# Optimization of a Crude Oil Transportation Network:A Linear Programming Approach

# Presentation Outline

### I.Problem Formulation

Defining the static transportation challenge.

### II.Model,Solution &Analysis

Solving the problem with Linear Programming and visualizing the optimal strategy.

### Ⅲ.Advanced Research &Discussion

Extending the model to a dynamic,24-hour cyclic scheduling problem.

# The Crude Oil Transportation Planning Problem

Suppose that we have known(a)the cost for transporting each ton of crude oil through each kilometer of the pipeline,(b)the lengths of the pipelines between every two nodes(i.e.,berths, stations and enterprises),(c)the demand of each type of oil from each enterprise,and (d)the amount of each type of crude oil stored in every oil transportation station.

**Core Mandate:**

…..You are required to make decisions on how much crude oil of each type will be transported from each oil transportation station to each enterprise,such that the demand of each type of oil from each enterprise can be satisfied and the total transportation cost can be minimized.

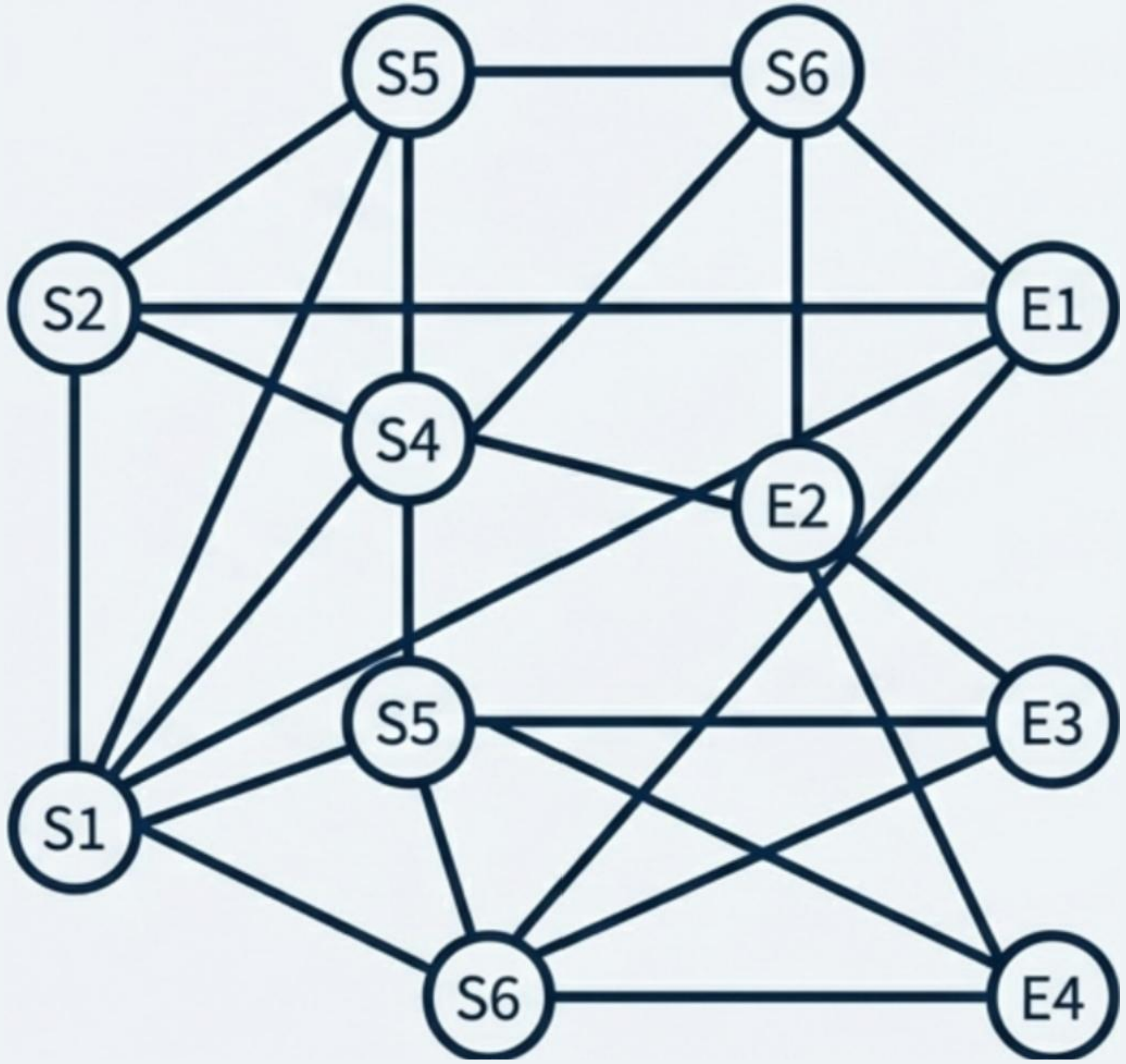



*Fig.1.Structure of the crude oil transportation network.*

# Core Challenge:A Static Optimization Model

### Objective

Minimize total transportation cost, measured in ton-kilometers.

