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Beyond Access : Analyzing the National Multimodal Public Transportation Network with Big Data and Functional Urban Area

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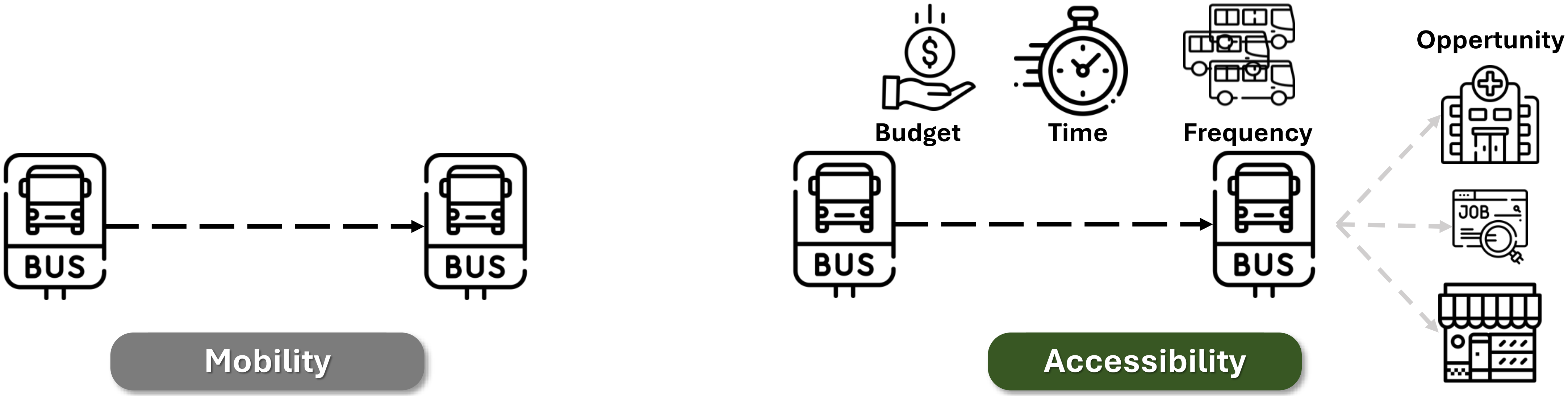
Introduction

- The goal of public transport is not just **Mobility**, but ensuring equitable **Accessibility** to opportunities (Geurs & Van Wee, 2004).
- True accessibility is a multidimensional concept defined by **Quality of Service**, including frequency, travel time, and transfer convenience (Bertolini et al., 2005; Kujala et al., 2018).
- This is a matter of **transport justice**, ensuring social inclusion for all citizens (Lucas, 2012; Verlinghieri & Schwanen, 2020).



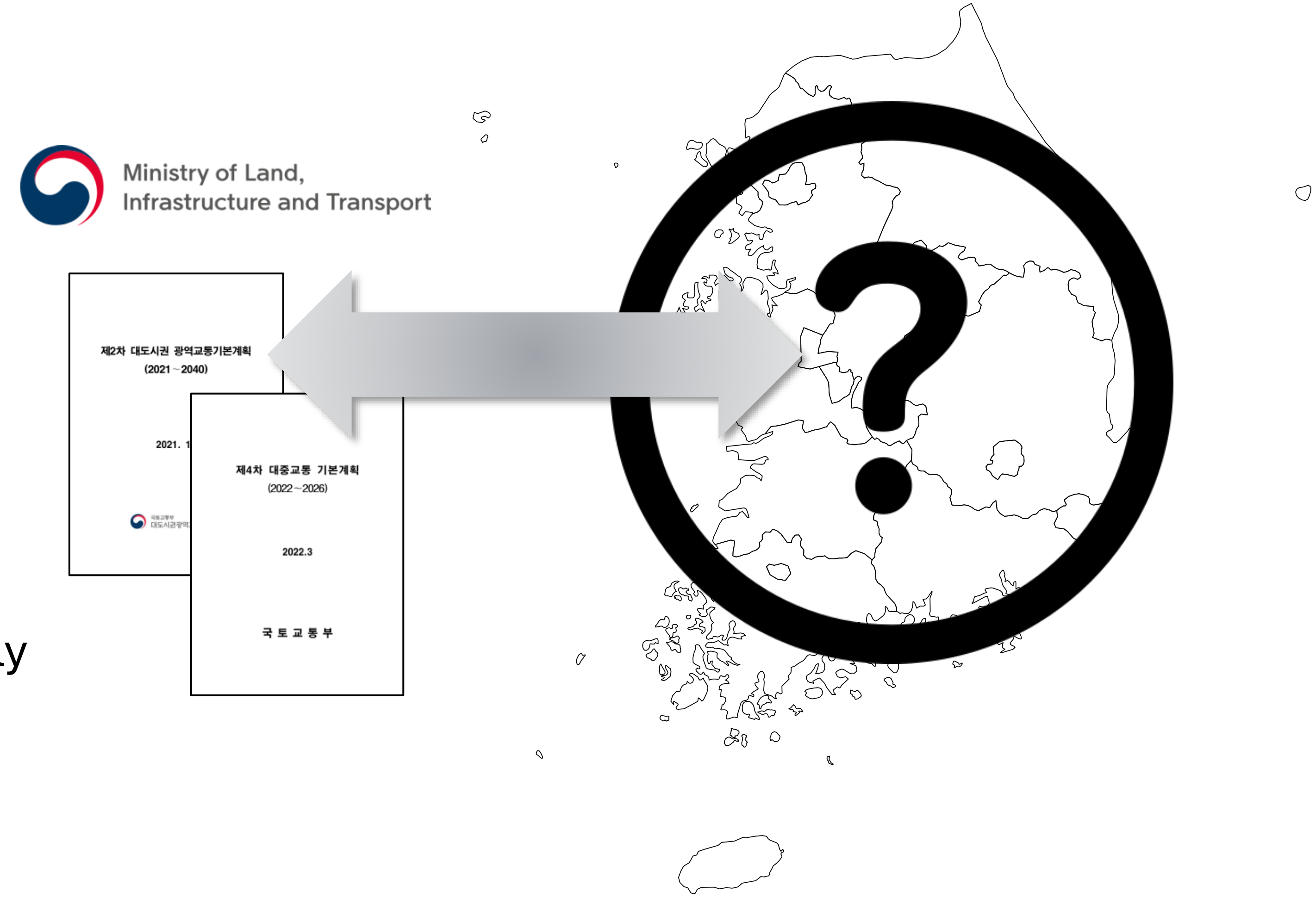
The Policy Imperative & The Research Gap

The Vision

The Korean government aims for a "hyper-connected" nation with reduced travel times and inclusive services (MOLIT, 2021a; 2022).

The Gap

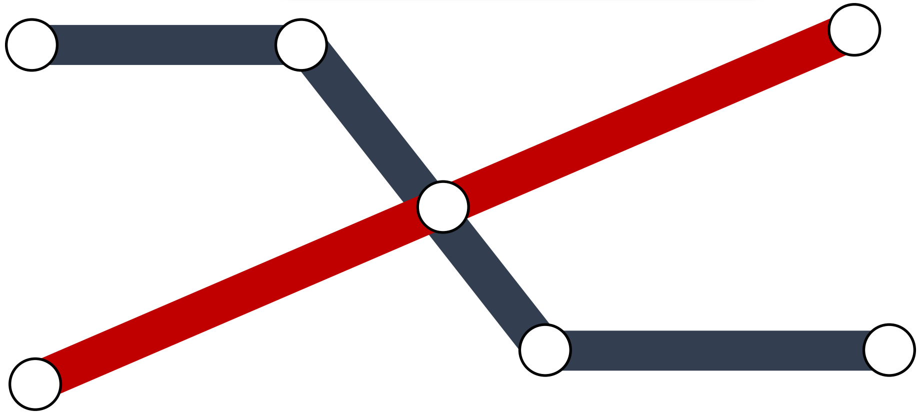
Are these national goals being met?
A comprehensive, evidence-based evaluation framework for the *entire national system* from the perspective of *actual living areas* is critically lacking.



The First Flaw: The Single-Mode Illusion

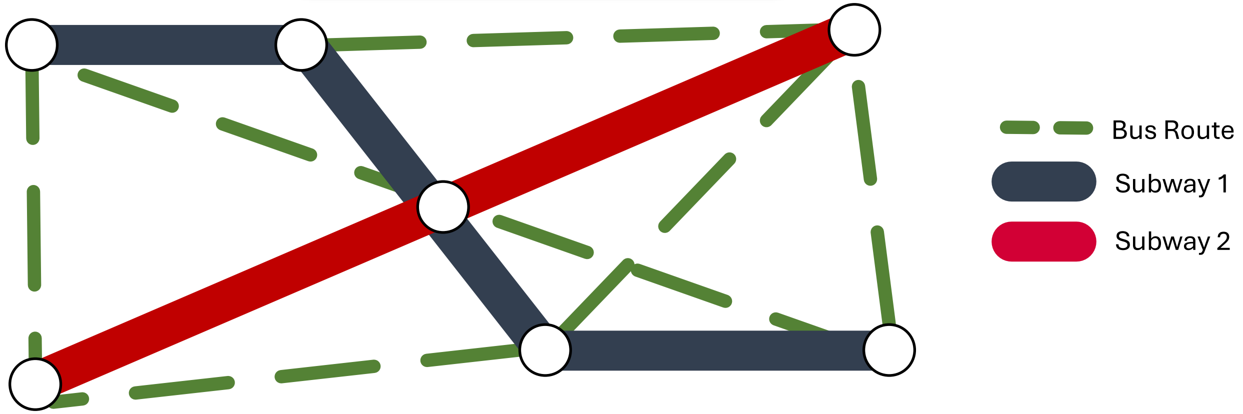
- Urban transport is an interdependent **multilayer network** (Aleta et al., 2017; Kurant & Thiran, 2006).
- Analyzing modes in isolation provides a **dangerously distorted picture** of system performance and resilience (Gattuso & Miriello, 2005).
- The synergy between modes can fundamentally alter our evaluation of the system's efficiency.

Subway Only



Inefficient, fragmented

Subway + Bus



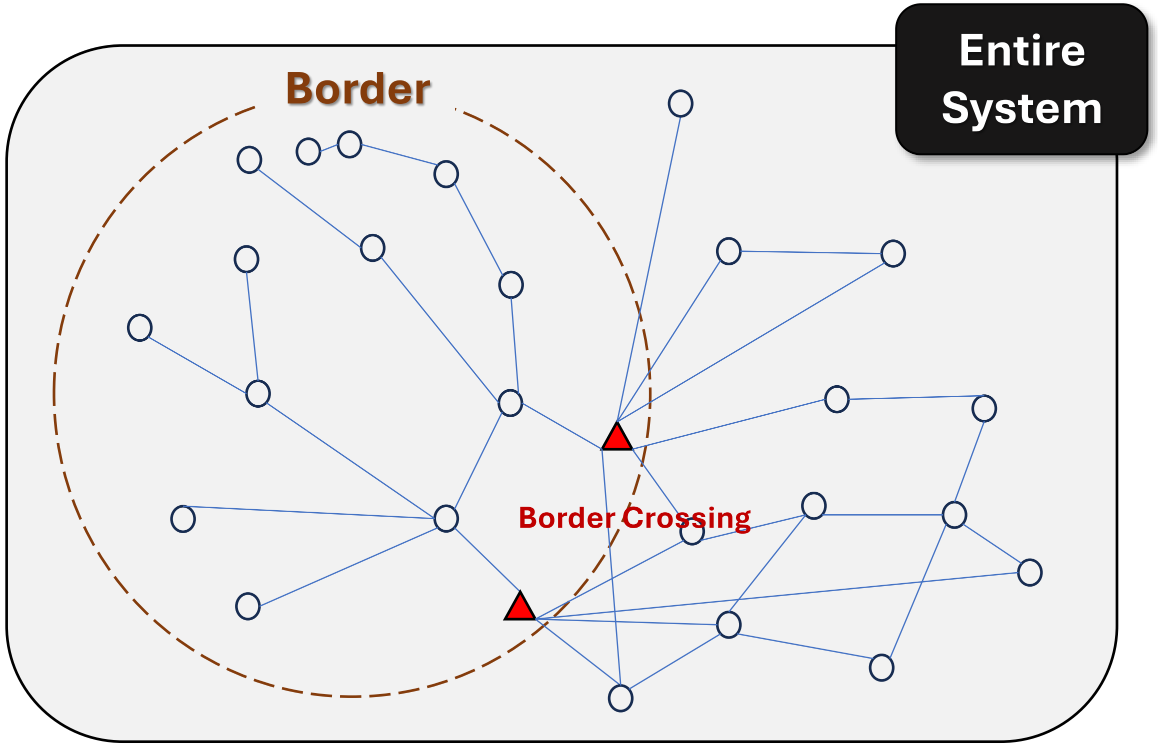
Small-world network (Efficient, integrated)

The Second Flaw:
The "Edge Effect" of Artificial Boundaries

•Network centrality is a **global property**, determined by the entire network's topology (Freeman, 1978).

•Analyzing a network within artificial boundaries (e.g., city limits) **systematically underestimates the importance of edge nodes** (Porta et al., 2006a; Buhl et al., 2006).

•This leads to flawed resource allocation and policy decisions.



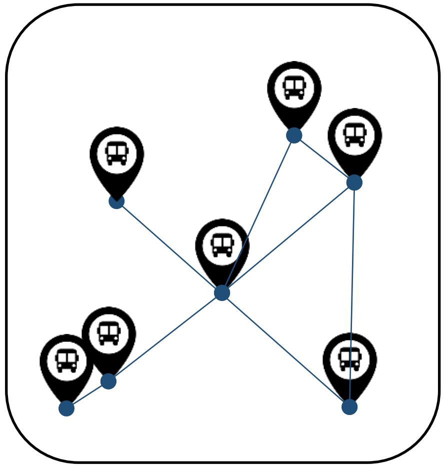
A critical hub becomes a mere periphery

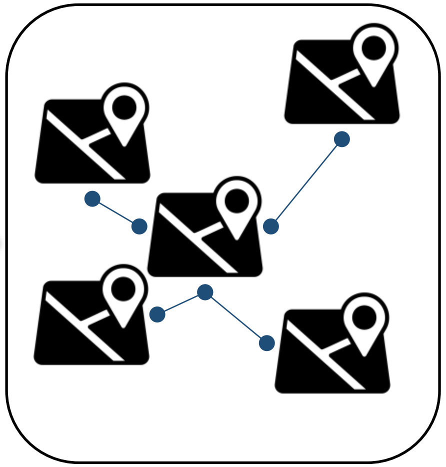
A Two-Fold Paradigm Shift is Needed

- To overcome these flaws, we must fundamentally shift our analytical paradigm in two dimensions.

