Enhancing Urban Resilience through Mobility-Based Heat Exposure Assessment and Urban Greening Strategies

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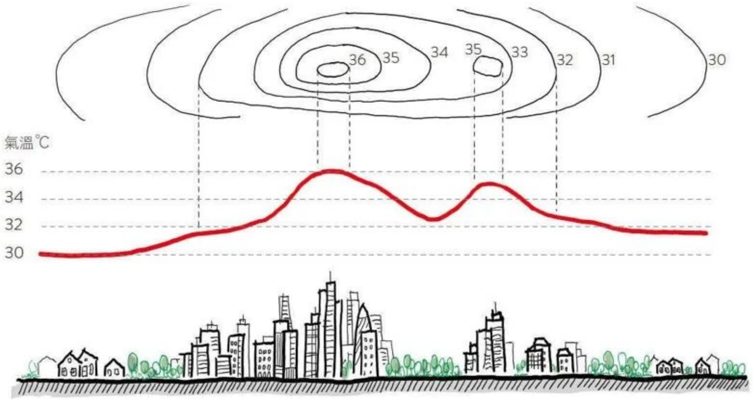
Research background



Urban Heat Exposure:

This term primarily refers to **the risk of high temperatures that people face in urban environments.**

As cities grow, concrete and asphalt replace natural vegetation, which lowers evaporation and increases temperatures. This urban heat island effect makes cities hotter than nearby rural areas, leading to risks like heat illnesses, more energy use, and stress.

Developing new methods to assess and lessen these heat risks is essential.

Why study mobility heat exposure?

Mobility Heat Exposure: Individuals' mobility behaviour in different spatial environments and the extent to which they are affected by heat risk.

Characteristics: Mobility heat exposure provides a more complete understanding of the **actual heat exposure** urban residents experience in daily life.

Dynamic Features of Heat Exposure: Tracking users through GPS shows that residents may experience higher heat exposure during daily activities than at home. This indicates that assessing heat exposure based only on residence may underestimate risks in frequently visited areas.

Environmental Justice: Low income and minority communities are often located in areas with higher heat exposure. Understanding these unequal risks helps create targeted interventions to reduce disparities.

Urban Planning: Understanding movement patterns helps better assess heat-related health risks and optimize the layout of green infrastructure to reduce heat impact on residents.

Research gaps

Limitations in Spatial and Temporal Resolution
Although existing studies use handheld GPS to quantify urban residents' heat exposure, relying on **limited study groups and time data** may not fully capture the dynamic changes in heat exposure.

Differences in Heat Exposure Among Diverse Populations
Research on differences in mobility and heat exposure among different social groups and age groups in urban heat environments is still insufficient, **especially regarding urban commuting, leisure activities, and the differences between active and passive exposure**.

Effectiveness of Mobility and Heat Exposure Intervention Strategies
Current research is insufficient on **how to effectively increase vegetation** to reduce heat exposure by understanding people's movement and heat exposure in cities.

Research Question

- How to construct a dynamic heat exposure index?
- What are the differences in heat exposure during commuting and leisure activities, and across various population groups?
- How can we use patterns of daily mobility to categorize urban areas into different heat risk areas?
- What strategies can be implemented to optimize urban green spaces effectively to reduce heat exposure?

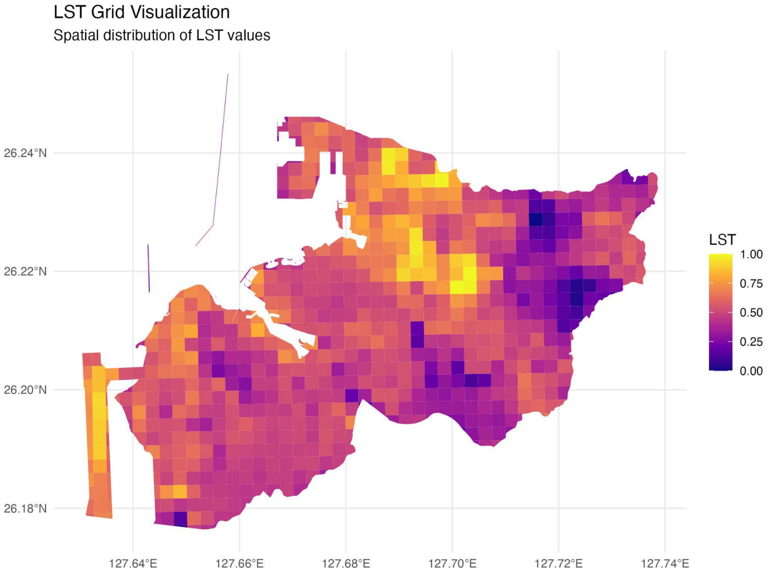
Research content

First, this study developed a novel mobility-based heat exposure assessment index that combines mobile phone mobile data with land surface temperature data (LST). Using this method, we conducted a quantitative analysis in August 2023 of the dynamic heat exposure of residents in 11 cities in Okinawa Prefecture. The study analysed the differences in heat exposure between residents' daily commuting and leisure behaviours, and how different groups receive heat risk.