### Decisions

Determine the quantity of each crude oil type (k)to transport from every supply station (S)to each enterprise(E).

### Constraints

1. Supply Limit: The total oil shipped from any station cannot exceed its available inventory for each oil type.
2. Demand Fulfillment: All demands from every enterprise for each oil type must be met exactly.

# Key Data Inputs

## Network Distances

The network consists of 9 key pipelines connecting 6 stations and 4 enterprises, with distances ranging from 150 km to 450 km.

## Enterprise Demands

4 enterprises require 6 unique oil types,resulting in 12 specific demand requirements.

## Station Stocks

6 stations hold inventory across 6 oil types,creating 20 distinct stock levels.

# Our Approach:A Two-Stage Optimization Method

### Step 1:Network Simplification

We first compute the shortest transportation path from every supply station to every enterprise using the Floyd-Warshall algorithm. This transforms the complex network into a direct cost matrix.

### Step 2:Model Formulation

We then construct a Linear Programming(LP) model.
LPis the ideal tool as it minimizes a linear cost function subject to linear supply and demand constraints.

### Step 3:Solution

The model is implemented and solved using MATLAB's `linprog` optimization toolbox.

# The Linear Programming Model

## Indices

$s \in S$: set of oil transportation stations (1 to 6)
$e \in E$: set of petrochemical enterprises (1 to 4)
$k \in K$: set of crude oil types (O1 to O6)

## Parameters

$c_{se}$: Shortest distance (cost) from station s to enterprise e
$Supply_{sk}$: Available stock of oil k at station s
$Demand_{ek}$: Demand for oil k at enterprise e

## Decision Variable

$x_{sek} \geq 0$: Quantity (in $10^4$ tons) of oil k transported from station s to enterprise e

## Objective Function (Minimize Total Cost)

$$\text{Minimize } Z = \sum_{s \in S} \sum_{e \in E} \sum_{k \in K} c_{se} * x_{sek}$$

## Constraints

1. Supply Constraint: $\sum_{e \in E} x_{sek} \leq Supply_{sk}$ (For all stations s and oil types k)
2. Demand Constraint: $\sum_{s \in S} x_{sek} = Demand_{ek}$ (For all enterprises e and oil types k)

# The Optimal Solution

Minimum Total Transportation Cost:

