Systems Analysis in Construction

CB312

Construction & Building Engineering Department- AASTMT

by

Ahmed Elhakeem & Mohamed Saeid

Resume

Dr. Mohamed Saeid Eid

- BS and MS in construction Engineering, AAST (2008, and 2012, respectively)

- PhD in Civil and Environmental Engineering, Construction focus, University of Tennessee, Knoxville (2017)

Syllabus

- What do you expect to learn?
  - Network theory
  - Transportation and assignment problems
  - Decision analysis
  - Game theory
- What will you gain from the class?
  - Advanced skills in optimization and system analysis
- What do I expect from my students?
  - Attention and participation
  - Curiosity to learn

Class rules

- Contact
  - No phone calls. Each call worth -5% of your grade.
  - eng.saeid@gmail.com
  - Use an appropriate subject title, and English language only
  - Website: Msaeideid.com
- Late assignments
  - No late assignments are accepted beyond due date
- Teamwork
- Class ethics and *Academic Honesty*
- NO CELL PHONES!

4. Linear Programming

Optimization

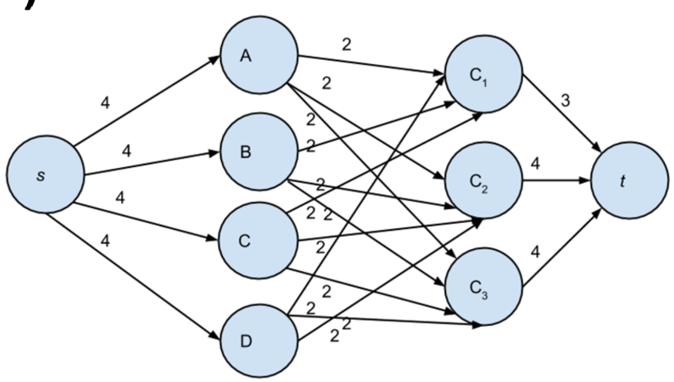
Network Models

- Shortest Route Problem
- Minimal Spanning Tree Problem
- Transportation Problem
- Assignment Problem

Introduction to Network Models

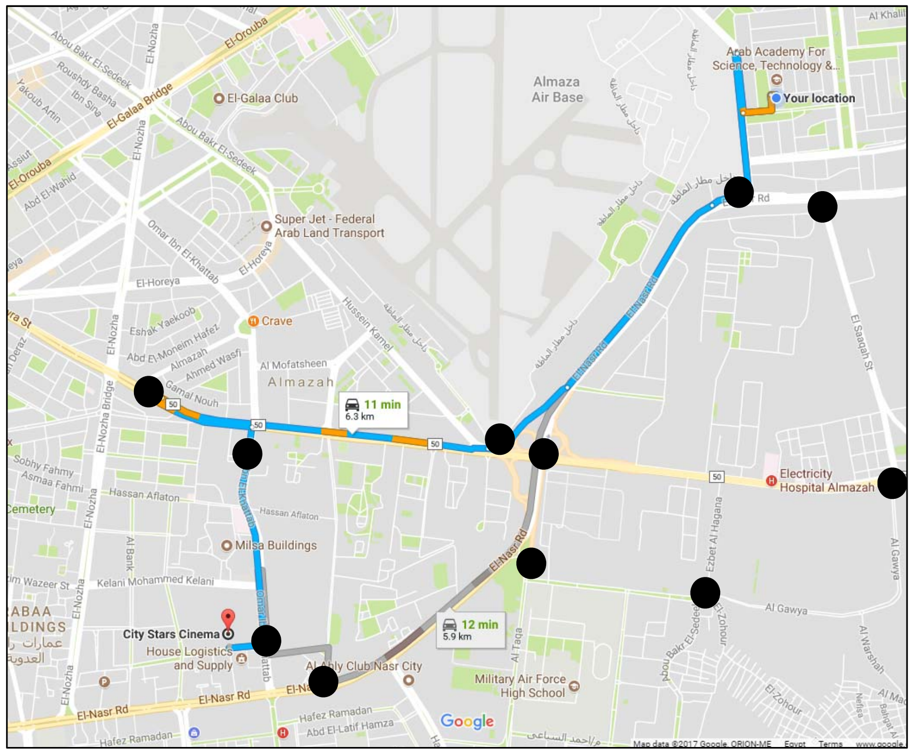
A Network is representation of a problem in form of nodes (n) and arcs (a).

A **network model** is one which can be represented by a set of nodes, a set of arcs, and functions (e.g. costs, supplies, demands, etc.) associated with the arcs and/or nodes.



Shortest-Route Problem

- The <u>shortest-route problem</u> is concerned with finding the shortest path in a network from one node to another node.



Shortest-Route Problem

- If all arcs in the network have nonnegative values then a **Greedy algorithm** can be used to find *the shortest paths from a particular node to all other nodes* in the network.

- The criterion to be minimized in the shortest-route problem is not limited to distance even though the term "shortest" is used in describing the procedure. Other criteria include time and cost. (Neither time nor cost are necessarily linearly related to distance.)

Shortest-Route Problem

Greedy algorithm

Is a heuristic algorithm that make local search per step in attempt to find a global optimal solution.

In greedy search, at each iteration, we attempt to locate the optimal local solution (here, minimum path), and declare it the new start.

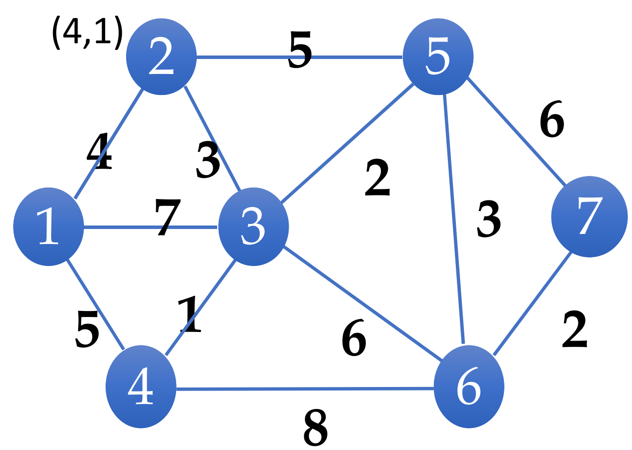
Following this approach recursively, we can find a global optimal solution.

Shortest-Route Problem – Greedy Search

Note: We use the notation **[d,n]** to represent a **permanent** label and **(d,n)** to represent a **tentative, or feasible** label.

d = the direct distance from node n to the node in question - this is called the distance value.

n = preceding node on the route from node in question



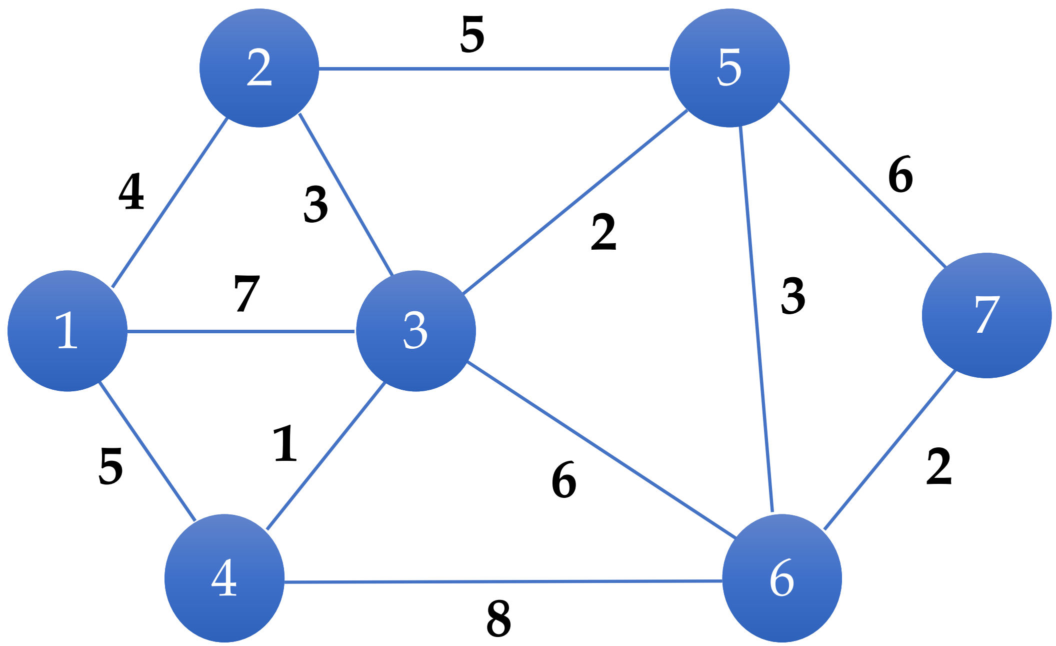
Shortest-Route Problem – Greedy Search

1. **Start at Node 1 with label [0,S].** The first number is the distance from node 1; the second number is the preceding node. Since node 1 has no preceding node, it is labeled *S* for the starting node.
2. For each node connected to current node, calculate d

   d= (arc distance from previous node to current one) + (distance value for previous node).
3. **Choose node with least d,** and label it with permanent label [d,n] as current node
4. **Repeat steps 2&3** till no more tentative labels.