Next, we classified the cities into extremely high risk, potential risk, and no risk areas by quantifying the change in heat exposure of residents from their place of home to the destination of their daily activities.

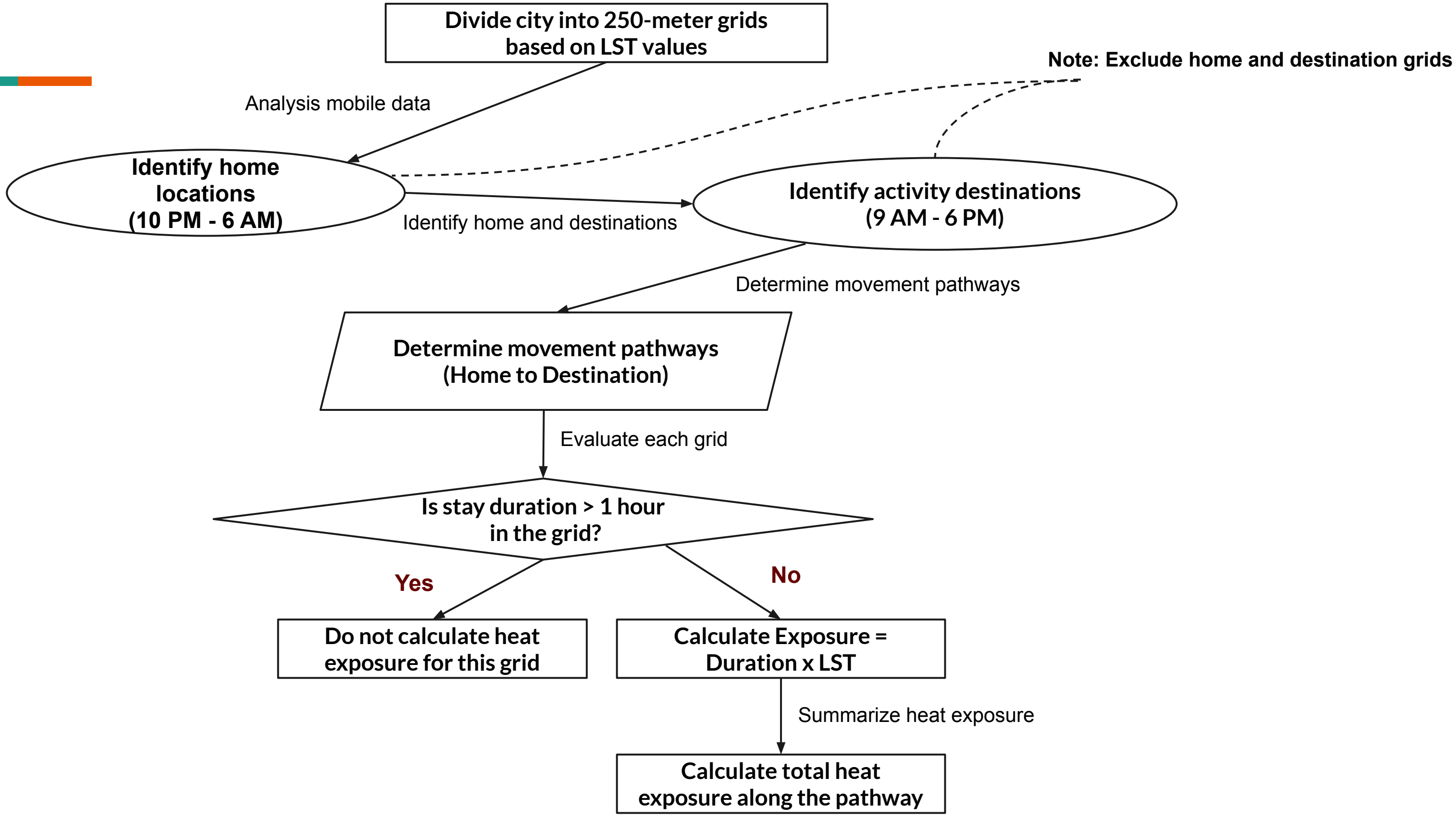
Finally, by constructing a spatial lag model (SLM), we simulate the best effect of optimising greening allocation for different thermal risk areas.

