URBAN LIVABILITY

Planning urban livability requires analyzing a range of factors, including environmental conditions, infrastructure, social dynamics, and economic opportunities. Several algorithms can be used to support urban livability planning by analyzing data, making predictions, and optimizing various aspects of the urban environment. Here are some key algorithms commonly employed in urban planning for livability:

**1. Multi-Criteria Decision Analysis (MCDA)**

* **Description**: MCDA is a decision-making algorithm used to evaluate and prioritize multiple conflicting criteria, such as environmental quality, accessibility, and affordability. It helps in assessing different planning alternatives by weighing factors like green space availability, transportation networks, and air quality.
* **Application**: MCDA can be used to make informed decisions about zoning, land use planning, and resource allocation in urban areas.

**2. Genetic Algorithms (GA)**

* **Description**: Genetic algorithms are optimization techniques inspired by the process of natural selection. They are used to search for optimal or near-optimal solutions in complex urban planning problems, where multiple variables and constraints exist.
* **Application**: GA can be used in designing urban spaces, optimizing transportation routes, or planning green spaces by evolving solutions that balance various livability factors (e.g., reducing traffic congestion or improving environmental sustainability).

**3. Cellular Automata (CA)**

* **Description**: Cellular automata are mathematical models used for simulating urban growth and land use changes. The model consists of a grid where each cell has a state, and the state of a cell evolves based on a set of rules influenced by neighboring cells.
* **Application**: CA can be used to model the spread of urban areas, analyze land use changes over time, and predict how these changes may affect livability factors such as accessibility, population density, and air quality.

**4. Agent-Based Models (ABM)**

* **Description**: Agent-based models simulate the interactions of individual agents (people, organizations, or vehicles) within an urban environment. Each agent follows specific rules based on its environment and goals.
* **Application**: ABM is useful for studying social dynamics, traffic flow, pedestrian movement, or how individuals interact with urban infrastructure. It can be used to simulate the effects of new policies (e.g., public transport systems) on overall urban livability.

**5. Geospatial Analysis with Machine Learning Algorithms**

* **Description**: Geospatial analysis combined with machine learning allows urban planners to analyze large spatial datasets (e.g., satellite imagery, land use data, traffic patterns). Algorithms like **Random Forests**, **Support Vector Machines (SVM)**, and **K-means clustering** are frequently used for classification and prediction.
* **Application**: These algorithms can classify land cover types (residential, commercial, industrial), predict urban heat island effects, and identify areas of high environmental risk. They help optimize city layouts and improve livability by focusing on areas that need the most intervention.

**6. Optimization Algorithms (Linear Programming, Integer Programming)**

* **Description**: These algorithms are used to optimize certain urban planning parameters, such as resource allocation, land use, and transportation networks. Linear programming (LP) deals with optimization problems where the objective function and constraints are linear.
* **Application**: Optimization algorithms are used to plan transportation networks, such as minimizing traffic congestion, optimizing public transit routes, or determining the best locations for amenities (e.g., hospitals, schools) to improve overall accessibility and livability.

**7. Spatial-Temporal Modeling (STMs)**

* **Description**: Spatial-temporal modeling combines spatial data (location) and temporal data (time) to analyze patterns over space and time. This approach is important in studying urban systems that evolve, such as air quality, noise pollution, and land use dynamics.
* **Application**: STM can help identify how factors like pollution change throughout the day, the seasonal effects on green spaces, or how noise levels fluctuate across urban areas. This helps urban planners make informed decisions about zoning, green spaces, and public health.

**8. Simulated Annealing (SA)**

* **Description**: Simulated annealing is a probabilistic optimization technique inspired by the annealing process in metallurgy. It’s used to find an approximate solution to optimization problems with a large search space.
* **Application**: SA can optimize complex urban planning problems, such as the optimal distribution of amenities (e.g., parks, hospitals), traffic flow, or public transport networks, while considering livability factors like accessibility and environmental impact.

**9. Artificial Neural Networks (ANN)**

* **Description**: Artificial neural networks, particularly deep learning models, can analyze large, complex datasets. They are often used for classification, prediction, and pattern recognition tasks.
* **Application**: ANN can predict urban growth trends, assess traffic patterns, predict energy consumption, or analyze noise pollution levels. They can be used to assess how different factors, such as infrastructure changes, may impact overall urban livability.