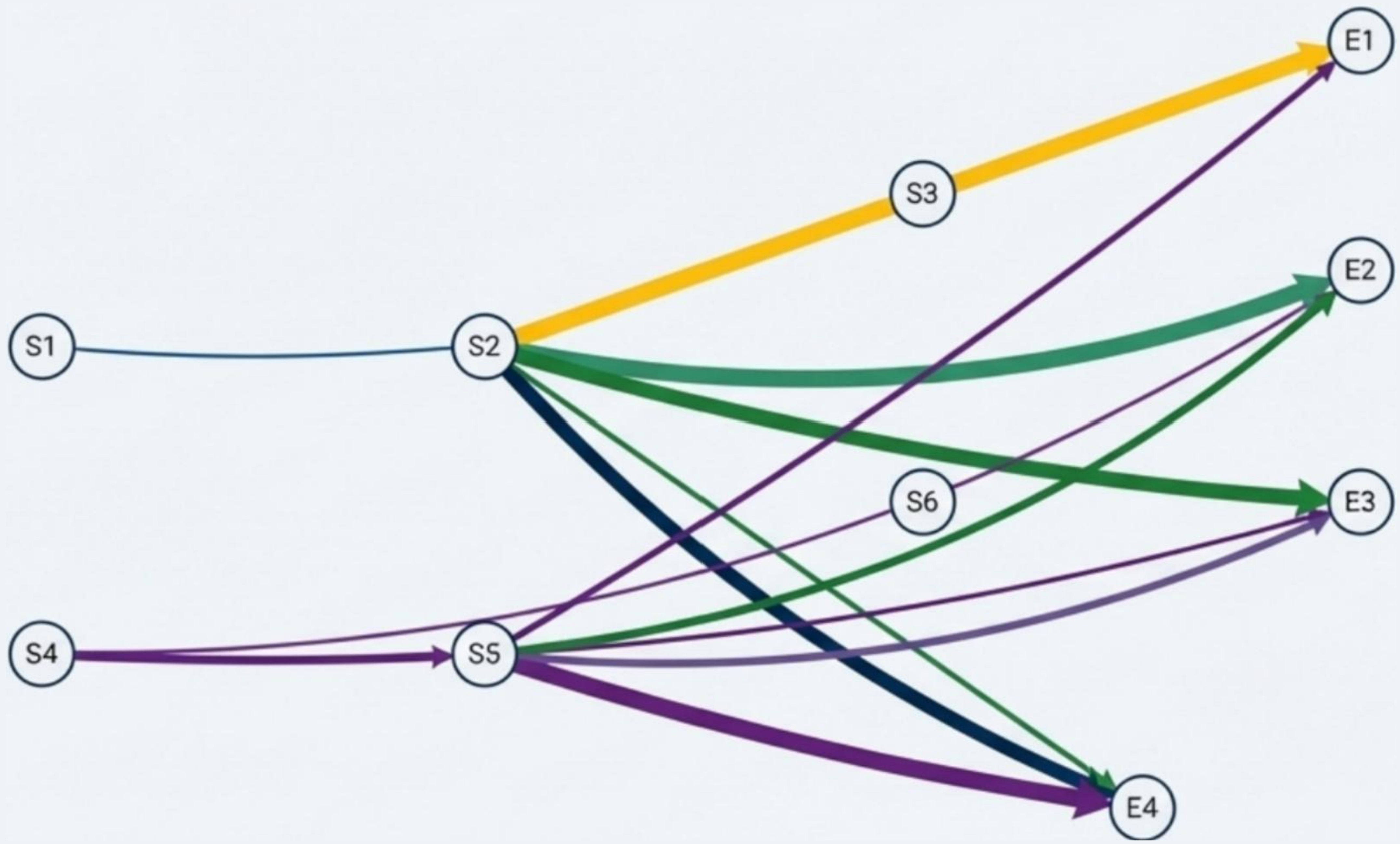
**39,400**

(x $10^4$ ton-km)

The model successfully identified a transportation plan that satisfies all 12 enterprise demands without exceeding any of the 20 station stock limits, achieving the lowest possible cost. The detailed plan is shown in the following visualizations.

