4. a) Importance of Central Place Theory in Designing Transportation Network Planning

Central Place Theory (CPT), developed by Walter Christaller, is fundamental in transportation network planning because it explains how settlements of different sizes are spatially distributed and interrelated. It helps planners understand the hierarchy of urban centers and their service areas, guiding efficient transport linkages. By identifying central places (cities/towns) and their hinterlands, CPT aids in designing transportation networks that optimize connectivity and accessibility between these points. In Nepal’s context, where geographic constraints are significant, CPT assists in planning routes that link smaller towns with larger cities, ensuring essential goods and services flow efficiently. This theory supports regional development by encouraging balanced urban growth and preventing congestion in major hubs. Thus, CPT offers a strategic framework for developing transport infrastructure that aligns with settlement patterns, facilitating economic integration and accessibility across diverse terrains.

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4. a) Categories of Adopters in Roger's Diffusion of Innovation and Its Application in Nepal's Transport Network Planning

Roger's Diffusion of Innovation model categorizes adopters into Innovators, Early Adopters, Early Majority, Late Majority, and Laggards based on their readiness to adopt new ideas or technologies. In transportation planning, this model helps identify stakeholders’ acceptance levels of innovations such as new road designs, traffic management systems, or sustainable transport modes. In Nepal, understanding adopter categories aids in effectively implementing transport projects by targeting Innovators and Early Adopters like government agencies or urban populations to champion innovations. This accelerates diffusion to the broader population, including rural areas, fostering gradual modernization of transport networks. For example, introducing digital traffic management systems or electric vehicles requires phased acceptance; Roger’s model helps plan outreach and education accordingly. Ultimately, it supports tailored strategies ensuring smooth adoption of innovations, improving the efficiency, sustainability, and accessibility of Nepal’s transport infrastructure.

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4. b) Agropolitan Approach for Regional Development

The agropolitan approach integrates agriculture-based rural development with urban functions to create balanced regional growth. It promotes developing small towns as centers for agricultural processing, marketing, and services, enhancing rural livelihoods while preventing excessive urban migration. This approach encourages decentralization by linking rural production with urban consumption, improving infrastructure, education, and healthcare in smaller towns. For Nepal, where rural areas dominate and agriculture is primary livelihood, the agropolitan model offers a sustainable path to regional development. By improving connectivity and facilities in agropolitan centers, it enhances local economies, reduces pressure on large cities, and supports balanced spatial development. This fosters employment and reduces regional disparities. Thus, the agropolitan approach acts as a bridge between rural and urban sectors, promoting inclusive growth and reducing migration-related challenges.

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1. a) Territorial Approaches to Analyzing Rural-Urban Interface

Territorial approaches analyze the rural-urban interface by considering the spatial, economic, social, and functional relationships between rural and urban areas. This approach views the interface as a dynamic zone where rural and urban characteristics blend, influencing land use, economic activities, and social interactions. It emphasizes integrated planning, recognizing the interdependence of rural hinterlands and urban centers. For example, rural areas supply food, labor, and resources, while urban areas provide markets, services, and infrastructure. Territorial analysis helps identify zones of conflict or cooperation, guiding policies to manage urban sprawl, protect agricultural land, and ensure sustainable development. This holistic perspective supports balanced growth and regional cohesion by addressing infrastructure, transportation, and environmental challenges across rural-urban boundaries.

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2. a) Stages of Idealized Sequence of Transport Network Development in Planar Graphs

The idealized sequence of transport network development in planar graphs typically includes four stages:

1. **Tree Stage:** The simplest network where nodes are connected by minimum links without loops, resembling a tree. This is cost-effective but lacks redundancy.
2. **Star Stage:** A central node connects directly to all others, optimizing accessibility to the center but may cause congestion.
3. **Grid Stage:** Nodes are interconnected with multiple routes forming a grid, increasing redundancy and flexibility but also cost.
4. **Complete Network Stage:** Every node is connected to every other node, maximizing connectivity and redundancy but at very high cost.

This staged development helps planners prioritize cost-efficiency and accessibility while gradually improving network robustness.

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2. b) Major Factors of Migration

Major factors influencing migration include:

- **Economic Factors:** Employment opportunities, income differences, and poverty drive people to migrate seeking better livelihoods.
- **Social Factors:** Family reunification, education, and social networks encourage movement.
- **Environmental Factors:** Natural disasters, climate change, and land degradation push populations to relocate.
- **Political Factors:** Conflict, persecution, or policies may force migration.
- **Infrastructure and Accessibility:** Availability of transport and communication networks facilitates migration flows.

In Nepal, mountainous terrain, economic disparities, and infrastructure development heavily influence migration patterns, often from rural to urban centers.

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6. a) Role of National Highways in Developing Road Networks and Current Status in Nepal

National highways are the backbone of Nepal's road network, connecting major cities, economic centers, and border points. They facilitate movement of goods, services, and people, stimulating economic growth and integration. Highways enable access to remote areas, promote tourism, and support national security.

Currently, Nepal's national highway network covers key corridors like East-West Highway and North-South connections. Despite progress, challenges remain due to difficult terrain, maintenance issues, and seasonal disruptions. Ongoing projects aim to expand and upgrade highways, improving connectivity and reducing travel time, crucial for national development.

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6. b) Benefits of Rural Roads

Rural roads enhance accessibility to markets, healthcare, education, and social services, improving rural quality of life. They stimulate economic activities by reducing transport costs, facilitating agricultural marketing, and creating employment. Improved roads also support poverty reduction and social inclusion by connecting isolated communities. In Nepal, rural roads are vital for integrating mountainous villages with urban centers, promoting balanced regional development.

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7. a) Effect of Highway Construction on Migration in Nepal

The rapid growth of highway construction in Nepal since the 1950s significantly influenced migration patterns. Improved road connectivity facilitated easier movement of people from remote rural areas to urban centers for employment, education, and better living conditions. Highways enabled rural populations to access markets and services, sometimes encouraging temporary or permanent migration. Additionally, new highways opened previously isolated regions, stimulating economic development and urbanization along corridors. This contributed to the growth of towns and cities near highways. However, it also led to challenges like urban congestion and strain on infrastructure. Overall, highway construction played a crucial role in reshaping Nepal’s demographic and spatial structure by accelerating rural-urban migration.

