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2024 AAG Annual Meeting, Hawaii

Assessing Spatial Accessibility in Forest Welfare for Enhanced Quality of Life

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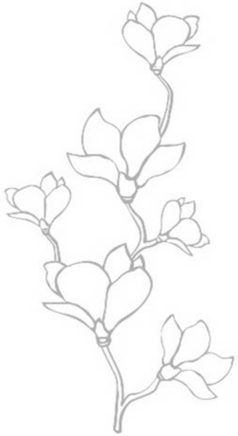


1) Forest Welfare

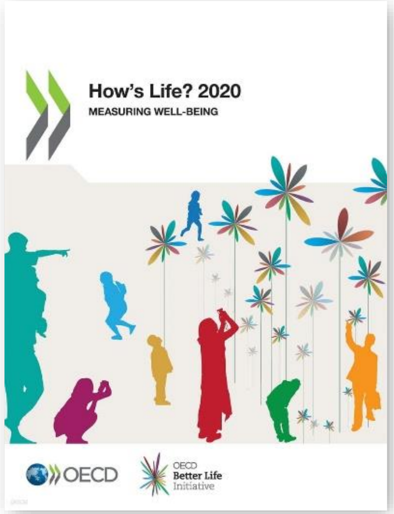
Urban Green Space Accessibility: Enhancing Quality of Life

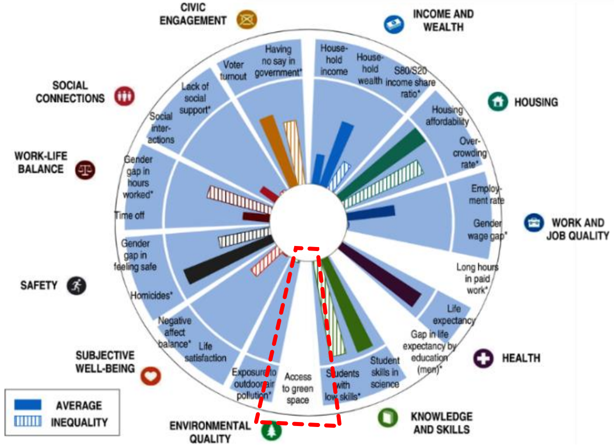
- The OECD recognizes the accessibility to urban recreational green spaces as a crucial factor in its **2020 Environmental Quality index.**

- Regular exposure to urban forests is linked to improved physical and mental health, advocating for integrated green infrastructure in city planning.

- Our research aligns with the OECD 'Better Life Index', emphasizing that **access to green spaces is essential for a high quality of urban life.**

- Ensuring green space accessibility in urban areas is a key step towards sustainable and livable city development and well-being.





1) Forest Welfare

Urban Green Initiatives: Elevating Life Quality in South Korea

- Leveraging over 70% of its forested landscape, South Korea remains committed to promoting forest welfare as a key to national well-being.

- Strategic initiatives such as the 6th Forest Basic Plan and the Forest Welfare Promotion Plan aim to integrate natural landscapes within urban planning to enhance well-being.

- Recent strategies extend beyond rural areas, embedding forest welfare within urban settings via new green spaces, thus enhancing sustainability and life quality for city dwellers.

- This holistic approach underscores the vital role of green spaces in urban life, aiming to enrich the living standards of a broader urban population through sustainable practices.

FoWI Korea Forest Welfare Institute

The Forest Healing Complexes operated by Korea Forest Welfare Institute(KoWI)

2) Quality of Life

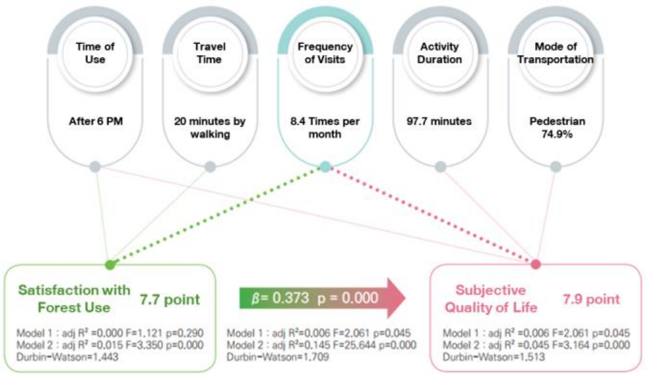
Life Quality and Forest Welfare: Measuring for Improvement