**10. Markov Decision Processes (MDP)**

* **Description**: MDPs are mathematical models used for decision-making where outcomes are partly random and partly under the control of the decision maker. These models are used to optimize processes in uncertain environments.
* **Application**: MDPs can be used in planning decisions for urban mobility systems, such as public transportation, where the outcomes are uncertain (e.g., fluctuating demand). They can also optimize resource management in cities, such as waste management and energy consumption, to enhance livability.

**11. Data Envelopment Analysis (DEA)**

* **Description**: DEA is a non-parametric method used to assess the efficiency of decision-making units (such as urban neighborhoods or districts) by comparing multiple inputs and outputs.
* **Application**: DEA can be applied to measure the efficiency of different urban areas in providing livability outcomes (e.g., comparing public service delivery, green space accessibility, or transportation efficiency across districts).

**Color Bands for different use cases**

To plan urban livability using **Copernicus** data, which primarily includes **Sentinel-2** satellite imagery, a combination of **optical and infrared bands** is often used to assess various aspects of urban environments such as vegetation, land cover, temperature, air quality, and urban heat island effects. The following color bands (or spectral bands) are particularly useful for planning urban livability:

**1. Red (Band 4)**

* **Wavelength**: 664 nm
* **Purpose**: Used for vegetation mapping and monitoring land cover. It helps distinguish between urban areas and natural landscapes. Red band data can be combined with other bands for vegetation index calculations and assessing infrastructure.

**2. Green (Band 3)**

* **Wavelength**: 560 nm
* **Purpose**: Useful for analyzing the amount of green vegetation, urban green spaces, and vegetation health. It also helps in monitoring vegetation changes in urban areas.

**3. Blue (Band 2)**

* **Wavelength**: 490 nm
* **Purpose**: Provides high-resolution data that is useful for water bodies, monitoring surface water quality, and enhancing urban landscape analysis. The blue band is used in urban studies to identify features like roads and built-up areas.

**4. Near-Infrared (NIR) (Band 8)**

* **Wavelength**: 842 nm
* **Purpose**: NIR is essential for vegetation analysis and urban planning as it helps differentiate between vegetation types and urban areas. It's used in creating vegetation indices like **NDVI (Normalized Difference Vegetation Index)** to analyze green space and vegetation cover, which directly impacts urban livability.

**5. Shortwave Infrared (SWIR) (Band 11 and Band 12)**

* **Wavelength**:
  + Band 11: 1610 nm
  + Band 12: 2190 nm
* **Purpose**: SWIR bands are particularly useful for monitoring moisture levels in urban areas and distinguishing between different land cover types, such as bare soil, water, and urban infrastructure. They also help in studying the thermal dynamics of cities, which contributes to understanding urban heat islands (UHI).

**6. Vegetation Indices**

* **NDVI (Normalized Difference Vegetation Index)**:
  + Calculated using NIR (Band 8) and Red (Band 4). NDVI = (NIR - Red) / (NIR + Red).
  + **Purpose**: NDVI is a widely used index for vegetation health and coverage. Higher NDVI values indicate healthy vegetation, which is crucial for urban livability, especially in assessing green spaces and their contribution to environmental quality.
* **MNDWI (Modified Normalized Difference Water Index)**:
  + Calculated using Green (Band 3) and SWIR (Band 11). MNDWI = (Green - SWIR) / (Green + SWIR).
  + **Purpose**: Used for identifying water bodies and assessing water availability in urban areas, which is vital for urban planning and livability.

**7. Urban Heat Island (UHI) Monitoring**

* **Thermal Infrared Bands (TIR)**: Sentinel-3 (not part of Sentinel-2 but part of the Copernicus program) provides thermal infrared bands that are useful for monitoring urban heat islands (UHI).
  + **Sentinel-3 TIR Bands**: 10.5 - 12.5 µm (useful for monitoring surface temperatures).
  + **Purpose**: UHI is an important factor in urban livability because high temperatures can negatively affect residents' health and comfort. Monitoring temperature patterns can help in planning cooling solutions in cities, such as increasing green cover or water bodies.