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7. b) Short Note: Gravity Model

The Gravity Model in transportation predicts interaction between two places based on their population size and distance. It assumes that larger populations attract more travel demand, while greater distances reduce it. The formula is analogous to Newton’s law of gravitation, reflecting how “mass” (population) and “distance” influence movement of goods and people. It helps planners estimate traffic flows, demand, and design efficient transport networks.

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7. b) Short Note: Green Transportation Hierarchy

Green Transportation Hierarchy prioritizes transport modes based on environmental sustainability: walking and cycling rank highest, followed by public transit, carpooling, and lastly single-occupant vehicles. This hierarchy guides planning towards reducing emissions, congestion, and resource consumption, promoting healthier and eco-friendly mobility options.

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7. b) Short Note: Total Transportation Cost

Total transportation cost includes all expenses incurred in moving goods or people: vehicle operation, infrastructure maintenance, time costs, environmental impact, and accidents. Understanding these costs helps optimize transport systems for economic and social efficiency.

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3. a) Relation Between Mobility and Accessibility and Their Role in Transportation System Evaluation

Mobility refers to the ability to move or travel freely and efficiently, while accessibility means the ease of reaching desired services, destinations, or activities. Both are key indicators in evaluating transportation systems. High mobility ensures fast and flexible movement, but without accessibility, travel may not lead to meaningful destinations. Conversely, good accessibility means destinations are reachable, which can sometimes compensate for lower mobility. Evaluating transport systems requires balancing these parameters to meet user needs. For example, a system with high mobility but poor accessibility may not serve the public well. In Nepal, ensuring both is critical due to mountainous terrain and scattered settlements. Planning should enhance connectivity (mobility) and provide access to essential services like health, education, and markets (accessibility). Thus, mobility and accessibility together measure the effectiveness and equity of transport infrastructure and services.

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3. b) Transportation Externalities in Detail

Transportation externalities are the indirect effects of transport activities that affect third parties or society, often not reflected in user costs. These include negative externalities like air pollution, noise, traffic congestion, greenhouse gas emissions, road accidents, and habitat disruption.
Positive externalities include improved accessibility, economic growth, and social integration. In Nepal, transportation externalities are significant due to increasing vehicle use, urban congestion, and fragile ecosystems. Addressing these externalities requires policies promoting sustainable transport modes, emission controls, road safety measures, and environmental conservation.
Internalizing external costs through taxes, regulations, or incentives encourages responsible transport behavior and investments. Understanding transportation externalities is vital for creating balanced policies that maximize benefits while minimizing social and environmental harm.

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b) Define Alpha, Beta, and Gamma Indices and Their Interpretation

- **Alpha Index (α):** Measures network connectivity by comparing the number of actual loops to the maximum possible loops. It ranges from 0 (no loops) to 1 (fully connected).
- **Beta Index (β):** Ratio of the number of links to nodes, indicating network density and redundancy.
- **Gamma Index (γ):** Ratio of existing links to the maximum possible links in a planar network, reflecting connectivity.

Interpreting these indices helps assess network robustness and efficiency. Higher values indicate more alternative routes, better resilience, and capacity. For example, a gamma index close to 1 suggests a highly connected network, reducing congestion risk and improving accessibility.

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b) Phases of Transportation Network Development Based on Rimmer's Model

Rimmer's model outlines transportation network development in phases:

1. **Initial Phase:** Basic routes connecting primary centers with minimal infrastructure.
2. **Expansion Phase:** Network grows with new links to secondary centers and hinterlands.
3. **Consolidation Phase:** Improvement of existing routes for capacity and reliability.
4. **Maturation Phase:** Development of dense networks with multiple routes and modes.

In Nepal, these phases reflect gradual road and transport infrastructure growth responding to economic and social needs, constrained by terrain and resources.

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5. a) Components of Transportation Network with Sketch Explanation

A transportation network comprises three main components: **nodes**, **links**, and **terminals**.

- **Nodes** represent points where trips begin, end, or transfer — such as cities, towns, or transit hubs.
- **Links** are the connections (roads, railways, or paths) that allow movement between nodes.
- **Terminals** are special nodes where passengers or goods transfer modes, like bus stations or ports.

Together, these form a system allowing efficient movement of people and goods. A well- designed network balances accessibility, capacity, and redundancy. In Nepal, diverse terrain makes node-link planning critical, ensuring rural areas link efficiently to urban centers. Sketches typically show nodes as dots and links as lines connecting them, highlighting network density and connectivity.

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5. b) Explain Major Factors of Migration

Migration is influenced by multiple factors:

- **Economic:** Employment opportunities or poverty push/pull migrants.
- **Social:** Family ties, education, and social services attract people.
- **Political:** Conflicts or policies may force movement.
- **Environmental:** Natural disasters, climate change, or land degradation cause displacement.
- **Infrastructure:** Improved transport and communication networks enable easier migration.

In Nepal, rural-urban migration is largely driven by economic needs and improved highways, changing demographic patterns significantly.

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1. b) Territorial Approaches to Analyzing the Rural-Urban Interface

Territorial approaches examine rural-urban interfaces as interconnected spaces rather than isolated zones. They focus on functional, economic, and social interactions between rural hinterlands and urban centers, highlighting interdependencies. This perspective helps address challenges like urban sprawl, land-use conflicts, and resource management by integrating planning across boundaries. Territorial analysis considers factors such as commuting patterns, service flows, and agricultural land preservation. In Nepal, this approach is vital to balance rapid urban growth with protection of rural livelihoods, ensuring sustainable development that accommodates migration, infrastructure needs, and environmental conservation at the rural- urban boundary.

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4. b) Agropolitan Approach for Regional Development

The agropolitan approach integrates agriculture, small-scale industry, and urban services within a regional framework to promote balanced development. It focuses on developing small towns as service and processing centers for surrounding rural areas, reducing rural poverty and limiting migration to large cities. By improving infrastructure, education, and markets in agropolitan zones, it strengthens local economies and enhances rural-urban linkages. In Nepal, with its predominantly rural population and agricultural economy, this model offers a sustainable path to regional growth by connecting remote villages with urban opportunities, reducing regional disparities, and fostering inclusive development.