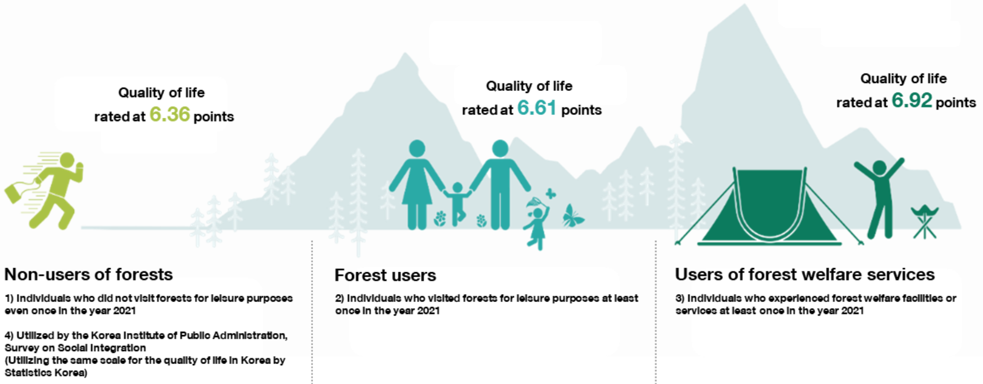
- Under the notion that **'what cannot be measured cannot be managed**,' the Korea Institute of Public Administration has been systematically quantifying the quality of life through annual surveys since 2011.

- The National Institute of Forest Science utilized these quantified indicators of life quality and validated the correlation and effect of **forest welfare services on improving life satisfaction**.

- 2023 study by Korea's National Institute of Forest Science reveals **visiting forests at least once yearly increases life quality scores by 3.8%**. **Regular use of forest amenities boosts life satisfaction by 8.8%,** with expert-led experiences yielding the most significant benefits.

- Urban dwellers show a propensity for more frequent visits to forests closer to home, ideally **within a 13-minute walking radius**. While **Europeans generally enjoy green space access within 10 minutes**, Koreans average an 18-minute journey to their urban nature spots.





3) Spatial Accessibility

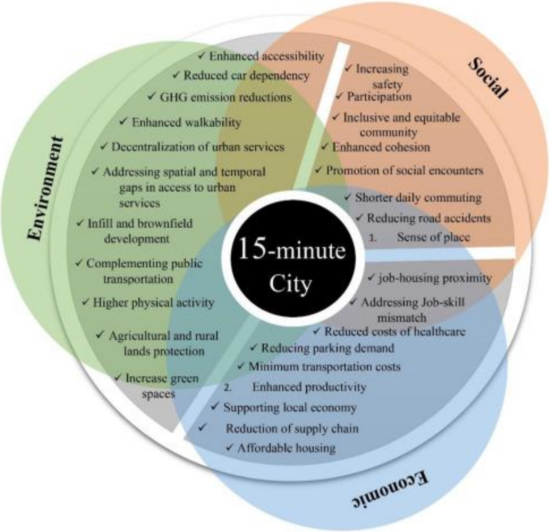
Enhancing Urban Livability through Green Spaces

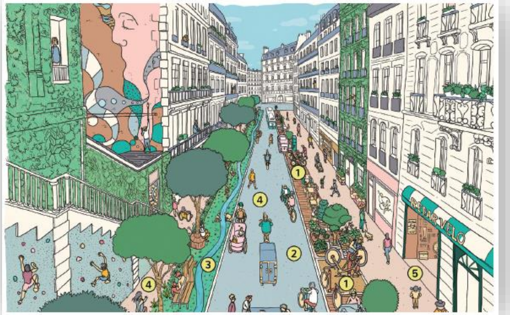
- Urban livability is intertwined with the **availability of accessible green spaces**, demanding research for effective policy-making.

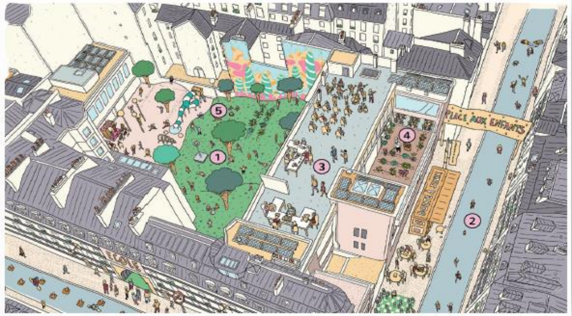
- The "**15-minute city**" concept by Paris showcases a commitment to ensuring everyday needs are within a **short walk** or cycle, aiming for ecological and social benefits.

- Accessibility indicators, measuring how urban infrastructure supports residents' daily lives, guide the planning of sustainable cities.

- This study adopts the **15-minute radius** as a benchmark for Seoul, integrating **spatial accessibility with forest welfare to elevate quality of life**.







3) Spatial Accessibility

- Accessibility quantifies the ease and convenience of reaching destinations from a specific origin (Hansen, 1959).
- Defines the scope of activities and destinations within a city reachable by particular transportation modes (Dalvi & Martin, 1976; Geurs & van Wee, 2004).

Perspectives in Assessing Accessibility (Geurs & van Wee, 2004):

1) Infrastructure-Based: Focused on available facilities.

2) **Location-Based:**

   - **Allows for quantitative analysis**
   - **favored by researchers and policymakers for its ease of interpretation.**

3) Person-Based: Centers on individual mobility.

4) Utility-Based: Considers the overall benefits and utilities.

Criteria for Choosing Accessibility Assessment Methods:

1) Theoretical basis for robust analytical grounding.

2) **Operationalization** for practical analysis and measurement.