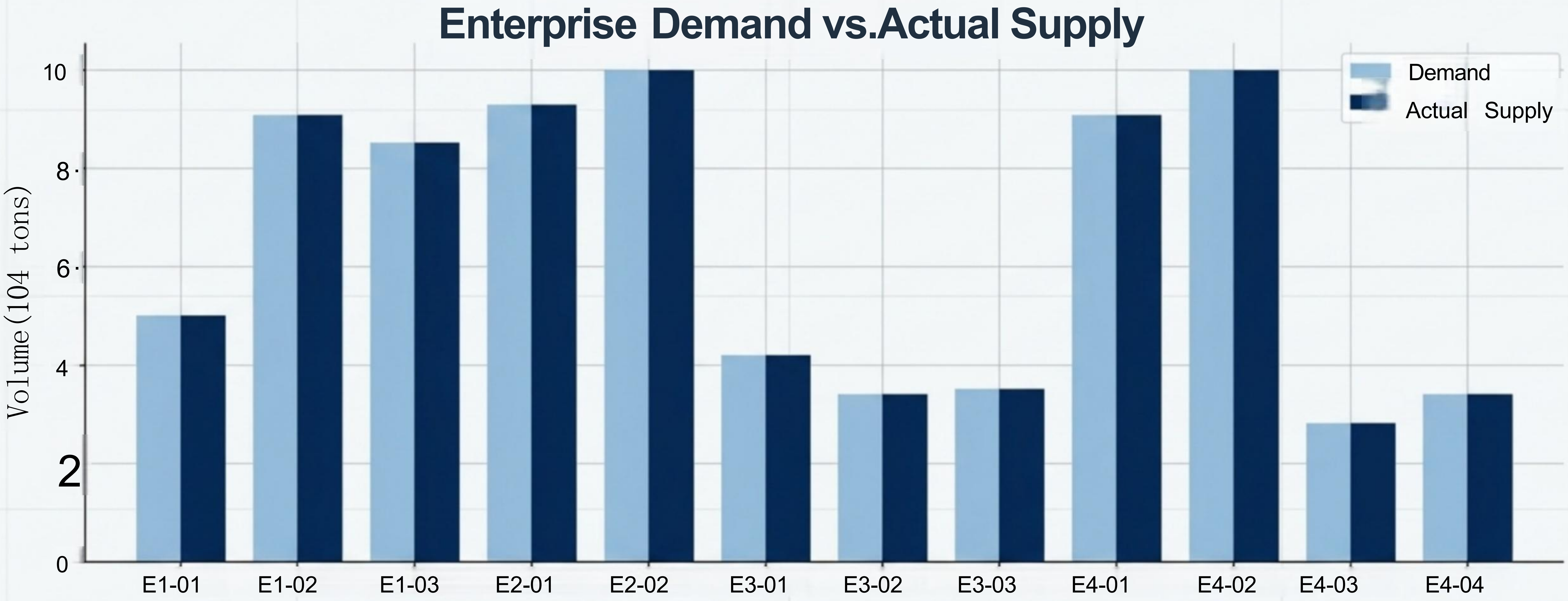
# Optimal Flow Distribution

## Optimal Transportation Flow by Route



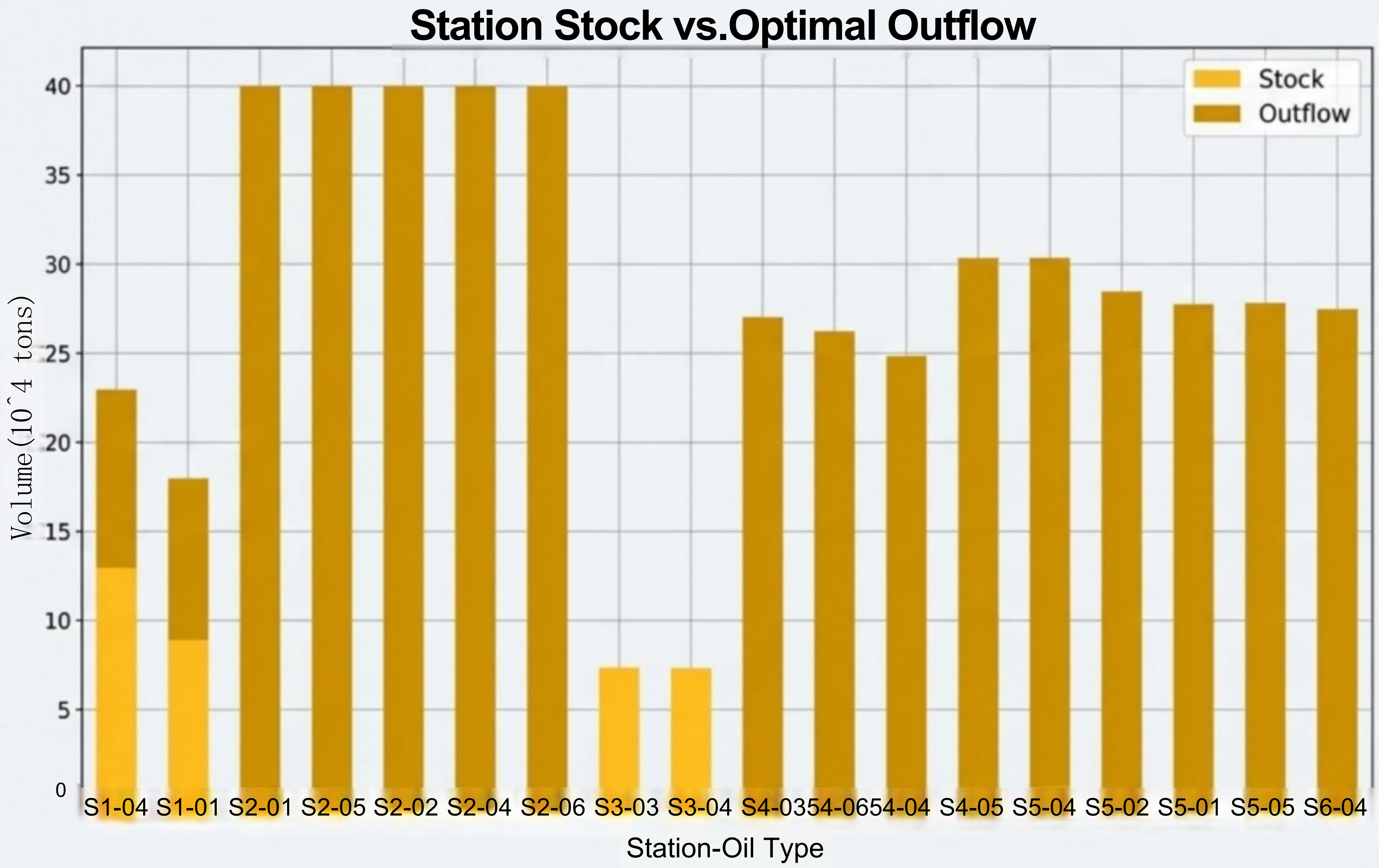

- This network graph visualizes the entire optimal solution. The thickness of each line is proportional to the total volume of oil transported.
- Station S2 is the primary hub, distributing oil to all four enterprises.
- Routes from S5 are also critical, particularly for supplying E4.
- Notably,some potential routes (e.g.,from S3)are not utilized, indicating they are not cost-effective in this optimal plan.