1. a) Network Resilience and Node Accessibility/Centrality

Network resilience refers to a transport network's ability to absorb disruptions and maintain connectivity. A resilient network ensures that nodes remain accessible even when links fail. Accessibility refers to how easily one can reach other locations from a node, while centrality indicates the node's importance within the network. A node with high centrality is critical; its failure may severely impact the system. Therefore, enhancing resilience often involves improving redundancy and ensuring that critical nodes maintain strong accessibility and backup links to prevent system-wide breakdowns.

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1. a) Agglomeration Economies and City Development

Agglomeration economies refer to the cost advantages businesses gain by locating near each other. These include shared infrastructure, labor pooling, and knowledge spillovers. Cities develop around such economic hubs, influencing their spatial and economic patterns. For example, Kathmandu's urban core attracts finance, tech, and service industries due to shared resources. This concentration boosts productivity and leads to urban expansion. However, excessive agglomeration can cause congestion, high living costs, and environmental stress, requiring balanced spatial planning.

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2. b) Internal Structure of Cities
Three urban models generalize city structure:

- **Concentric Zone Model**: Cities grow in rings—central business district (CBD), transitional zone, working-class area, suburbs.
- **Sector Model**: Growth occurs along transport corridors in sectors from CBD outward.
- **Multiple Nuclei Model**: Cities develop around several nodes (e.g., commercial, industrial, residential).
  Sketches show spatial variation of land use. Kathmandu exhibits a hybrid form, with older concentric cores, sector-based development along roads, and nuclei like Baneshwor or Kalanki as commercial sub-centers.

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3. a) Economic, Transport & Commercial Geography
Economic geography studies resource distribution and economic activity spatial patterns. Transport geography analyzes movement of people and goods across space. Commercial geography focuses on trade flows and business locations. These are interdependent—transport geography links producers and consumers, shaping economic geography. In Nepal, rugged terrain influences transport routes, impacting trade and settlement patterns. Integrated understanding helps plan efficient transport and economic systems, supporting regional growth and connectivity.

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3. b) Efficiency vs. Synergy Goals in City Networks
Efficiency goals aim to optimize resource use, minimizing travel time, cost, or energy. Synergy goals emphasize collaboration among cities to share resources, enhance innovation, and improve collective outcomes. Both promote connectivity but differ in focus—efficiency is internal (individual city optimization), synergy is external (regional cooperation). In Nepal, improving road links between cities like Pokhara and Kathmandu enhances both efficiency (faster travel) and synergy (joint tourism or trade development), supporting regional development strategies.

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4. a) Economic Dynamism and Urban-Rural Differentiation
Dynamic economies show faster change in employment, technology, and services, leading to urban expansion and modernization. Rural areas, with slower economic change, often remain agriculture-based. In Nepal, cities like Kathmandu attract investment and skilled labor, while rural areas lag in infrastructure and innovation. This spatial differentiation shapes migration, land use, and service delivery. Understanding economic dynamism helps target rural development to reduce disparities and encourage balanced growth.

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4. b) Functional Integration vs. Location-Allocation Approaches
Functional integration focuses on aligning urban services with rural needs, emphasizing coordination (e.g., regional health or education centers). **Location-allocation** uses mathematical models to optimize the placement of facilities to serve rural areas effectively (e.g., placing a market within reach of multiple villages). While functional integration supports long-term planning, location-allocation is more quantitative and specific. Both help bring services to rural Nepal but must consider terrain, culture, and mobility constraints.

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5. a) Transport Principle in Central Place Theory (CPT) and Rule of Four
The transport principle in CPT emphasizes locating central places to minimize total transportation costs. It arranges markets along major routes forming a k=4 hexagonal hierarchy. The "Rule of Four" means each central place serves four surrounding centers. It optimizes efficiency in delivering goods/services. In Nepal, highway-aligned towns like Hetauda exemplify this principle, providing central functions to nearby rural areas. However, geography and socio- political factors may distort ideal patterns.

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5. b) Cooperative Farming and Peri-Urban Areas
Cooperative farming involves collective agricultural production and resource sharing. In Nepal's peri-urban areas, such as outskirts of Pokhara or Chitwan, farmers collaborate to boost yields and access urban markets. These zones benefit from both urban infrastructure and rural land availability. Cooperative farming supports commercialization, improves income, and sustains food supply for cities. It strengthens rural-urban linkages, reduces rural poverty, and promotes sustainable land use in growing urban fringes.

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6. Minimum Spanning Tree (MST) – Kruskal's and Prim's Algorithm
Using **Kruskal's Algorithm**, we sort edges by weight and add shortest non-cyclic links until all nodes are connected.
Prim's Algorithm starts from a node, adds the nearest neighbor not yet in the tree, repeating until complete.
Both yield the MST but differ in process.
In transport studies, MST helps design minimum-cost road networks (e.g., rural road expansion).
MST is efficient but doesn't consider demand, terrain, or traffic, limiting practical application without supplementary models.

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7. Short Notes (any two):

a) Weber's Least Cost Theory
This theory locates industries where transport, labor, and agglomeration costs are minimized. It

assumes rational decision-making and equal terrain. It’s useful in site selection but less accurate in uneven or politically constrained landscapes like Nepal.

b) Features of Rural (Low Density) Economy

Rural economies are resource-based, labor-intensive, and have limited infrastructure. They depend on agriculture, forestry, and livestock. Limited market access and services often hinder growth. However, they also preserve cultural identity and ecological balance.

1. a. Graphical Network and Indices (Alpha, Beta, Gamma):
Using the given road network in Table-1, a graphical representation (node-link diagram) should be plotted with nodes connected as per tabulated links. From this graph:

- **Beta Index (β)** = e/v; where e = number of edges, v = number of vertices (nodes). It indicates average connectivity.
- **Gamma Index (γ)** = e / (3(v−2)) × 100; shows the ratio of actual connections to the maximum possible in a planar graph.
- **Alpha Index (α)** = (e−v+1)/(2v−5) × 100; measures number of circuits/loops compared to maximum possible.
  Interpretation:
- Higher values of these indices indicate more robust and connected networks.
- If α = 0, network is a tree. If γ = 100%, network is maximally connected. These indices help assess resilience and redundancy of the transport network.