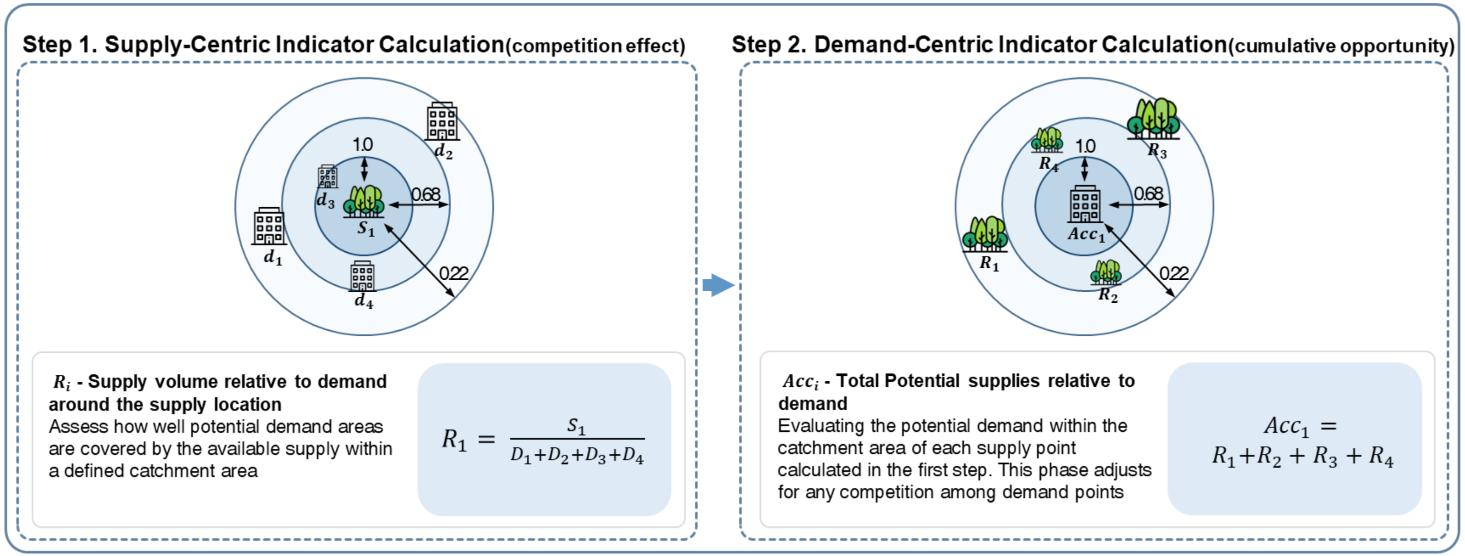
3) **Interpretability and communicability** for clear understanding and wider application.

4) Functionality as a social indicator to inform public policies.

5) Relevance as an economic indicator for economic planning and development.

3) Spatial Accessibility

2-Step Floating Catchment Area(2SFCA)



Demand and supply dynamics play a critical role in urban green space as a form of forest welfare services. For example, while spaces like the River parks are open to all, the available spots for activities like picnicking are limited, leading to competition even within the same park for preferred spots. Consequently, accessibility research calls for analytical methods that consider both demand and supply. Techniques like the 2-Step Floating Catchment Area (2SFCA) approach, introduced by Luo & Wang (2003), are widely adopted for this purpose in various studies. **The 2SFCA method delineates accessible areas from supply and demand points and quantifies supply and demand within these areas to calculate accessibility**

1) Research Goals

Pedestrian Road Network

Network Data Preprocessing

- **Openstreetmap(OSM)** Network
- Python OSMnx
- Filter **Pedestrian Roads** only.
- Joining Network data with SRTM DEM data, sampling **altitude** attribute.
- Adjust walking speed **according to the inclines**

Catchment Area Calculation

- Compute shortest path between each nodes using Dijkstra Algorithm through NetworkX library.
- Construct Non-Relational Database (Python dictionary)

Population per Building Unit

De Facto Population Data

Census block size data with Time Unit & Demographic attributes

Time unit : Date, Hourly, Weekday/Weekend
Demographic: Age, sex

Estimating population per building unit

Dasymetric Analysis - Distributing population proportional to each building's gross floor area* within a census block. (More Population in a larger building)

* [Gross floor area (GFA) = Building boundary X level]

Urban Green Space

Integrating Multidimensional Greens

(1) Ecological green space
- Ecological land cover data constructed by Ministry of Environment

(2) Urban administrative green space
- Parks with address in "Road Name Address System" constructed Ministry of the Interior and Safety

(3) Community-driven green space
- Urban Green Space boundary data collected through Openstreetmap

Partitioning Each green space

Merge -> Generate 100m by 100m grid -> Clip -> Single Part

Gaussian based 2SFCA Accessibility Analysis

Urban Green Space Accessibility for Individual Buildings (From the Demand Perspective)
Urban Building Accessibility for Individual Green Spaces (From the Supply Perspective)

2) Study Area

- Seoul spans 605 km², characterized by **a basin formed by surrounding mountains**, **with over a quarter forested(25.3%)**, enhancing urban life through nature's benefits.

