Neeta Mishra (TGT)
Surendranath Centenary School
Ranchi, Jharkhand.

Topic: Coding for Social Good
Class: 8

Understanding Algorithms: Solving Real World Problems

The ambulance dilemma:
Rahul's friend, Rohan, met with an accident while playing football (Fig.1). Rahul immediately called the ambulance (Fig.2), but the traffic in the city was terrible. The ambulance was stuck in traffic, and Rohan's condition was worsening.

Figure-1: Rohan is playing football

The Problem:
The ambulance driver, Mr Kumar, knew every shortcut but the traffic was unpredictable. He needed a way to find the quickest route to the hospital.

Figure-2: Ambulance

Algorithm to the rescue:
Rahul's classmate, Ahana, had learnt about algorithms in school. She remembered the concept of the shortest path in algorithm. Ahana quickly:

1. Mapped the city's roads and traffic patterns.
2. Identified possible routes to hospital.
3. Applied algorithm to find the shortest path.

Solution:
Ahana's **algorithm** calculated the optimal route, avoiding congested areas. Mr Kumar followed the route, and the ambulance reached the hospital 15 minutes faster than expected time. Rohan received timely treatment and recovered.

So, let us first understand:

1.What is an algorithm?
Algorithm is a set of step-by-step instructions that describe how to perform a task.

Example 1: Your mother asks you to bring bread from the market. What will be your steps?

Figure-3: Bread

Step 1: Determine Bread Requirements

1. Decide on bread type (e.g., whole wheat, white, sourdough).
2. Choose bread quantity (e.g., one loaf, two loaves).
3. Consider additional features (e.g., gluten-free, organic).

Step 2: Locate a Bread Source

1. Find nearby bakeries, grocery stores or supermarkets
2. Check store hours and availability.
3. Optionally, search online for bread delivery services.

Step 3: Purchase Bread

1. Go to the selected store or website.

2. Select the desired bread type and quantity.
3. Pay for the bread (cash, card, or digital payment).
4. Receive the bread and verify its correctness.

Optional Steps

1. Check expiration date or freshness.
2. Consider purchasing additional items (e.g., spreads, cheese).
3. Provide feedback or rating (e.g., online review).

Now on the other hand, what do you think happens if you miss a step. (Activity- Think and answer)

Missing Step 1: Determine Bread Requirements

1. Incorrect bread purchase: Buying the wrong type or quantity of bread.
2. Wasted resources: Returning or disposing of unwanted bread.
3. Inconvenience: Needing to revisit the store or reorder online.

Missing Step 2: Locate a Bread Source

1. No bread availability: Stores may be closed or out of stock.
2. Increased travel time: Visiting multiple stores to find bread.
3. Higher costs: Purchasing from a more expensive store.

Missing Step 3: Purchase Bread

1. No bread purchased: Forgetting to complete the transaction.
2. Payment issues: Insufficient funds or incorrect payment method.
3. Bread not received: Failing to collect the bread.

Missing Optional Steps

1. Stale or expired bread: Not checking freshness or expiration dates.
2. Missing complementary items: Forgetting spreads, cheese, or other essentials.

So, we all agree that all steps are equally important to execute a task. Bread is just one item, but sometimes we need to visit different shops to buy multiple items.What strategy should we follow in such a scenario?

Now we will discuss different types of algorithms and how to use these to approach our problems optimally.

1. Prim's Algorithm
2. Kruskal's Algorithm

Below, we try to use each algorithm to calculate the path with the shortest distance covering all nodes.

Prim's Algorithm

Development

1. **(1930)** Czech mathematician Vojtěch Jarník first described the algorithm.
2. **(1957)** Robert C. Prim, an American computer scientist, independently developed and popularised the algorithm.
3. **(1959)** Prim published his work, "Shortest Connection Networks and Some Generalizations," in the Bell System Technical Journal.