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2. a. Mobility vs Accessibility:
Mobility refers to the ability to move people or goods from one place to another, typically measured by speed and travel time. Accessibility, on the other hand, indicates how easily people can reach desired services, destinations, or opportunities. While mobility focuses on movement, accessibility centers on the ease of reaching specific goals. High mobility does not always guarantee high accessibility. For example, a high-speed road might bypass towns, reducing access despite increased speed. In transport planning, both concepts are vital. Accessibility ensures inclusiveness and land-use integration, while mobility focuses on efficient movement.
Balanced planning combines both to ensure effective service delivery and urban functionality.

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2. b. Garden City-Based Network for Dang-Deukhuri (like Canberra):
Applying Garden City Theory, the capital city of Dang-Deukhuri can be planned with a radial-concentric transport network. The core includes administrative buildings and civic centers.
Around this, green belts and residential zones are arranged with roads radiating outward and linked by concentric rings. Key features include:

- Main arterial roads connecting city center to provincial and national highways.
- Public transport terminals placed along main radial routes.
- Green buffers between zones to control sprawl.
- Separate pathways for pedestrians and bicycles.
  The network ensures efficiency, environmental harmony, and aesthetic design—replicating Canberra's decentralized structure with centralized accessibility.

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3. a.

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3. b. Accessibility Analysis and Most Accessible Node (from Table-1):
Accessibility of a node can be measured using:

- **Degree of Node**: Number of direct connections to other nodes.
- **Valued Graph or L-Matrix**: Summing the weights (lengths or costs) of links connected to a node.
  Node with the highest degree or lowest total cost in the L-matrix is the most accessible.
  From Table-1, Node 2, with degree = 4 and highest summed connection value, emerges as most accessible.
  Such analysis helps identify central hubs for public transport terminals or logistics centers, aiding planners in optimizing network efficiency and service delivery.

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4. a. Transport Network Development by TMG Model:

The **Transport Morphogenetic Growth (TMG) Model** explains how transport networks evolve over time influenced by land use, economic activity, and population density. Initially, networks grow linearly along major corridors (spine model). With urban expansion, they become grid-like or radial as accessibility needs increase. The model integrates feedback loops where transport infrastructure stimulates land use, which in turn influences further transport development. In Nepal, highways like East-West Highway followed linear growth, while cities like Kathmandu now show more nodal and complex networks. TMG helps in predicting future development patterns and planning infrastructure accordingly.

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4. b. Von Thunen’s Urban Land Use Theory:

Von Thunen’s theory, developed in 1826, explains land use in concentric rings around a central market based on transportation cost and perishability of products. The city center is surrounded by rings of farming:

1. Dairy and vegetables (closest due to perishability)
2. Forest (fuel)
3. Grains

4. Ranching (farthest due to low perishability)
   Sketch: ○Center →☐☐→🌲→🌾→🐄
   In urban contexts, this model helps explain urban sprawl, zoning, and transportation costs. Its assumptions (uniform land, market access) are idealized, but it remains foundational for understanding land value and accessibility in transport planning.

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5. a. Importance of SRN in Nepal's Economy:
Nepal's **Strategic Road Network (SRN)** includes national highways, feeder roads, and border corridors, forming the backbone of economic and regional integration. SRN enables:

- Inter-provincial connectivity
- Access to markets, health, and education
- Facilitation of trade through border linkages
- Disaster relief and security movement
  Over 80% of freight and passenger traffic uses SRN. Projects like Postal Highway and Mid-Hill Highway enhance accessibility in remote regions, directly supporting agriculture, tourism, and industries. Thus, SRN is essential for inclusive development, national unity, and economic resilience.

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5. b. Tunnel Roads vs Normal Roads – Justification in Nepal:
Though tunnel construction costs are significantly higher, they are justified in Nepal due to:

- **Geographic constraints**: Steep mountains limit traditional road development.
- **Time and distance savings**: Tunnels drastically reduce travel time and fuel costs.
- **Weather resistance**: Unlike mountain roads, tunnels are less prone to landslides and blockages.
- **Environmental protection**: Tunnels minimize deforestation and ecosystem disruption. Projects like **Nagdhunga-Naubise Tunnel** show cost-benefit efficiency over time. Thus, for mountainous regions, tunnel roads offer long-term economic, safety, and environmental advantages.

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5. c. Evaluation of Intercity Modes in Nepal (Airways, Roadways):
Mobility: Roadways provide flexible point-to-point service across Nepal. Airways offer fast inter-city mobility, especially for remote or time-sensitive travel.
Accessibility: Roadways reach deeper into rural areas. Airways are limited to cities with airports.
Efficiency: Airways are faster but costly and infrastructure-dependent. Roadways are cost-effective for freight and regular travel.
Integration of both modes improves redundancy, disaster resilience, and economic efficiency. A

multimodal strategy combining roads for short-haul and airways for long-haul ensures balanced national connectivity.

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6. a. Core-Periphery Model by John Friedmann (1966):
The Core-Periphery model explains spatial economic disparities. The **core** has concentrated wealth, infrastructure, services, and influence, while the **periphery** remains less developed. According to Friedmann:

- Development begins at the core.
- Growth radiates to nearby areas via linkages.
- Periphery lags behind unless integrated by infrastructure and policy.
  In Nepal, Kathmandu acts as a core, with better roads, education, and healthcare. The model promotes development of regional centers (secondary cores) and better transport linkages to reduce disparity. It guides transport planners in balanced growth strategies.

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6. b. Historical Development of Rural Roads in Nepal:
Rural road development in Nepal began intensively after the 1970s, with programs like **Rapti Doon Integrated Development Project** and **Rural Access Programme (RAP)**. Earlier, trails and mule tracks served remote regions. Post-1990, decentralization enabled local governments to build earthen roads. With donor support (ADB, DFID), rural roads expanded to support agriculture, health, and education. The GoN's **Rural Transport Policy** and **Local Infrastructure Development** frameworks now focus on climate-resilient, inclusive, and economically viable rural networks.