- It's framed by a **green belt**, limiting expansion since 1971, contributing to its dense urban fabric yet high living standards, supported by a robust infrastructure network.

- With a population density surpassing most major cities at 16,181 per km², Seoul is a core city in the **Greater Seoul Area, which houses nearly 24 million people**.

- Internationally acknowledged for its urban quality, Seoul is a top city in global rankings, reflecting its **competitive edge and citizens' well-being**.

- The forward-looking "**2030 Seoul Plan**" fosters a participative, thoughtful **urban environment, prioritizing harmonious spatial and residential zone development**.

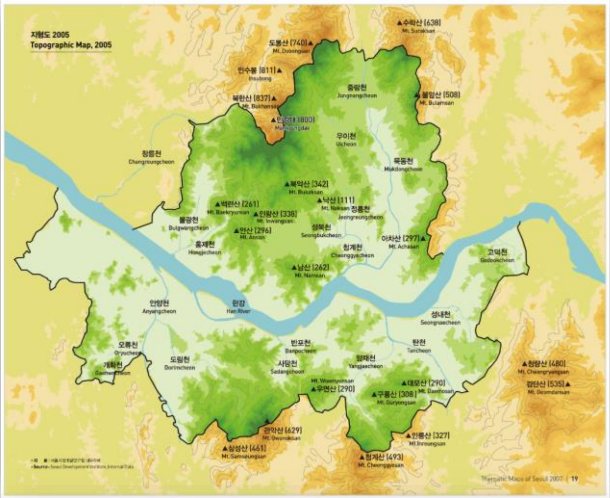
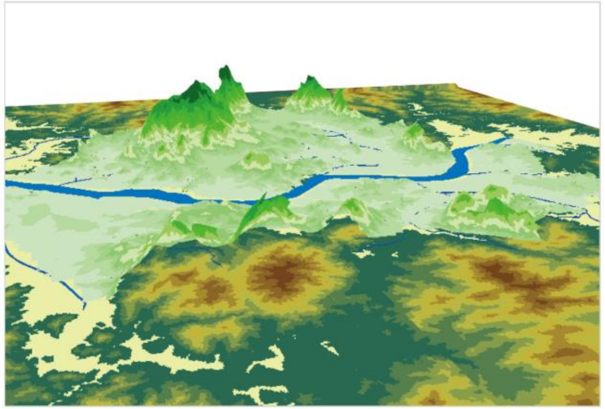


그림 1. 3차원 지형도
Figure 1. 3D Topographic Map



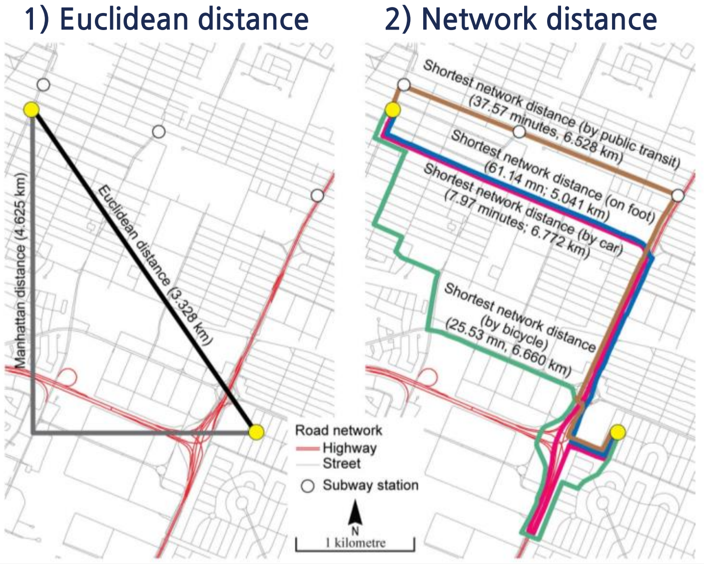
3) Methodology – Network-based Catchment Area

- Methods of calculating distances between supply and demand points include straight-line (Euclidean distance) and network-based (Network distance) approaches, **with network distances providing more accurate and realistic measurements of reach** (McGrail, 2012).

- Pedestrian-based green space access times are computed using OpenStreetMap (**OSMnx**) road networks and **NetworkX** libraries within **Python**

- **Walking speeds are adjusted for inclines**, with a maximum speed of 1.4575 m/s at a -3° slope and a minimum speed of 0.972 m/s at a 7° slope, reflecting up to a 34% **pedestrian resistance** due to inclines (Wei, et al. 2024)

- This study calculates **the catchment area from individual buildings** within a threshold time and analyzes **urban green space within these living areas**. It also identifies and **analyzes building clusters** that fall into similar forest welfare service accessibility.