Key Milestones

1**. 1960s:** Prim's algorithm became widely accepted and implemented in various fields.
2**. 1970s:** Algorithmic improvements and optimizations emerged.
3. **1980s:** Prim's algorithm was integrated into computer networks and telecommunications.
4. **1990s:** Applications expanded to transportation, logistics, and GIS.

Let us discuss basic terms used in this algorithm:

Graph: In Mathematics and Computer Science, a graph refers to a non - linear data structure consisting of the below key components:

1.**Nodes (Vertices):** We represent it as points or circles. We can say that these are the basic building blocks.
2.**Edges:** Lines connecting nodes representing relationship or connection.

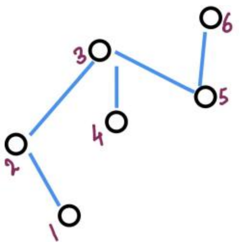
Types of Graphs:

1. Undirected Graph: Edges have no direction (arrows).
2. Directed Graph: Edges have direction (arrows)
3. Weighted Graph: Edges have weight or labels.
4. Unweighted Graph: Edges have no weights.
5. Cyclic Graph: Contains cycles (loops)
6. Acyclic Graph: No cycles.
7. Spanning Tree: It is a subgraph of a connected, undirected graph that connects all vertices, and no paths form any loops.

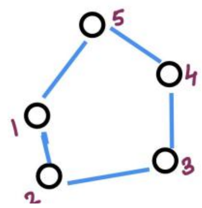
EXERCISE -1

Given here are some figures. Classify each of them on the basis of the following.

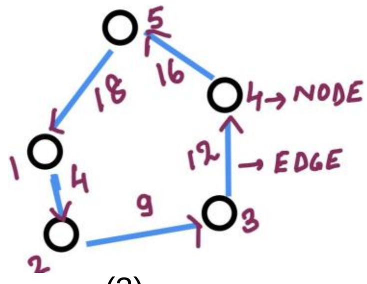
- Directed /Undirected graph
- Weighted/ Unweighted graph
- Cyclic/Acyclic Graph



(1)



(2)



(3)

Now, Prim's algorithm can be adapted to find the best traffic route of shortest distance. Here's how:

1.**Weighted graph**: Represent the traffic network as a weighted graph, where each edge's weight represents the distance or travel time between intersections.
2.**Starting Point:** Your location is the starting point (source node) and the hospital is the destination point (sink node) in the story at the start of the document.
3.**Edge selection**: Select edges with the shortest distance or travel time, considering traffic conditions.

You are all 21st century learners. You use Google maps in navigation, finding places, traffic and planning trips. Figure-4 shows a map with routes highlighting location and destination.