**8. Sentinel-1 Radar Data (for urban infrastructure monitoring)**

* **Wavelength**: SAR (Synthetic Aperture Radar) bands
* **Purpose**: While Sentinel-1 is primarily a radar mission, its data can be used to monitor changes in urban infrastructure (e.g., detecting subsidence, deformation, or urban expansion), which is important for assessing and planning sustainable urban environments.

**Combining Bands for Livability Analysis:**

For effective urban livability analysis, you would typically combine these bands to create indices or maps that assess the following:

* **Vegetation coverage** (NDVI)
* **Urban heat island effect** (combining SWIR and thermal data)
* **Green spaces** and their accessibility (Green and NIR bands)
* **Water bodies** (MNDWI, NDWI)
* **Infrastructure health** (using multi-temporal and multi-spectral data)

1. **Urban Land Cover Classification**:
   * **Red (Band 4)**, **Green (Band 3)**, **Blue (Band 2)**
   * **Purpose**: Classifying urban areas (e.g., built-up land, vegetation, and water bodies).
2. **Vegetation Health Monitoring**:
   * **Near-Infrared (Band 8)**, **Red Edge Bands (Band 5, Band 6, Band 7)**
   * **Purpose**: Evaluating the health and coverage of urban green spaces using **NDVI** or other vegetation indices.
3. **Urban Heat Island (UHI) Effect Monitoring**:
   * **SWIR (Band 11 & Band 12)**, **NIR (Band 8)**
   * **Purpose**: Identifying areas that experience higher temperatures, which are critical for improving urban livability.
4. **Water Body and Wetland Mapping**:
   * **Blue (Band 2)**, **Green (Band 3)**, **MNDWI Index** (using **Band 3** and **Band 11**)
   * **Purpose**: Monitoring the extent and quality of urban water bodies and wetlands.
5. **Atmospheric and Air Quality Analysis**:
   * **Water Vapour (Band 9)**, **Cirrus (Band 10)**
   * **Purpose**: Understanding atmospheric conditions and their impact on urban air quality and climate.
6. **Coastal Urban Areas**:
   * **Coastal Aerosol (Band 1)**
   * **Purpose**: Analyzing coastal urban areas, important for cities near water, to understand how water quality and coastal vegetation influence livability.

**Urban Land Cover Classification** **formulae:**

**1. Normalized Difference Vegetation Index (NDVI)**

**Formula**:

NDVI=(NIR−Red)/(NIR+Red)

* **NIR (Near-Infrared Band)**: **Band 8** (842 nm)
* **Red Band**: **Band 4** (664 nm)

**Purpose**:

* NDVI is used to classify vegetation. Higher NDVI values indicate more dense and healthy vegetation, which helps in differentiating urban green spaces from other land types.
* Values range from -1 to +1. Values closer to +1 indicate healthy vegetation, while values closer to 0 or negative values indicate non-vegetated areas.

**2. Normalized Difference Built-up Index (NDBI)**

**Formula**:

NDBI=(SWIR−NIR)/(SWIR+NIR)

* **SWIR (Shortwave Infrared Band)**: **Band 11** (1610 nm) or **Band 12** (2190 nm)
* **NIR (Near-Infrared Band)**: **Band 8** (842 nm)

**Purpose**:

* NDBI helps classify built-up areas. Higher NDBI values typically indicate built-up areas (urbanized land), while lower values indicate natural vegetation or water bodies.
* NDBI values range from -1 to +1. Higher values are associated with built-up areas, while lower or negative values are associated with non-urban land cover.

**3. Normalized Difference Water Index (NDWI)**

**Formula**:

NDWI=(Green−SWIR)/ (Green + SWIR)

**Green Band**: **Band 3** (560 nm)

* **SWIR (Shortwave Infrared Band)**: **Band 11** (1610 nm)

**Purpose**:

* NDWI is used to distinguish water bodies from other land cover types. Positive NDWI values generally indicate water bodies, while values near 0 or negative are associated with vegetation or built-up areas.

**4. Urban Land Classification Using Combined Indices:**

In urban land cover classification, you can combine multiple indices and band ratios to refine classification. For example:

* **Vegetated areas**: Identified using high NDVI values.
* **Built-up areas**: Identified using high NDBI values.
* **Water bodies**: Identified using NDWI.