출처 : Apparicio et al., 2017

3) Methodology – Shortest Path Finding (Dijkstra Algorithm)

1. Calculating Travel Time from Orientations to Network

① Search for the Nearest Link from the Orientation

② Explore Possible Exit Paths and Nodes

- Apply the Pedestrian resistance by the inline of the link in the travel speed (Wei, 2024)
- Add to the task list as a pending item

③ Retrieve tasks from the task list and decide whether to proceed

Condition 1: Must be faster than any existing record at the node

Condition 2: Must be within the allowable time

④ Search for new routes and add to the queue

- Repeat steps ② to ③ until the task list is empty

2. Calculating Travel Time from Network to Destinations

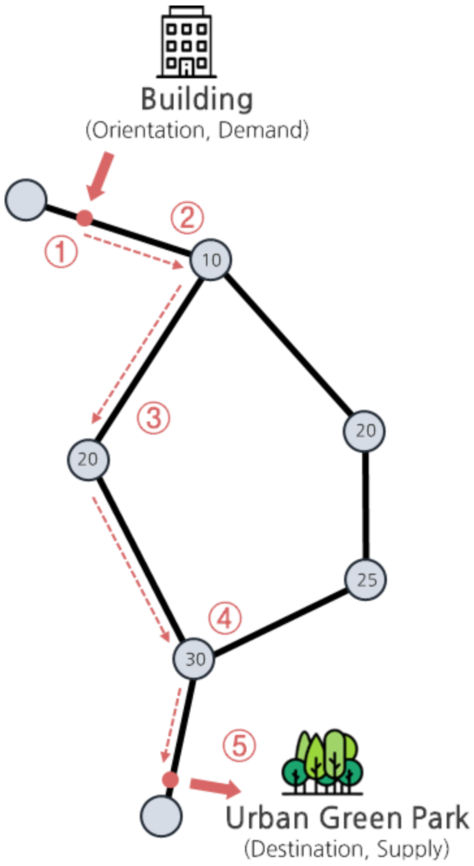
⑤ Search for the Nearest Link to the Destination

⑥ Refer to the values entered in neighboring nodes to calculate the travel time from supply points to demand points

3. Building a Time-Distance Database Between Supply and Demand Points

⑦ Construct a database with the structure { Orientation : { Destination : Travel Time } }

- Use a non-relational database structure (Python dictionary) for rapid computation and application in subsequent accessibility calculations



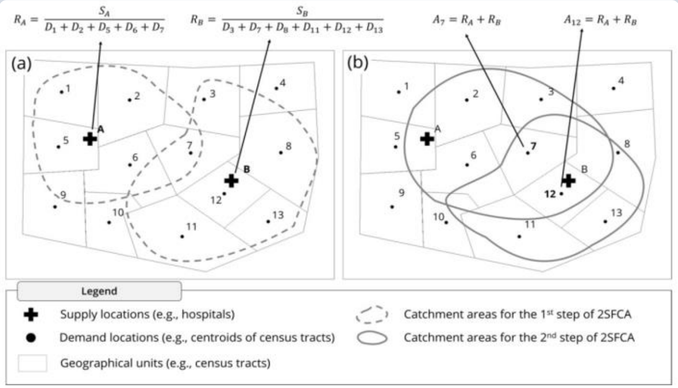
3) Methodology – 2 Step Floating Catchment Area

Quantifies accessibility by accounting for the **cumulative opportunities at service providers** and the **competitive effects experienced by users**.

① Reflects the competitive effect among demand points that can be accessed from a supply point.

② Reflects the cumulative opportunities at supply points that can be accessed from a demand point.

⇨ Classify urban living area types based on the variance in accessibility to urban green spaces.



Distance Decay - Gaussian Probability Density Function

- Accessibility to specific locations or services decreases with increasing distance. This **distance decay** is incorporated using weights based on the **Gaussian Probability Density Function.**

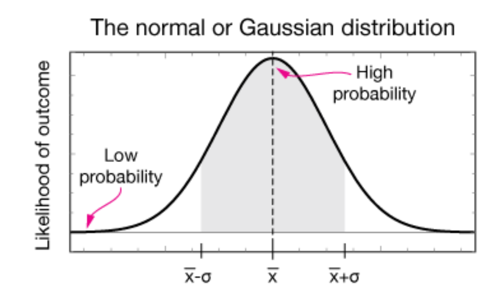
Examples: (In case of 900 second catchment area)

ex1) Located in 100 seconds - 0.9844

ex2) Located in 300 seconds - 0.8627

ex3) Located in 600 seconds - 0.4936

ex4) Located in 900 seconds - 0.0



$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

```
import numpy as np
def gaussian_weight(distnace_between_kj, catchmentarea_j):
    if distnace_between_kj <= catchmentarea_j:
        # Gaussian function implementation
        value = (np.exp(-0.5 * (distnace_between_kj / catchmentarea_j) ** 2) - np.exp(-0.5)) / (1 - np.exp(-0.5))
    else:
        value = 0
    return value
```