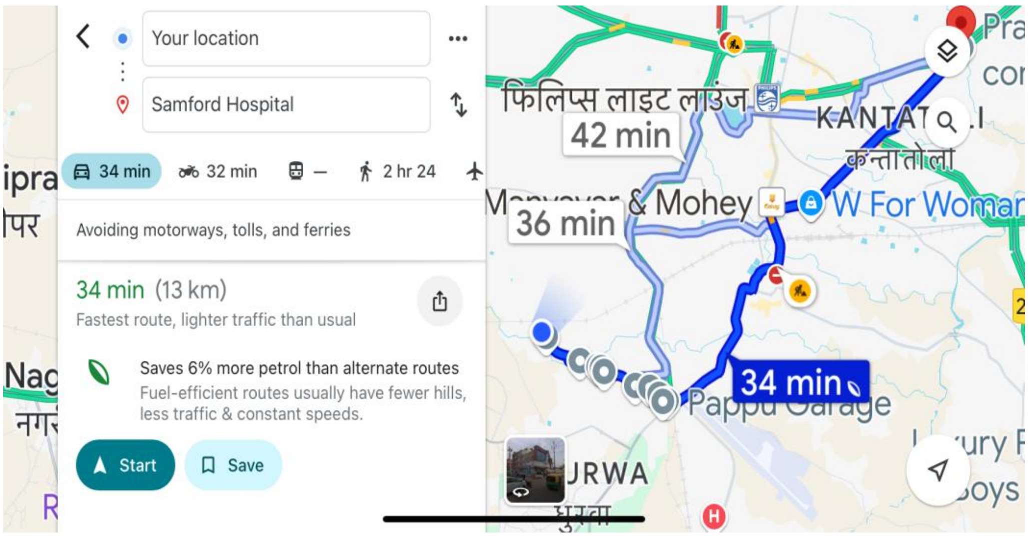
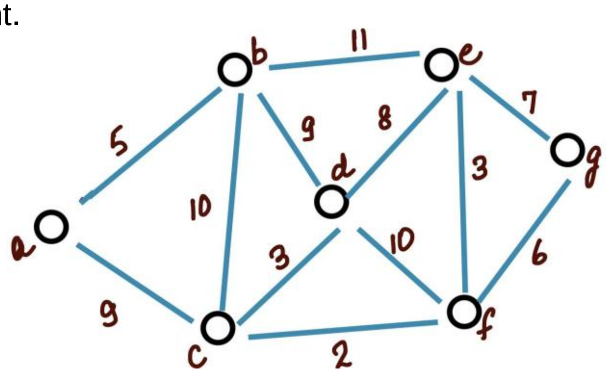
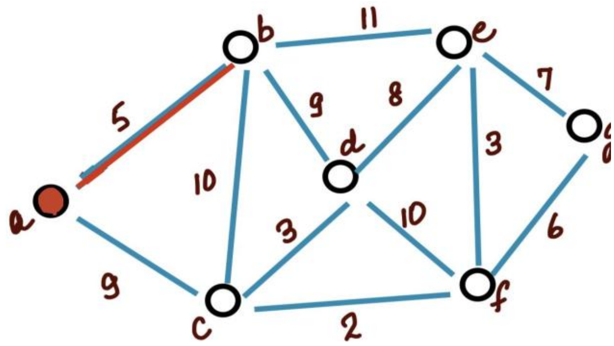


Figure-4

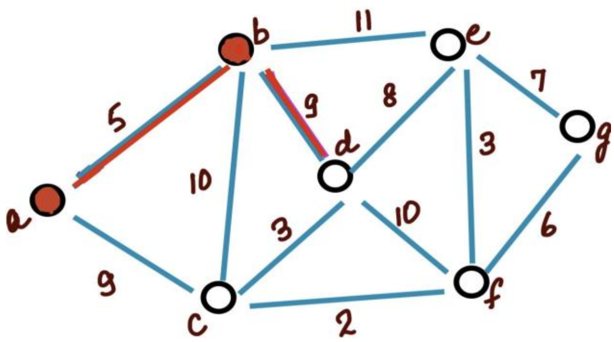
Let us take an example to calculate the shortest path where travel time in minutes is given and your location is at node (a) and you have to reach node (g) which is our destination point.



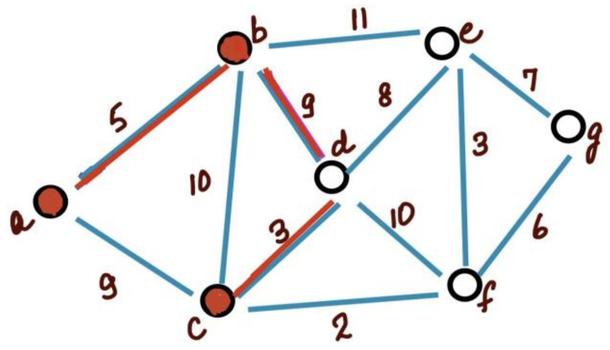
Step 1: a to b = 5 minutes and a to c = 9 minutes
Since, 5< 9
So, the route **(ab)** is followed with a minimum time of 5 minutes.