# Result Analysis:Demand Fulfillment



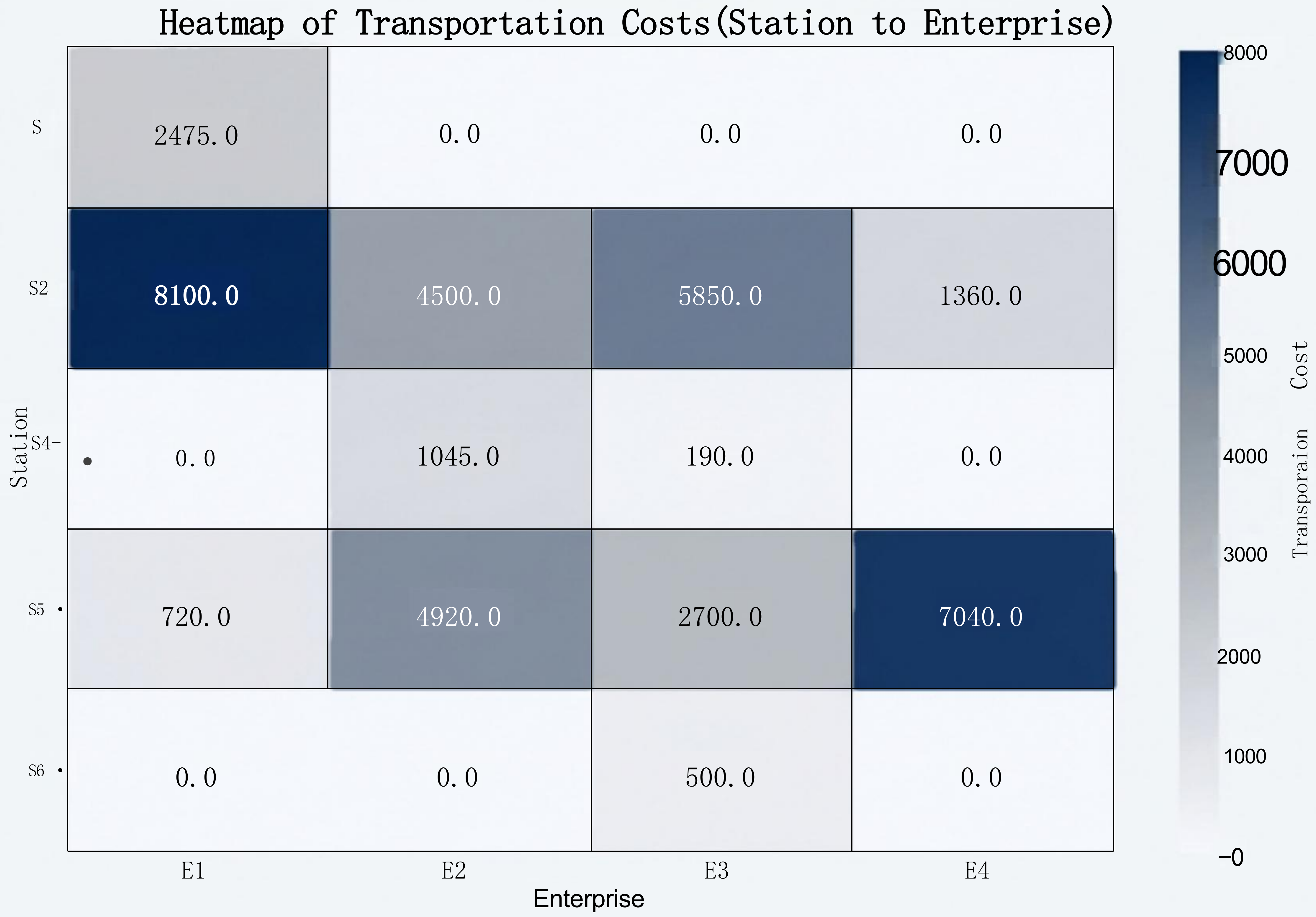

- The model successfully meets 100%of the demand for every oil type at all four enterprises.
- The light blue bars(Demand)are perfectly matched by the dark blue bars(Actual Supply)for all 12 enterprise-oil combinations,confirming the feasibility of our solution.

