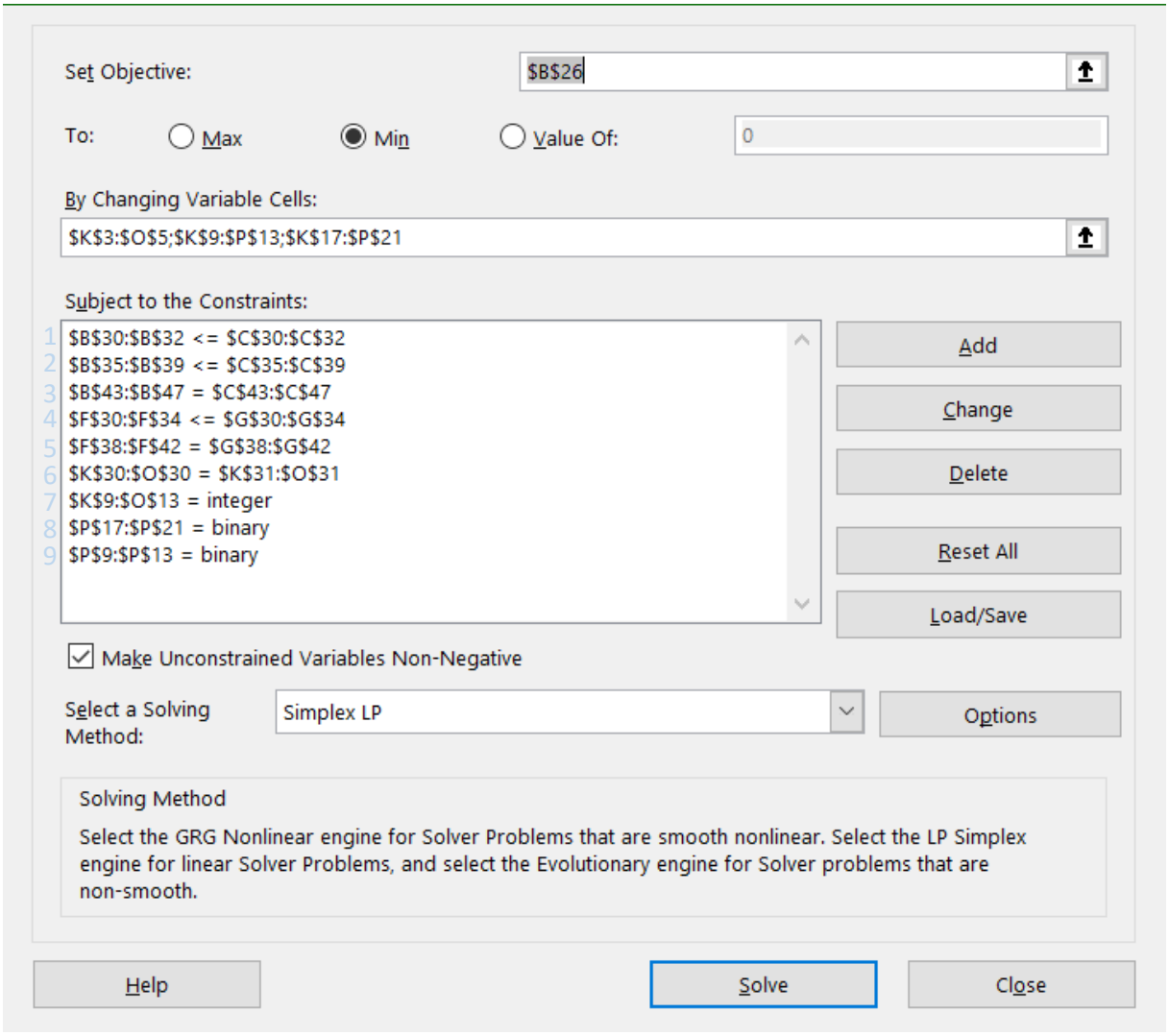
	N. America	S. America	Europe	Asia	Africa
Amount Supplied	140	=SUM(L17:L21)		150	40
Demand	140			150	40