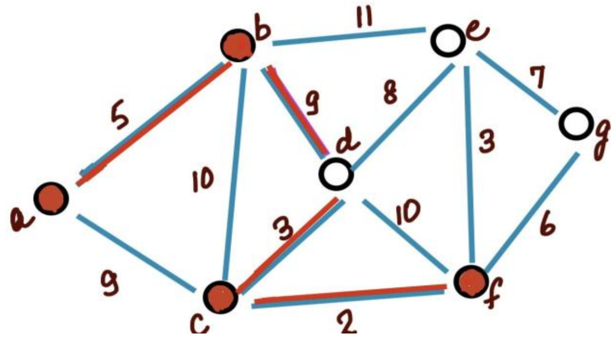
Step 2: b to c = 10 minutes, b to d = 9 minutes and b to e =11 minutes
9< 10 <11
So, the route **(bd)** followed with a minimum time of 9 minutes.



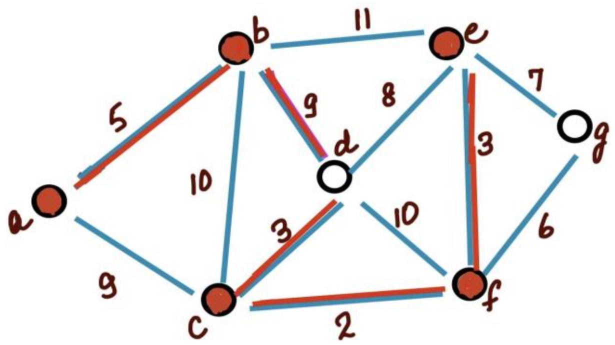
Step 3: d to c = 3 minutes, d to e = 8 minutes and d to f =10 minutes
3< 8 <10
So, the route **(dc)** followed with a minimum time of 3 minutes.



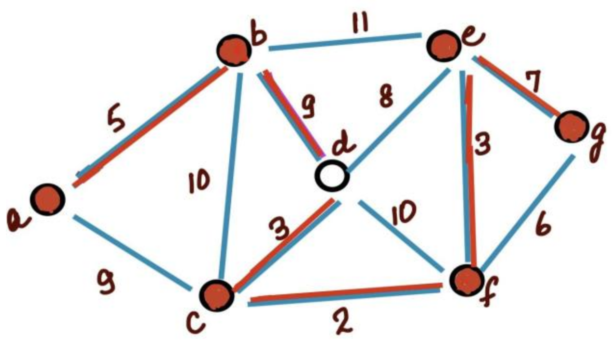
Step 4: c to f = 2 minutes



Step 5: f to e = 3 minutes, f to g = 6 minutes
3 < 6
So, the route **(fe)** followed with a minimum time of 3 minutes.



Step 6: e to g = 7 minutes



The route (abdcfeg) = 5+9+3+2+3+7=29 minutes is the shortest path covering all nodes.

YouTube link: Prim's algorithm

Limitations:

1. Assumes static traffic conditions
2. Does not account for dynamic traffic changes
3. Requires accurate traffic data

ACTIVITY-2

1.Take help of google map of your city, take at least 5 nodes and find the shortest route between 2 places. Suppose there is traffic congestion and road repair work too, then how do you adjust for these changes?

2.Your school bus has 10 bus stops, and the administration wants to minimise the total distance travelled. Use Prim's algorithm to optimise the route.

3.Rohan, a Class 8 student, lives in a residential colony with 7 neighbouring friends (A, B, C, D, E, F, and G). They want to create a network of pathways to visit each other's homes. The distances between their homes are given in the grid below.

	A	B	C	D	E	F	G
A	0	5	9	7	3	10	8
B		0	4	6	2	11	9
C			0	8	6	7	5
D				0	9	3	4
E					0	8	10
F						0	6
G							0

Find the shortest pathway network connecting all 7 friends’ homes using Prim's algorithm.