Shift in Unit

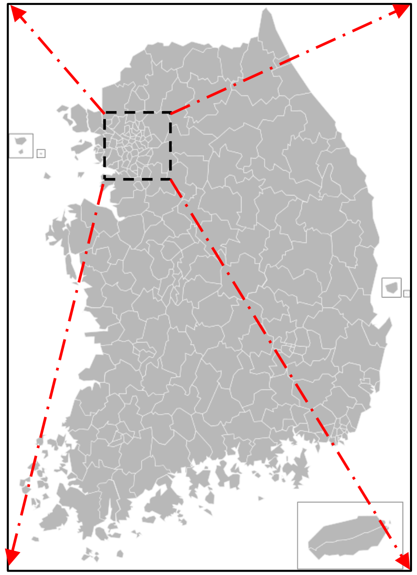
From Points (Stops) → To Areas (Living Spheres)





Shift in Scope

From a City (Fragmented) → To the Nation (Holistic)



Shift 1: From Points to Functional Areas

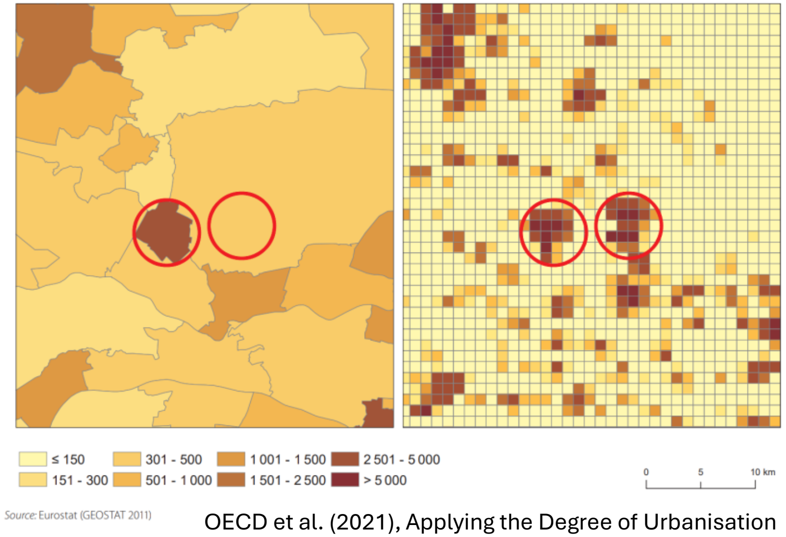
Previous

Point-to-Point models based on stops are insufficient for macro-policy insights.

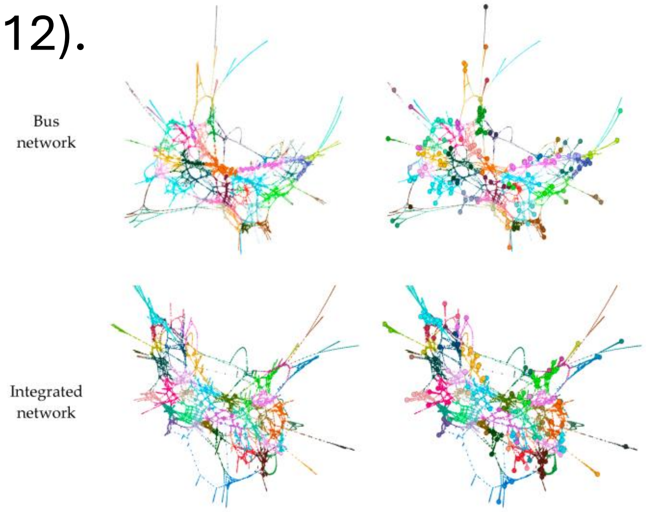
My Approach

Area-to-Area models using **Functional Urban Areas (FUAs)**.

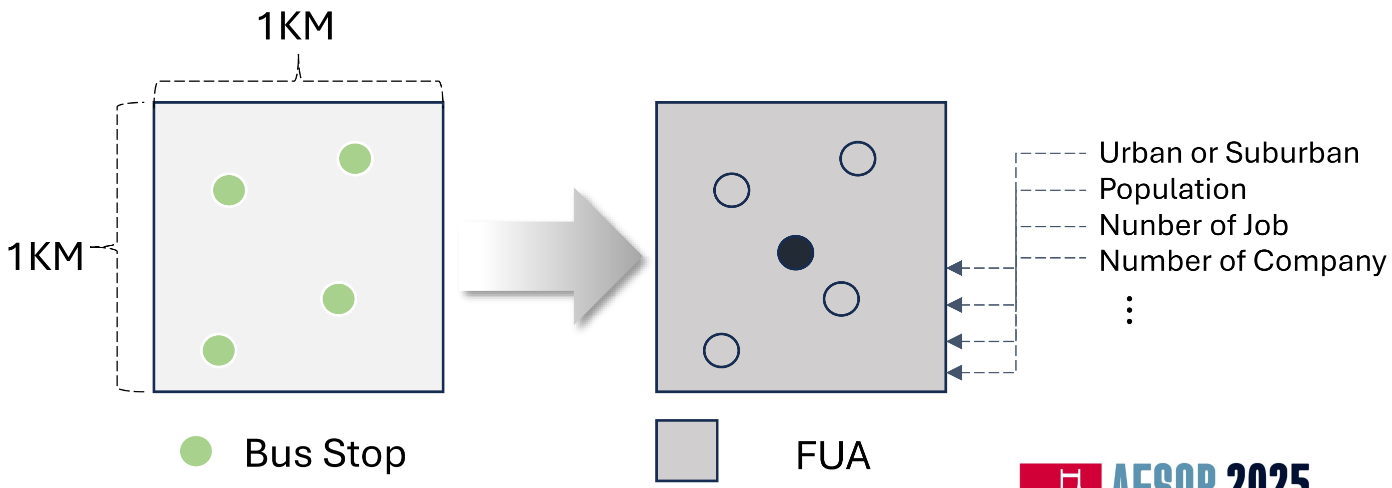
This aligns the analysis with how human mobility is actually structured within hierarchical **"spatial containers"** (Alessandretti et al., 2020) and reflects policy-makers' interests in functional regions (OECD, 2012).



OECD et al. (2021), Applying the Degree of Urbanisation

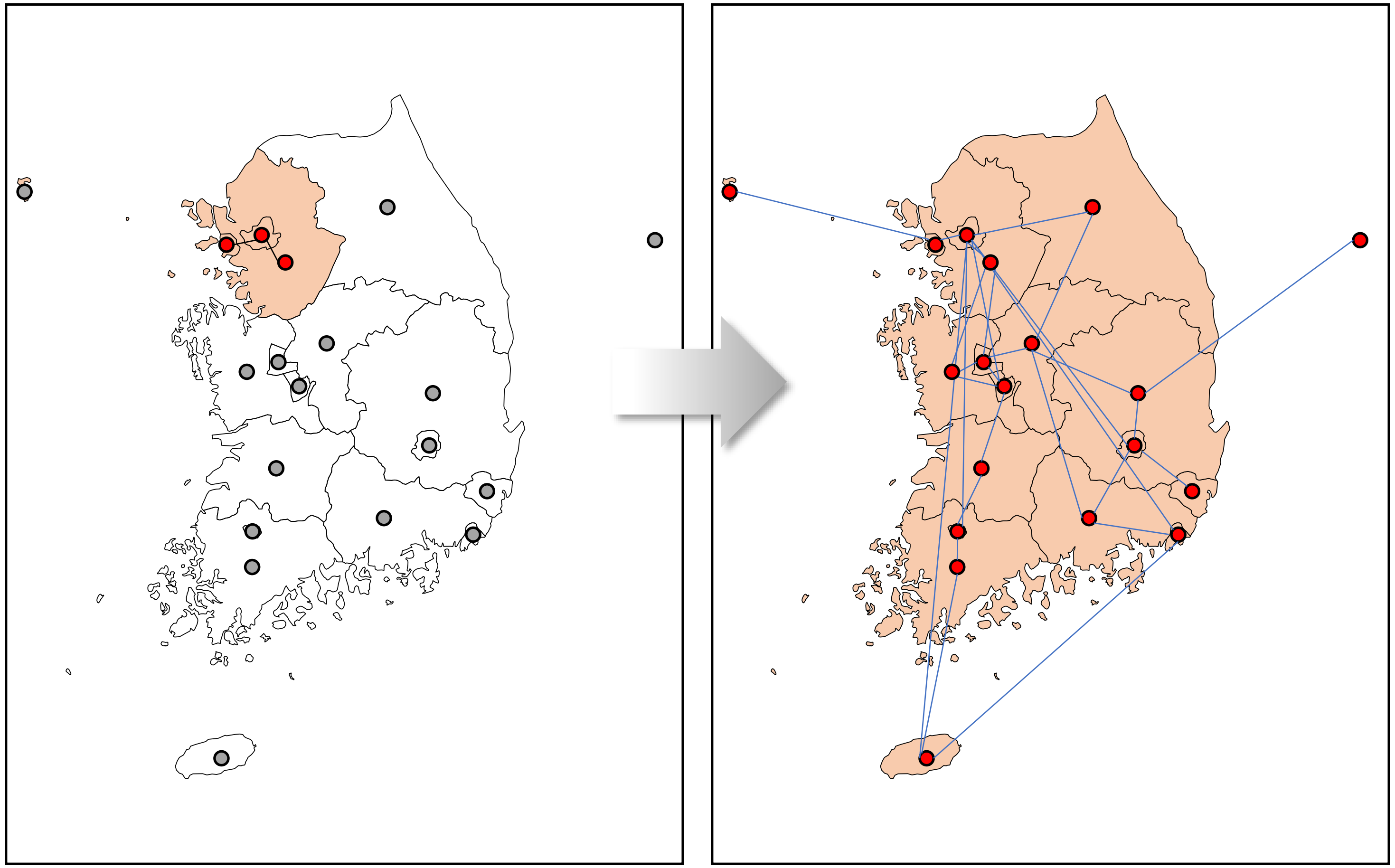


Hong J.Y. et al. (2019),



Shift 2: From Bounded Cities to the Holistic Nation

- The only way to eliminate the **"edge effect"** is to expand the scope to a **closed system** (Strahler, 1952; Porta et al., 2006b).
- For domestic transport, the **entire nation** is the most logical closed system.
- This approach ensures technical accuracy and enables a comprehensive evaluation of inter-regional connectivity and equity.



The Enabler: Big Data & Advanced Computing

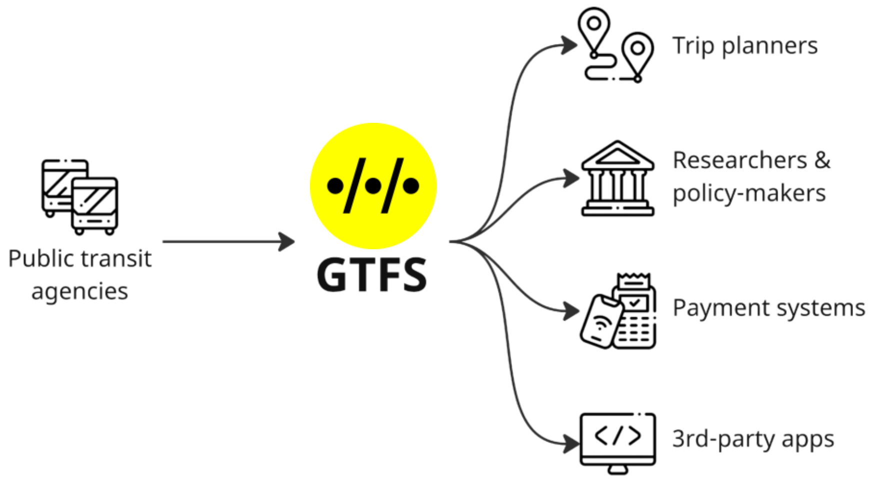
This approach has only recently become possible.

The Breakthrough

Standardized national **GTFS(General Transit Feed Specification) Big Data** (Kujala et al., 2018; Zhong et al., 2016).

High-Performance Computing

Using Distributed processing (Dask) and GPU acceleration (NVIDIA RAPIDS) to handle massive scale (~200k nodes, ~33M edges).



dask

RAPIDS

Accelerated with NVIDIA

Research Framework : Methodology Overview

This slide visually summarizes the entire research flow from raw data to policy insights.

Step 0 – Data Processing

Nationwide GTFS Data (Bus, Express Bus, Subway, Railway, Aviation, Maritime)

Step 1 - Point-to-Point Network

Build raw edge list (33M+ edges). Data cleaning based on speed profiles.

Step 2 - Multilayer Model Network

Construct 6 "Super Layers" (one for each mode) using a complete-graph approach within each route.

Step 3 - Weighted Network Analysis

Aggregate the network to FUA polygons. Analysis network topology metrics (Centrality, etc.) using frequency as weights to measure the actual service level.

Step 4 - Synthesis & Policy Insights

Correlate the calculated service level metrics with socio-economic data.

Building the Network: A Two-Step Aggregation Framework

Level 1: Route Layer

Raw GTFS data. Each of the 25,000 bus routes is a separate layer. Contains massive redundancy and overlap.

Level 2: Super Layer

A Point-to-Point network for each transportation mode. Reveals the infrastructural connectivity of the entire mode.

Level 3: FUA Layer

An Area-to-Area network. Reveals the macro-level functional connectivity between living spheres.