Test data

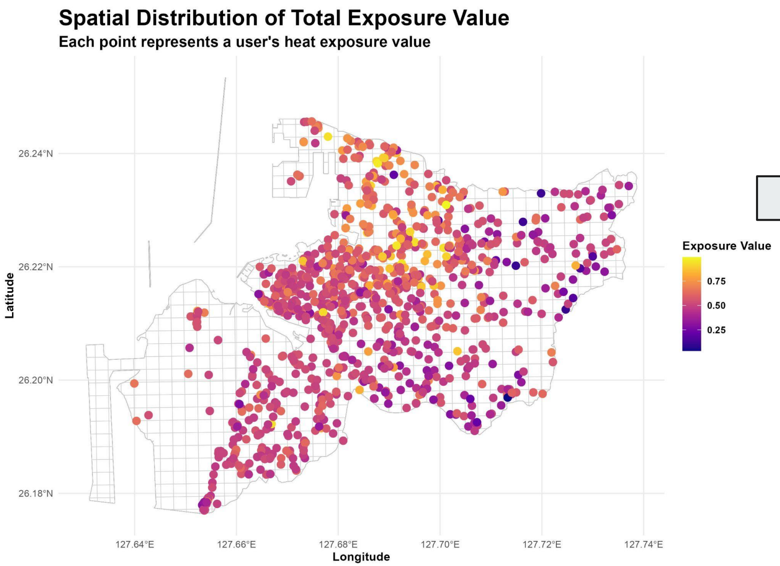


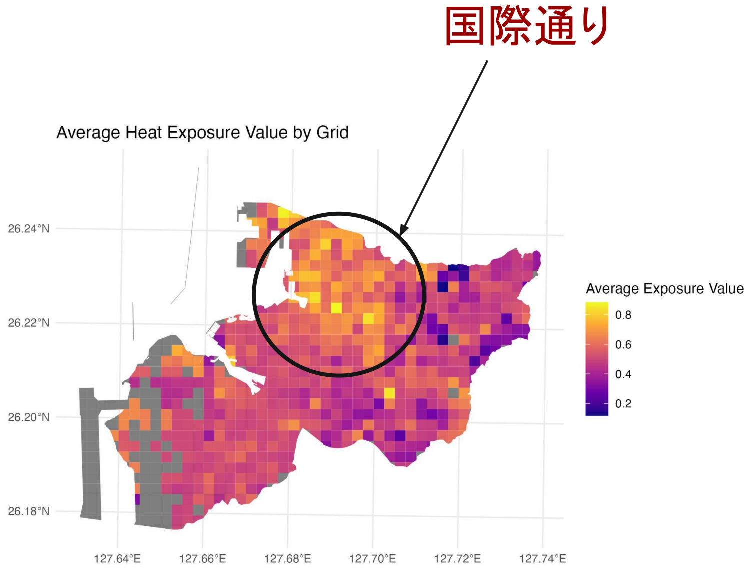
- **Data Testing**: 2023/8/1
- **Test Area**: Naha City
- **Population**: Naha City residents (excluding tourists)
- **Urban Land Surface Temperature (LST)**
- **Urban Heat Risk Classification**: Based on the 90% threshold of LST from 2023/6-9.
- **Urban Grid Size**: 250m x 250m