Example 1

Find the Shortest Route From Node 1 to All Other Nodes in the Network:



1. Start at Node 1 with label [0,S].
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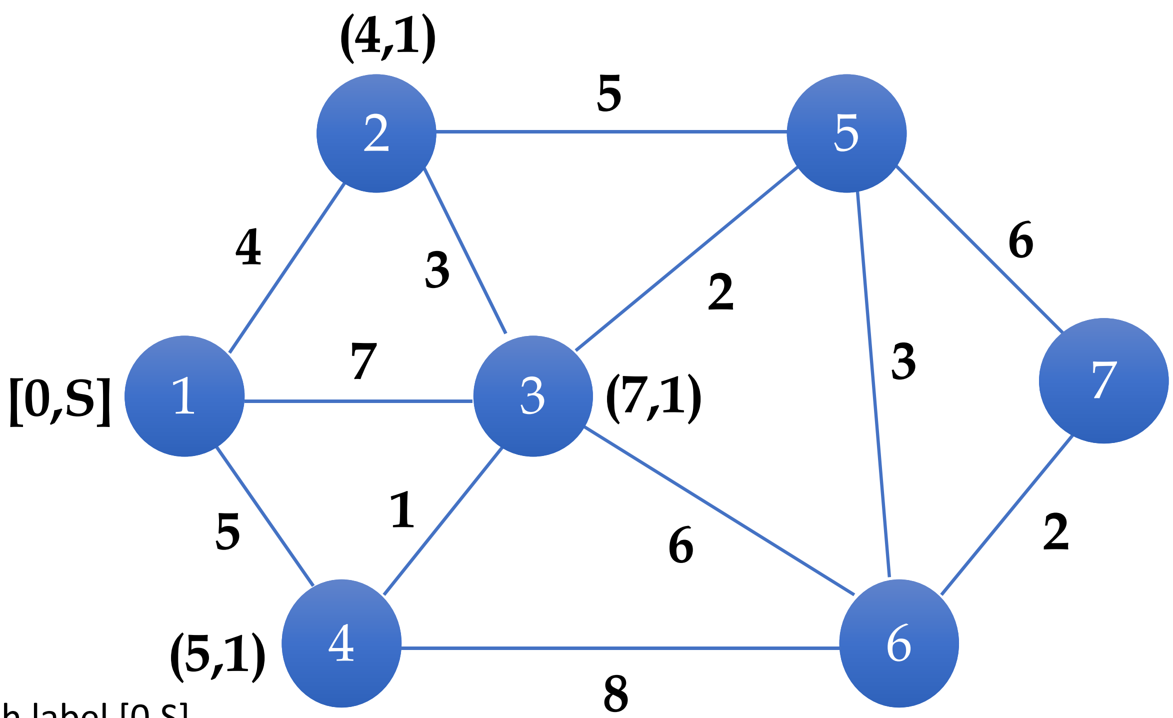
3. Choose node with least d, Repeat steps 2&3

Example 1

- **Tentative Labels Shown**



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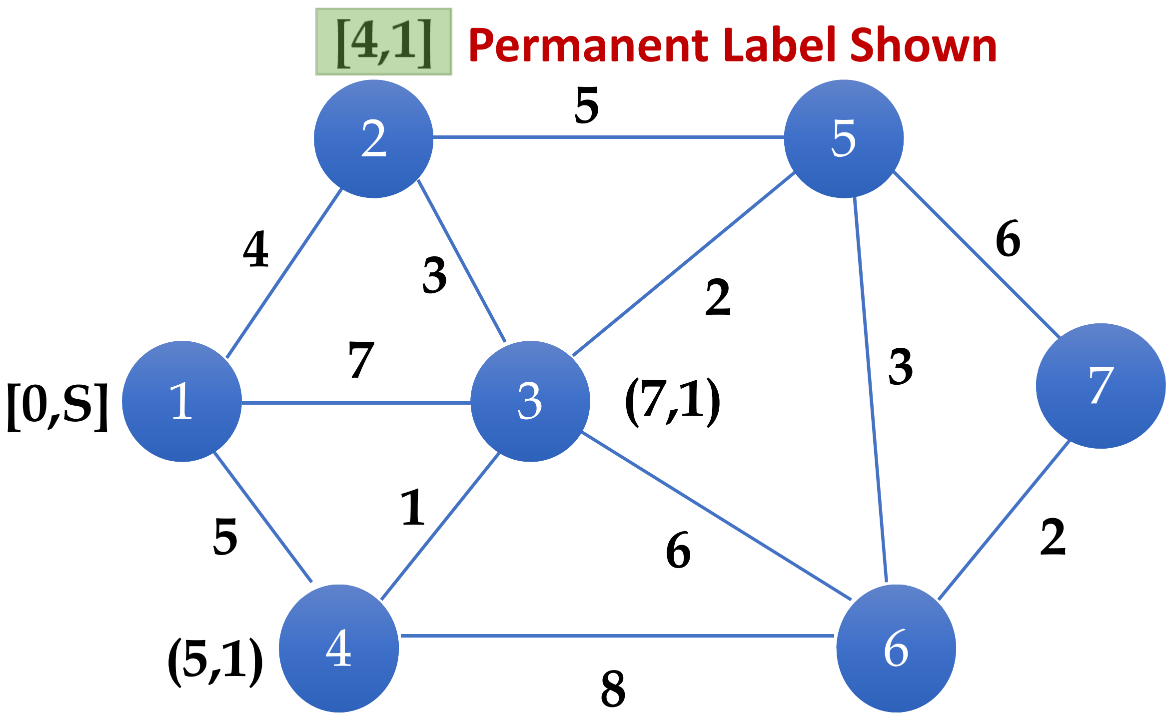

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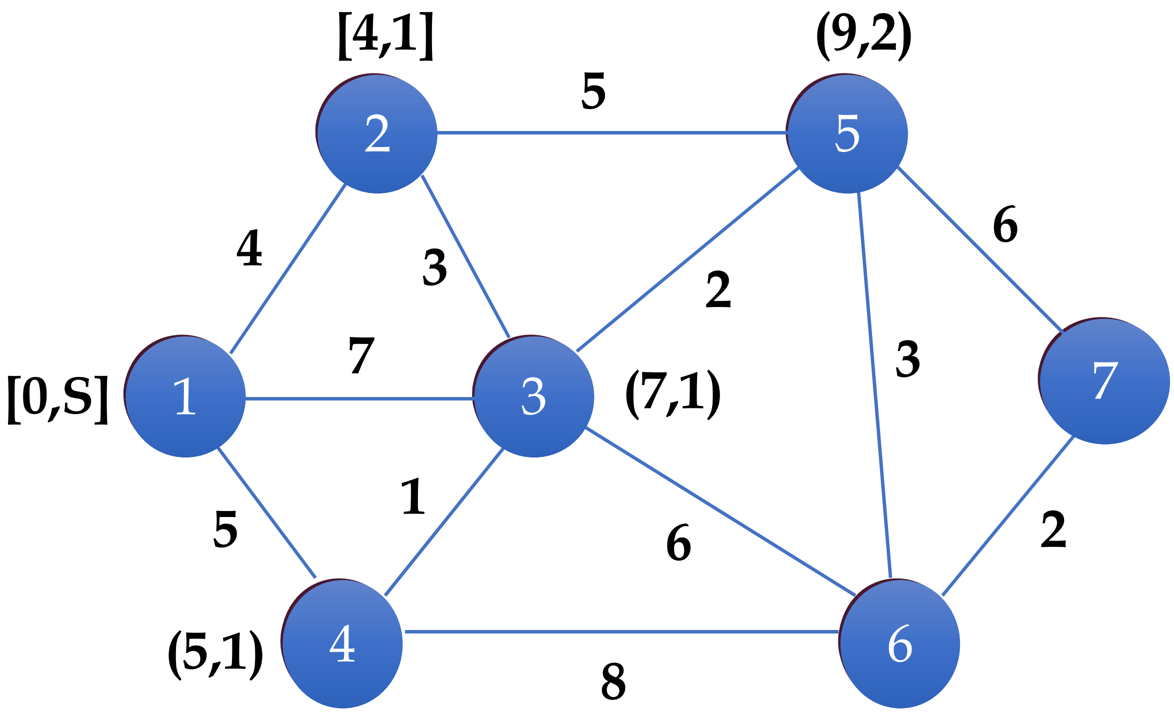