1) Data Collection and Processing – Openstreetmap Network Data

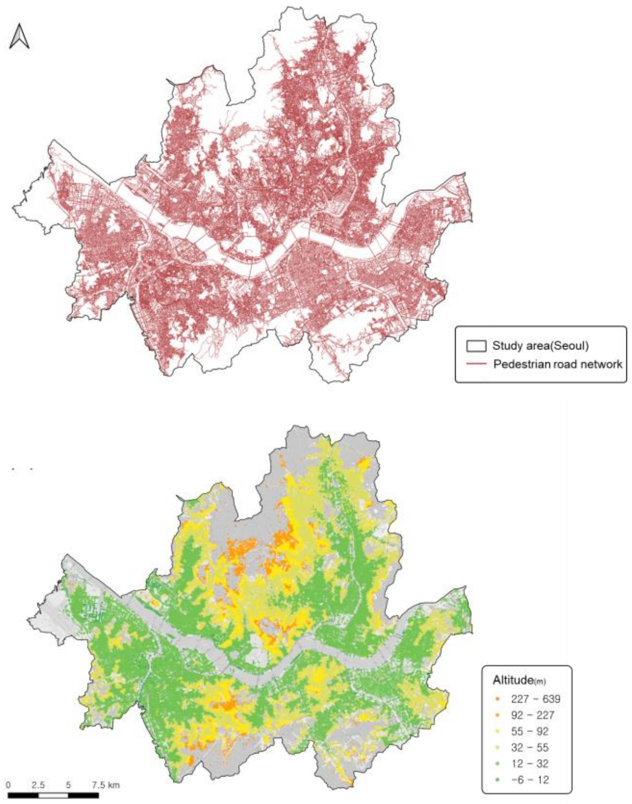
Openstreetmap Pedestrian Road Network from OSMnx API(Python)

- For precise pedestrian network usage, roads are filtered against actual conditions. Out of 27 road categories classified as 'highway', 24 are used, excluding three inaccessible to pedestrians (motorway, trunk, busway).

- Pedestrian **speed adjustments based on incline**, utilizing SRTM DEM elevation data. Referencing Wei (2024) to account for speed variations: **1.4575 m/s on a -3° decline, 0.972 m/s on a 7° incline.**

- Python's non-relational database structure (dictionary) is employed for rapid data processing.

- Dijkstra's algorithm (single_node_dijkstra) is used to calculate travel time between points.



Openstreetmap Pedestrian Road Network

1) Data Collection and Processing – Urban Green Space Data

Integrating Green Space Data from Multiple Perspectives

(1) Ecological Perspective:
Utilizing the **Ministry of Environment's biotope maps** following the 2008 guidelines, this includes land use, impermeable paving, existing vegetation, and biotope types for urban ecological status mapping.

(2) Urban Administrative Perspective:
Based on the **Road Name Address System data from the Ministry of the Interior and Safety**, leveraging information on small parks and children's parks managed by the Seoul Metropolitan Government.

(3) Community Experience Perspective:
Crowdsourced data from Openstreetmap, crafted by direct community engagement, encapsulates potential green space usage by local residents and includes attributes like land use and points of interest

Integrating Green Space Data from Multiple Perspectives

1) Data Collection and Processing – Urban Green Space Data

- Considering the variance in size from extensive mountainous areas to smaller neighborhood parks, the largest forested area in Seoul covers 7% of the total metropolitan area.

- To minimize analysis error, **green spaces were segmented into units less than 1ha, resulting in approximately 47,000 individual green spaces**.

- The **total green area was identified as 28.67% of Seoul**, closely aligning with the Forest Service's estimate of 25.32%, confirming the inclusion of neighborhood parks and suggesting **a realistic representation of the city's green data.**

1) Data Collection and Processing – Building based De Facto Population Data

Population :

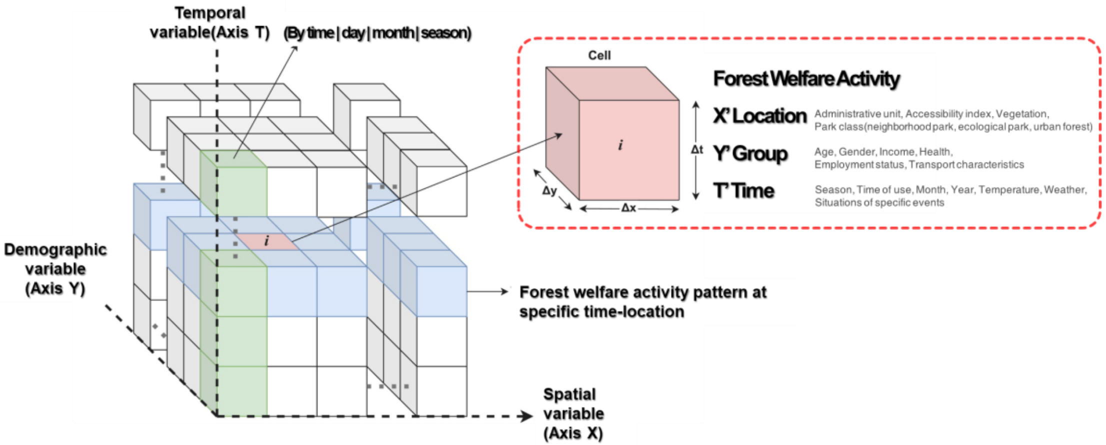
Seoul's Census Block Level De facto population data provided by Seoul Metropolitan Government's. Spatial data combined from Government's own big data and **Korean major mobile carriers' data(KT).** The data includes various attributes such as **age, gender, and collection time** frames, allowing for detailed research analysis. Blocks averaging 30,000 m² with about 26 buildings.