**Urban Heat Island (UHI) Monitoring formulae**:

**1. Urban Heat Island (UHI) Index Calculation (using SWIR and NIR bands)**

Although **Sentinel-2** doesn’t provide direct thermal data, you can use **SWIR (Band 11 & Band 12)** and **NIR (Band 8)** to help calculate potential temperature patterns.

**Modified Normalized Difference Built-up Index (MNDWI)**

* **Formula**:

MNDWI=(Green−SWIR)/(Green+SWIR)

**Bands**:

* + **Green Band (Band 3)**: 560 nm
  + **SWIR Band (Band 11)**: 1610 nm or **Band 12**: 2190 nm
* **Purpose**:  
  MNDWI is useful for identifying built-up areas and is often used to analyze urban heat in relation to land cover types. Urban areas, which have more impervious surfaces (such as concrete), absorb more heat, contributing to the UHI effect.

**2. Estimating Surface Temperature from SWIR and NIR Bands**

You can approximate surface temperatures based on the **normalized difference** between **NIR** and **SWIR** bands. While this does not give you actual temperature values (like thermal infrared would), it can provide relative heat differences across the landscape.

**Normalized Difference Built-up Index (NDBI) for Surface Temperature Estimation:**

* **Formula**:

NDBI=(SWIR−NIR)/(SWIR+NIR)

* **Bands**:
  + **SWIR (Band 11 or 12)**: 1610 nm or 2190 nm
  + **NIR (Band 8)**: 842 nm
* **Purpose**:  
  The NDBI helps highlight built-up areas, which are typically hotter due to the heat-retaining properties of urban surfaces. Higher NDBI values often correlate with higher surface temperatures and the UHI effect.

**3. Land Surface Temperature (LST) from Thermal Infrared Data**

For direct **UHI** assessment, **thermal infrared (TIR)** data is typically required, as it provides actual surface temperature readings. This data is available from **Sentinel-3 SLSTR** or other satellites like Landsat.

If you were using **Sentinel-3** or **Landsat TIR data**, you could use the following formula to convert **Top-of-Atmosphere (TOA) radiance** into **Land Surface Temperature (LST)**.

**Land Surface Temperature (LST) from TIR data (General Approach):**

* **Formula**:
* LST= (K2/ ln(Lλ​K1​​+1))​​−273.15
* **Where**:
  + **K1** and **K2** are calibration constants specific to the sensor.
  + **Lλ** is the TOA radiance in the thermal infrared band.
  + **LST** is the land surface temperature in Celsius.

**For UHI Effect:**

* **UHI = LST (Urban Area) - LST (Rural Area)**
* **Purpose**: This equation calculates the temperature difference between urban and rural areas, which is the essence of the **UHI effect**. The greater the difference, the stronger the UHI.

**4. Use of NDVI for UHI Monitoring**

Although **NDVI** (Normalized Difference Vegetation Index) doesn't directly measure temperature, it is an indirect indicator of how much vegetation is present. Areas with less vegetation are more likely to experience higher temperatures, contributing to UHI.

**NDVI Formula:**

NDVI=(NIR−Red)/(NIR+Red)

* **Bands**:
  + **NIR (Band 8)**: 842 nm
  + **Red (Band 4)**: 664 nm
* **Purpose**:  
  NDVI helps identify areas with dense vegetation that can reduce the UHI effect by providing cooling. Cities with higher NDVI values tend to have lower UHI effects because of increased vegetation.

**4. Land Surface Temperature**

Land Surface Temperature, or LST, refers to the temperature of the Earth's surface as measured from space using remote sensing. It represents how hot the surface of the land

**🌿 2. Moisture Index: What is it and why use it?**

The **Moisture Index** is a spectral index used to estimate surface moisture. It uses bands that are sensitive to water content in vegetation and soil.

A popular form using Sentinel-2 is:

A black and white math equation

AI-generated content may be incorrect.

* **B8A (865 nm)**: NIR – reflects well from healthy vegetation.
* **B11 (1610 nm)**: SWIR – sensitive to moisture; absorbs more with higher water content.

When soil/vegetation is dry, SWIR reflectance increases (so B11 ↑), reducing the MI. When soil/vegetation is moist, SWIR reflectance decreases (B11 ↓), increasing MI.

**🔥 Land Surface Temperature (LST) – Color Interpretation**

A screenshot of a computer

AI-generated content may be incorrect.

**5. Noise Measurement**