Consolidate all routes of the same mode. Parallel edges between the same two stops are merged into a single, weighted edge

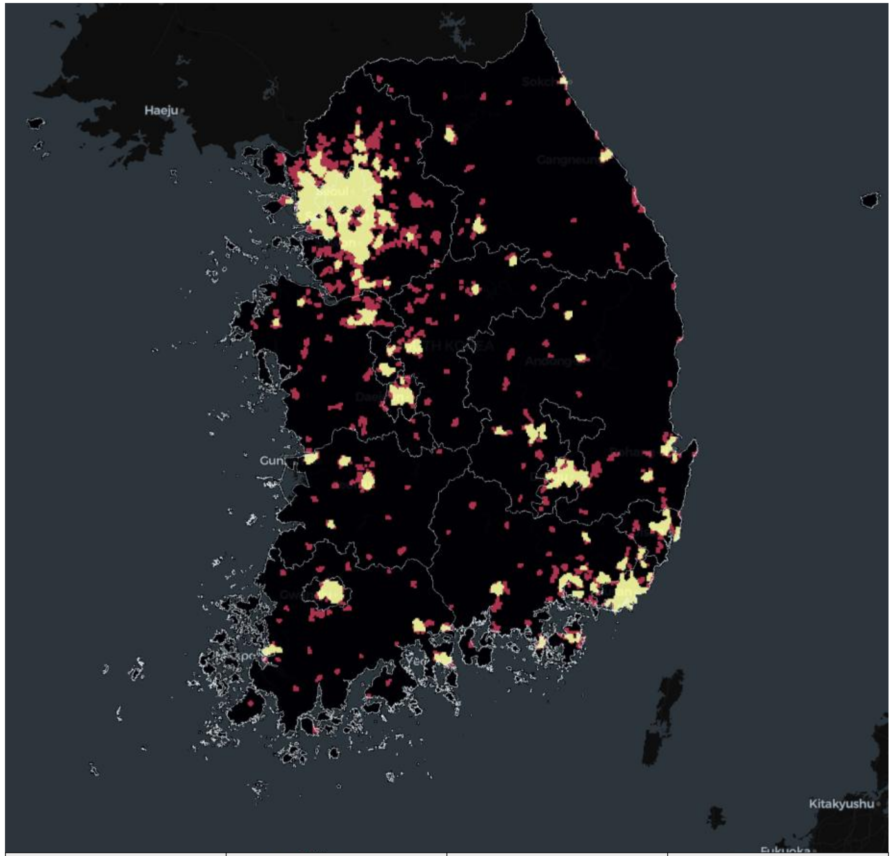
Aggregate all stops within the same Functional Urban Area into a single node.

Used Dataset

Data	Contents	Year	Source
GTFS (General Transit Feed Specification)	Nationwide GTFS Data for Bus, Express Bus, Subway, Railway, Aviation, Maritime	2024. 12	TMAP
Urbanization Area GRID	The 1 km x 1 km grid SHP file based on the FUA methodology includes data on population, households, businesses, and number of employees, as well as Urban centres, Urban clusters, and Rural classifications.	2022	SGIS

Transportation

Mode	Number of Stops	Number of Routes	Number of Edges	Operation Frequency
Subway	1,082	57	50,144	5,398,849
Bus	192,411	24,973	33,957,996	791,064,563
Express Bus	1,426	11,851	18,332	87,540
Railway	235	12,807	12,807	56,911
Aviation	13	34	34	468
Maritime	340	2,335	2,335	4,632
Total	195,507	52,057	34,041,648	796,612,963



Total	Urban Centres	Urban Clusters	Rural
107661	5680	6140	95841

Research Questions & Key Contributions

RQ1 What is the true structure of Korea's national public transport network when viewed holistically?

RQ2 How does the **actual level of service** (beyond mere access) vary across different regions and transport modes?

RQ3 What is the relationship between this **quantified service level** and key socio-economic characteristics?

A New Lens (FUA Nodes)

Overcomes the 'edge effect' and provides macro-level insights relevant for policy (Porta et al., 2006a; OECD, 2012).

A Complete Picture (Multilayer Network)

Avoids the single-mode illusion by integrating all transport modes (Aleta et al., 2017; Latora & Marchiori, 2002).

Beyond "Access" (Weighted Analysis):

Evaluates actual service quality by incorporating frequency, not just connectivity (Bertolini et al., 2005).

What Aggregation Reveals: The Functional Hierarchy of Transport

Mode	Number of Stops	Number of Routes	Number of Link Route Layer	Number of Link Super Layer	Number of Link FUA Layer	Route → Super Layer (Preservation Rate 1)	Super → FUA Layer (Preservation Rate 2)
Subway	1,082	57	50,144	41,262	35,471	82%	86%
Bus	192,411	24,973	33,957,996	17,825,689	2,119,588	**52%**	**12%**
Express Bus	1,426	11,851	18,332	16,196	13,072	88%	81%
Railway	235	12,807	12,807	9,252	9,248	**72%**	**100%**
Aviation	13	34	34	34	34	100%	100%
Maritime	340	2,335	2,335	2,335	2,041	100%	87%

Step 1: Consolidating Service Redundancy

Bus: 48% of links are redundant routes.

Step 2: Identifying Functional Scale & Role

Bus (12%): → High Consolidation reveals Local / Capillary role.

Massive link reduction due to:

Numerous **Intra-FUA** links.

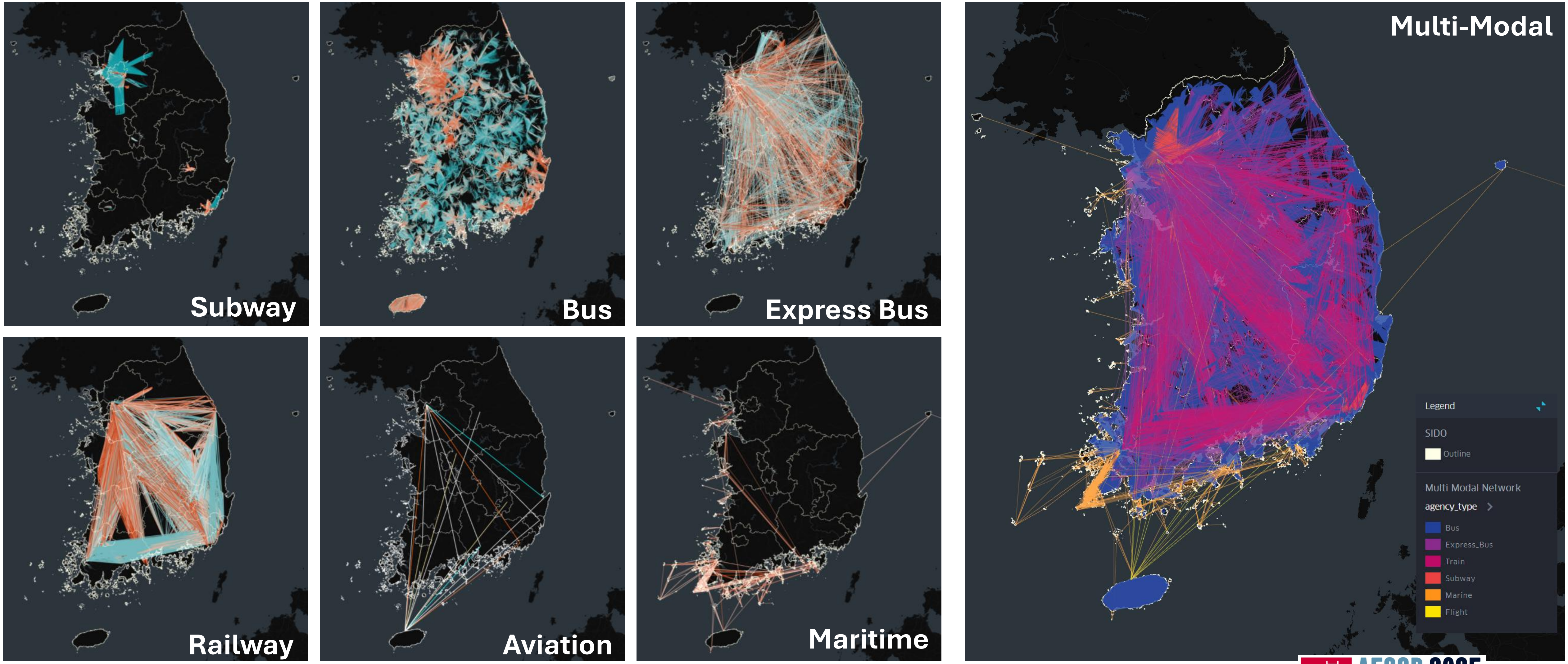
Redundant **Inter-FUA** links between various stops.

Railway (100%): → No Consolidation reveals National / Trunk role.

Each stop-to-stop link represents a unique area-to-area connection.

Methodology reveals the Functional Hierarchy of the national transport system.

Multimodal Public Transport Network Visualization



Macro-Structure: Connectivity and Fragmentation

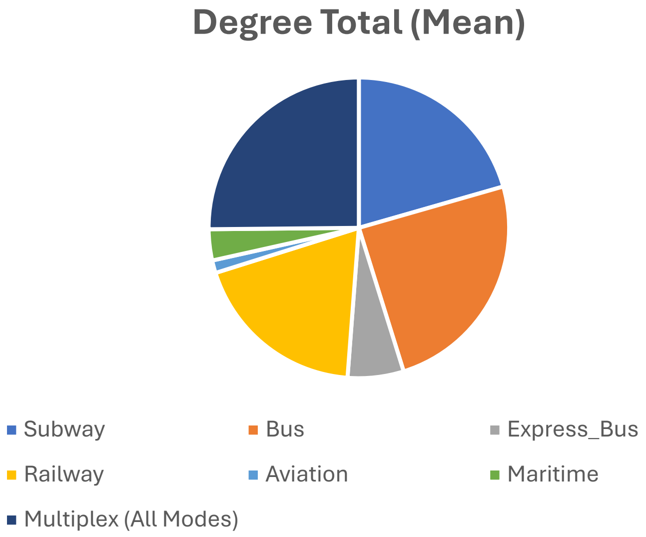
Type	Num Vertices	Num Edges	Density	Global Clustering Coefficient	LCC Ratio
Subway	827	35471	0.052	0.691	0.69
Bus	41283	2119588	0.001	0.445	0.98
Express_Bus	1040	13072	0.012	0.306	1.00
Railway	234	9248	0.170	0.642	1.00
Aviation	12	34	0.258	0.199	1.00
Maritime	293	2041	0.024	0.762	0.78
Multiplex (All Modes)	41552	2179454	0.001	0.430	1.00

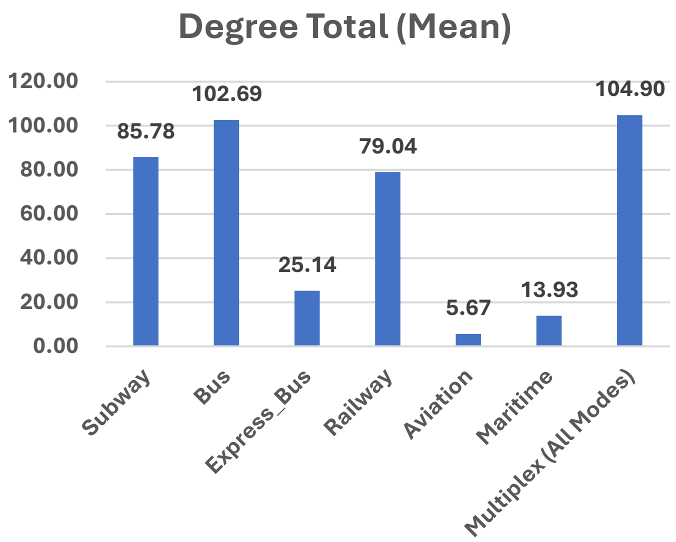
- **High Clustering (Subway, Maritime):** Networks are formed by tightly-knit regional clusters.
- **Regional Fragmentation (Subway, Maritime):** LCC Ratio < 1.0 indicates that these modes operate in geographically disconnected pockets (e.g., Seoul vs. Busan subway).
- **National Integration:** The **Multiplex (All Modes)** network forms a single, fully connected system (LCC Ratio = 1.00).

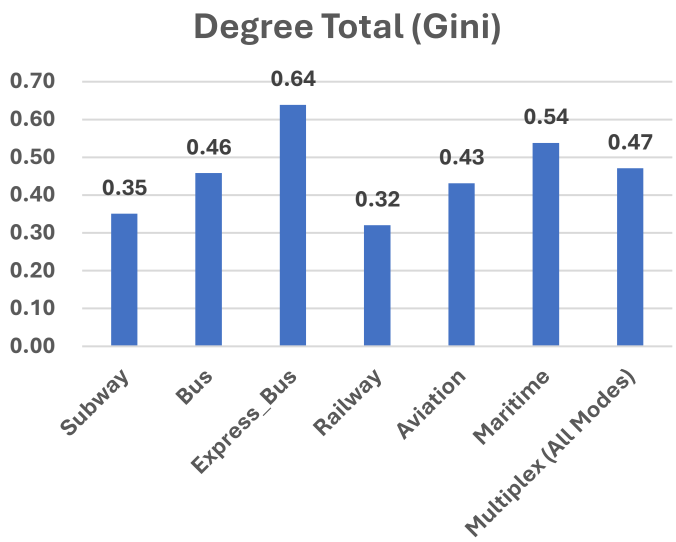
Connectivity Structure: Ubiquitous vs. Hierarchical

Type	Degree Total (Mean)	Degree Total (Std)	Degree Total (CV)	Degree Total (Gini)
Subway	85.78	58.72	0.68	0.35
Bus	102.69	106.76	1.04	0.46
Express_Bus	25.14	40.79	1.62	0.64
Railway	79.04	45.76	0.58	0.32
Aviation	5.67	5.82	1.03	0.43
Maritime	13.93	17.05	1.22	0.54
Multiplex (All Modes)	104.90	115.78	1.10	0.47

Connectivity Structure: Ubiquitous vs. Hierarchical







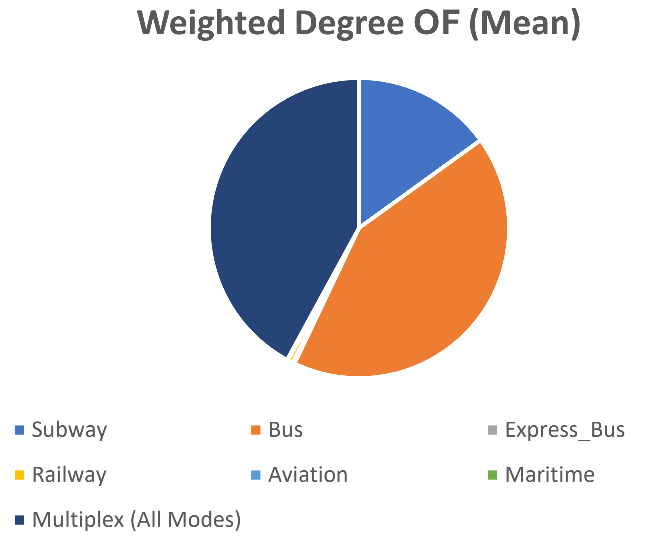
•**Ubiquitous Connector (Bus):** The highest mean degree signifies that the bus network connects to the most diverse range of areas.
•**Hierarchical Hub-and-Spoke (Express Bus):** The highest Gini coefficient indicates a strong hierarchical structure. A few hub terminals connect to many destinations, while most others have few connections.
•**Egalitarian Structure (Railway):** The lowest Gini coefficient suggests a more balanced and linear connection structure.