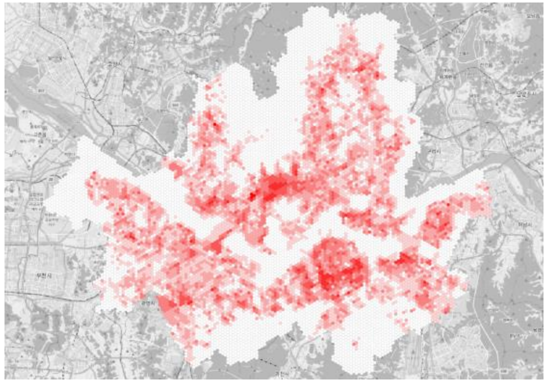
Building Unit :

Building unit data provided by Ministry of Public Administration and Security. Applied to building block level research. Utilized **gross floor area(GFA)** attribute.

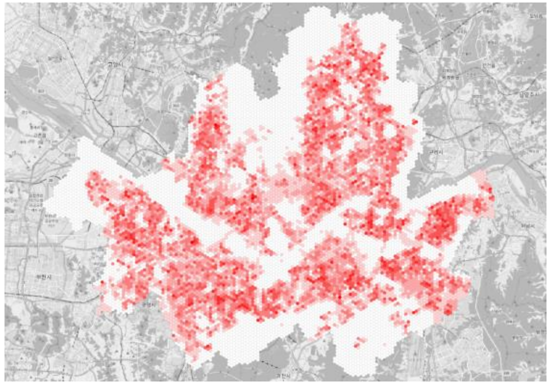
Population Estimation based on building sizes:

Using **Dasymetric** techniques, the study estimates based on building's gross floor area sizes, **assuming larger structures correspond to increased green space usage. This approach quantifies urban green space demand for comprehensive urban analysis.**





April 1st, 2024 14:00
(Day time)

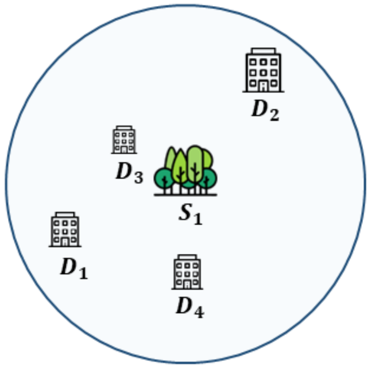


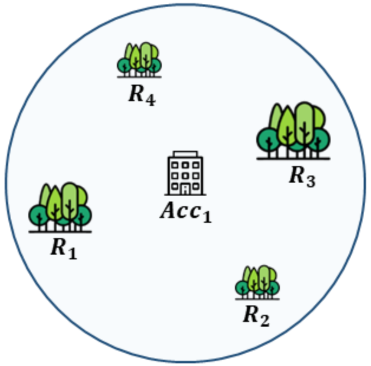
April 1st, 2024 23:00
(Night time)

2) Accessibility Analysis – Gaussian based 2SFCA

Gaussian based 2-Step Floating Catchment Area(G2SFCA)

2-Step Floating Catchment Area(2SFCA)