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6. c. Rural Roads for Poverty Alleviation:
Rural roads enhance access to markets, schools, and hospitals, directly impacting livelihoods. In Nepal, improved rural connectivity has:

- Increased agricultural income by reducing transport costs.
- Enabled school attendance and healthcare access.
- Promoted local employment during construction.
  Donor-funded programs like RAP have demonstrated measurable reductions in poverty through rural road projects. Roads serve as a catalyst for inclusive growth, market integration, and social development.

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7. a. Bid Rent Theory:
Bid Rent Theory explains how land value changes with distance from a central point (CBD). Commercial users bid highest for central locations due to high foot traffic, while residential and

industrial users prefer outskirts due to lower rent. It informs urban zoning and transport planning, predicting land use patterns based on accessibility.

7. b. Roger's Model of Diffusion of Innovation:
This model categorizes adopters of new innovations into innovators, early adopters, early majority, late majority, and laggards. In transport planning, it helps predict how new systems (e.g., metro, EVs) will be accepted by the public and guides phased implementation.

7. c. Gateways in Nepal:
Gateways are strategic points for entry and exit—Nepal's key gateways include border towns like Birgunj, Bhairahawa, and Kakarbhitta. These serve as trade and transit hubs connecting Nepal to India and China, vital for imports, exports, and regional cooperation.

1a.

1b. Diagram: Relationship between Mobility and Accessibility
Mobility refers to the ability to move people and goods, while accessibility indicates the ease of reaching destinations.

- **Highways**: High mobility, low accessibility (e.g., long-distance travel, few entry points).
- **Arterial Roads**: Moderate mobility and accessibility (connect cities and towns).
- **Local Roads**: High accessibility, low mobility (serve residential or rural areas).
  Sketch Description:
  Draw three horizontal lanes:

1. Top lane (Highways) – few large access points.
2. Middle lane (Arterials) – more entry points than highways.

3. Bottom lane (Locals) – dense intersections and short links.
   Label Y-axis as **Mobility** (high to low), X-axis as **Accessibility** (low to high). Plot a curve sloping down from left to right indicating inverse relation.
   This visualization aids transport planners in designing balanced networks optimizing both criteria.

2a. Garden City Theory Based Network

As a transport planner, applying Garden City Theory involves designing a transportation network that integrates green spaces, satellite towns, and central hubs in a balanced, self-contained manner. The city center is surrounded by radial roads leading to satellite towns with green belts separating each zone. A ring road links these towns, ensuring circular mobility. Local roads and footpaths encourage non-motorized transport, while arterial roads support public transit and controlled vehicular flow. Public transport hubs are placed at junctions to enhance interconnectivity. The core principle is decentralization, reducing urban congestion by distributing services and population evenly. This model is ideal for Nepal's mid-hills and plains, promoting ecological sustainability and ease of access. Sketch includes central node (CBD), green buffers, radial roads to sub-centers, and ring roads. It reflects Ebenezer Howard's idea of a harmonious blend between town and country, supporting efficient, environmentally conscious transport planning and livability.

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3a.

3b. Bid Rent Theory

Bid Rent Theory explains how land values and land use patterns vary based on distance from the central business district (CBD). Land users compete by offering rent depending on accessibility. Commercial users pay the most to access customers centrally, followed by industrial users, then residential. As distance increases, accessibility decreases, and rent value drops. This leads to concentric land use zoning. The theory helps planners understand urban density and transportation demand. In Nepal, cities like Kathmandu show this pattern—commercial centers are denser and more expensive. Bid Rent Theory supports transit-oriented development and decentralization by integrating land use with transportation corridors. It encourages planners to invest in public transport to raise accessibility and reduce sprawl.

4a. Von Thünen's Urban Land Use Theory

Von Thünen proposed concentric land use zones surrounding a central market city to minimize transportation cost. The ideal layout includes:

1. Central City
2. Perishable goods (dairy, vegetables)
3. Forest (timber, fuel)
4. Animal ranching
5. Grain farming
   Each zone reflects the balance between transport cost, perishability, and land rent. Perishable products locate close to markets; durable goods are farther away.
   In Nepal, this can be applied in planning mid-hill towns like Hetauda or Tansen. Vegetables and dairy farms are typically found near urban cores; grains and livestock zones are in outer belts. By applying this model, local planners can reduce travel time and fuel costs, enhance market efficiency, and ensure sustainable land use. Though simplified, it's

effective for framing spatial planning in agriculturally-driven economies like Nepal.

4b. Hexagonal vs Circular Settlement Arrangement (Central Place Theory)

Central Place Theory advocates hexagonal arrangements over circular ones for service centers. A circular layout leads to overlapping or uncovered zones, causing inefficiencies. Hexagons tile seamlessly, covering areas uniformly and minimizing redundancy.
Sketch:

- **Hexagon:** One central place, six equally spaced surrounding nodes.
- **Circle:** Multiple overlapping circular zones with gaps.
  Advantages of hexagons include:
- Uniform service reach
- Equal travel distances
- Better regional planning
  In Nepal's hilly and Terai regions, such layouts help design school locations, health centers, and administrative hubs. For example, planning markets or road networks in Karnali Province using hexagonal logic ensures equal access and resource efficiency. This geometric insight enhances the spatial effectiveness of public investment and reduces service duplication.

5a. Strategic Road Network (SRN) in Nepal

Nepal's Strategic Road Network (SRN) includes highways and major feeder roads that form the backbone of national mobility and development. It supports internal trade, national integration, tourism, and disaster response. The SRN includes East-West Highway, Mid-Hill Highway, and North-South corridors linking Indian and Chinese borders.
It connects Kathmandu, Pokhara, Birgunj, and border customs points. In a country with rugged topography, SRN ensures access to remote areas and promotes socio-economic growth.
For example, the Koshi and Kaligandaki corridors improve rural access and agricultural market linkages. SRN also supports emergency logistics during floods or earthquakes. Expanding and maintaining SRN is essential for reducing poverty, fostering regional equity, and strengthening Nepal's competitiveness in regional trade.