<u>Kruskal's Algorithm</u>

Development

1. **(1956)** Joseph Bernard Kruskal, an American mathematician and computer scientist, developed the algorithm.
2. **(1956)** Kruskal presented his work in a talk titled "On the Shortest Spanning Subtree of a Graph and the Travelling Salesman Problem" at the Sixth Summer Mathematics Symposium.
3. **(1956)** The algorithm was first published in the Proceedings of the American Mathematical Society.

Key Milestones

1. **1950s:** Kruskal's work built upon earlier research by:
* Alan Turing (1940s)
*Claude Shannon (1940s)
* Harold Kuhn (1950s)
2. **1960s:** Kruskal's algorithm gained popularity and was widely implemented.
3. **1970s:** Algorithmic improvements and optimizations emerged.

Kruskal's algorithm is an algorithm used to find the Minimum Spanning Tree (MST) of a connected, undirected, and weighted graph.

Steps

1. Sort edges: Sort all edges in ascending order of their weights.
2. Initialize MST: Create an empty Minimum Spanning Tree (MST).
3. Select edges: Iterate through the sorted edges. For each edge:
* If the edge connects two disjoint sets (i.e., no cycle forms), add it to the MST.
*Otherwise, discard the edge.
4. Union operation: When adding an edge, merge the two disjoint sets using the union operation.
5. Repeat: Continue selecting edges until all vertices are connected (i.e., MST is complete).

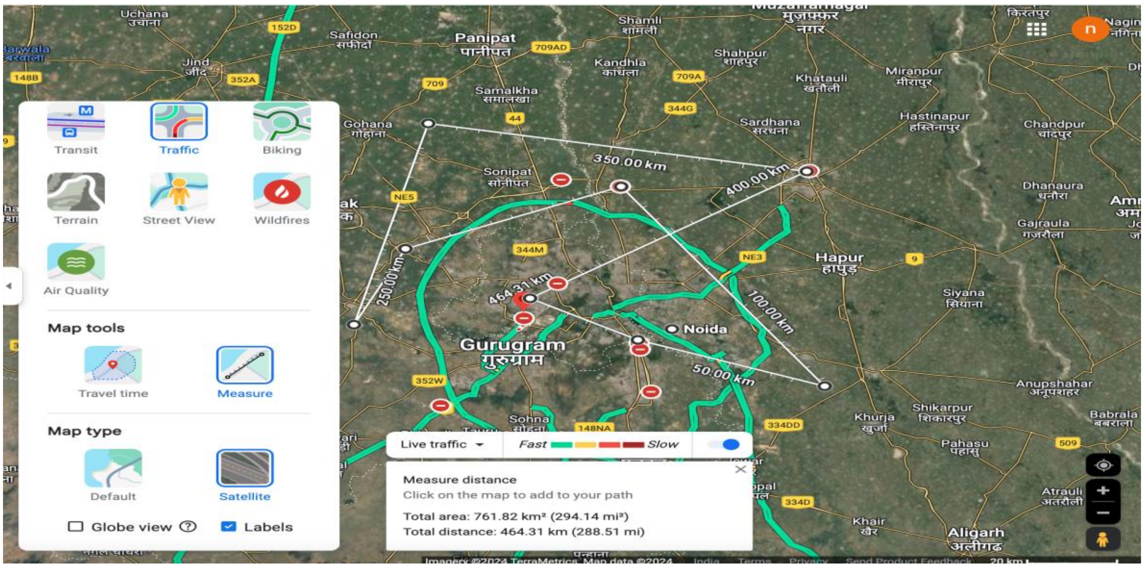
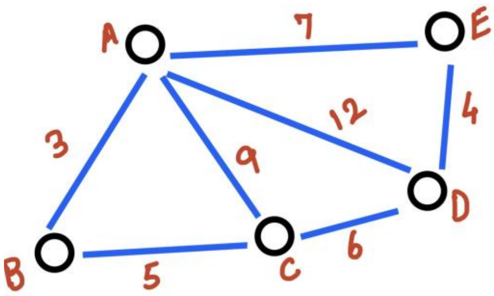