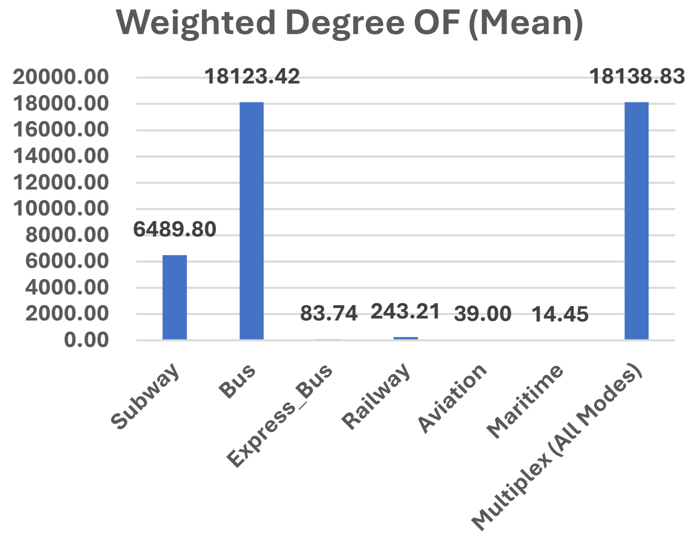
Service Level Analysis:
The Overwhelming Dominance of Local Transit

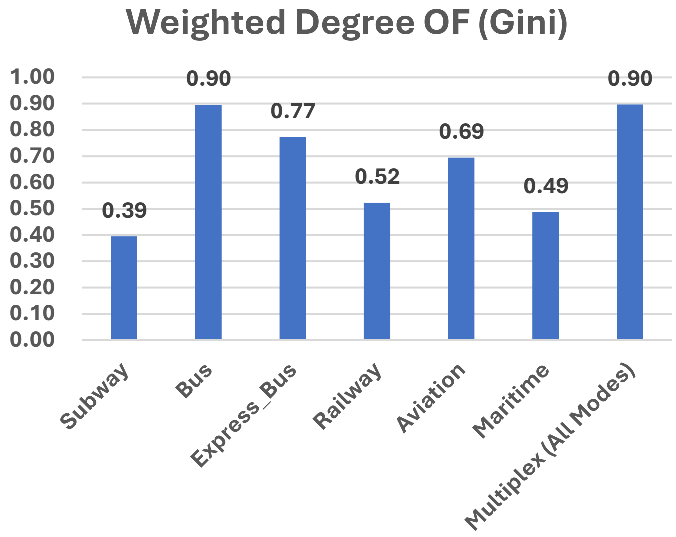
Type	Weighted Degree OF (Mean)	Weighted Degree OF (Std)	Weighted Degree OF (CV)	Weighted Degree OF (Gini)
Subway	6489.80	5280.23	0.81	0.39
Bus	18123.42	65246.84	3.60	0.90
Express_Bus	83.74	215.88	2.58	0.77
Railway	243.21	286.18	1.18	0.52
Aviation	39.00	61.37	1.57	0.69
Maritime	14.45	14.64	1.01	0.49
Multiplex (All Modes)	18138.83	65702.98	3.62	0.90

*** 'OF' means 'Operation Frequency'**

Service Level Analysis: The Overwhelming Dominance of Local Transit







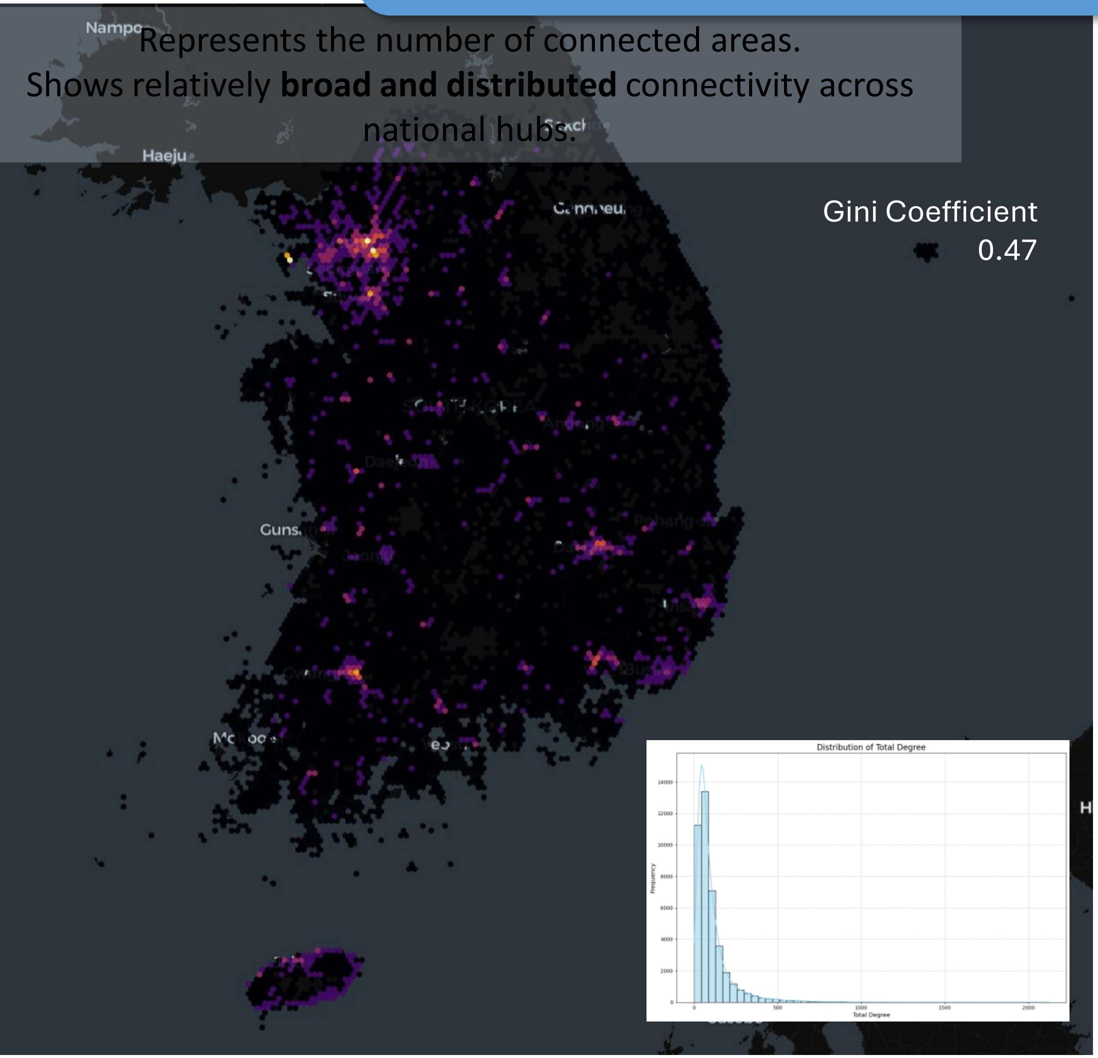
- **Dominance in Service Volume:** Bus and Subway overwhelmingly dominate the total volume of public transport services.
- **Extreme Inequality (Bus):** The Gini coefficient of **0.90** for the bus network reveals a "hyper-hierarchical" structure in service levels.
- **The Punchline:** While the bus network connects *everywhere* (ubiquity), the actual high-frequency services are extremely concentrated on a few key corridors.

*** 'OF' means 'Operation Frequency'**

Connectivity and Operation Frequency

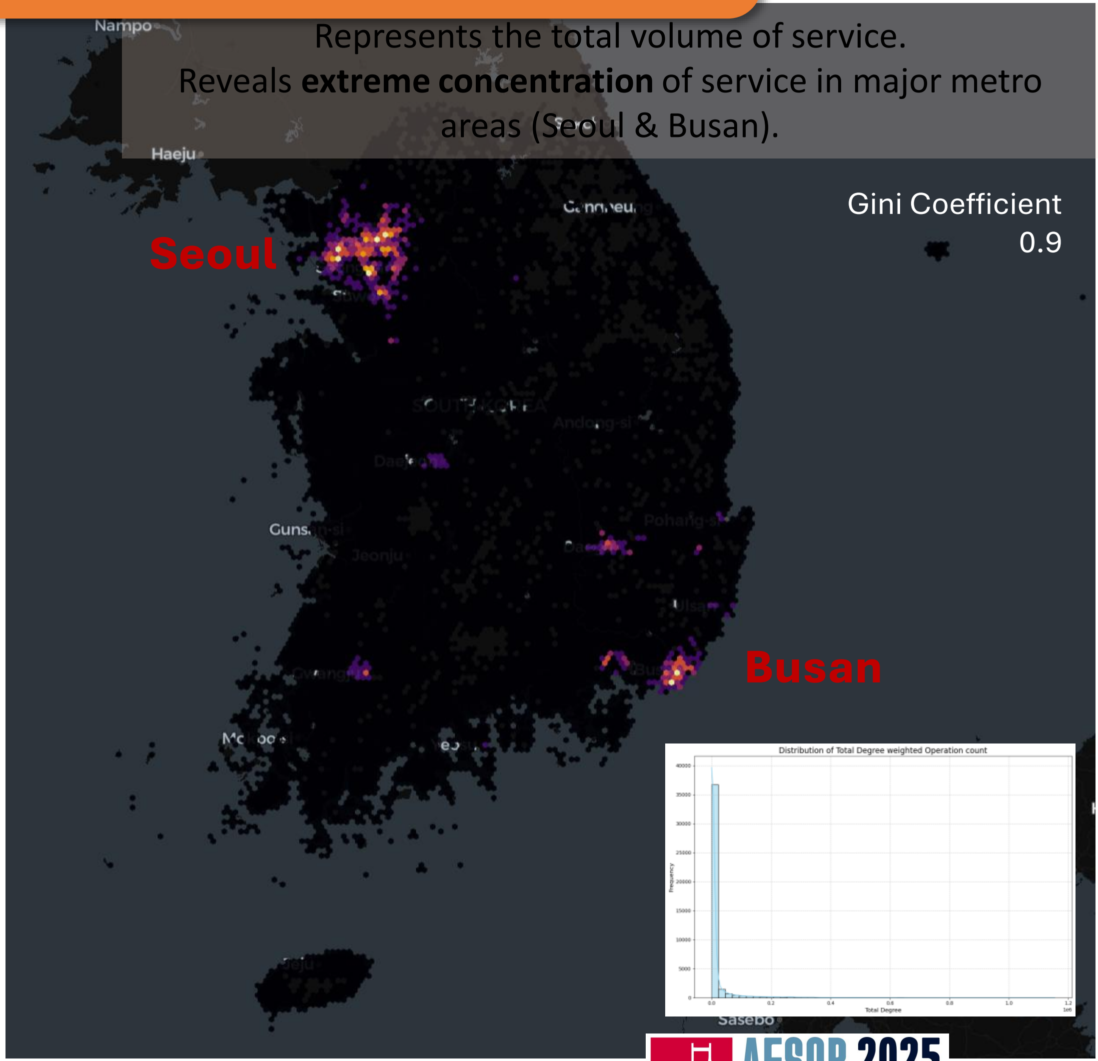
Degree Centrality

Represents the number of connected areas.
Shows relatively **broad and distributed** connectivity across national hubs.



