Developing a New Model

Transporting high-performance engines through sea

Wassil Mian

Individual Group

Course Project: Application of Optimization Models in Business

The University of Texas at Dallas

OPRE 3333.004: Quantitative Business Analysis

Negin Ahangar

December 3rd, 2023

Problem Definition

RedBull, a leading F1 racing team, is tasked with transporting high-performance engines from three different manufacturers—Ferrari Motors, Mercedes Engines Ltd., and Renault Racing Tech—to five Grand Prix host countries: USA, Italy, Germany, France, and Japan. The challenge is to optimize the allocation of engine shipments from each manufacturer to the five countries in order to minimize the total transportation cost of sending shipping containers by sea.

The three engine manufacturers, Ferrari Motors, Mercedes Engines Ltd., and Renault Racing Tech, produce engines with varying specifications and performance levels. The transportation cost is influenced by factors such as distance, capacity of shipping containers, and the number of engines transported. The team needs to determine the optimal distribution of engines from each manufacturer to the five countries to ensure an efficient and cost-effective supply chain.

Each country represents a unique destination for RedBull, and the demand for engines in each country is known in advance. The objective is to meet the demand for engines in each country while minimizing the total transportation cost incurred by the team. The transportation cost may vary based on the manufacturer, the country of destination, and the quantity of engines shipped.

The team must decide how many engines to ship from each manufacturer to each country, considering the constraints of production capacity, transportation capacity, storage capacity on the shipping containers, and the demand for engines in each destination. The optimization problem involves finding the optimal allocation strategy that minimizes the overall transportation cost, taking into account the specific transportation costs and limitations associated with each manufacturer-country pair.

For example, shipping engines from Ferrari Motors to Italy might have different associated costs compared to shipping them to Germany. Similarly, the transportation cost from Renault Racing Tech to Japan may differ from that to the USA.

This transportation optimization problem is crucial for RedBull to enhance operational efficiency, reduce costs, and ensure that they have the right number of engines available at each destination to meet the Grand Prix racing requirements while ensuring transportation is feasible. The decision variables involve determining the quantity of engines to be shipped from each manufacturer to each country. The objective is to formulate a mathematical model that achieves the most cost-effective distribution strategy, taking into account the unique transportation costs and limitations associated with each manufacturer-country pair.

Problem Formulation

We define the sets, parameters, and variables used to formulate the problem

Sets:

- M : the set of manufacturers
- C : the set of countries

Parameters: ̂

- mi : manufacturing capacity of each manufacturer i, $i \in M$
- dj : demand for engines during GrandPrix from each country j, $j \in C$
- sj : storage capacity of shipping containers transported to each country j, $j \in C$
- cij : cost of shipping engines from manufacturer i to country j, $i \in M$, $j \in C$

Decision variables:

- xij : the quantity of Engines shipped from manufacturer i to country j , $i \in M$, $j \in C$

Formulation of this problem is given by:

- **min Z =** $\sum_{i \in M} \sum_{j \in C}$ **cij xij**

St.

Manufacturing Capacity Constraints

- C1: Engine Production: $\sum_{j \in C} xij \leq mi$, $i \in M$

Demand Constraints of Countries

- C2: Engines Shipped: $\sum_{i \in C} xij \geq dj$, $j \in C$

Storage Capacity Constraints

- C3: Storage Requirement: $\sum_{i \in C} xij \leq sj$, $j \in C$

Non-Negativity Constraint

- C4: Sign Restriction: $xij \geq 0$ and integer, $i \in M$, $j \in C$

The objective of this model is to minimize the cost borne by shipping Formula 1 engines for Grand Prix events in 5 different countries from 3 different manufacturers. Constraint C1 ensures the total number of engines manufactured **does not surpass** the manufacturing capacity of each company. Constraint C2 ensures the total number of engines shipped to each country is **at least greater than or matches** demand and also reflects the minimum storage requirement for shipping. (For example, if the minimum demand for engines is 1000, the minimum storage requirement will also be 1000 engines). Constraint C3 ensures that the total storage requirement for transport engines **does not exceed** the storage capacity of each destination country's shipping container. Lastly, Constraint C4 defines the integer and nonnegativity restrictions on the decision variables.