Figure-5: Google maps showing measure of distance

Steps to access the distance in google maps

1. Open google maps
2. Tap layers in top right
3. Tap measure to know the distance

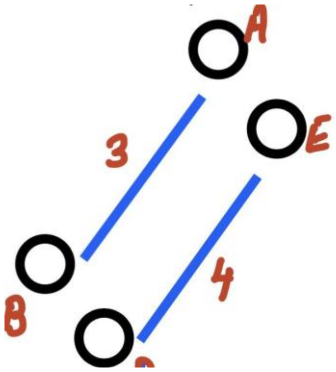
Now, we take an example and try to find the minimum total distance covering all nodes according to Kruskal's algorithm.



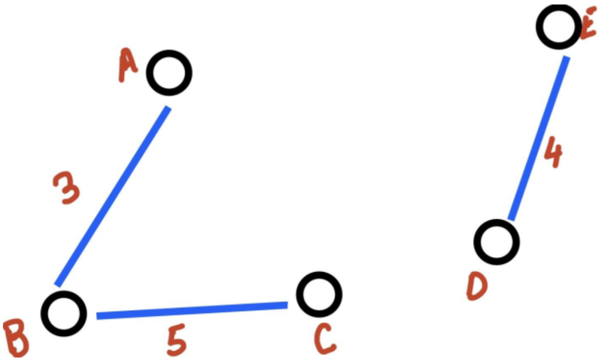
Step 1: We sort all edges

EDGE	WEIGHT
AB	3
DE	4
BC	5
CD	6
AE	7
AC	9
AD	12

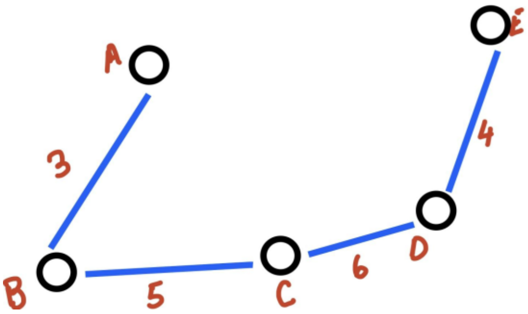
Step 2: The edge AB has minimum weight, so we add the edge AB and then we add the edge DE as we can see that it does not form a cycle.



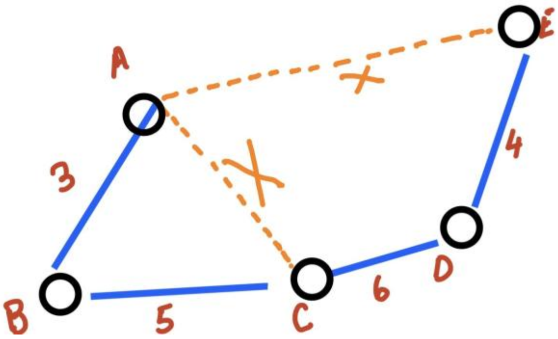
Step 3: Next edge is BC with weight 5, as it does not form a cycle.



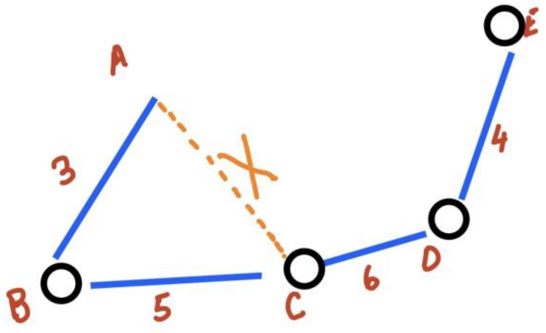
Step 4: Next edge is CD with weight 6, as it does not form a cycle.