Dynamic heat exposure calculation



Dynamic Heat Exposure Measurement

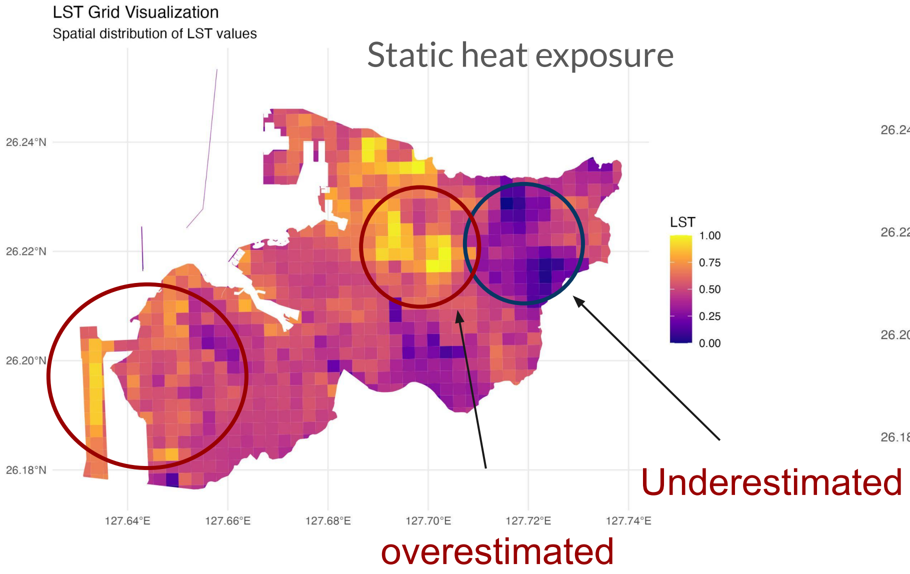


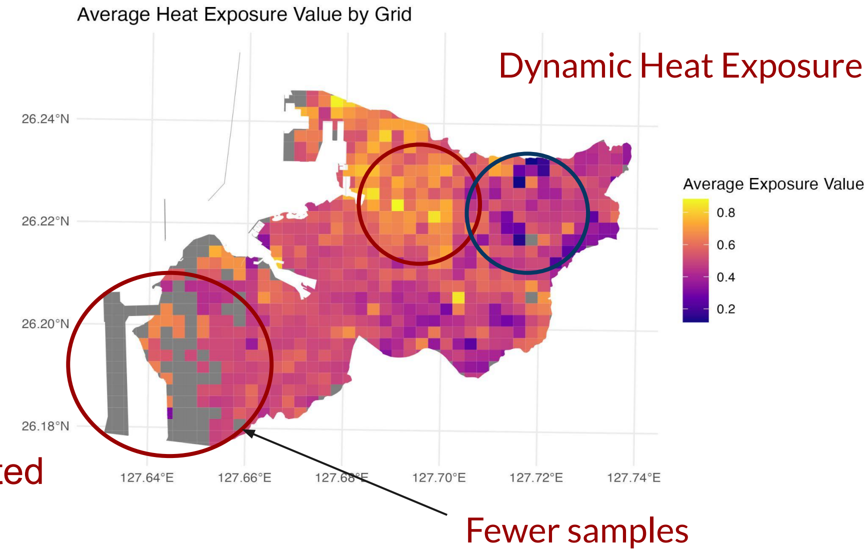


Target resident: 1490 people（with home information）

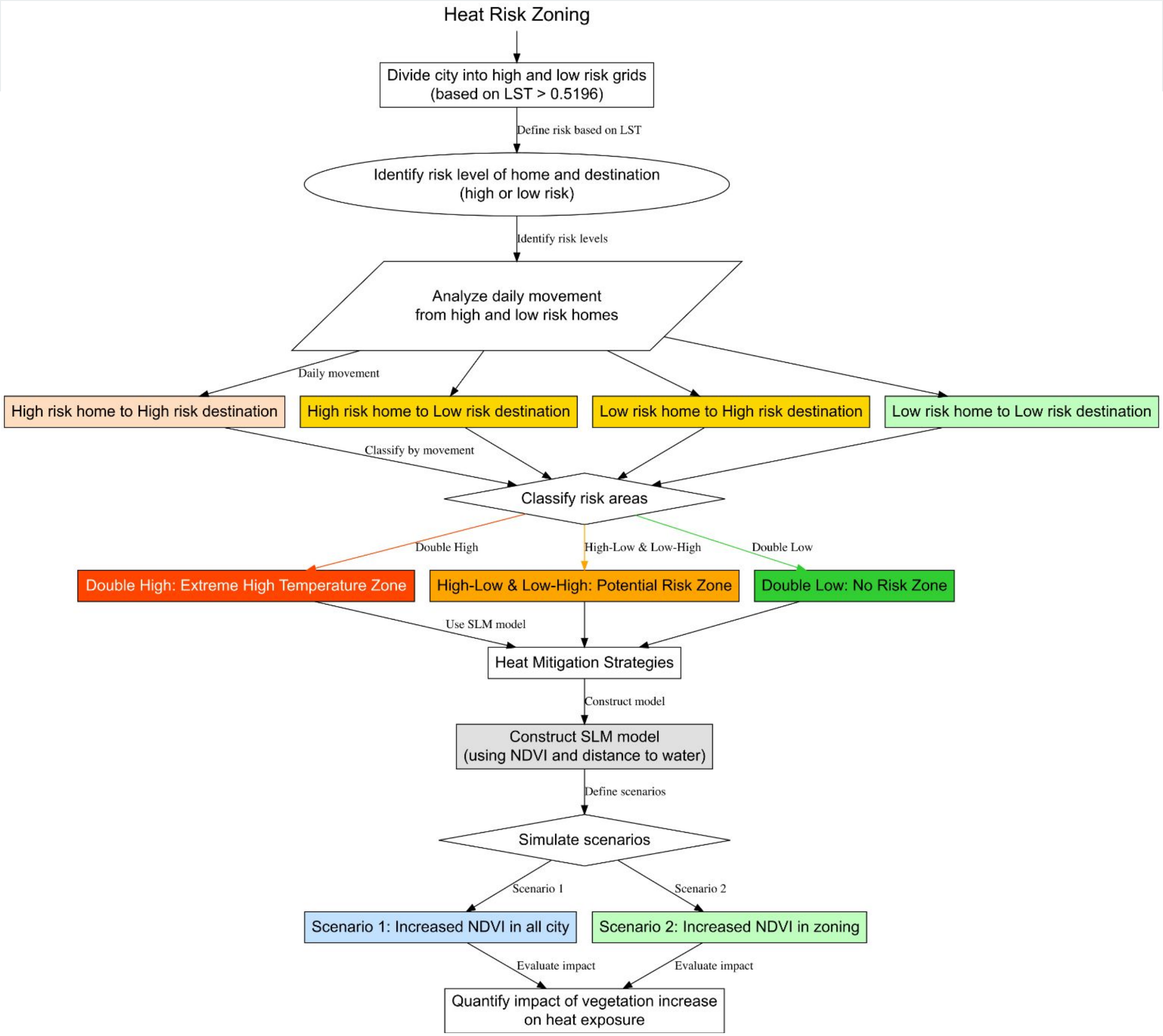
- Focusing individual heat exposure values into grid analyses;
- City centre has high heat risk