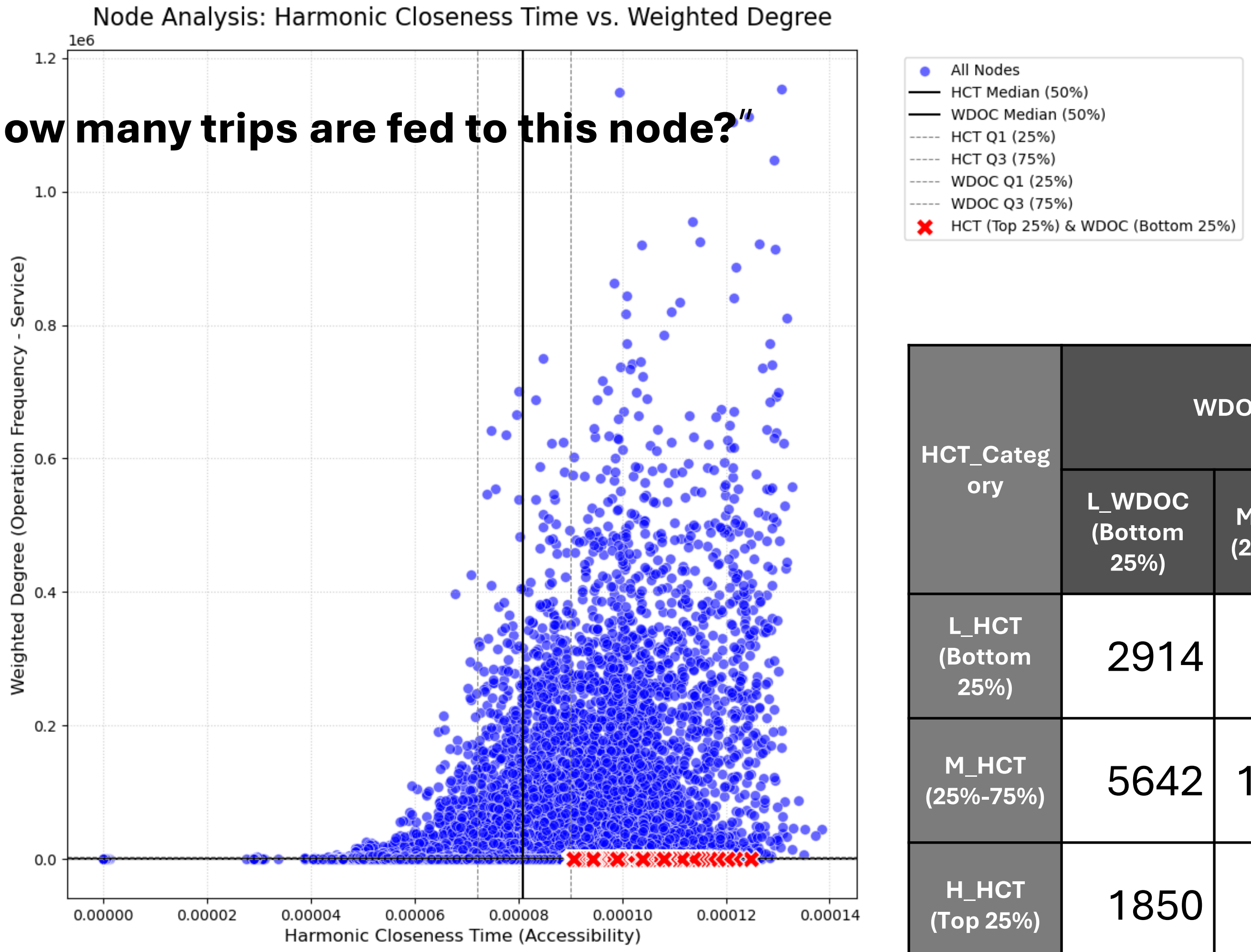
Weighted Degree Centrality (OF)

Represents the total volume of service.
Reveals **extreme concentration** of service in major metro areas (Seoul & Busan).



A 2D Framework for Node Classification: Accessibility vs. Service Level

"How many trips are fed to this node?"



"How easy is it for this node to reach the rest of the network?"

HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	2914	5791	1683
M_HCT (25%-75%)	5642	10610	4524
H_HCT (Top 25%)	1850	4359	4179

Harmonic Closeness Centrality

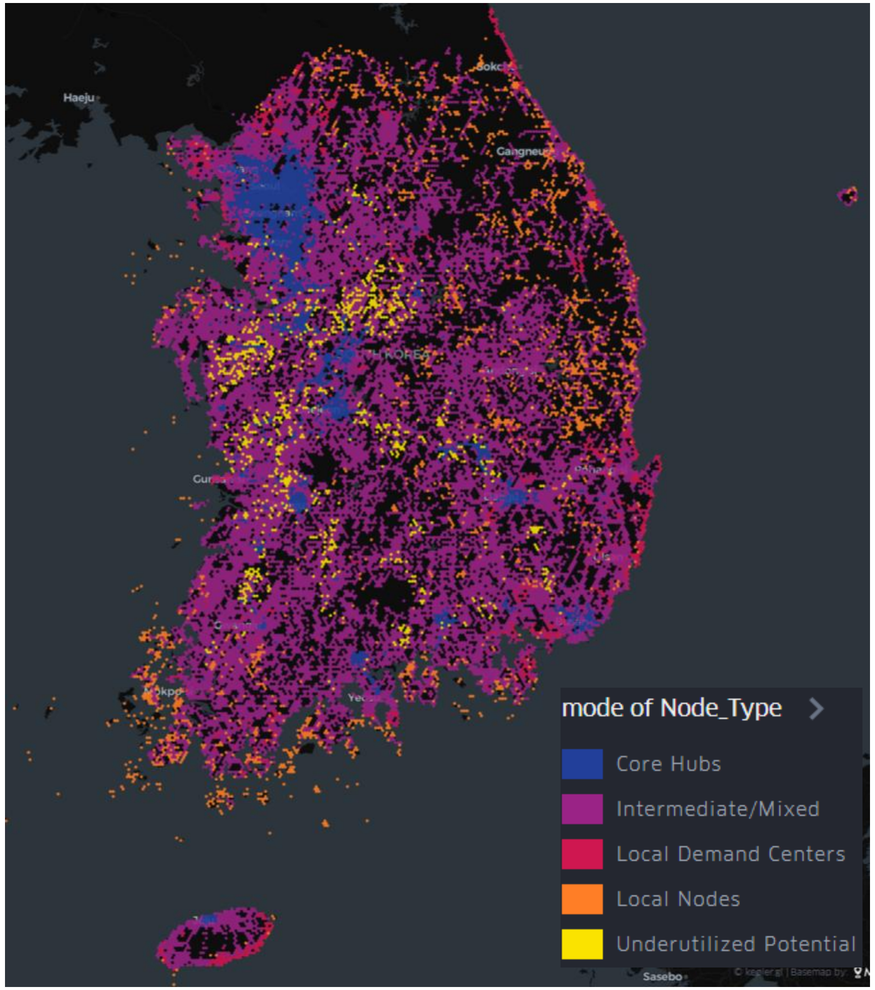
$$H_i = \sum_{j \neq i} \frac{1}{d(i,j)}$$

d(i,j): Shortest path time based distance from i to j

- All nodes are plotted based on these two key metrics.
- The plot is divided into quadrants by the median/quartiles to classify each node into a specific archetype.

Four Faces of the Network: A National Node Typology

	Low Service Volume	High Service Volume
High Accessibility	**Underutilized Potential** High accessibility, low service need to expand/streamline services 4.45% (1,850)	**Core Hubs** High Access, High Service The Heart of the National Network 10.06% (4,179)
Low Accessibility	**Local Nodes** Low accessibility, low service local transit-oriented 7.01% (2,914)	**Local Demand Centers** Low access, high service high demand exists in the region 4.05% (1,683)



Conclusion: Summary of Key Findings

A Functionally Differentiated Ecosystem

The national transport network operates as a complementary ecosystem of **Trunk Networks** (Rail, Express Bus) and **Capillary Networks** (Bus, Subway).

The Gap Between Connectivity & Service

A significant gap exists between potential connectivity (reach) and actual service levels (volume). Service volume is **extremely concentrated** in major metropolitan areas (Seoul & Busan).

A New Typology for Policy

Functional areas (nodes) can be classified into four distinct archetypes: **Core Hubs, Underutilized Potential, Local Demand Centers, and Local Nodes.**

Discussion & Policy Implications

Beyond Infrastructure Expansion → Towards System Optimization

Shift policy focus from simply building new lines to optimizing the *existing multi-layered system*.

Data-Driven, Targeted Investment

Utilize the node typology for targeted strategies: enhance 'Core Hubs', activate 'Underutilized Potential', and improve connectivity for 'Local Demand Centers'.

A New Tool for Evaluation & Monitoring

Our framework provides a more realistic tool for evaluating the effectiveness of national and regional transport plans.

Limitations & Future Research

Limitations

- **Static Analysis:** This study uses a static GTFS snapshot, not capturing real-time dynamics or demand fluctuations.
- **Supply-Side Focus:** The analysis is based on service supply, not yet incorporating actual passenger demand data (e.g., smart cards).
- **Simplified Weights:** Weights are based on frequency; incorporating time, cost, and transfer penalties would offer a more nuanced view.

Future Research

- **Temporal Network Analysis:** Analyzing network changes over time (daily, weekly, seasonal).
- **Integrating Demand Data:** Combining supply (GTFS) with demand (smart card data) to model actual passenger flows.
- **Policy Simulation:** Using the model to simulate the network-wide impact of new projects or policy changes (e.g., "What if we add a new Subway line?").

Thank you!

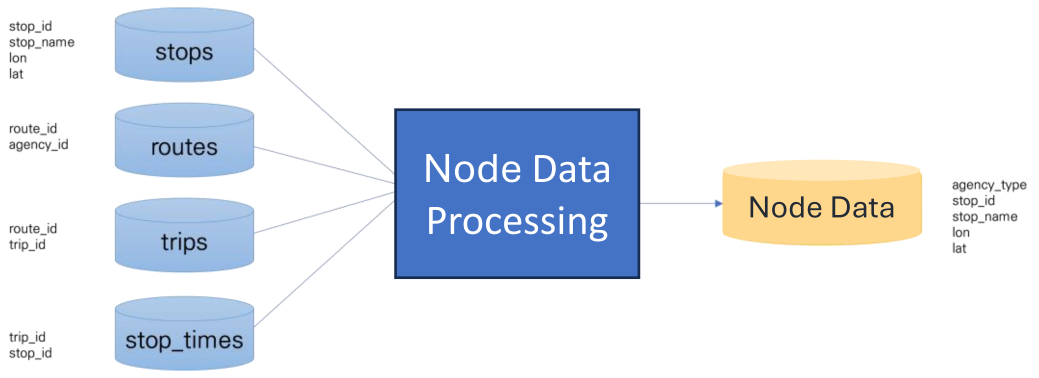
Appendix : The contents of a GTFS feed

Filename	Required	Defines
agency.txt	Required	One or more transit agencies that provide the data in this feed.
calendar.txt	Required	Dates for service IDs using a weekly schedule. Specify when service starts and ends, as well as days of the week where service is available.
calendar_dates.txt	Optional	Exceptions for the service IDs defined in the calendar.txt file. If calendar_dates.txt includes ALL dates of service, this file may be specified instead of calendar.txt.
fare_attributes.txt	Optional	Fare information for a transit organization's routes.
fare_rules.txt	Optional	Rules for applying fare information for a transit organization's routes.
feed_info.txt	Optional	Additional information about the feed itself, including publisher, version, and expiration information.
frequencies.txt	Optional	Headway (time between trips) for routes with variable frequency of service.
routes.txt	Required	Transit routes. A route is a group of trips that are displayed to riders as a single service.
shapes.txt	Optional	Rules for drawing lines on a map to represent a transit organization's routes.
stop_times.txt	Required	Times that a vehicle arrives at and departs from individual stops for each trip.
stops.txt	Required	Individual locations where vehicles pick up or drop off passengers.
transfers.txt	Optional	Rules for making connections at transfer points between routes.
trips.txt	Required	Trips for each route. A trip is a sequence of two or more stops that occurs at specific time.

The contents of a GTFS feed. Despite the .txt filename extensions, all files are comma-separatedvalues (CSV) files. This table is an excerpt from the “General Transit Feed Specification Reference” (https://developers.google.com/transit/gtfs/reference/) by Google LLC, licensed under http://creativecommons.org/licenses/by/3.0/CC BY 3.0.

Appendix : Data Processing Based on GTFS Format

Node Processing

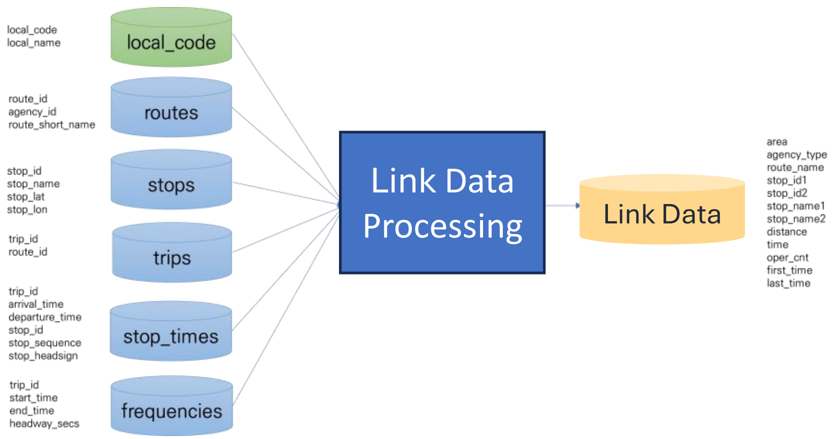


Example of node.csv

agency_type	stop_id	stop_name	lon	lat
지하철	110108	양주	127.04471949401754	37.77415521195541
지하철	110116	방학	127.0443216240006	37.66734597685274
지하철	110118	녹천	127.05134595858827	37.64473568323408
지하철	110144	개봉	126.8587755433411	37.494620838489
지하철	110197	신창	126.9514545802984	36.76967441481851
지하철	110202	을지로입구	126.98227478479744	37.56604377394995
지하철	110203	을지로3가	126.99092966020605	37.566286979853714
지하철	110213	구의	127.08610838670045	37.537142844521306
지하철	110229	봉천	126.94163774395902	37.482474355206115
지하철	110234	신도림	126.89118169025292	37.508951263229406

Using the stops, routes, trips, and stop_times information from the GTFS dataset, we extracted basic attributes such as the ID, name, and location of each stop to build detailed information about the stops.