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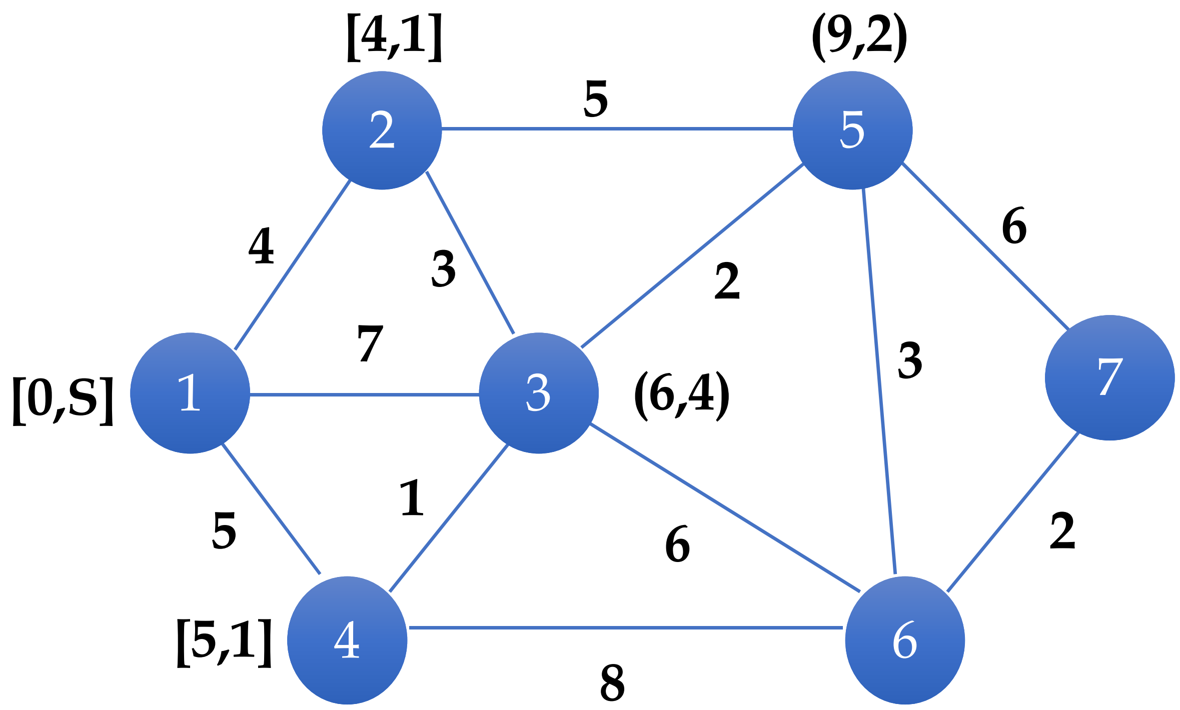

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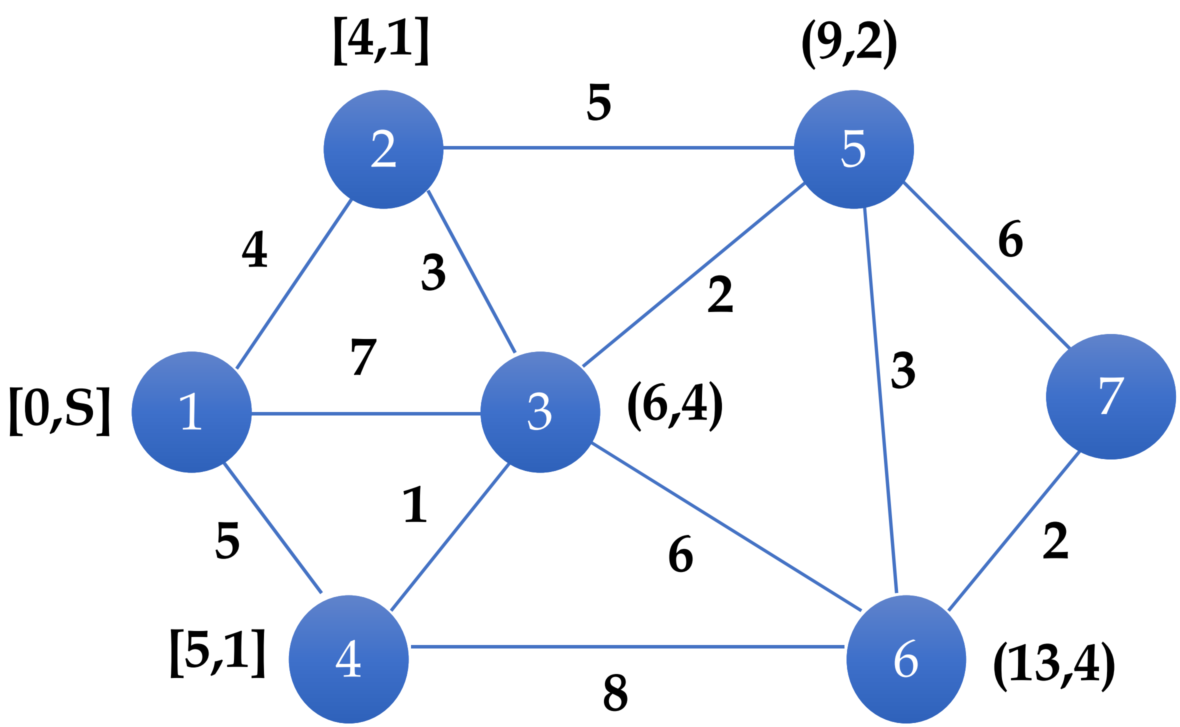

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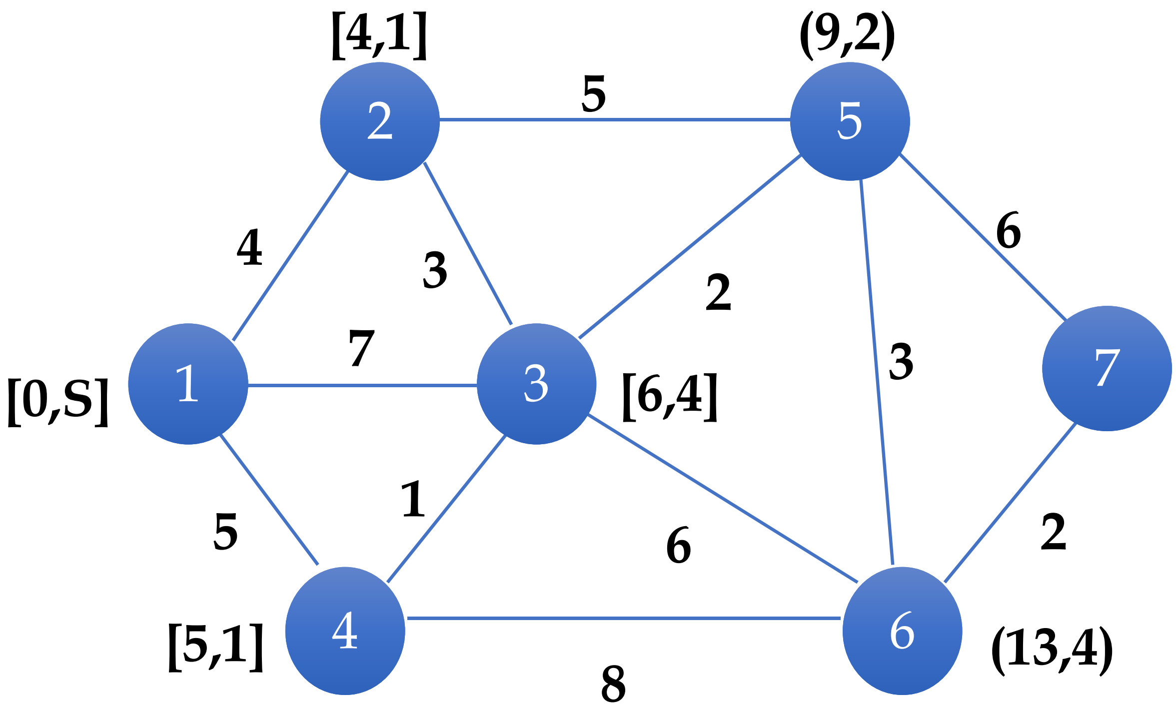