Static VS Dynamic Exposed Values

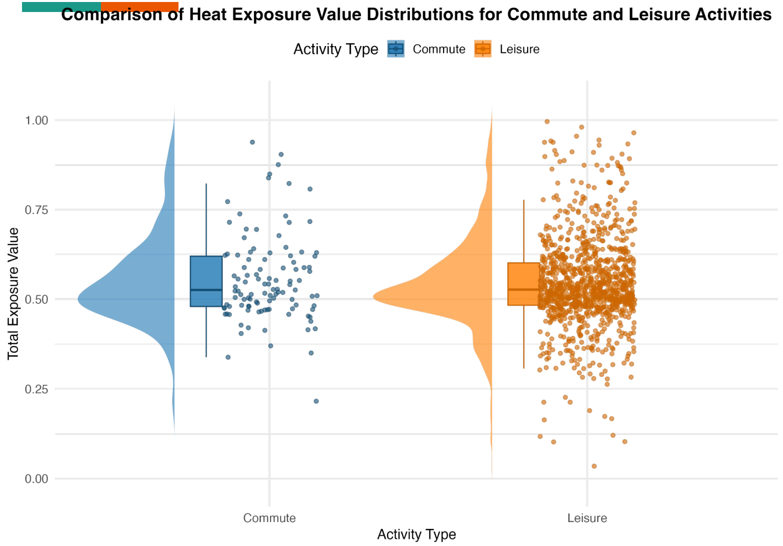


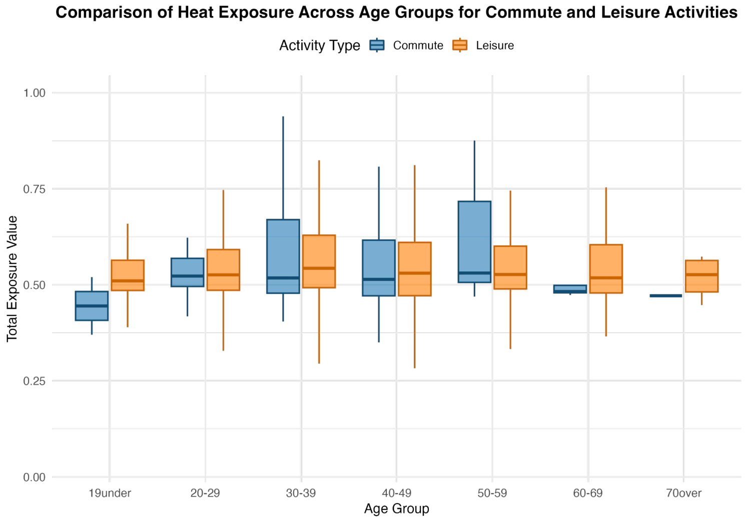


Static heat exposure: home grid LST value x population density
Dynamic heat exposure: activity path grid LST x residence time (≤1h)
Comparison: overestimation/underestimation of heat exposure values for static presence


Heat Risk Zoning
Divide city into high and low risk grids (based on LST > 0.5196)
Define risk based on LST
Identify risk level of home and destination (high or low risk)
Identify risk levels
Analyze daily movement from high and low risk homes
Daily movement
High risk home to High risk destination
High risk home to Low risk destination
Low risk home to High risk destination
Low risk home to Low risk destination
Classify by movement
Classify risk areas
Double High
High-Low & Low-High
Double Low
Double High: Extreme High Temperature Zone
High-Low & Low-High: Potential Risk Zone
Double Low: No Risk Zone
Use SLM model
Heat Mitigation Strategies
Construct model
Construct SLM model (using NDVI and distance to water)
Define scenarios
Simulate scenarios
Scenario 1
Scenario 2
Scenario 1: Increased NDVI in all city
Scenario 2: Increased NDVI in zoning
Evaluate impact
Evaluate impact
Quantify impact of vegetation increase on heat exposure

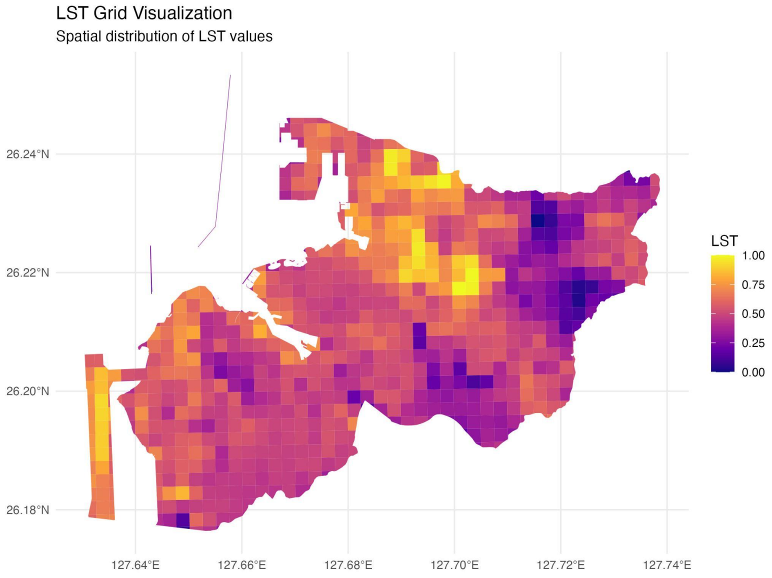
Analysis of activity patterns (commute/leisure)