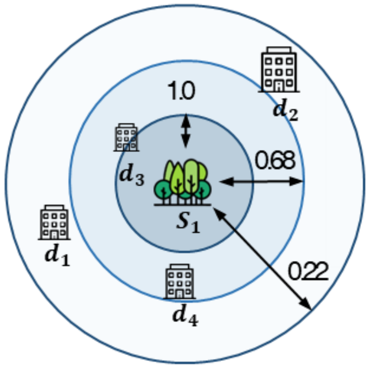
$$R_1 = \frac{S_1}{D_1+D_2+D_3+D_4}$$

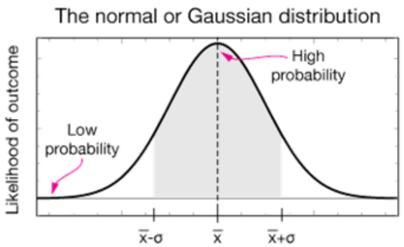
Competition Effect

$$Acc_1 = R_1 + R_2 + R_3 + R_4$$

Cumulative Opportunity

+



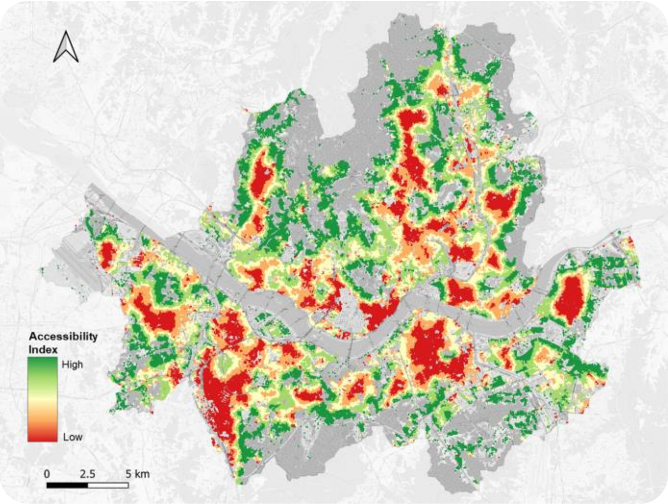


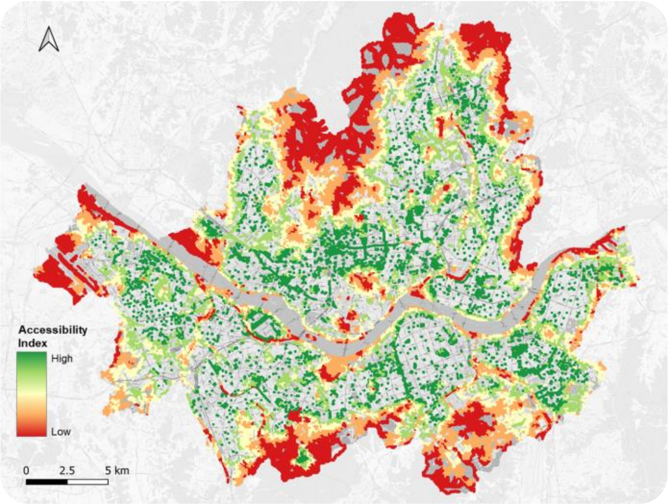
$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Distance Decay based on
Gaussian probability distribution function
(Dai, 2011)

Examples (In case of 900 second catchment area)
ex1) Located in 100 seconds - 0.9844
ex2) Located in 300 seconds - 0.8627
ex3) Located in 600 seconds - 0.4936
ex4) Located in 900 seconds - 0.0

Snapshot of Accessibility Index – April 1st , 2024 11:00AM (Whole Population Group)





Urban Green Space Accessibility for Individual Buildings

- A **high accessibility index** indicates that an area surrounding a specific point has a **rich distribution of green spaces relative to the local population**. This suggests that **residents have better opportunities to access urban greenery**.
- Conversely, a **low accessibility index** means that there is a **scarcity of green spaces around certain areas**, compared to the population density. This may indicate a need for urban planning to increase green spaces in these underserved areas.
- Analysis of different clusters within the study area can identify potential sites for expanding green spaces and services, allowing for strategic urban development.

Urban Building Accessibility for Individual Green Spaces

- **High indexes** indicate dense populations around green spaces, suggesting **high usage potential and frequent visitor access**. This can be interpreted as **a high demand for these green resources by the local community**.
- **A low accessibility index** means fewer people are living around these green spaces, suggesting **limited interaction and a potential underutilization** of available green resources.
- For green spaces with low accessibility scores, **formulating policies to improve access, such as constructing trails, is crucial**. In areas with high accessibility, **prioritizing environmental enhancement efforts is essential to maintain quality and usability due to high user engagement.**

Summary

- Our study, conducted in Seoul, employed the **Gaussian-based 2-Step Floating Catchment Area (G2SFCA)** method and Dijkstra's algorithm to meticulously **quantify the accessibility of urban green spaces relative to population demands**, ensuring a detailed analysis of spatial accessibility.

- By integrating pedestrian road network data, we analyzed **walkable catchment areas and adjusted for pedestrian resistance using terrain inclines,** providing a realistic assessment of **green space accessibility within a 15-minute reach.**

- Our results identified zones with varying accessibility levels; high accessibility indexes were noted in areas with abundant greenery, suggesting these regions offer excellent urban green space coverage and should be maintained as high-usage zones.

- Conversely, regions with low accessibility indexes highlighted a deficiency in green space relative to population density, signaling critical areas for urban development and green space expansion.

- This strategic analysis assists city planners and policymakers in targeting interventions to improve green infrastructure, aiming to enhance **urban living standards by ensuring equitable access to green spaces**.

- Ultimately, our research promotes sustainable urban development by proposing tailored improvements that increase forest welfare services, thereby contributing to a healthier, more vibrant urban environment.

Future Works

- Future studies will **focus on specific areas** to explore the impact of forest welfare services **on urban quality of life using simulations like Agent-Based Modeling.**

- We aim to **combine extensive big data, such as mobile data, to analyze demographic and temporal patterns in forest welfare zones** for deeper policy insights.

- This research will target the identified imbalances in service demand and supply, enhancing the effectiveness of urban forest management strategies.

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2024 AAG Annual Meeting, Hawaii

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Acknowledgment: This research was supported by the NIFOS(National Institute of Forest Science), Republic of Korea under the project named Development of a Model to Enhance Forest Welfare Services for Quality of Life Effects Based on Measurement in Living Areas*.

National Institute of Forest Science

* 삶의 질 효과 측정 기반 생활권 산림복지서비스 증진 모델 개발