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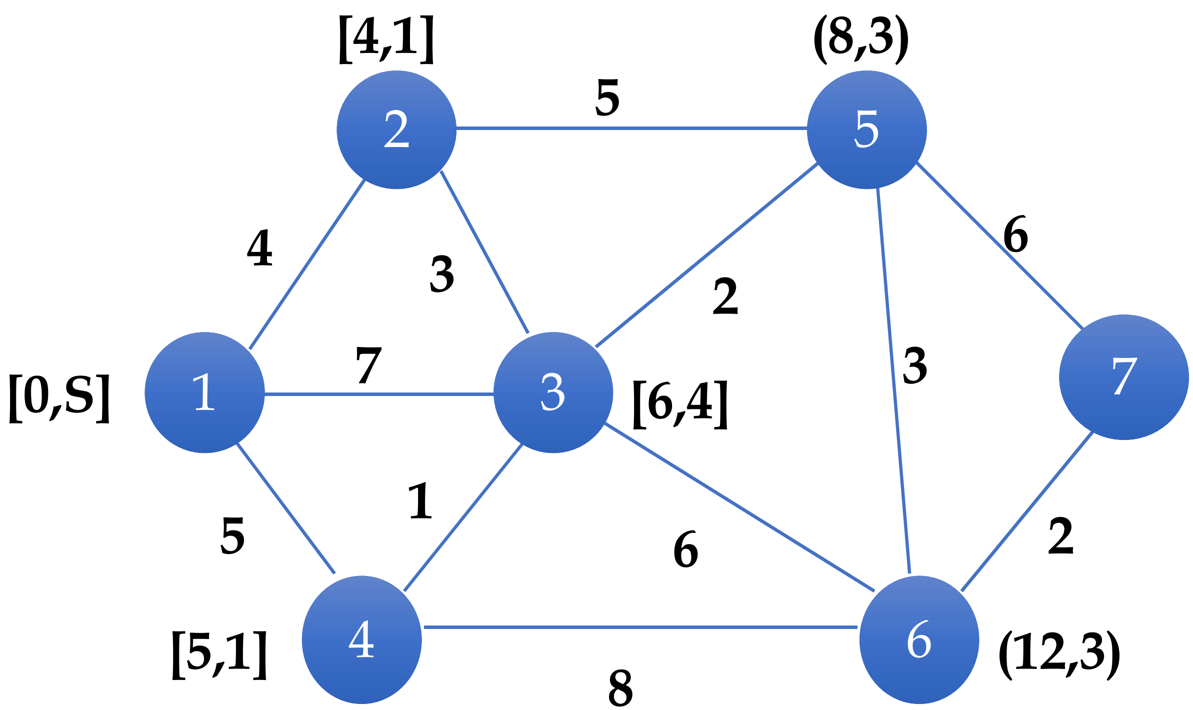

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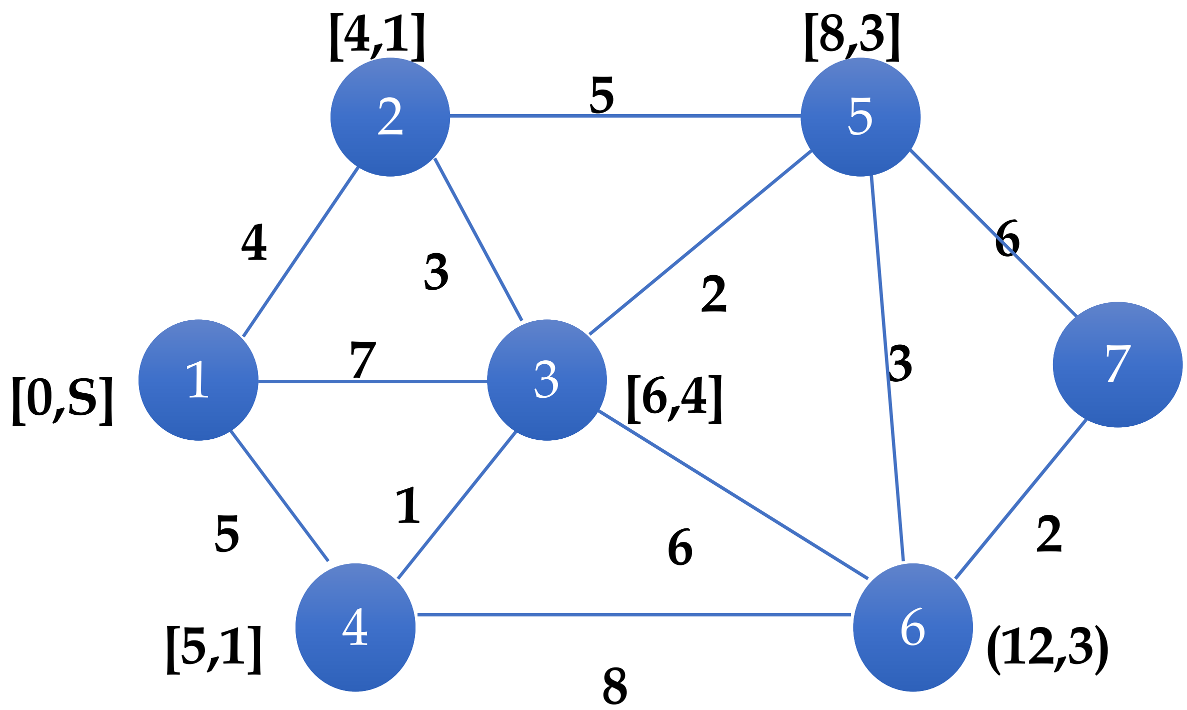

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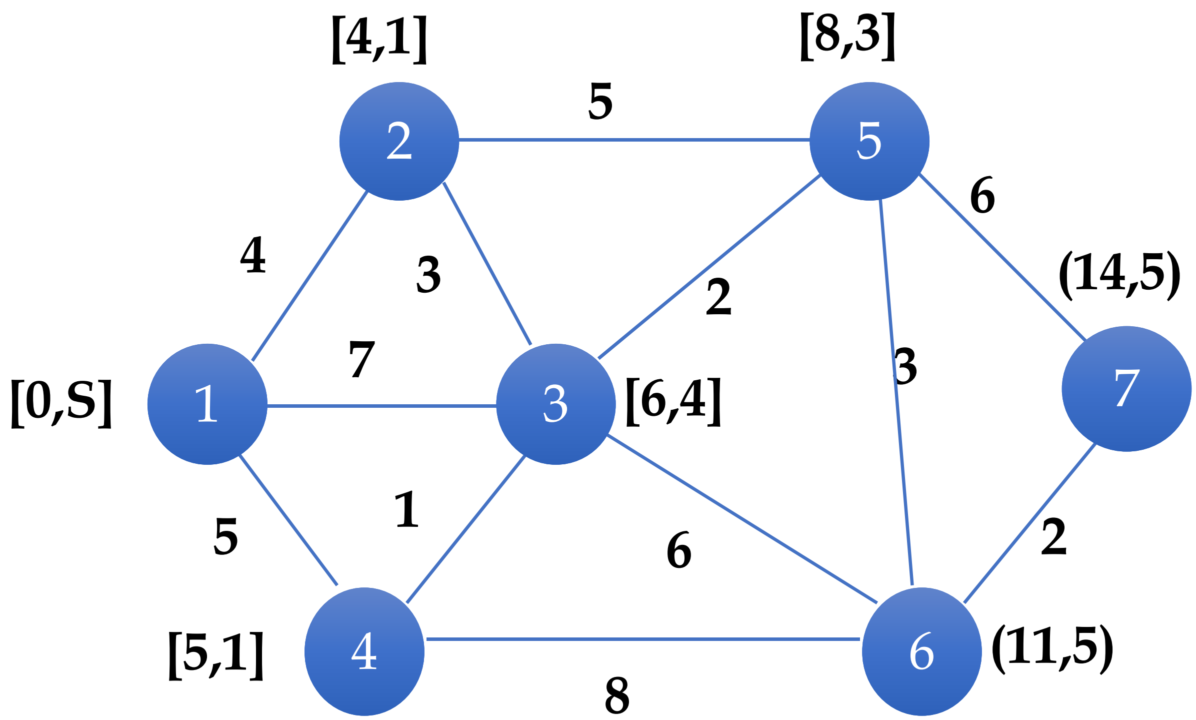