Link Processing



Example of link.csv

area	agency_type	route_name	stop_id1	stop_id2	stop_name1	stop_name2	distance	time	oper_cnt	first_time	last_time
서울특별시	고속/시외버스	시외버스:동서울-기성	300001	200938	동서울종합터미널	기성터미널	224817	15780	2	07:10:00	15:25:00
서울특별시	고속/시외버스	시외버스:동서울-꽃동네_맹동	300001	200637	동서울종합터미널	꽃동네_맹동	78427	6000	5	09:10:00	18:10:00
서울특별시	고속/시외버스	시외버스:동서울-낙동_상주	300001	201412	동서울종합터미널	낙동_상주	168467	8520	1	11:20:00	11:20:00
서울특별시	고속/시외버스	시외버스:동서울-낙산	300001	200454	동서울종합터미널	낙산종합버스터미널	149753	12120	11	06:30:00	18:40:00
서울특별시	고속/시외버스	시외버스:동서울-남교	300001	200479	동서울종합터미널	남교	127921	7500	5	06:49:00	19:15:00
서울특별시	고속/시외버스	시외버스:동서울-내촌_포천	300001	200292	동서울종합터미널	내촌_포천	30247	2400	14	06:50:00	19:30:00
서울특별시	고속/시외버스	시외버스:동서울-논산	300001	200718	동서울종합터미널	논산시외버스공용터미널	147745	12360	2	12:10:00	14:20:00
서울특별시	고속/시외버스	시외버스:동서울-농암	300001	200843	동서울종합터미널	농암정류소	131445	10800	3	07:50:00	17:50:00
서울특별시	고속/시외버스	시외버스:동서울-다목	300001	200584	동서울종합터미널	다목시외버스터미널	80977	9600	3	14:40:00	16:20:00
서울특별시	고속/시외버스	시외버스:동서울-다인	300001	200953	동서울종합터미널	다인	164747	12480	3	07:00:00	16:20:00

Using the routes, stops, trips, stop_times, and frequencies information from the GTFS dataset, we derived combinations of departure and arrival stops that can be traveled between without transfers for each route.

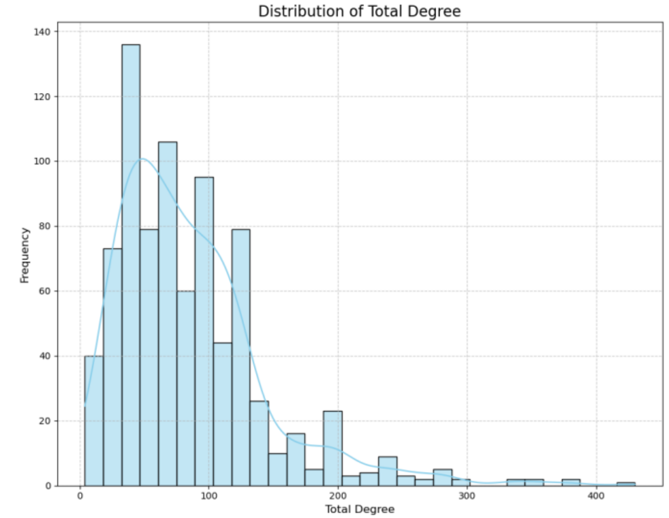
Appendix : Network Construction Framework

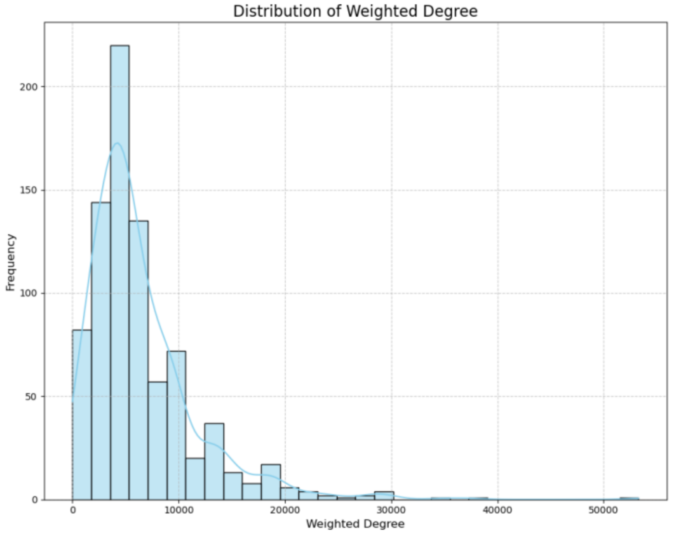
Process Stage	Intuitive Definition	Formulation
Route Layer	Considering an individual route (r) as a layer. Direct connection of all pairs of stops (i, j) belonging to the same route.	$G_r = (V, E_r)$ $where\ an\ edge\ (i, j)\ \ in\ E_r\ exists\ if\ stop\ i, j$
Super Layer	Consolidate all routes within a mode of transportation m. The frequency of all overlapping routes connecting the same two stops (i,j) is summed to create a single weighted trunk line for transportation m.	$A\ Point-to-Point\ graph\ G_S^m = (V, E_S^m, W_S^m).$ $he\ weight\ of\ an\ edge\ (i, j) for\ mode\ m\ is:$ $w_{ij}^{\{S,m\}} = \sum_{\{r \in R_m\}} f_{\{ijr\}}$ • R_m: *The set of all routes d belonging to transportation mode m*
FUA Layer	Aggregate the stops of mode m into functional areas (FUAs). Sum the weights of all “stop-to-stop” connections of mode m between two FUAs (f_a, f_b) to create a “region-to-region” connection for mode m.	$An\ Area-to-Area\ graph\ G_F^m = (F, E_F^m, W_F^m).$ $The\ weight\ of\ an\ edge\ (f_a, f_b) for\ mode\ m\ is:$ $w_{\{ab\}}^{\{F,m\}} = \sum_{\{i \in f_a, j \in f_b\}} w_{\{ij\}}^{\{S,m\}}$

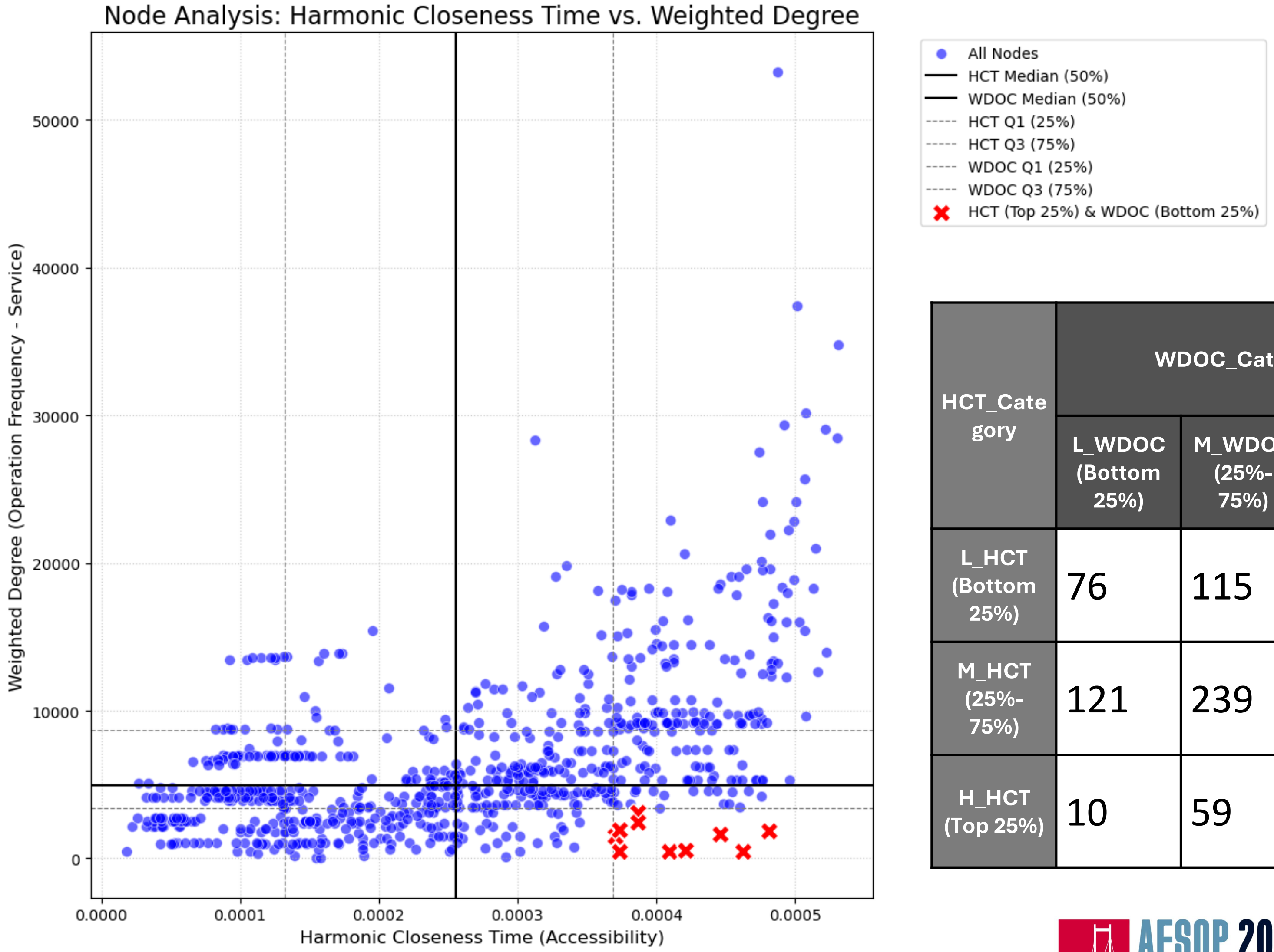
Appendix : Network Analysis Metrics

Metric	Intuitive Definition	Mathematical Formula	
Degree Centrality	How many other nodes a node (region) is directly connected to (extent of connectivity).	$k_i = \sum_{j-1}^{N} A_{ij}$	A_{ij}: i if connected j , =1 , ≠ 0
Weighted Degree Centrality	The sum (weighted) number of trips of all connections to a node. (actual service delivery)	$s_i = \sum_{j-1}^{N} w_{ij}$	w_{ij}: i if connected j , Operation Frequency weighting of connections
Density	How many actual connections exist out of all possible connections (network denseness).	$\frac{Number\ of\ Edges}{Maximum\ Possible\ Edges}$	
Global Clustering Coefficient	How strong is the tendency for “my friend's friend is my friend” across the network (degree of network cohesion).	$C = \frac{3\ \times (number\ of\ triangles)}{(number\ of\ connected\ triplets)}$	
LCC Ratio	Percentage of nodes that belong to the largest connectivity network, out of all nodes. (Integrity/disjointness of the network)	$\frac{Nodes\ in\ Largest\ Connected\ Component}{Total\ Number\ of\ Nodes}$	
Coefficient of Variation (CV)	Standard deviation relative to the mean. Indicates the relative variability of the distribution. (relative unevenness of connectivity)	$CV = \frac{\sigma_k}{\mu_k}$	μ_k: Mean σ_{k_k}: Standard deviation
Gini Coefficient	Used to measure income inequality. 0 (perfect equality) to 1 (perfect inequality). (absolute inequality in connectivity)	$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} \lvert x_i - x_j \rvert}{2\sum_{i=1}^{n}\sum_{j=1}^{n} x_j}$	
Harmonic Closeness Centrality	How easy it is for one node to reach all other nodes (accessibility of the network).	$H_i = \sum_{j \neq i} \frac{1}{d(i,j)}$	d(i,j): Shortest path time based distance from i to j