# Result Analysis:Supply Chain Contribution



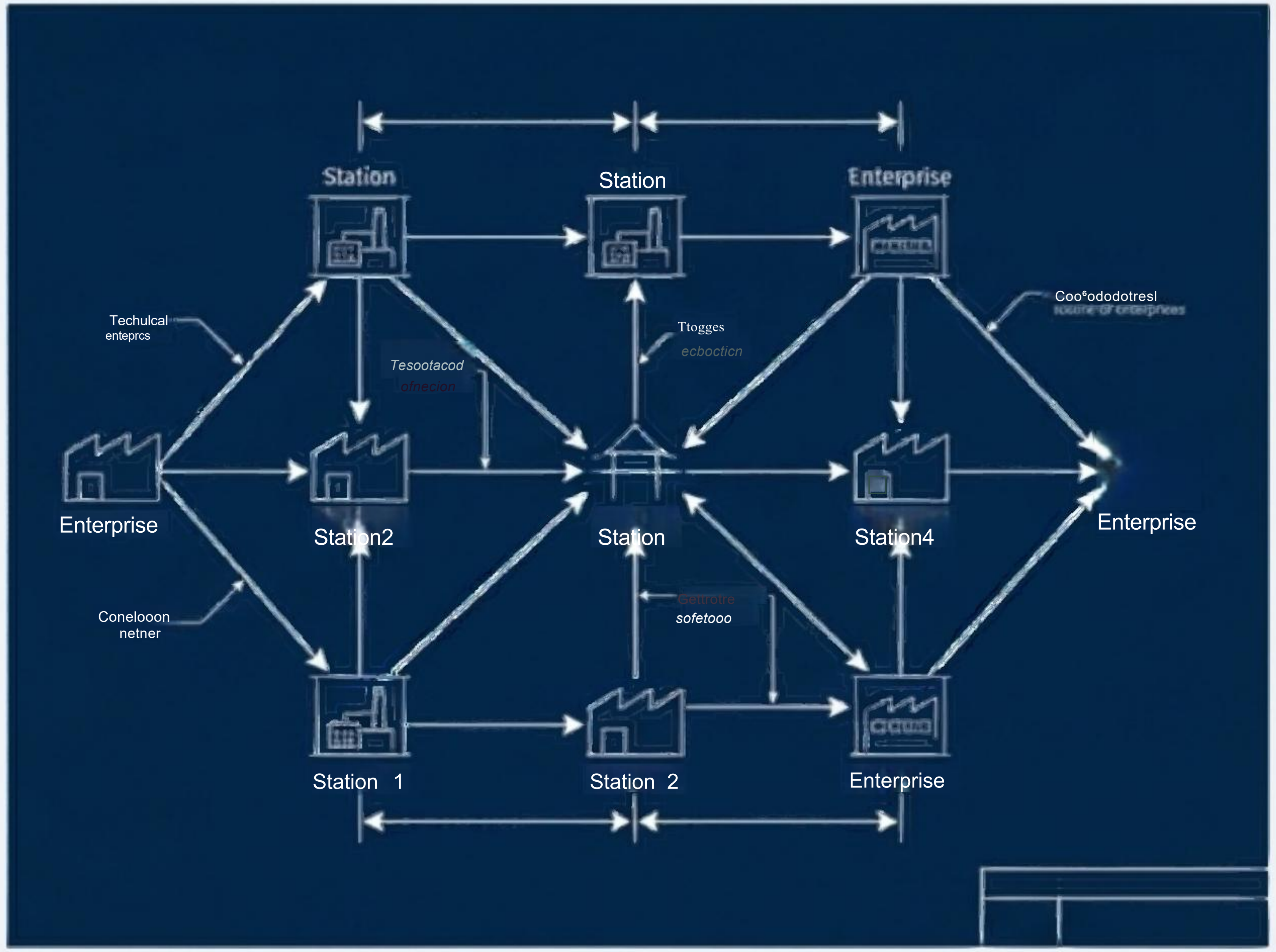

- **High Utilization:** Station S2 utilizes 100%of its inventory across all six oil types, highlighting its critical role as a distribution hub.
- **Partial Utilization:** Stations S1, S4,and S5 contribute significantly but retain surplus stock.
- **Zero Utilization:** Station S3's inventory is entirely unused.This is likely due to its less favorable network position relative to demand,suggesting potential for inventory consolidation.

# Result Analysis:Cost Breakdown




- The heatmap visualizes the cost contribution of each station-enterprise pairing.Darker shades represent higher total costs.