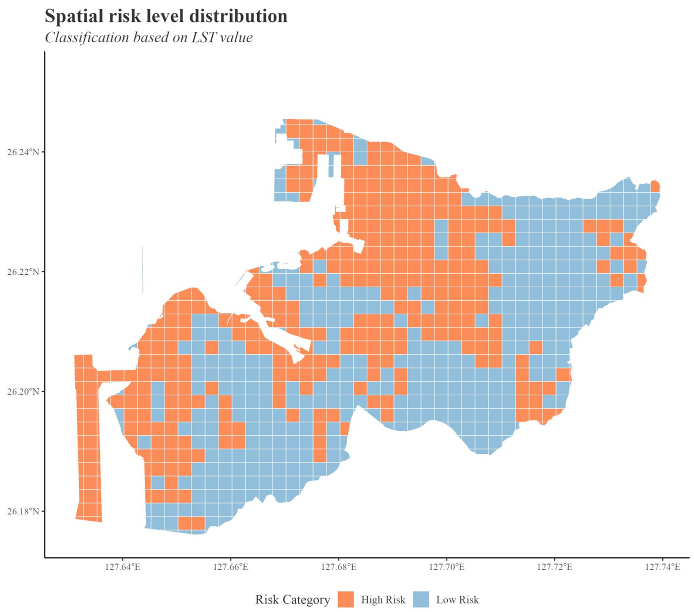




- Commuting behaviour: 9AM-18AM, ≥4h stay on the same grid
- Commuting (86), recreation (623), mainly concentrated in the 0.5-0.6 heat exposure range.
- Leisure faced a higher risk of heat exposure than commuting.
- Older adults and students had higher heat exposure during leisure;
- 50-59 year olds had higher commuting exposure.

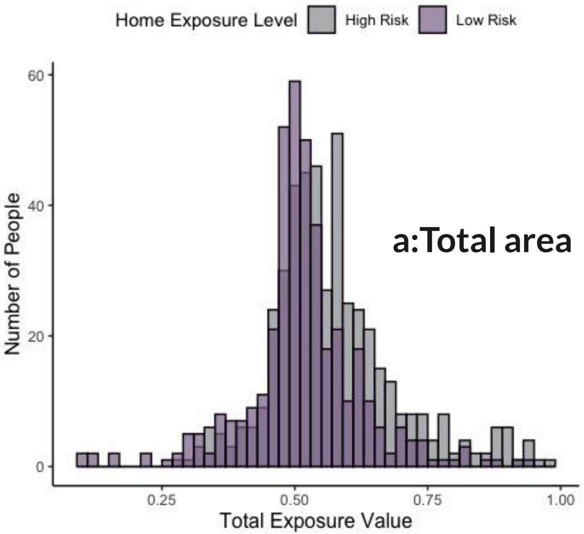
Urban spatial heat zoning

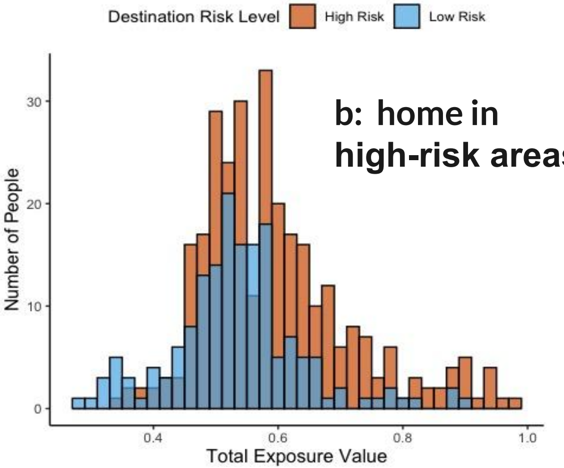


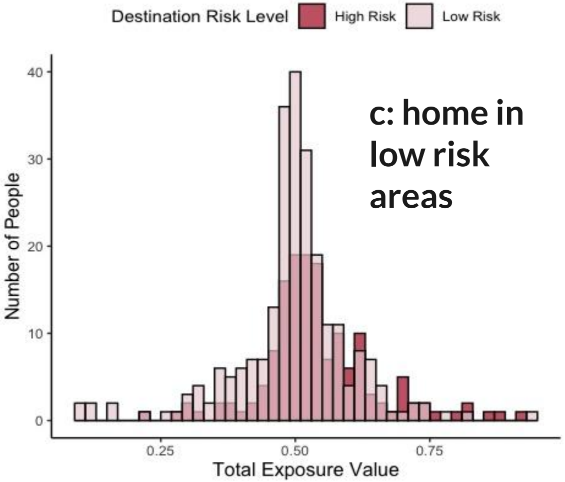


- Basis: 90 per cent LST value for partitioning
- Specific: Standardised to 0.5196
- LST ≤ 0.5196, low risk
- LST >0.5196, high risk