Appendix : Subway Network

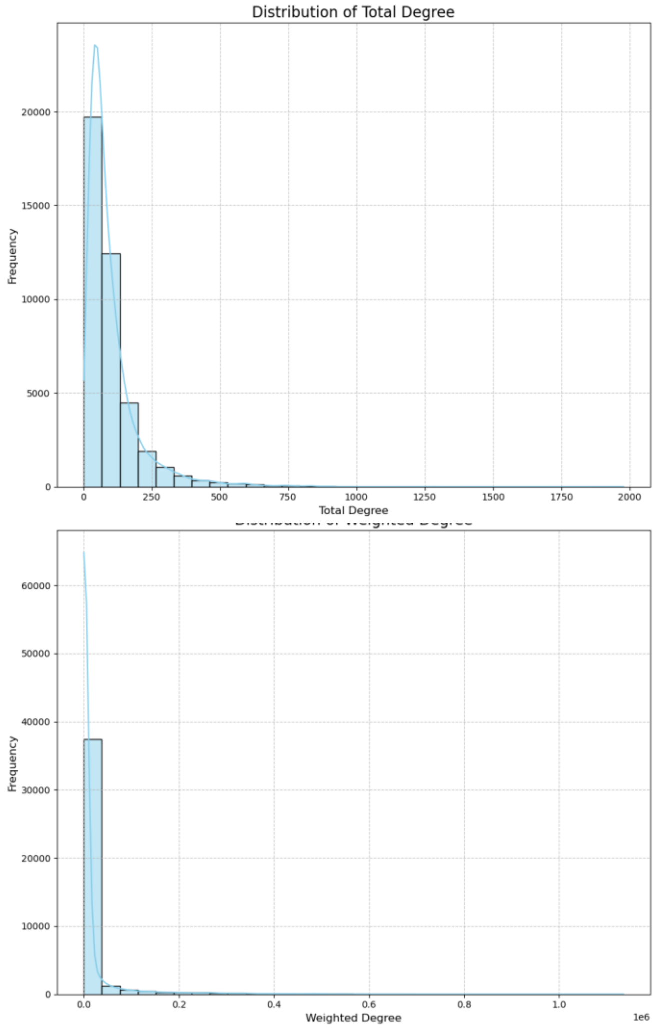


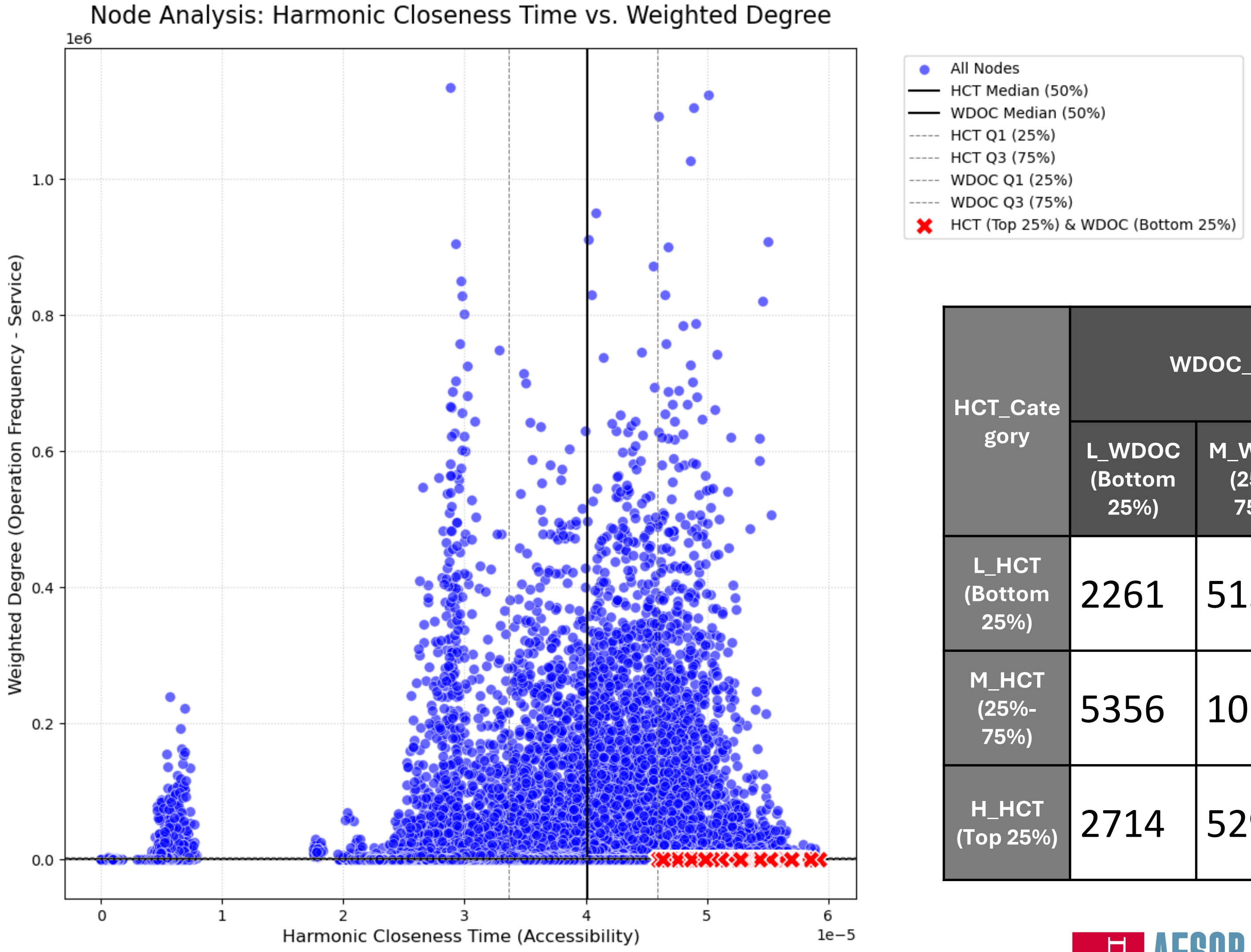




HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	76	115	16
M_HCT (25%-75%)	121	239	53
H_HCT (Top 25%)	10	59	138

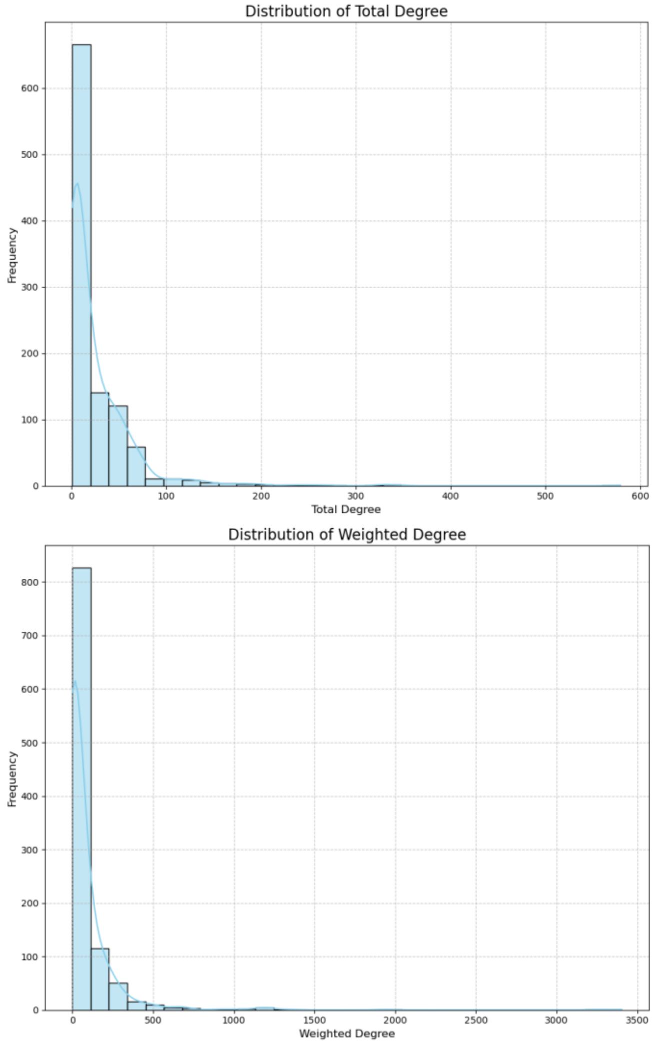
Appendix : Bus Network

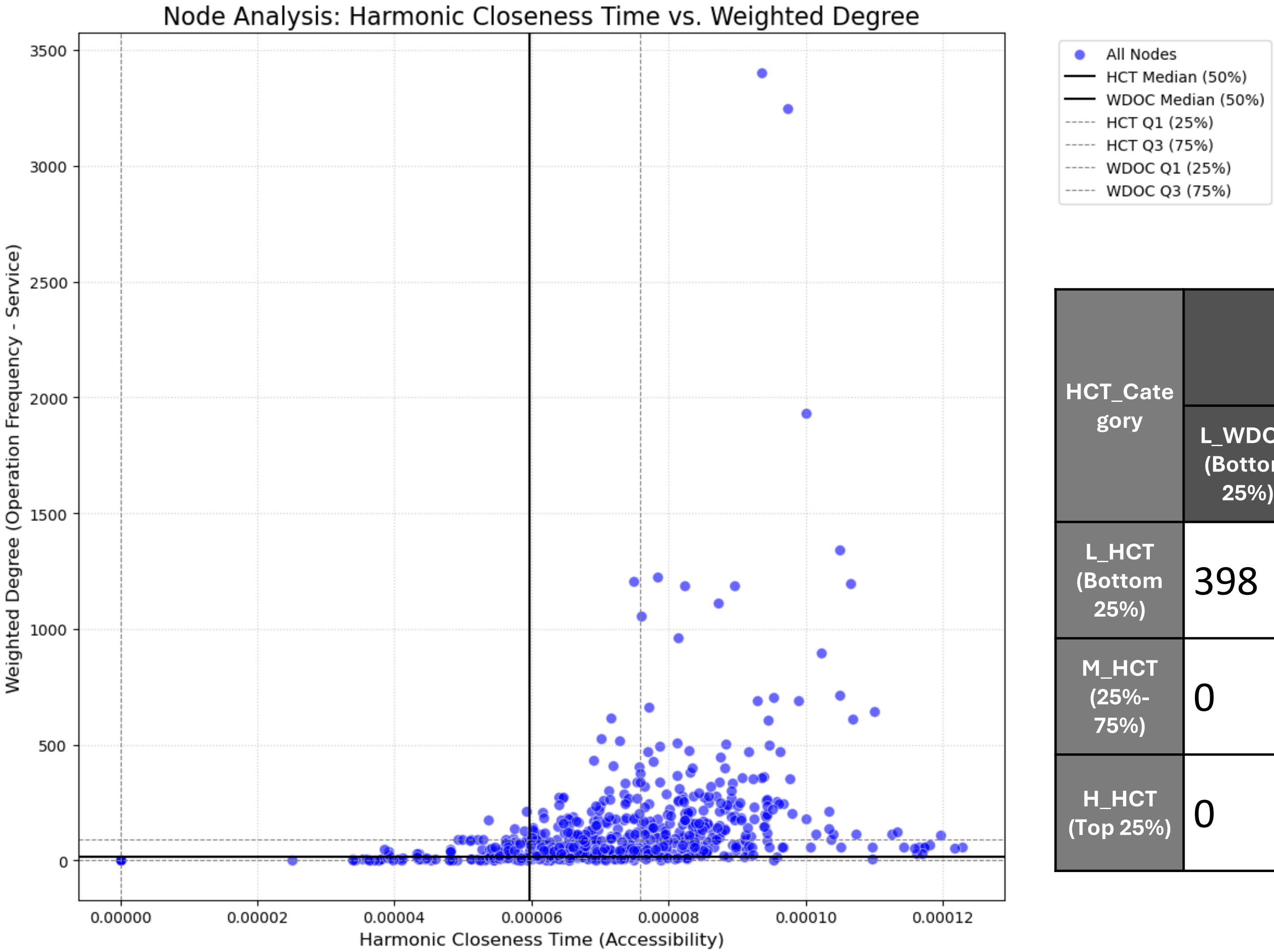




HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	2261	5154	2906
M_HCT (25%-75%)	5356	10187	5098
H_HCT (Top 25%)	2714	5290	2317

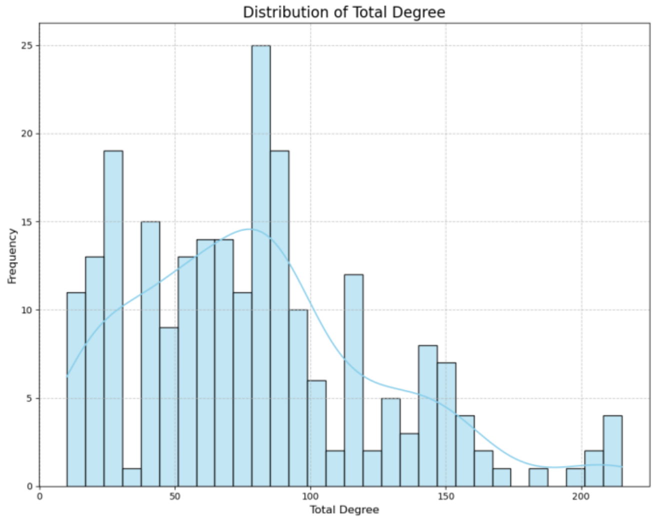
Appendix : Express Bus Network

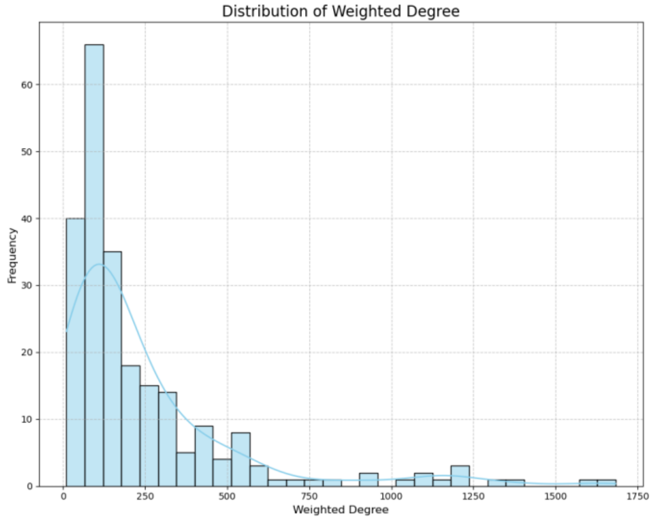


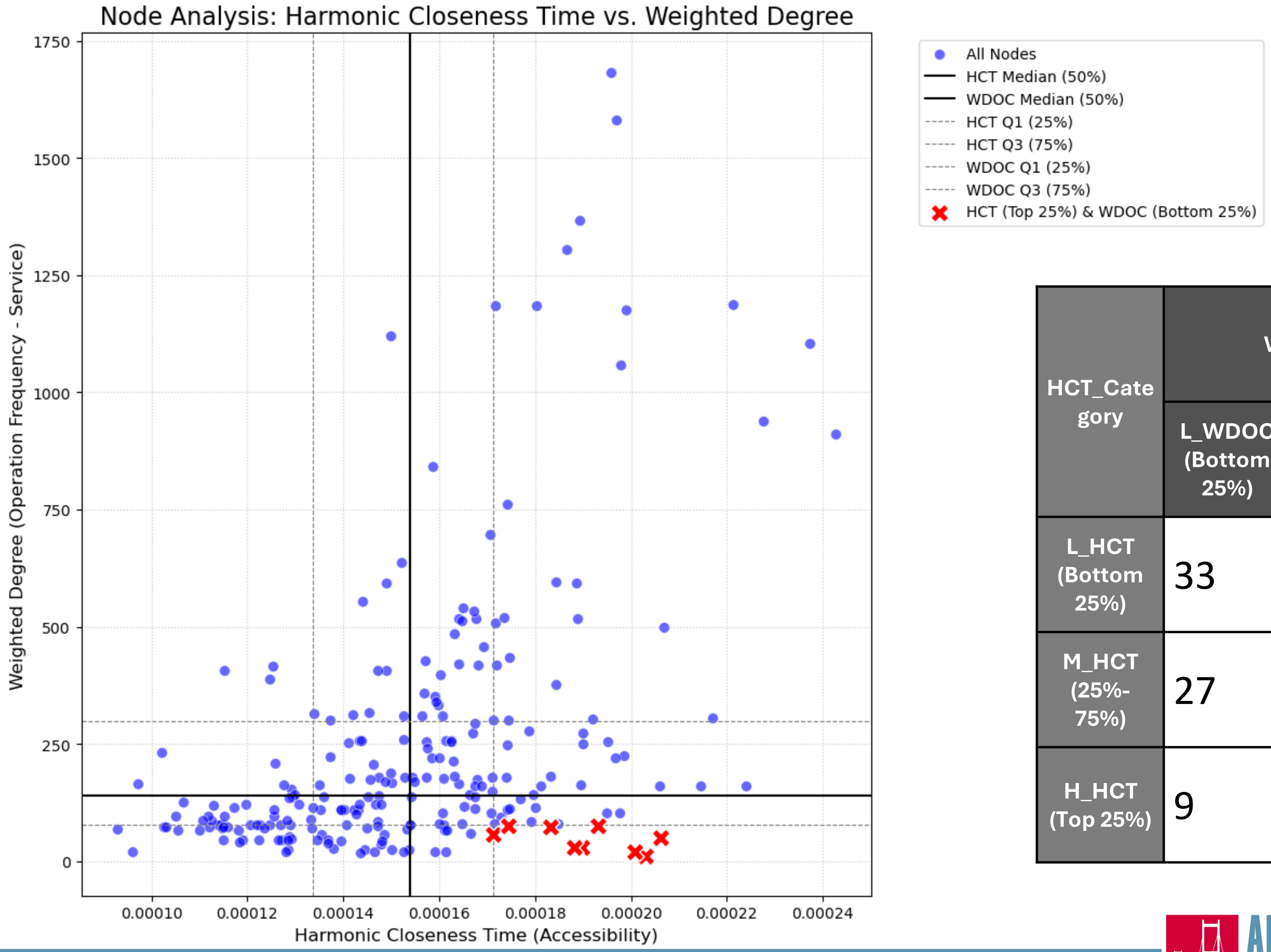


HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	398	0	0
M_HCT (25%-75%)	0	292	90
H_HCT (Top 25%)	0	98	162