- The most significant costs are incurred on the S5→E4 route (7040 units)and the S2→E1 route(8100 units),driven by a combination of large volumes and/or long distances.
- This analysis helps pinpoint the most expensive links in the supply chain,which could be targets for future logistics optimization.

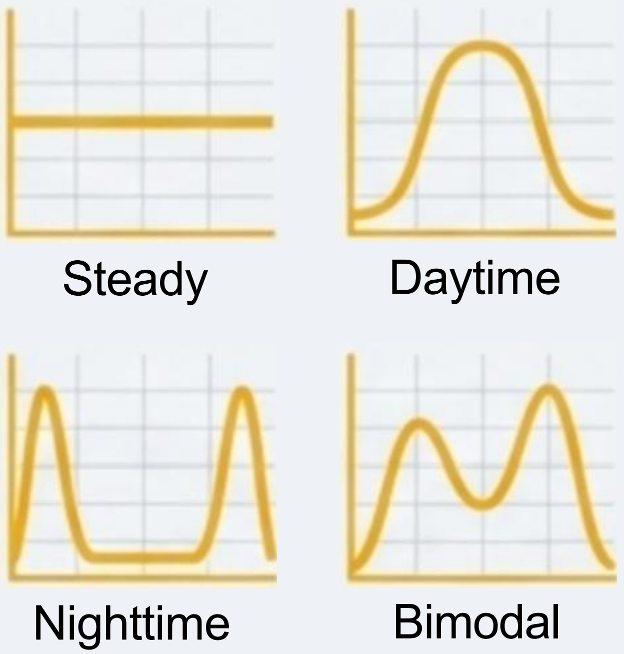
# Beyond the Static Model:From a Plan to Dynamic Operations




The initial LP model provides a valuable strategic blueprint for total volume distribution.

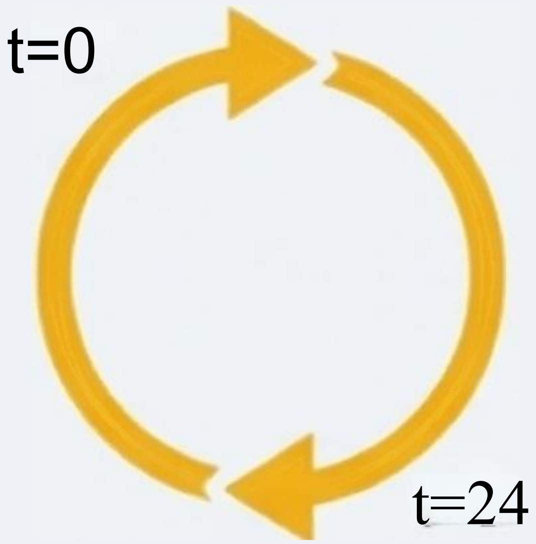
However,real-world operations are not static;they are governed by **time** and complex operational constraints.We now extend our research to create an actionable,24-hour schedule.