Dynamic heat exposure risk characterisation

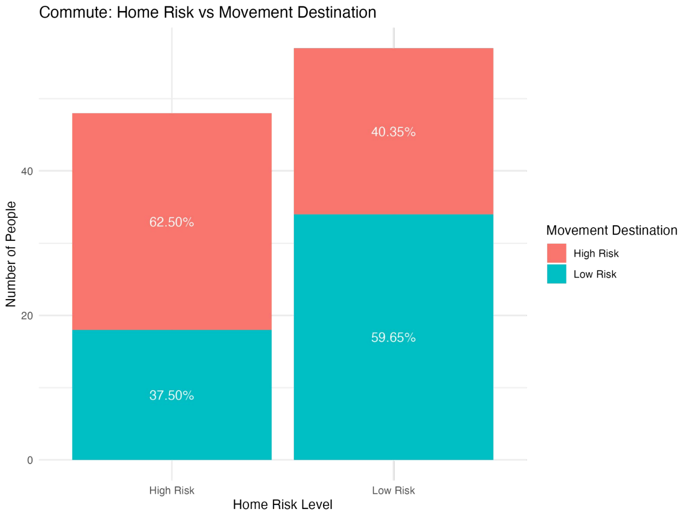


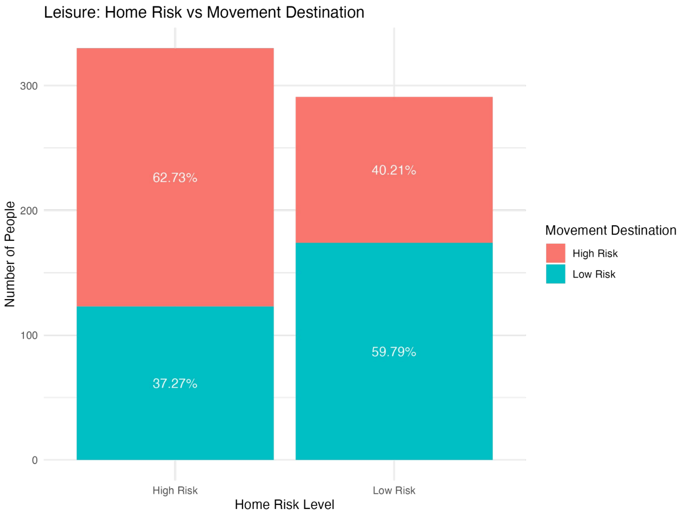




- **a :** Overall, heat exposure is higher in homes with high risk than in homes with low risk
- **b and c :** represent the risky migration of people from high/low-risk residential areas to their destinations
- **b :** heat exposure is generally higher to high-risk destinations
- **c :** heat exposure is generally higher to low-risk destinations