Appendix : Railway Network

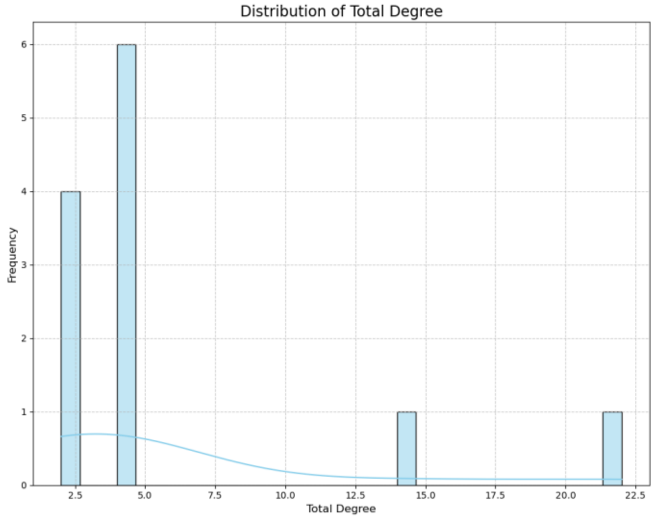


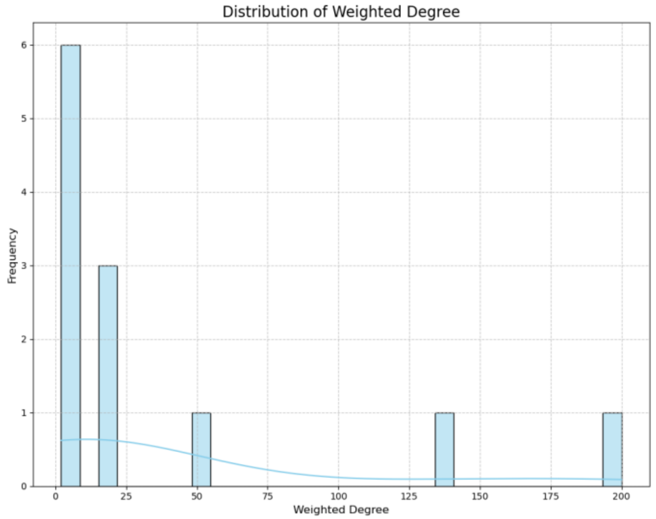


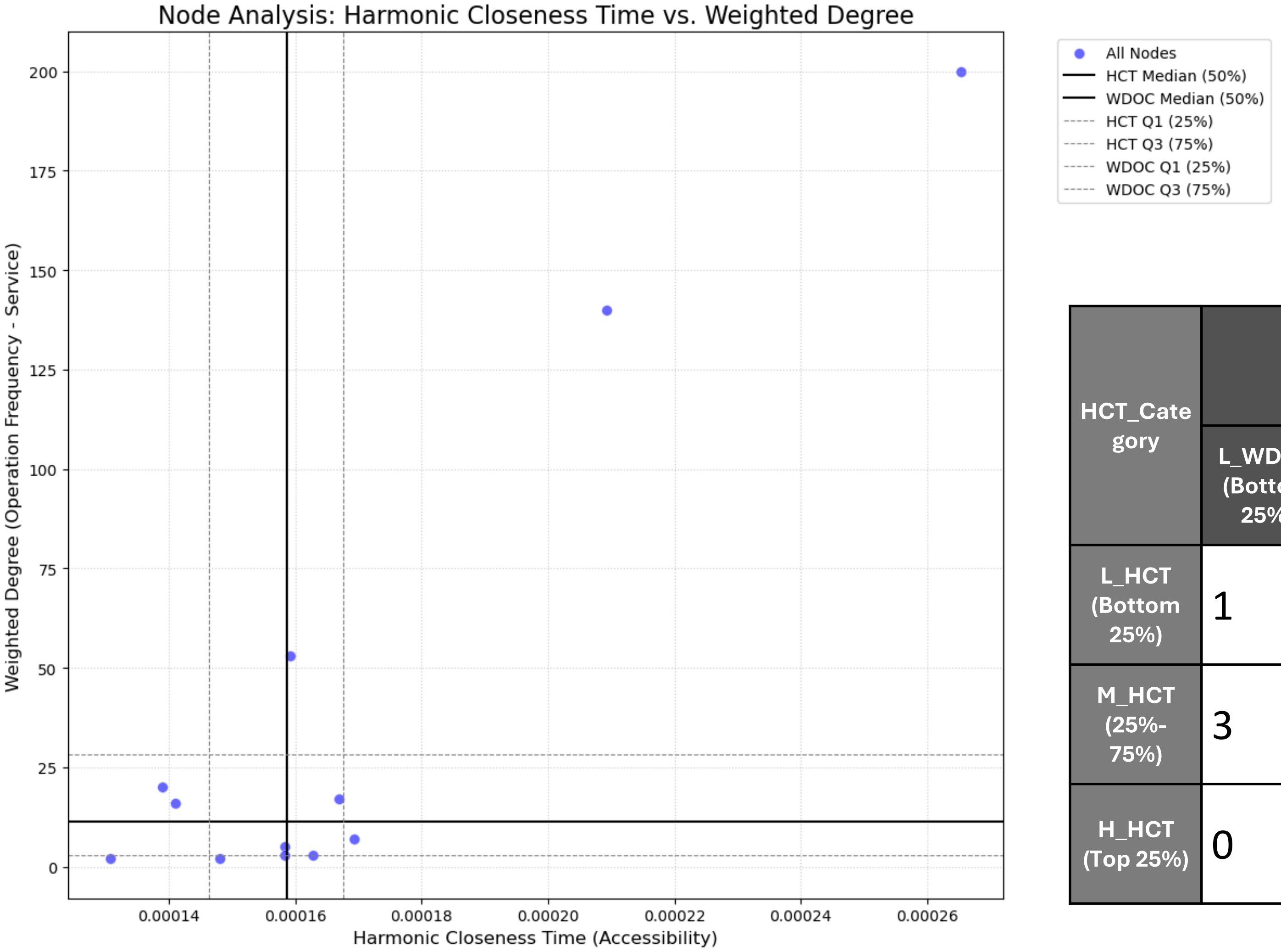


HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	33	23	3
M_HCT (25%-75%)	27	58	31
H_HCT (Top 25%)	9	25	25

Appendix : Avation Network

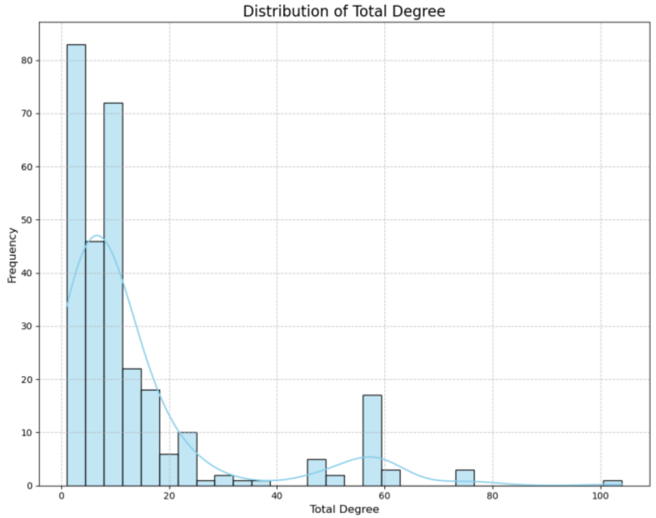


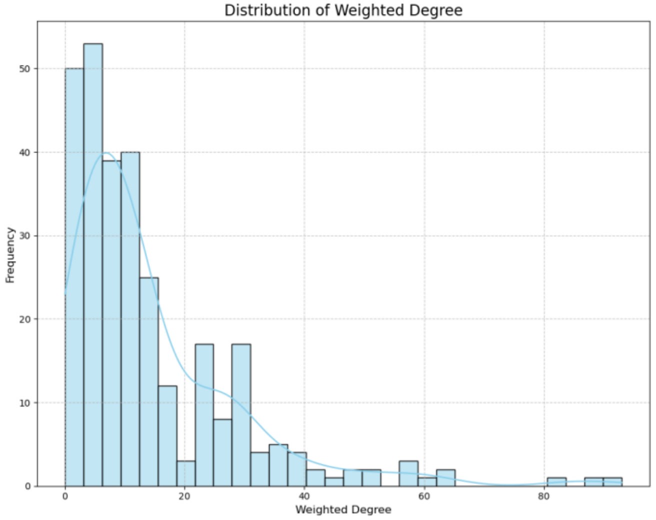


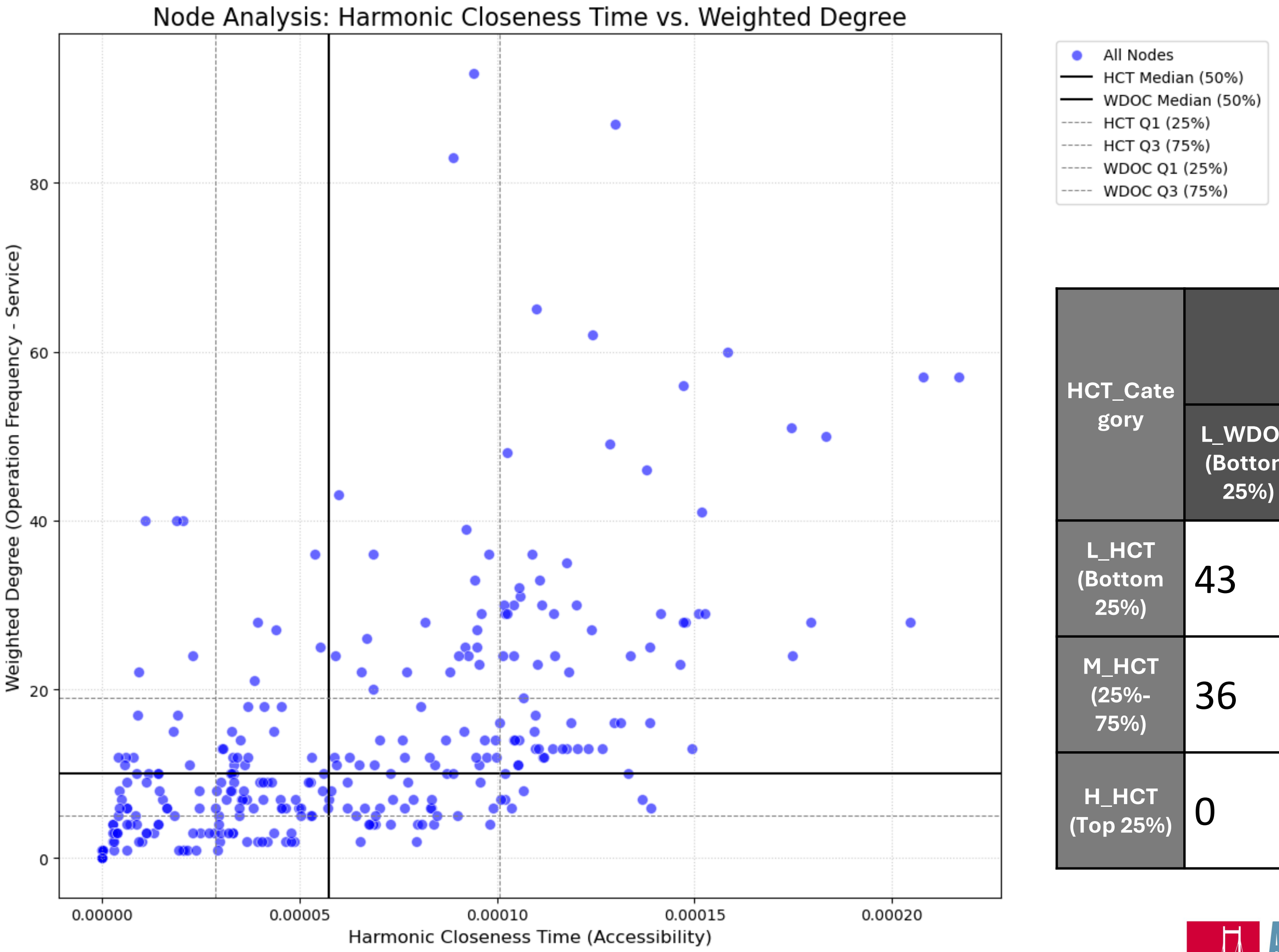


HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	1	2	0
M_HCT (25%-75%)	3	2	1
H_HCT (Top 25%)	0	1	2

Appendix : Maritime Network







HCT_Category	WDOC_Category		
	L_WDOC (Bottom 25%)	M_WDOC (25%-75%)	H_WDOC (Top 25%)
L_HCT (Bottom 25%)	43	26	5
M_HCT (25%-75%)	36	84	26
H_HCT (Top 25%)	0	31	42

Appendix : HCT & WDOC Multimodal Network