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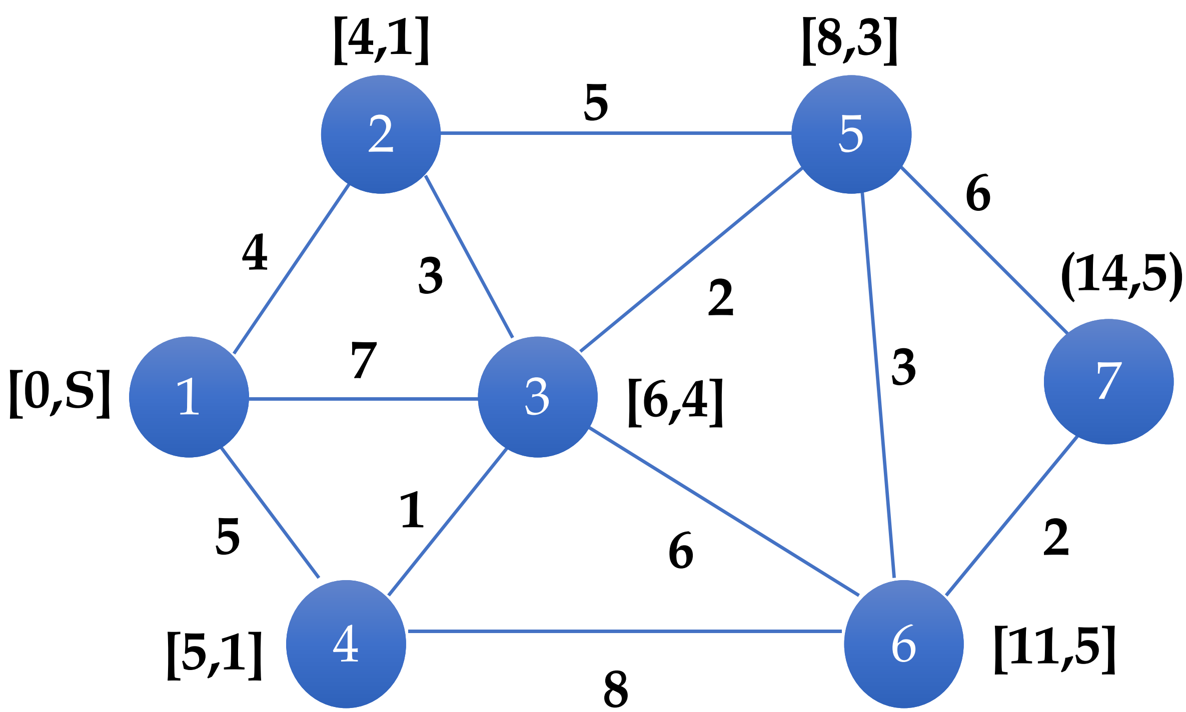

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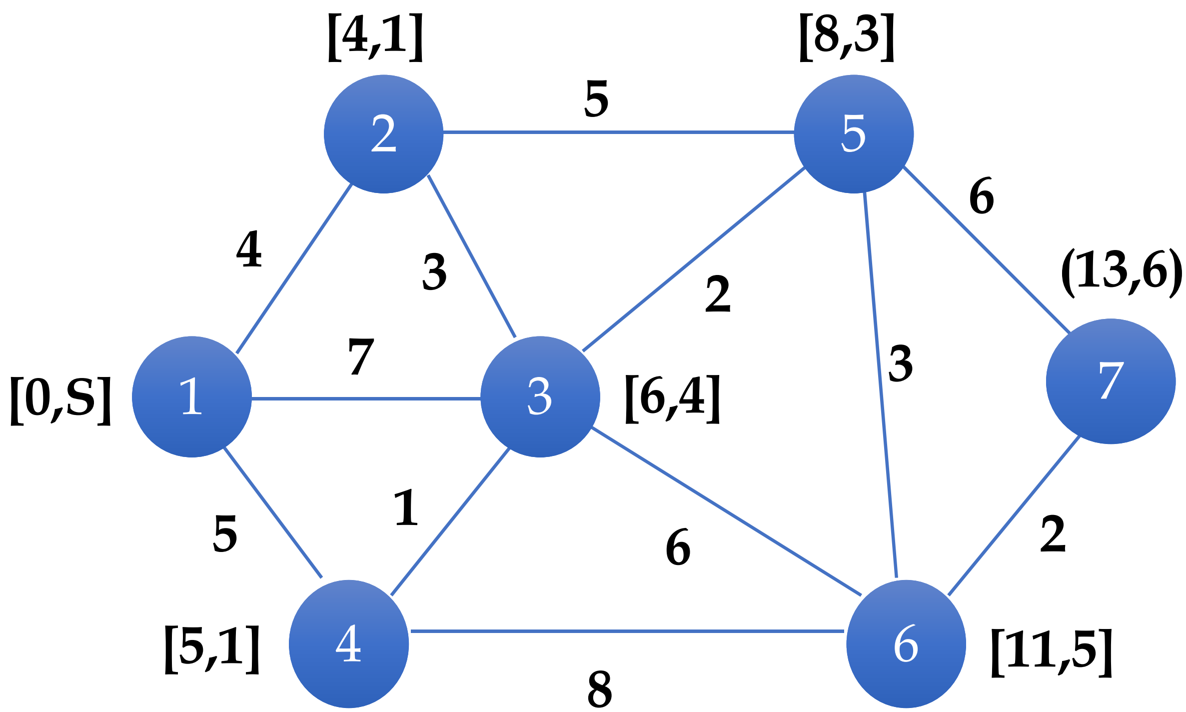

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Example 1

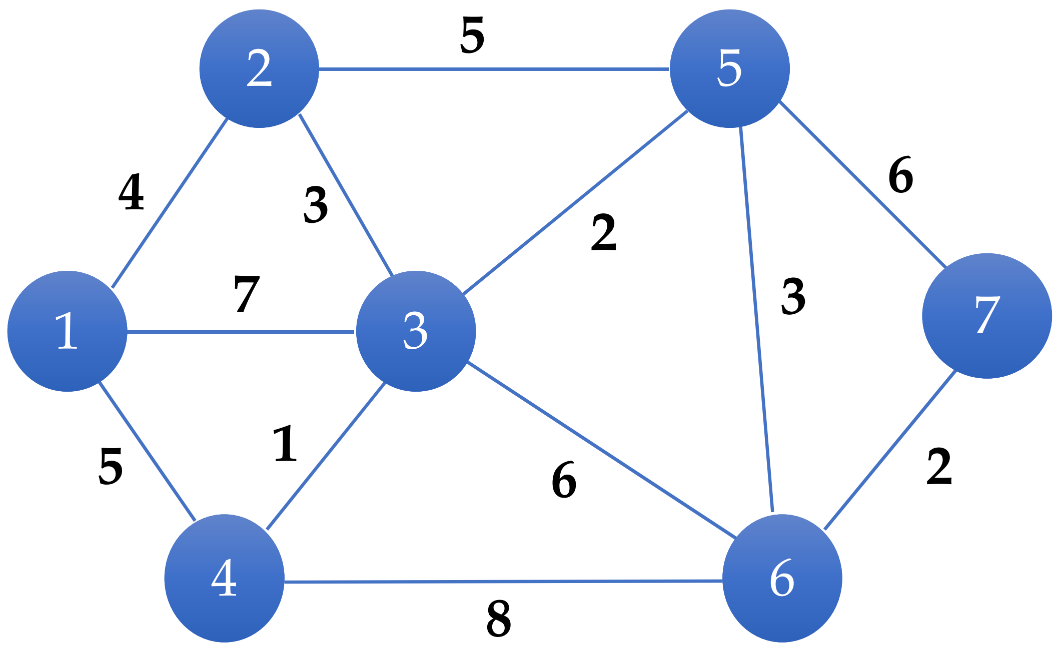
- **Solution Summary from Node 1 the distance to**

Node	Minimum Distance	Shortest Route
2	4	1-2
3	6	1-4-3
4	5	1-4
5	8	1-4-3-5
6	11	1-4-3-5-6
7	13	1-4-3-5-6-7

Longest Route Problem?