5b. Evaluation of Airways vs Highways in Nepal

Mobility: Airways provide faster mobility across long distances, ideal for Nepal's mountains and remote districts. Highways are slower but serve more users.
Accessibility: Highways reach more destinations, including rural areas. Airports serve fewer cities due to infrastructure limits.
Efficiency: Airways are costlier per passenger but crucial in high terrain zones (e.g., Lukla, Jomsom). Highways handle more freight and daily movement.
Combined use enhances resilience and redundancy in Nepal's transport system. For example, Kathmandu–Pokhara is connected by air for tourism and road for mass travel. Future plans must support multi-modal networks to boost efficiency and coverage.

6a. Core-Periphery Linkage Model (Friedmann, 1966)

Friedmann’s Core-Periphery Model explains regional inequality where development begins in a “core” (e.g., Kathmandu Valley) with access to capital, labor, and infrastructure. The “periphery” (e.g., Karnali or Sudurpashchim) lags due to isolation and fewer resources.
Over time, development diffuses from the core to the periphery through investment, migration, and improved transport links.
In Nepal, roads like the Mid-Hill and North-South Corridors exemplify this diffusion. Connecting remote areas enables market access, service delivery, and inclusive growth. Planners must focus on equitable investment to balance development. Core-periphery dynamics highlight the need for targeted interventions in lagging regions to reduce disparities.

7b. Historical Development of Rural Roads in Nepal

Nepal’s rural road development began with foot trails and mule tracks before the 1960s. The first mechanized road-building efforts came in the 1970s through donor projects like the World Bank’s Hill Transport Project.
In the 1980s and 1990s, decentralization enabled District Development Committees (DDCs) to develop feeder roads. After 2000, the Local Governance and Community Development Programme (LGCDP) and Rural Transport Infrastructure (RTI) programs expanded rural networks.
Today, rural road length exceeds 60,000 km. Despite progress, challenges like poor quality, monsoon damage, and lack of maintenance remain.
Well-designed rural roads reduce poverty, improve access to schools and health services, and boost agricultural trade, especially in the hills and Terai.

8a. TMG Model for Road Network Development

The Transportation Master Grid (TMG) model helps design hierarchical road systems. It classifies roads into expressways, arterials, collectors, and locals for orderly expansion.
TMG integrates transport with land use and socio-economic goals. It provides modular planning that allows flexibility for future growth.
In Nepal, TMG supports cities like Kathmandu, Butwal, and Bharatpur in planning new corridors, minimizing congestion, and integrating bus and non-motorized travel lanes.
It guides strategic investment and sustainable growth. For example, designing a smart city using TMG ensures efficient allocation of space, traffic distribution, and service accessibility.

8b. Rogers' Model of Diffusion of Innovation

Rogers' model divides adopters into five categories:

1. Innovators
2. Early adopters
3. Early majority
4. Late majority
5. Laggards
   The model tracks how innovations spread. In transportation, it helps understand how new technologies—like e-ticketing, EV buses, or ITS—are adopted in Nepal.
   Innovators may include Kathmandu's public operators, while rural areas might fall under late majority or laggards.
   Understanding this helps plan rollouts, training, and incentives. For example, electric vehicle adoption in Lalitpur shows early adoption, requiring targeted policies to expand elsewhere.

8c. Gateways in Nepal

Nepal's transport gateways connect it to global and regional trade networks. Major gateways include:

- **Birgunj (Simara)**: Main trade route with India, linked to Raxaul rail.
- **Bhairahawa (Siddharthanagar)**: Border town and industrial hub.
- **Kodari & Rasuwa**: Connect Nepal to China's Tibet.
- **Tribhuvan International Airport**: Main air entry for passengers and cargo.
- **Pokhara & Lumbini Airports**: Boost tourism and regional connectivity.
  Gateways facilitate import-export, improve accessibility, and support tourism. Their development is crucial for Nepal's economic integration and resilience, especially under federal structure and cross-border agreements.

1a. Microscopic Perspective of Evolution of Transport Network (with Nepal example):
The microscopic perspective of transport network evolution emphasizes individual-level

decisions, such as route choices, land access, and economic activity patterns, that collectively shape the broader network. These small-scale interactions often result in self-organizing systems, where transport networks evolve over time due to user demand, accessibility needs, and feedback loops. In Nepal, a suitable example is the road development from Mugling to Narayanghat.
Initially a narrow track, it was upgraded as settlements, trade hubs, and vehicle usage increased. The route evolved to a highway as local mobility demands accumulated. This gradual transition shows how micro-level accessibility needs and settlement growth stimulated infrastructural investment, reflecting a bottom-up evolution of transport networks. Such perspectives help understand non-linear growth and inform policies based on dynamic user behavior and spatial interactions.

1b. Alpha, Beta, and Gamma Indices of Network Connectivity:
Alpha, Beta, and Gamma indices are graph-theoretical tools to measure the connectivity of transport networks.

- **Beta Index (β)** = e/v, where *e* = edges, *v* = vertices. It indicates the average number of links per node.
- **Gamma Index (γ)** = e/3(v−2), expressing connectivity as a percentage of the maximum possible edges in a planar graph.
- **Alpha Index (α)** = (e − v + 1)/2v − 5, which measures the number of actual cycles compared to maximum possible, showing network redundancy.
  Comparatively, the Beta index offers a basic idea of complexity; Gamma provides relative connectivity; and Alpha highlights redundancy and robustness. For instance, a high Gamma with a low Alpha suggests connectivity without alternative routes. In planning, combining all three provides a robust picture of network efficiency and resilience.

2a. Provisions for Road Transport Sector in Nepal's National Transport Policy:
The National Transport Policy of Nepal aims to develop a safe, accessible, economical, and sustainable transport system. For the road transport sector, the policy prioritizes expansion of road networks connecting remote, rural, and border areas to promote inclusivity and economic

growth. It emphasizes the development of all-weather roads, maintenance systems, and strategic road corridors to integrate national and international markets. The policy promotes public-private partnerships (PPP) for infrastructure financing and encourages environmentally friendly technologies in road construction and transport operations. Special attention is given to road safety measures, including awareness programs, enforcement, and blackspot improvement.
Moreover, institutional reforms and capacity building are highlighted to enhance service delivery and planning efficiency. The integration of transport with land use planning is also a key provision. These measures collectively aim to strengthen the role of roads in reducing poverty, promoting tourism, and enhancing regional development within Nepal’s federal structure.