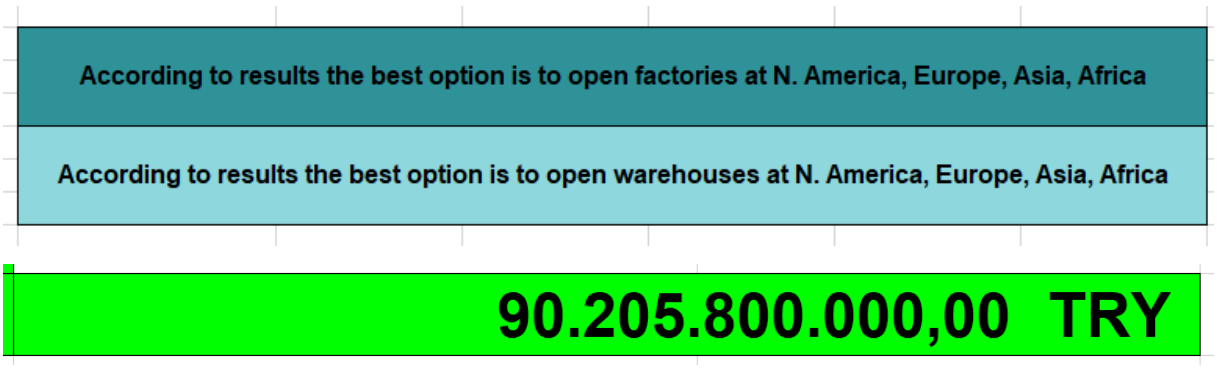
SUM(**number1**; [number2]; ...)

Besides of calculations above, the constraints are given to the Excel Solver.

- Constraint 1 represents the supply availability.
- Constraint 2 represents the plant available capacity.
- Constraint 3 represents flow conservation between Supplier-Plant-Warehouse.

- Constraint 4 represents the demand watehouse available capacity.
- Constraint 5 represents flow conservation between Plant-Warehouse-Retail.
- Constraint 6 represents meeting the demand of each retail store.
- Constraint 7 represents the integrality constraint.
- Constraint 8 and 9 represents the binary constraints.





90.205.800.000,00 TRY

Conclusion & Recommandation

In conclusion, a comprehensive analysis of Ford Otosan's supply chain processes was provided, encompassing various aspects from transportation modes and inventory management to optimal lot quantities and associated costs. The optimal lot size for Ford Otosan's products was determined through a meticulous examination of disaggregate and aggregate considerations. Safety inventory calculations were performed for disaggregated orders, yielding metrics such as expected shortage per cycle fill rate and cycle service level. Additionally, a safety inventory was recalculated to achieve a 95% customer service level.

Furthermore, the study's scope extended to evaluating Ford Otosan's suppliers' capacities, locations, and shipping costs, along with the demands, locations, and shipping costs of retail customers. A model was devised and solved to minimize costs while meeting demand through potential plant and warehouse locations. The findings of this study contribute to a deeper understanding of Ford Otosan's supply chain dynamics and provide valuable insights for optimizing efficiency and reducing costs.

In order to reduce material handling costs and because it is suitable for this type of transportation, intermodal transportation, which they actually use, is recommended to the company. In the analyses, eoq was calculated for both aggregate and disaggregate orders. As a result, aggregate production has emerged at a lower cost. This situation may change periodically. To manage this, the company is expected to manage information well. The company should reduce lead time and demand uncertainty to reduce safety stock. According to the multi-echelon capacitated plan model created, the effect of fixed cost, unit product shipping cost and demand on the

facility decision to be established was seen and it was deemed appropriate to open both warehouses and plants in North America, Asia, Africa and Europe.

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