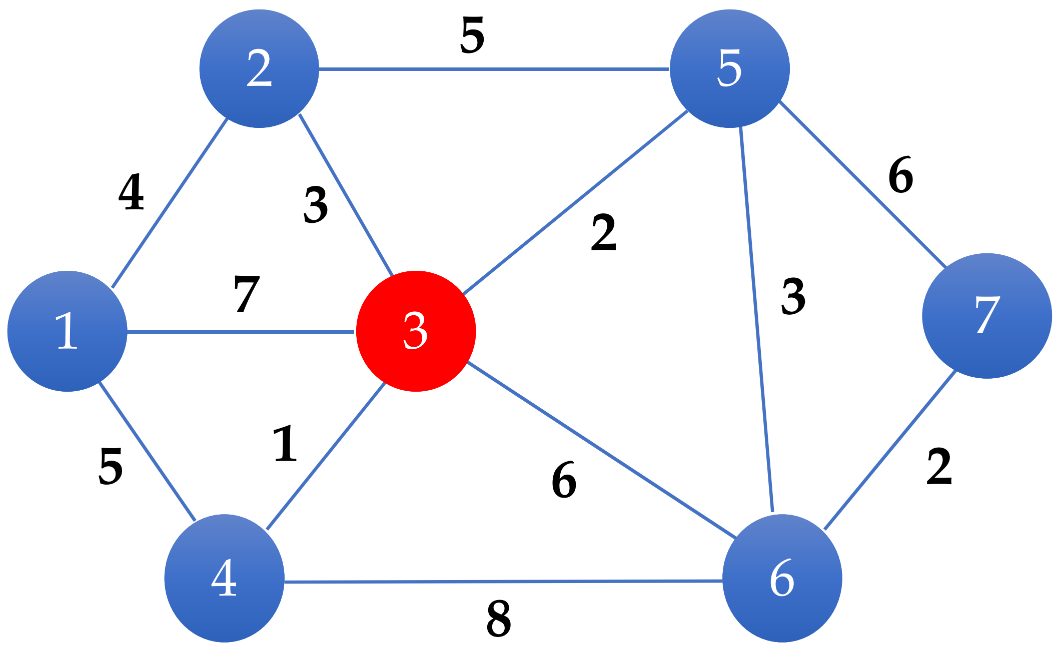
Minimal Spanning Tree Problem

- The minimal spanning tree problem is concerned with finding the minimum length (cost) sub network that connects all nodes in a network



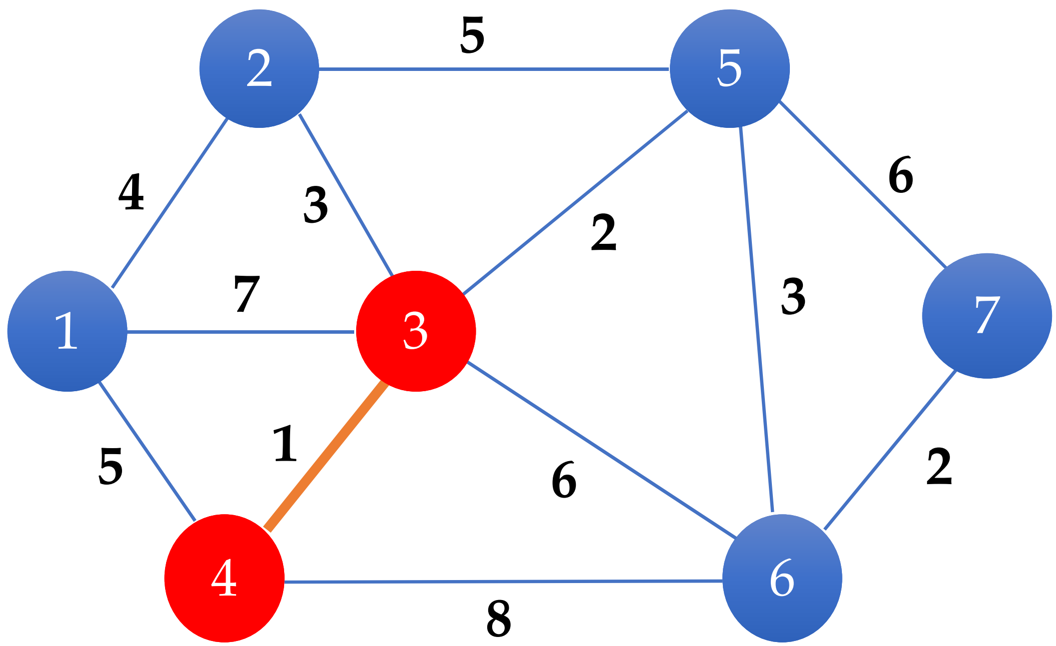
Minimal Spanning Tree Problem

- Start from any node then connect to this node another one with minimum length. Let us start from node 3



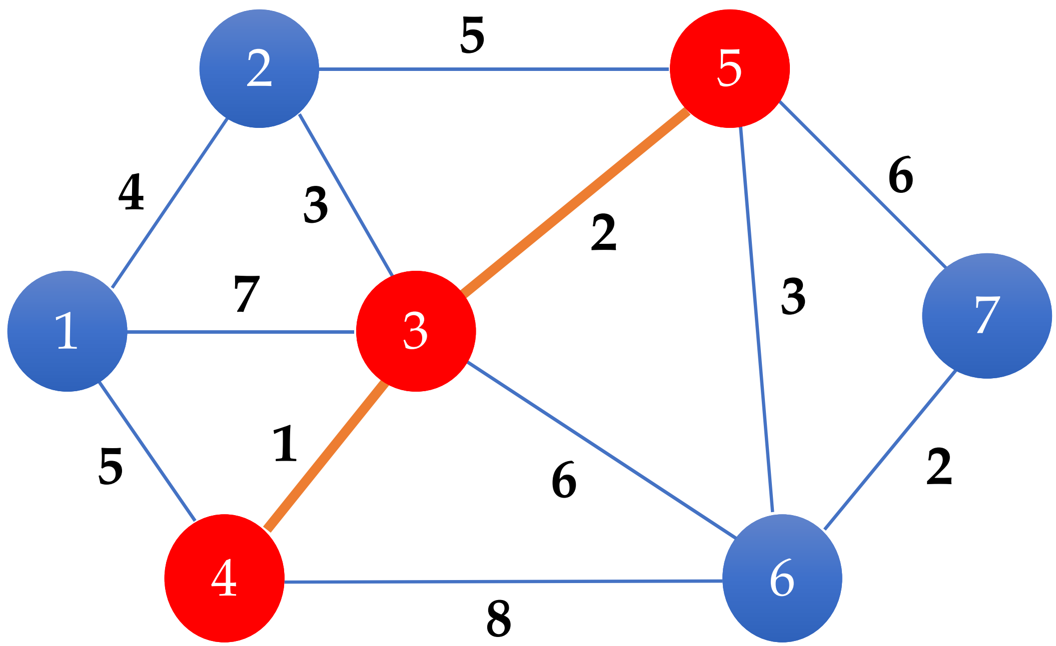
Minimal Spanning Tree Problem

- It is possible to connect nodes 1,2,4,5, &6 to node 3 select node 4 with minimum length
- The next step is to add new node to the connected ones (3 &4)