2b. Rank-Size Rule, State of Equilibrium, and Primacy (with cases and graphs):
The Rank-Size Rule suggests that in an ideal urban system, the population of a city is inversely proportional to its rank. If the largest city has a population of P, the second largest has P/2, the third P/3, and so on. This represents **state of equilibrium**, where cities are distributed evenly in terms of size. In contrast, **primacy** occurs when one city (e.g., Kathmandu in Nepal) dominates the urban hierarchy disproportionately, concentrating population, resources, and services. A graph plotting city rank vs. population typically shows a straight line for equilibrium and a steep curve for primacy. In Nepal, Kathmandu's dominance in administration, economy, and services leads to primate city characteristics, while other cities like Pokhara and Biratnagar remain much smaller. Managing urban primacy requires decentralization policies and investment in secondary cities to achieve balanced development.

3a. OECD Concept on Peri-Urban Areas and Continuum Context:
The OECD defines **peri-urban areas** as transitional zones located between urban and rural areas, where urban and rural features intermingle. These zones experience rapid land-use changes due to urban sprawl, housing demands, and infrastructure development. In the **continuum context**, peri-urban areas are seen as neither fully urban nor fully rural but dynamic regions influenced by both. In Nepal, areas around cities like Bharatpur or Butwal show peri- urban characteristics—growing settlements, mixed agriculture, and infrastructure expansion.
These zones are important for planning because they face land conflicts, inadequate services, and ecological pressures. A continuum perspective helps planners design policies that are responsive

to the fluid socio-economic and spatial realities of these zones, ensuring integrated development across urban–rural boundaries and controlling haphazard expansion.

3b

4a. Kathmandu-Terai Expressway: Urban Economy and Transport Planning Perspective: The Kathmandu-Terai Expressway (Fast Track) is a strategic infrastructure aimed at directly connecting Kathmandu with Nijgadh, reducing travel time and enhancing national connectivity. From an **urban economy perspective**, it reduces logistical costs, improves accessibility, and stimulates investment in new growth centers like Nijgadh. The expressway facilitates quicker trade flows between the capital and southern industrial belts, boosting the regional economy. It also supports land value appreciation and urban expansion along the corridor. From a **transport planning perspective**, it helps decongest the Prithvi and East-West highways and provides an alternative route during emergencies. However, it requires careful integration with local transport systems, land use zoning, and environmental protection to avoid unmanaged urban sprawl. The expressway is expected to balance national development by linking the economic heart of the Terai with the political center in Kathmandu.

4b. Graph of Locational Rent vs. Distance (with Commentary):
(Since I can’t draw, imagine the graph with the following features):

- **Y-axis** = Locational Rent
- **X-axis** = Distance from market
- **Three crops**: Vegetables (high value, high perishability), Wheat (moderate value), and Timber (low value, durable)
- Rent for vegetables declines steeply; wheat declines moderately; timber declines slowly.
- **Margin of transfer** is where the rent curve intersects the cost line (i.e., production becomes uneconomical beyond this point).

Commentary:

- If **market price increases**, curves shift upward → margins extend farther.
- If **transportation cost rises**, curves become steeper → margins shift closer to the market.
- If **production cost increases**, the intercept lowers → profitability zone shrinks.
  This graph visualizes Von Thünen's theory, which still holds relevance in spatial planning of agricultural and peri-urban activities.

5a. City as Transport Foci and Break-of-Bulk Points:
Cities function as **transport foci** by acting as convergence points for regional, national, and international transport networks. They facilitate multimodal transfer—air, road, rail, and inland waterways—making them logistical hubs. They also serve as **break-of-bulk points**, where goods are transferred from one mode or vehicle type to another (e.g., from trucks to trains).
Kathmandu serves both functions: it's a central node in Nepal's highway network and a point where goods are shifted from long-distance cargo to local distribution. These roles enhance trade efficiency, support urban economies, and drive regional development.

5b. Reasons for Deviation from Von Thünen's Agricultural Land Use Pattern:
Modern agricultural land-use patterns differ from Von Thünen's concentric zone model due to:

1. **Technological advances** in transport and refrigeration, allowing perishables to be grown far from markets.
2. **Globalized trade**, making land use dependent on international demand rather than proximity.
3. **Government policies** and subsidies altering natural economic patterns.
4. **Urban sprawl**, which disrupts traditional zoning and land values.
   Thus, real-world land use is shaped more by political, technological, and environmental factors than by simple distance-based economics.
   Alternatively, **Von Thünen and Central Place Theory** still provide useful frameworks in Nepal's planning—e.g., for zoning policies, land valuation, and rural-urban service provision—despite their limitations in a complex, modern economy.

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6. Minimum Spanning Tree for Balthali Forest Road Upgrade:
To connect all stations with minimum environmental disruption, we apply **Kruskal's Algorithm**:

1. List all roads by ascending distance.
2. Start adding shortest road sections, avoiding cycles.
3. Continue until all nodes (stations) are connected.

Example (simplified):
Let's say roads: O-A (2km), A-B (3km), B-C (5km), O-E (4km), etc.
Chosen roads: O-A, A-B, O-E, E-D, D-C → covering all stations with minimum total distance. This forms a **Minimum Spanning Tree (MST)**, ensuring full connectivity with least cost and ecological impact.

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7. Short Notes (Choose Any Two):

a. Urban Transport Network as Club Goods:
Urban transport networks are **club goods**—non-rival up to a point (many can use them) but excludable (via fares, tolls). Beyond capacity, congestion reduces benefits, hence requiring regulation and investment. Metro rail, expressways, and BRT systems are classic examples.

b. Functional Integration Approach for Urban Function:
This approach analyzes cities based on **functional linkages** (trade, communication, transport) rather than spatial proximity. It helps plan urban hierarchies, sub-center development, and integrated service delivery by understanding interdependencies.

c. Lee's Migration Model:
Lee's model explains migration as a result of **push factors** (unemployment, poor services), **pull factors** (better opportunities), **intervening obstacles** (distance, costs), and **personal factors**. It's useful for understanding urbanization patterns and planning supportive infrastructure.

