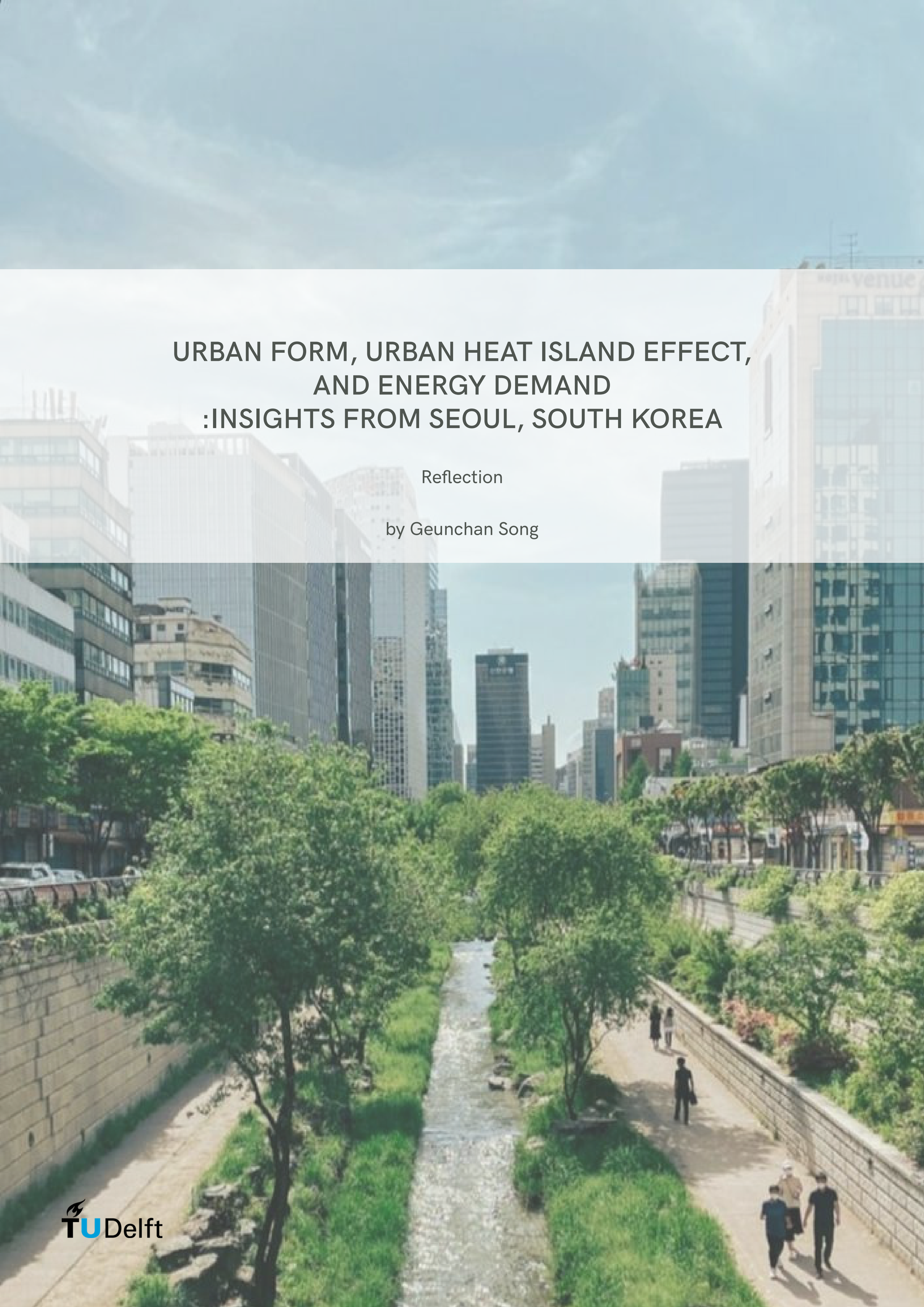

URBAN FORM, URBAN HEAT ISLAND EFFECT, AND ENERGY DEMAND :INSIGHTS FROM SEOUL, SOUTH KOREA

Reflection

by Geunchan Song

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Research Approach and Academic Value

My graduation project on urban form elements, urban heat island effects, and energy consumption in Heukseok-dong relates to other master tracks in the MSc Architecture, Urbanism and Building Sciences program. It connects directly to the Building Technology track by analyzing how urban structures affect microclimate performance and energy use, while incorporating Urbanism through its examination of decade-long urban transformation patterns.

The strength of my methodology is integrating satellite imagery, building data, and energy consumption records over 10 years, capturing actual urban changes rather than static conditions. The Multi-Layer Perceptron neural network successfully converted LST to air temperature with high accuracy (R^2 = 0.9684), tested through independent S-DoT sensors with known systematic temperature difference reported by Seoul municiaplity. More importantly, combining the Genizi method with Partial correlation analysis addressed the critical issue of multicollinearity that often misleads urban studies, revealing both relative importance and directional effects of urban form elements.

My findings provide valuable academic insights into scale-dependent relationships. Energy consumption patterns emerged clearly at the 100m scale while temperature variations required 300m analysis, suggesting that different urban phenomena need different analytical scales. I also analyzed different types of building uses in Heukseok-dong to distinguish the building volume and energy consumption. This finding is connected to the discovery that vegetation's cooling effect diminishes in summer when building characteristics dominate challenges conventional urban cooling strategies. The validation through District 3's real-world transformation strengthens these statistical findings, showing how huge development can partially mitigate temperature increases through careful design.