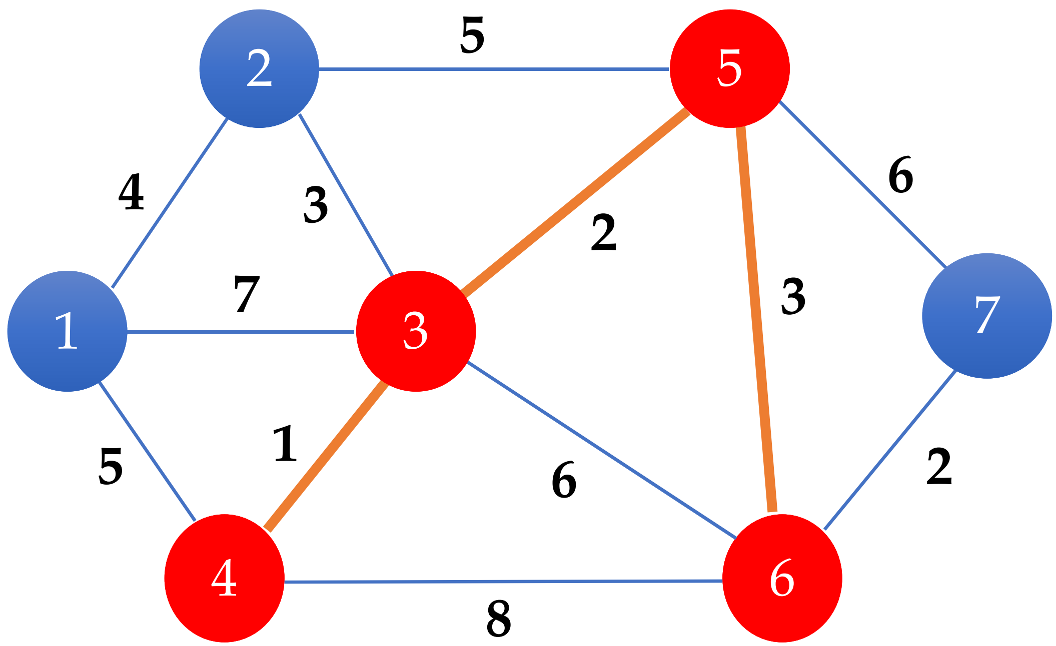
Minimal Spanning Tree Problem

- Link 5 to 3



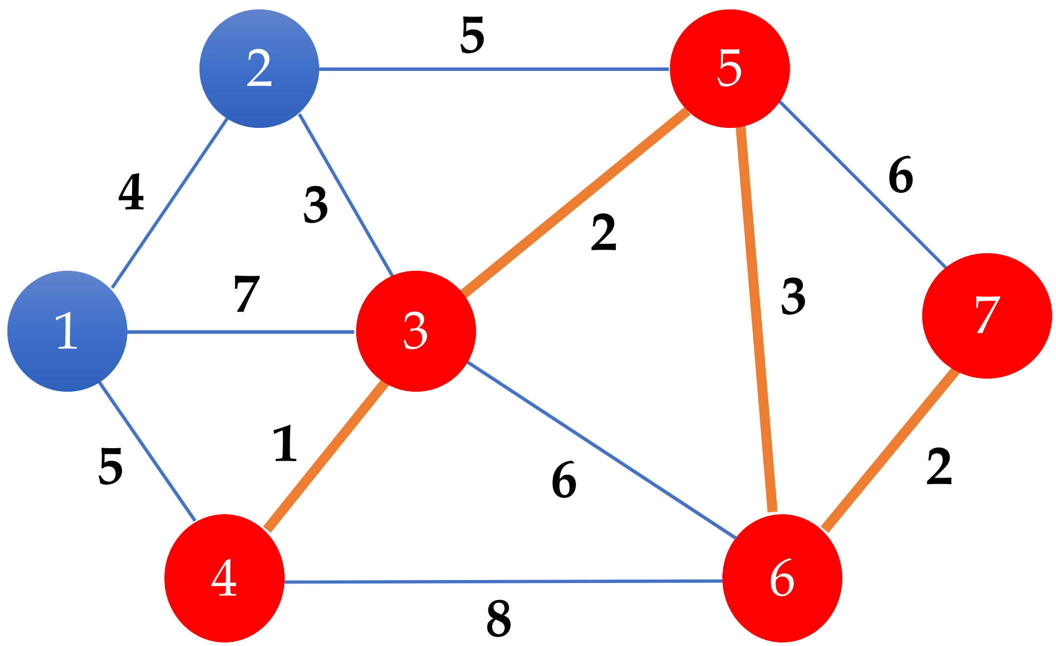
Minimal Spanning Tree Problem

- Link 6 to 5 OR Link 2 to 3



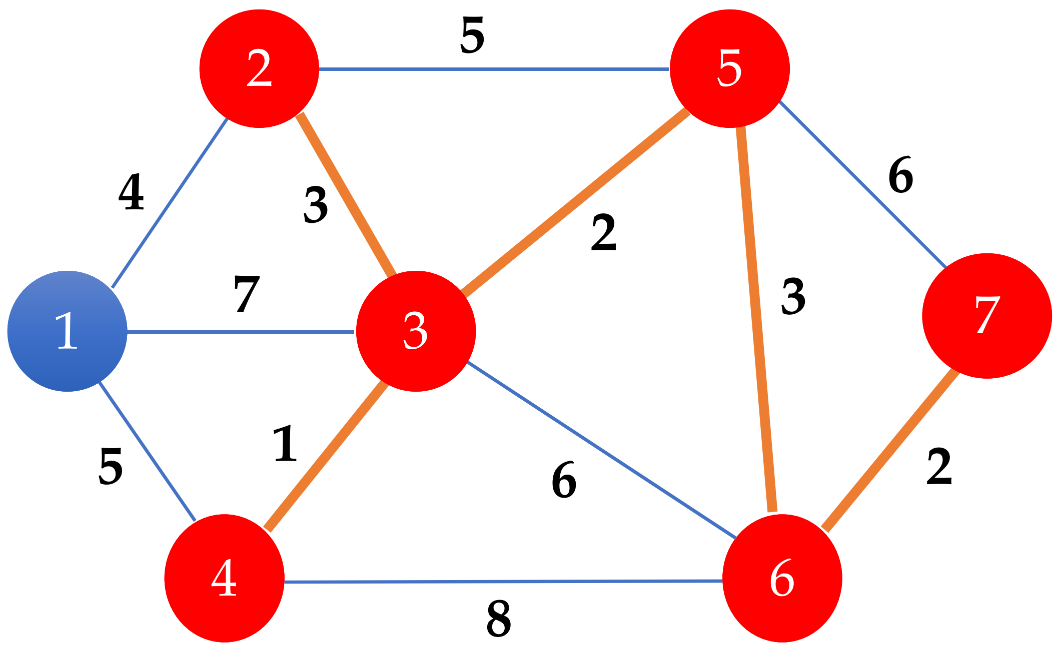
Minimal Spanning Tree Problem

- Link 7 to 6



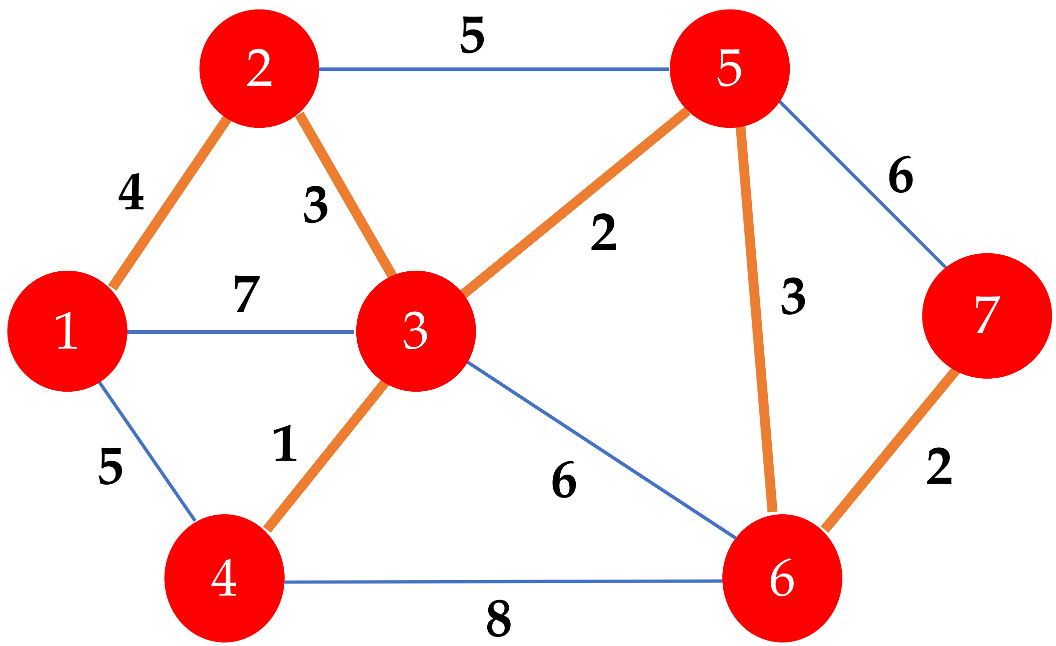
Minimal Spanning Tree Problem

- Link 2 to 3



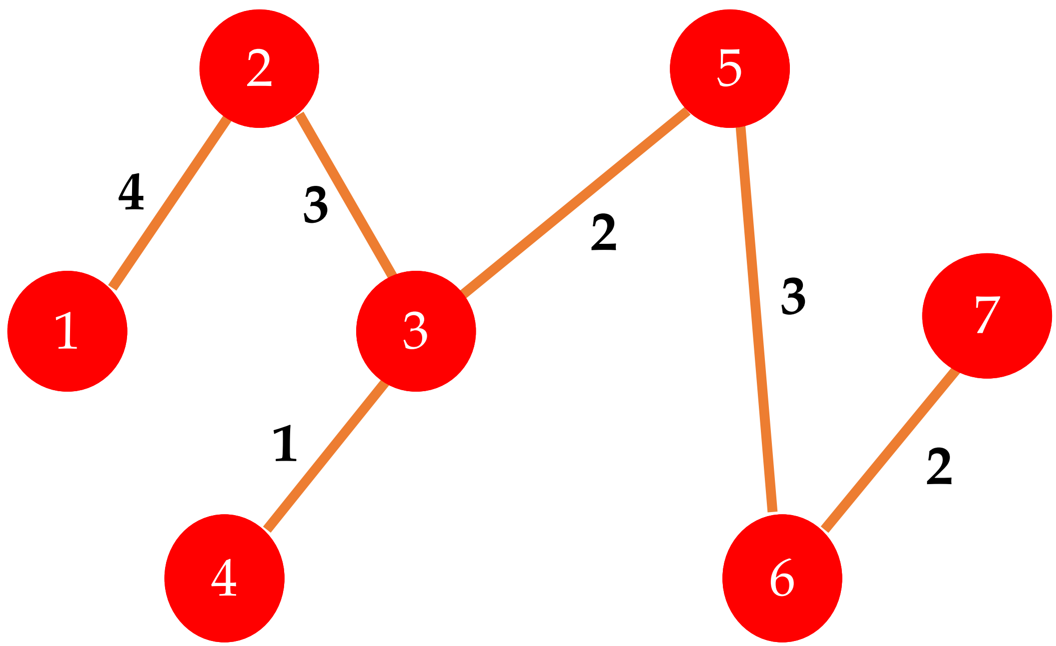
Minimal Spanning Tree Problem

- Link 1 to 2



Minimal Spanning Tree Problem

- The minimal Spanning Tree is shown with length (cost) = 15



Transportation and Assignment Problems

- **Transportation Problem**
  - Network Representation
  - General LP Formulation