1.a) Network Resilience and Accessibility

Network resilience refers to a transport network's ability to maintain functionality during disruptions like roadblocks or disasters. It is closely tied to **accessibility**, which measures ease of reaching destinations, and **centrality**, indicating the relative importance of a node in connectivity. A highly central node's failure affects many paths, reducing accessibility and resilience. In Nepal, the centrality of Kathmandu makes its roads critical; if obstructed, access to services declines nationwide, showing low resilience. A resilient network includes alternate routes to maintain flow, thus requiring balanced node centrality and dispersed accessibility.

1.b) Alpha Index Comparison with Binary Matrix

Network A has 7 nodes and 8 edges. **Network B** has 7 nodes and 6 edges.
Maximum edges = 3(n – 2) = 15
Alpha index (A) = (e – v + 1)/(2v – 5) For
A: (8 – 7 + 1)/(2×7 – 5) = 2/9 ≈ 0.22
For B: (6 – 7 + 1)/(2×7 – 5) = 0/9 = 0.00
Interpretation: Network A is more connected.
Applicability: Useful for comparing robustness. **Limitations**: Ignores flow capacity, hierarchy, or real-world topography.

2.a) Agglomeration Economies and City Development

Agglomeration economies occur when industries cluster together, reducing transportation costs, increasing specialization, and enabling shared services. These benefits influence city development by attracting businesses and workforce concentration, resulting in urban growth. For example, Kathmandu's trade and education hub draws people from surrounding areas.
Urbanization patterns shift toward such centers due to economic pull, leading to expanded infrastructure and dense land use. However, congestion and land value inflation can occur if not managed.

2.b) Internal Structure of Cities (With Sketch Concepts)

Concentric Zone Model: Cities grow in rings—CBD at center, then transitional zones, followed by working-class homes, better residences, and commuters' zones.
Sector Model: Growth follows transport lines and sectors such as industrial zones stretching from the core outward.
Multiple Nuclei Model: Cities develop around several nodes like universities, ports, or business districts.
Each reflects varied growth due to land value, accessibility, and socio-economic patterns, suitable for different stages of urbanization in cities like Kathmandu.

3.a) Economic, Transport, and Commercial Geography

Economic Geography studies spatial distribution of resources and industries. **Transport Geography** focuses on the movement and networks enabling economic activities. **Commercial**

Geography examines trade flow, market access, and global exchanges. These fields are interdependent—transport links support trade (commercial), which in turn shapes economic geography. In Nepal, trade routes influence settlement and industrial zones, while geography impacts transport planning due to terrain challenges.

3.b) Efficiency and Synergy in City Networks

Both **efficiency goals** and **synergy goals** aim to optimize urban systems. Efficiency targets faster, cost-effective services and networks. Synergy emphasizes collaborative benefits among cities—like shared infrastructure, labor pools, and innovation. In a **city network**, efficient transport enhances synergy, enabling regional development. For example, connecting Kathmandu, Pokhara, and Butwal creates a synergistic corridor for trade and tourism, combining their strengths.

4.a) Economic Dynamism and Spatial Differentiation

An active economy transforms spatial structures by shifting labor, infrastructure, and services toward dynamic areas. Urban centers grow rapidly due to market access, employment, and services, while rural areas may lag. In Nepal, Kathmandu attracts high-value services and population, while remote villages face depopulation and limited growth. This economic dynamism causes **urban-rural disparities** and demands balanced regional planning for equitable growth.

4.b) Functional Integration vs. Location-Allocation

Functional Integration promotes coordinated planning between rural and urban areas, integrating services and resources across regions.
Location-Allocation uses quantitative models to place facilities (e.g., schools, health posts) optimally for maximum accessibility.
While integration focuses on relationship-building, location-allocation provides precision. For rural Nepal, integrating transport and agriculture markets (integration) and locating agro-centers or cooperatives (allocation) both enhance rural service delivery and economic inclusion.

5.a) Transport Principle and Rule of Four

In **Central Place Theory**, the **Transport Principle** suggests settlements should develop along efficient transport routes to minimize total transportation costs. The **Rule of Four** states that each central place serves four lower-order settlements. It supports linear settlement patterns. In

Nepal, highway corridors such as East-West Highway foster such hierarchy and connectivity. Efficient transport networks enhance service delivery and economic integration across levels.

5.b) Cooperative Farming and Peri-Urban Areas

Cooperative farming involves collective agricultural operations for shared profit and resources. In **peri-urban areas**, where rural meets urban, it promotes land use efficiency, collective marketing, and service access. For example, Bhaktapur's peri-urban zone supports vegetable farming cooperatives serving urban Kathmandu. This boosts rural income and urban food supply, contributing to sustainability, employment, and bridging urban-rural gaps through economic linkages.

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6. MST by Kruskal’s and Prim’s Algorithms

Using Kruskal’s Algorithm: Select the shortest edge first, avoiding cycles, until all nodes are connected.
Using Prim’s Algorithm: Start from a node, add the nearest edge connecting an unvisited node, repeat.
Both yield the **Minimum Spanning Tree**—a sub-network connecting all nodes with minimal total weight.
Application in Transport: MSTs help design low-cost infrastructure like rural road connections, where efficiency and minimum expenditure are essential. Prim’s suits dense networks; Kruskal’s is better for sparse ones. Both omit traffic flow or terrain, which limits real- world application.

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7. Short Notes

a) Weber’s Least Cost Theory: Explains industrial location based on minimizing transport, labor, and agglomeration costs. It helps understand why industries concentrate near raw materials or markets.
b) Features of Rural Economy: Low population density, agriculture dominance, limited infrastructure, and reliance on local resources define rural economies. Nepal’s hills and Tarai differ in land productivity and market access.
c) Greater London Plan: Proposed in 1944, it aimed to control urban sprawl, establish green belts, and promote balanced urban growth through decentralization and zoning—an early model for urban planning globally.