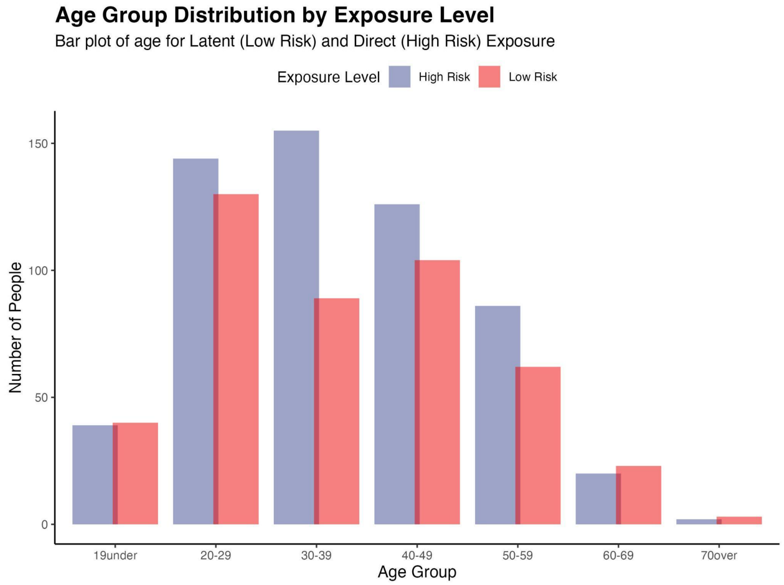
Activity Risk Proliferation Behaviour

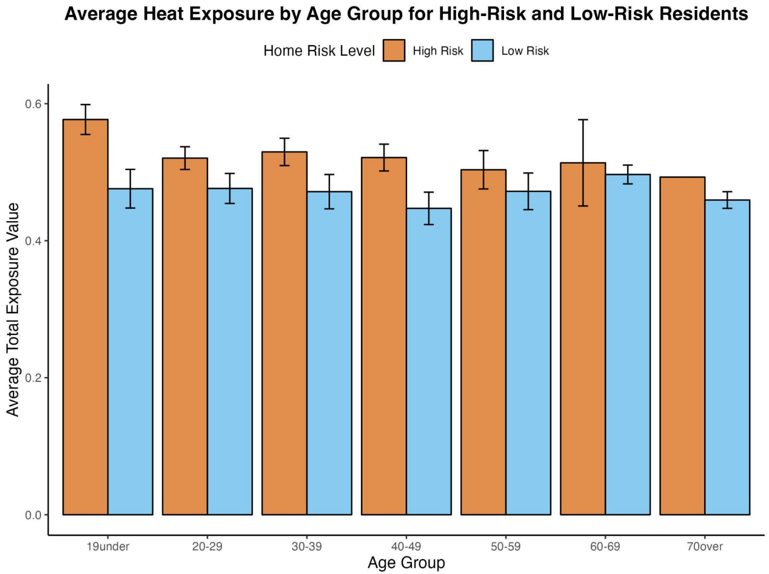




- Whether for commuting or recreation, **residents of high-risk areas are predominantly active in high-risk areas**, and **residents of low-risk areas are mostly active in low-risk areas**.
- The risk level of a neighbourhood has an impact on an individual's choice of location for daily activities.

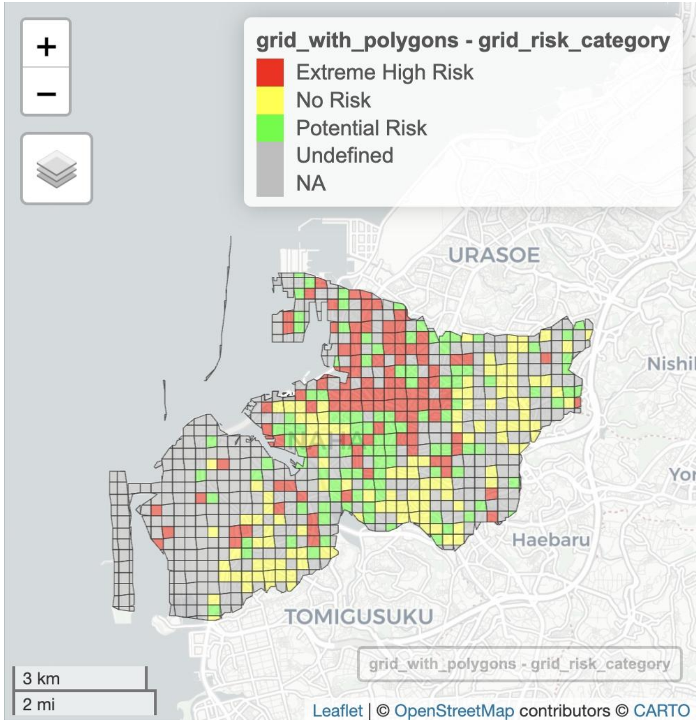
Characteristics of the distribution of population attributes

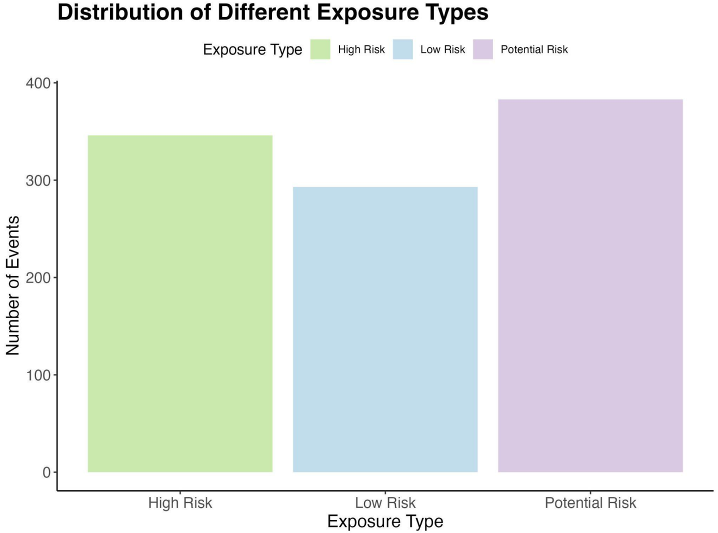




- Higher activity in the 20-29 and 30-39 age groups
- Above 60 years of age, low-risk heat exposure decreases
- The average heat exposure of residents living at high risk was higher than those living at low risk.
- Age did not appear to be a major differentiating factor.

Heat Exposure Risk Zoning





- **Extremely high risk area:** housing and activities in high heat areas.
- **Potential risk zone:**
  housing in high-heat areas, activities in low-heat areas.
  Housing in low-heat zones, activities in high-heat areas.
- **No-risk zone:** both housing and activities are in low-heat zones.

The spatial distribution of heat exposure in Naha City is dominated by potential risk characteristics

The next step is to calculate the Spatial Lag Model