- **Assignment Problem**
  - Network Representation
  - General LP Formulation

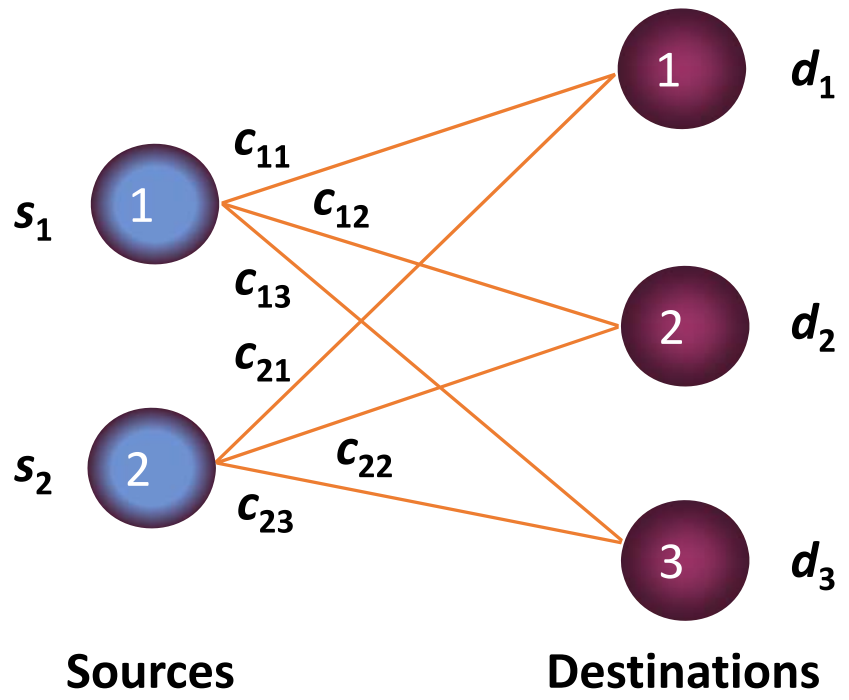
Transportation Problem

- The **Transportation Problem** seeks to minimize the total shipping costs of transporting goods from *m* origins (each with a supply s_i) to *n* destinations (each with a demand d_j), when the unit shipping cost from an origin, *i*, to a destination, *j*, is c_{ij}.

- The network representation for a transportation problem with two sources and three destinations is as follows.

Transportation Problem

- **Network Representation**



Transportation Problem

- **LP Formulation**

The LP formulation in terms of the amounts shipped from the origins to the destinations, x_{ij}, can be written as:

$$\text{Min} \quad \sum_i \sum_j c_{ij} x_{ij}$$

$$\text{s.t.} \quad \sum_j x_{ij} \leq s_i \qquad \text{for each origin } i$$

$$\sum_i x_{ij} = d_j \qquad \text{for each destination } j$$

$$x_{ij} \geq 0 \qquad \text{for all } i \text{ and } j$$

Illustration: Acme Block Co.

Acme Block Company has orders for 80 tons of concrete blocks at three suburban locations as follows:

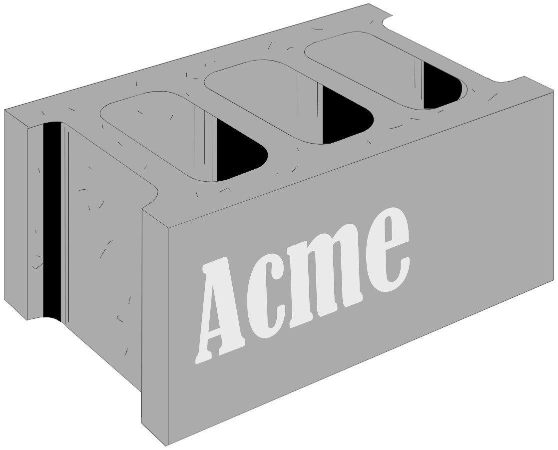
Northwood → 25 tons,

Westwood → 45 tons, and

Eastwood → 10 tons.

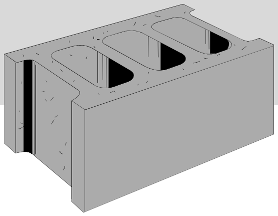
Acme has two plants, each of which can produce 50 tons per week.

Delivery cost per ton from each plant to each suburban location is shown on the next slide.



How should end of week shipments be made to fill the above orders?

Illustration: Acme Block Co.



Delivery Cost Per Ton

	Northwood	Westwood	Eastwood
Plant 1	24	30	40
Plant 2	30	40	42

Draw a network for this problem

Transportation Simplex Method:
A Special-Purpose Solution Procedure

Transportation Simplex Method

- A <u>transportation tableau</u> is given below. Each cell represents a shipping route (which is an arc on the network and a decision variable in the LP formulation), and the unit shipping costs are given in an upper right hand box in the cell.

	D1	D2	D3	Supply
S1	15	30	20	50
S2	30	40	35	30
Demand	25	45	10	

Transportation Simplex Method

- The transportation problem is solved in **two phases**:
  - Phase I – Finding an **Initial Feasible Solution**
  - Phase II – **Iterating** to the **optimal solution**
- In Phase I, the North West, Minimum-Cost Cell, Vogal's Approximation can be used to establish an initial feasible solution without doing numerous iterations of the simplex method.
- In Phase II, the Stepping Stone Method, using the MODI method for evaluating the reduced costs may be used to move from the initial feasible solution to the optimal one.

Transportation Simplex Method

- **Phase I – Vogal's Approximate Method**
  - **Step 1:** Form a table with all variables under consideration, rows for supply, and column for demand.
  - **Step 2:** Choose the next variable based on the Max-difference criteria in transportation cost.
  - **Step 3:** Allocate the needed quantities to use up the remaining supply or fill the needed demand at this step.
  - **Step 4:** Eliminate the row or column from further consideration (or both if they are mutually met).
  - **Step 5:** Repeat steps 2-4 till no more supply and demand exists.

Example 1: Acme Block Co.

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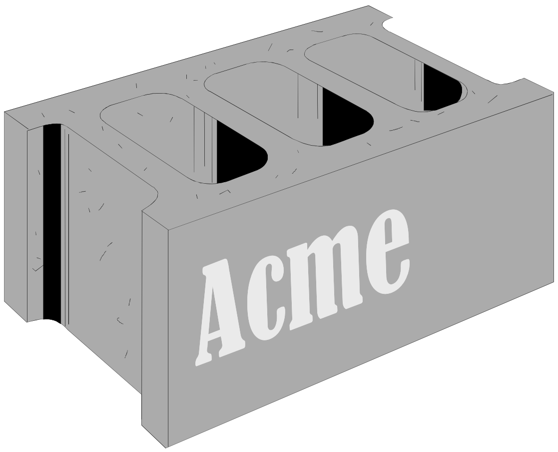

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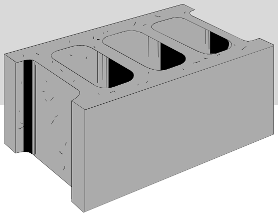

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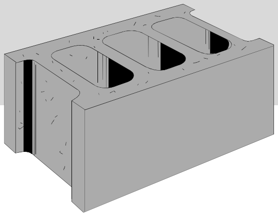
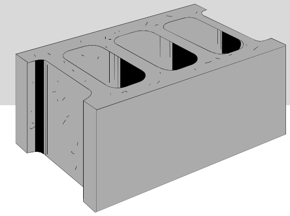


Initial Transportation Tableau

Since total supply = 100 and total demand = 80, a dummy destination is created with demand of 20 and 0 unit costs. (North-West Corner)

	Northwood	Westwood	Eastwood	Dummy	Supply
Plant 1	24	30	40	0	50
Plant 2	30	40	42	0	50
Demand	25	45	10	20	

Example 1: Acme Block Co.



Initial Transportation Tableau (Initial Feasible Solution)

Vogal's Approximation **Cost=________**

	Northwood	Westwood	Eastwood	Dummy	Supply
Plant 1	24	30	40	0	50
Plant 2	30	40	42	0	50
Demand	25	45	10	20	