# An Advanced Model:24-Hour Cyclic Scheduling(MILP)



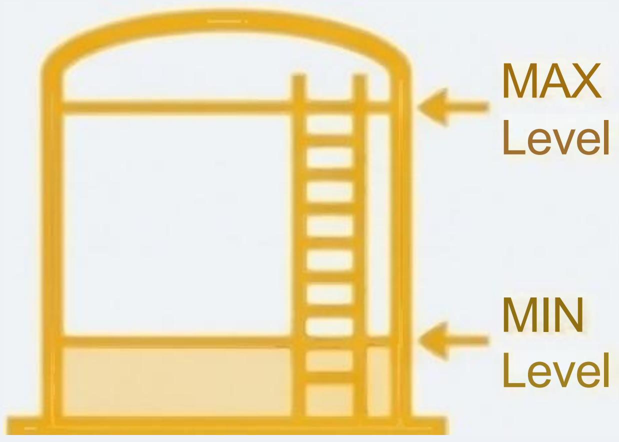

## 1.Time Dimension & Dynamic Demand

The model operates in 1-hour intervals over a 24-hour cycle. Enterprise demands are now time-variant,with unique daily profiles (Steady,Daytime, Nighttime,Bimodal).



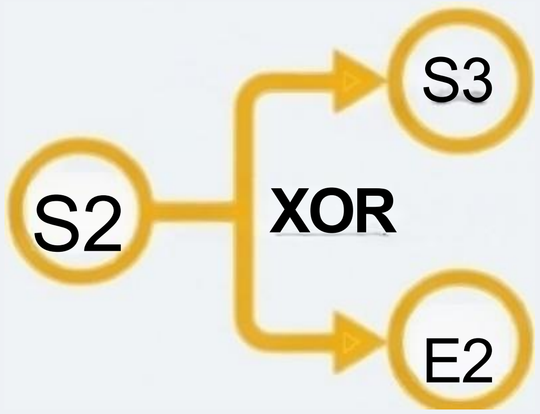

## 2.Cyclic Steady-State

Inventory at 't=24`must equal the initial inventory at 't=0.The initial inventory is now a decision variable to be optimized for sustainability.




## 3.Physical Constraints

Pipelines have maximum hourly flow capacities,and storage tanks have defined upper and lower inventory limits.




## 4.Hub Exclusivity Logic (Binary Constraint)

A Mixed-Integer Linear Program (MILP)is required to model S2's operational limits:S2→S3 and S2→E2 are mutually exclusive, as are S2→S6 and S2→E4.

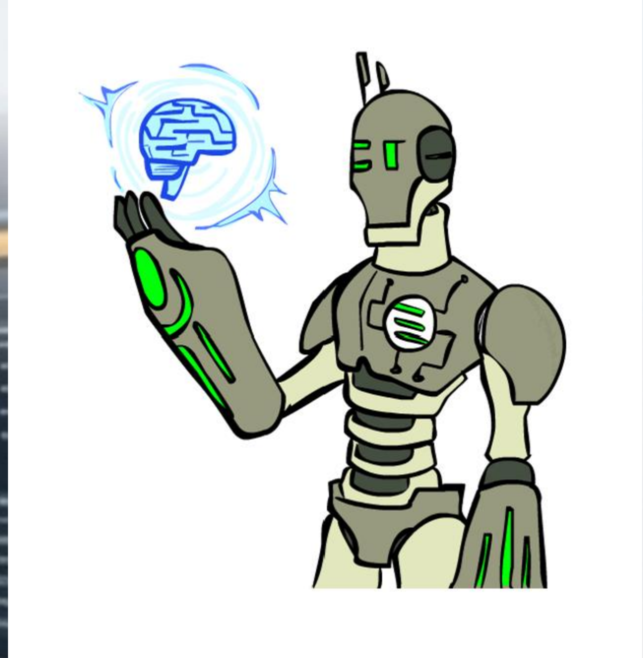
# Conclusion &Future Outlook

## Summary

- We successfully solved the static crude oil transportation problem using Linear Programming,achieving a minimum cost of $39{,}400\times10^4$ton-km .
- The analysis revealed S2's critical role as a distribution hub and identified underutilized assets like Station S3.

## Future Outlook

- The proposed dynamic Mixed-Integer Linear Programming model represents a significant step towards a realistic operational tool.
- Solving it would yield an hourly schedule, optimize initial inventory levels,and manage complex flow constraints at key network hubs.
- Further extensions could include incorporating transportation time lags,pipeline switching costs,or stochastic(uncertain)demand.



**Many thanks for coming here!**
**It will be highly appreciated if you offer any suggestion.**

Yunyixuan Zhang , Xiaoyu Gu , Yiming Zhou
This work was conducted under the supervision of **Prof. Wang**.
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