Scaled-down Representation of Model (1/unit = 1/engine)

Table 1. Manufacturing Supply Capacity for high-performance Formula 1 Engines:

Origin	Manufacturer (set of 3 manufacturers in order)	Production Capacity (units)
1	Ferrari Motors	5000
2	Mercedes Engines Ltd.	8000
3	Renault Racing Tech	4500
	Total	17500

Table 2. Forecast of Demand (Storage Requirement) and Storage Capacity for five countries:

Destination	Country (set of 5 countries in order)	Demand Forecast (units)	Allowed shipping storage (units)
1	USA	2500	4000
2	Italy	4000	4000
3	Germany	2500	7500
4	France	6500	7500
5	Japan	1000	1500
	Total	16500	24500

Table 3. Transportation cost per engine for RedBull ($):

(Distribution of 15 Routes)	Destination				
Origin	USA	Italy	Germany	France	Japan
Ferrari Motors	7	2	4	3	1
Mercedes Engines Ltd.	3	6	5	4	2
Renault Racing Tech	2	3	1	4	5

Table 4. Matrix locations Xij for each manufacturer-country pair

X11	X12	X13	X14	X15
X21	X22	X23	X24	X25
X31	X32	X33	X34	X35

LP Model

We define 15 decision variables to model the no. of engines transported from 3 manufacturers between 5 countries. The formulation of this problem is given by:

X_{ij}: # of engines transported from manufacturer i to country j, where i=1,2,3 and j=1,2,3,4,5

$$\min Z = \mathbf{7}X_{11}+\mathbf{2}X_{12}+\mathbf{4}X_{13}+\mathbf{3}X_{14}+\mathbf{1}X_{15}+$$
$$\mathbf{3}X_{21}+\mathbf{6}X_{22}+\mathbf{5}X_{23}+\mathbf{4}X_{24}+\mathbf{2}X_{25}+$$
$$\mathbf{2}X_{31}+\mathbf{3}X_{32}+\mathbf{1}X_{33}+\mathbf{4}X_{34}+\mathbf{5}X_{35}$$

s.t.

Capacity:

C1: $X_{11}+X_{12}+X_{13}+X_{14}+X_{15} \leq 5000$

C2: $X_{21}+X_{22}+X_{23}+X_{24}+X_{25} \leq 8000$

C3: $X_{31}+X_{32}+X_{33}+X_{34}+X_{35} \leq 4500$

Demand (Storage Requirement):

C4: $X_{11}+X_{21}+X_{31} \geq 2500$

C5: $X_{12}+X_{22}+X_{32} \geq 4000$

C6: $X_{13}+X_{23}+X_{33} \geq 2500$

C7: $X_{14}+X_{24}+X_{34} \geq 6500$

C8: $X_{15}+X_{25}+X_{35} \geq 1000$

Storage:

C9: $X_{11}+X_{21}+X_{31} \leq 4000$

C10: $X_{12}+X_{22}+X_{32} \leq 4000$

C11: $X_{13}+X_{23}+X_{33} \leq 7500$

C12: $X_{14}+X_{24}+X_{34} \leq 7500$

C13: $X_{15}+X_{25}+X_{35} \leq 1500$

Sign Restriction: $X_{ij} \geq 0$ and integer, $i \in M, j \in C$

Solution

The model is solved in the attached Excel file.

Below is a screenshot of the optimal solution, alongside an answer report.

The Optimal Solution is a minimal cost of ***$43000***. *This optimal solution was found keeping in mind a minimum demand of 16500 engines will be transported across 5 countries while ensuring manufacturing and storage capacities are not exceeded.*

RedBull LP		X_11	X_12	X_13	X_14	X_15	X_21	X_22	X_23	X_24	X_25	X_31	X_32	X_33	X_34	X_35			
	Variables	0	4000	0	0	1000	500	0	0	6500	0	2000	0	2500	0	0			
	OF	7	2	4	3	1	3	6	5	4	2	2	3	1	4	5	**43000**		
Capacity	C1	1	1	1	1	1											**5000**	<=	5000
	C2						1	1	1	1	1						**7000**	<=	8000
	C3											1	1	1	1	1	**4500**	<=	4500
Demand	C4	1					1					1					**2500**	>=	2500
	C5		1					1					1				**4000**	>=	4000
	C6			1					1					1			**2500**	>=	2500
	C7				1					1					1		**6500**	>=	6500
	C8					1					1					1	**1000**	>=	1000
Storage	C9	1					1					1					**2500**	<=	4000
	C10		1					1					1				**4000**	<=	4000
	C11			1					1					1			**2500**	<=	7500
	C12				1					1					1		**6500**	<=	7500
	C13					1					1					1	**1000**	<=	1500

Further, an Answer Report verifies all the constraints were satisfied.

Microsoft Excel 16.79 Answer Report
Worksheet: [Sample Project(1).xlsx]RedBull Cost Minimization
Report Created: 12/1/23 12:23:40 AM
Result: Solver found a solution. All constraints and optimality conditions are satisfied.
Solver Engine
Solver Options

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$R$3	OF	43000	43000

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$C$2:$Q$2				

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$R$12:$R$16 <= $T$12:$T$16					
$R$4:$R$6 <= $T$4:$T$6					
$R$7:$R$11 >= $T$7:$T$11					
$C$2:$Q$2=Integer					