Societal Impact and Practical Applications

My research provides practical guidance for urban planners and policymakers in Seoul and similar dense Asian cities undergoing rapid transformation. The statistical analysis across Heukseok-dong suggests that maintaining lower ground coverage while increasing vegetation can help moderate temperature increases during redevelopment. The seasonal variations discovered, where building characteristics overtake vegetation's cooling effect in summer. It indicates that fixed urban design standards may be less effective than adaptive strategies that change with seasons. District 3's transformation is a good example of these relationships in practice, showing how even dramatic improvements in urban form can only partially mitigate warming effects.

These insights have direct implications for energy management and societal equity. The positive correlation between building volume and EUI, despite normalization, indicates that larger buildings require more intensive energy efficiency measures. This is particularly important for affordable housing policies, as residents in older, smaller buildings may actually have lower energy costs per square meter than those in newer, larger developments. Understanding these patterns helps prevent energy poverty while pursuing urban densification. By analyzing the factors that drive air temperature and energy consumption in buildings, residents and urban planners can design cities to be more sustainable and energy-efficient.

The 10-year analysis of District 3 demonstrates both possibilities and limitations of urban interventions. Despite increasing building volume by over 2,000% and improving vegetation by up to 168%, temperatures still rose 5-11%, which are further explained by using the trend lines over a decade, though less than in the entire Heukseok-dong. This real-world evidence can argue that while we cannot completely prevent urban warming, thoughtful design can provide meaningful temperature mitigation. My research offers a methodology for predicting temperature and energy outcomes of proposed developments, enabling evidence-based decision-making rather than relying on assumptions.

Transferability and Future Directions

While my research focused on Heukseok-dong in Seoul, the methodology can be applied boradly. The MLP model for converting LST to air temperature, tested with independent sensors, could be adapted for any city with satellite coverage. The combined use of the Genizi method and partial correlation to handle multicollinearity while revealing directional effects addresses a common challenge in urban studies worldwide. However, the specific relationships and findings between urban form and energy consumption would be different as this research uses the air temperature at 11:12 AM, while other areas would have different timings. Also, the results can would be varied by climate, building stock age, and cultural factors.

This research found that energy patterns emerge at 100m while temperature requires 300m analysis, which provides methodological guidance for urban studies globally. The seasonal reversal of vegetation's importance offers insights particularly relevant to cities experiencing hot summers, though the specific thresholds would differ. Cities with similar characteristics to Seoul like dense residential areas with mixed building ages undergoing rapid redevelopment, would benefit most directly from these findings (most likely at noon or at near 11:12 AM).

Future research could enhance practical applicability by integrating with Seoul's actual development plans rather than hypothetical scenarios. The low R^2 indicate a big need for improvement by incorporating building age and HVAC system data, the factors my research identified as likely explaining much of the variance. Extending the temporal analysis beyond the single satellite overpass time would better capture diurnal patterns crucial for understanding peak energy demands. Moreover, since occupant behaviors significantly impact energy consumption, it is highly recommended to include occupant behavior data in future research to analyze the cascade effects in more detail.

This research establishes a methodological framework for analyzing cascade effects from urban form through temperature to energy consumption. By demonstrating how to handle statistical complexities while validating findings through real-world transformations, it provides both theoretical advances and practical insights for creating more sustainable urban environments in rapidly developing Asian cities.

Personal Reflection

During this graduation project, I learned valuable lessons that extended far beyond technical skills. Throughout my bachelor's degree and first year of master's, I focused mostly on building scale energy analysis. Choosing to analyze energy consumption at urban scale was a big step outside my comfort zone. While it initially looked similar to my previous work, urban-scale analysis was fundamentally different, requiring consideration of microclimate factors and spatial relationships I had never encountered before.

The project had significant challenges. Implementing machine learning for urban analysis was new, especially without prior Python experience. However, with guidance from my mentors and considerable efforts, I not only completed the analysis but gained proficiency in Python and machine learning techniques. These skills extend beyond this project, providing a great tool for future energy consumption research.

Determining the appropriate methodology required extensive iteration. Limited input data constrained my options, and I spent considerable time evaluating different approaches. While statistical analysis in Excel would have been simpler, I decided to use machine learning for its novelty and analytical power. After discussing various techniques with my mentors, including multi-task learning and multi-layer perceptron approaches, we selected MLP as most suitable for handling limited inputs while achieving desired outcomes.

Not only the methodologies, but it was a great opportunity to study how temperature, energy consumption and urban form elements are interrelated, which I was not considered before. Thanks to this project, I gained lots of interests of working on urban scales. The importance of urban form elements was surprising and I would like to study more on this when I get chances.

It would have been really nice if I could have analyzed the whole city (Seoul) with more extensive data, including occupant behaviors and more detailed building characteristics with various urban form elements. However, due to time limitations and available datasets, I was not able to include everything that I wanted. I hope this research can serve as a reference for ideas or methodologies for those who wish to extend their work further in the future.

Researching my home country added personal significance to this work. Local knowledge was very helpful, and winter break discussions with Korean professors, facilitated by my mentor, improved my understanding. Analyzing familiar urban environments made the research more engaging and meaningful.

Despite many challenges and setbacks, it was a very fun project. The project pushed me to acquire new skills that will benefit my future career. While acknowledging its limitations, I believe this research contributes novel insights by analyzing 10 year relationships between air temperature, urban form elements, and energy consumption, which is an approach rarely attempted in existing literature. The experience reinforced that meaningful research often requires stepping beyond comfort zones and having unfamiliar methodologies.