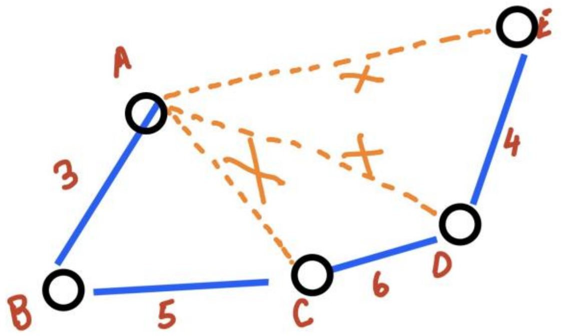
Step 5: Next edge is AE with weight 7, but it forms a cycle, so we will not include it.



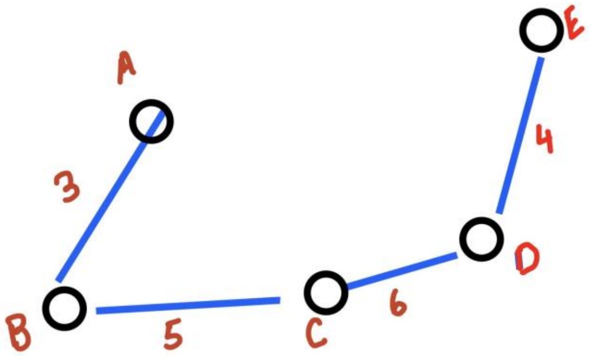
Step 6: Next edge is AC with weight 9, but it forms a cycle, so we will not take it.



7.Next edge is AD with weight 12, but it forms a cycle, so we will not take it.



8.The minimum spanning tree is (ABCDE) with weights 3 +5+6+4 = 18



YouTube link: [Kruskal's Algorithm]

Limitations:

1. Time consuming if the graph is dense.
2. Designed for undirected graphs.
3. Only edge weights are considered.

ACTIVITY-3

1. Riya’s school is planning a network of pathways connecting 7 buildings: Classroom Block (A), Library (B), Auditorium (C), Cafeteria (D), Sports Field (E), Science Lab (F), and Administration Block (G). The school wants to minimise construction costs. Distances between nodes are given in the table below:

	A	B	C	D	E	F	G
A	0	10	15	8	20	12	18
B		0	7	9	14	11	16
C			0	5	10	8	12
D				0	6	4	9
E					0	7	11
F						0	5
G							0

Use Kruskal's algorithm to find the shortest network of pathways connecting all 7 buildings.

2. Raj wants to buy groceries from three stores: Store A, Store B and Store C. She needs to minimise travel distance.

Distance Matrix

	A	B	C
A	0	5	7
B		0	3
C			0

Items to Buy

1. Store A: Milk, Bread
2. Store B: Eggs, Chicken
3. Store C: Vegetables, Fruits

Use Kruskal's algorithm to find the shortest route for Raj to buy all items.

Differences between Prim’s Algorithm and Kruskal’s Algorithm

Prim’s Algorithm	**Kruskal ‘s Algorithm**
1.Starts with a random node and grows the minimum spanning tree by adding edges.	Sort all edges by weight and adds them to the minimum spanning tree only if they don’t form a cycle.
2.Used for dense graph	Used for small graph as for dense graph it is time consuming in sorting all edges.

<u>Additional Real-life examples</u>

Infrastructure Development:

1. Road Network Design: Use Prim's or Kruskal's to optimise road connections between cities, minimising construction costs.
2. Telecommunication Networks: Design efficient fibre optic cable layouts connecting cities or buildings.
3. Water Supply Systems: Optimise pipe networks to distribute water across cities.

Transportation:

1. Delivery Route Optimization: Use Prim's or Kruskal's to find the shortest routes for delivery trucks.
2. Airline Route Planning: Optimise flight routes to minimise fuel consumption.
3. Public Transportation Systems: Design efficient bus or metro networks.

Computer Networks:

1. Internet Backbone Design: Optimise internet connectivity between servers.
2. Wireless Network Optimization: Improve wireless network coverage.
3. Data Centre Connectivity: Design efficient data centre networks.

Conclusion: Following an algorithm helps you plan, execute, and manage tasks efficiently.