International Journal of Applied Engineering & Technology

DEEP LEARNING APPROACH TO ANALYZE URBAN SPATIAL DISPARITIES IN RASON, NORTH KOREA: USING SATELLITE, GIS AND INTERVIEW DATA

Sihyo Lee
Soongsil Institute for Peace and Unification, Soongsil University, South Korea
leesihyo@gmail.com

ABSTRACT

This study reveals spatial disparities in Rason, a representative SEZ city in North Korea, through a combination of deep learning analysis and in-depth interviews. For quantitative analysis, the entire city of Rason was divided into 68 zones and satellite, GIS, and big data data were extracted, and in-depth interviews were conducted with seven defectors from Rason for cross-checking. The spatial disparity analysis showed that the upper class lived mostly in the city center, the middle and upper class lived near the city center, around the waterfront, and in new building complexes, and the lower class lived on the outskirts of the city or under the mountain behind the docks. The cross-checking of in-depth interviews confirmed the validity of the deep learning spatial disparity analysis, as the city center has higher land prices and the upper class has been living there for a long time. Furthermore, the city's restrictions on relocation and the fact that those who have accumulated capital do not leave their old neighborhoods, means that the wealthy do not tend to cluster in any one area. This study is of academic significance because it represents a new methodological approach to an extremely closed and under-documented city, and the first detailed study of the city and daily life in Rason.

Keywords: Rason, spatial disparity, special economic zone, North Korea, deep learning.

INTRODUCTION

North Korea is the world's most closed state with a totalitarian character. Continually tightening sanctions, a post-coronavirus border lockdown, and recent arms deal with Russia have further isolated the country from international relations. At the same time, North Korea is undergoing many internal changes. In the 1990s, North Korea's economy collapsed and an estimated 250,000 to 1.17 million people starved to death. In 2002, North Korea officially introduced a market system, which has since been transforming its people's consciousness, daily lives, and urban spaces (Lee 2004; Park, 2021; Yang and Lim, 2022). Residents obtain most of their goods, including their livelihoods, through markets rather than rationing. Emerging capitalists, or *"donju,"* who have accumulated capital through market activities, are involved in the production, distribution, and consumption of goods in collusion with those in power. In this process, inequality among North Koreans is increasing (Lim, 2016; Jung 2015; Kwak and Moon, 2017; Lee, 2016). North Korea is currently a system of both totalitarian control and marketization, and the market system is transforming politics, economy, and society and reinforcing class mobility and disparities.

Rason is a unique city that blends North Korea's closure, market system, and international investment. In 1991, when the regime change cut off cheap oil supplies from China and Russia and North Korea's economy showed signs of collapse, North Korea designated Rason as a special economic zone to bring in foreign currency. North Korea chose Rason as its first free trade zone because it was politically distant from Pyongyang and located on the border, a favorable location to attract Chinese and Russian investment. China, whose Northeast region is landlocked, saw the Rason port as a place to open a route to the Pacific Ocean and expand trade to Japan and the Americas. For Russia, Rason was attractive because it had an all-season ice-free port and access to the Trans-Siberian Railroad (TSR).

Although not as successful as the North Korean regime envisioned, foreign investment in the zone has transformed the urban space and daily life in Rason. The Rason Special Economic Zone (SEZ) has not performed as well as intended due to sanctions, poor infrastructure, the autonomy of the SEZ, and high investment risks (Woo, 2019). Nevertheless, it did have some success in attracting foreign investment in the 2010s. Between 2010

and 2015, the Rason SEZ hosted 70 foreign companies and "flooded the market with goods ranging from Mickey Mouse shoes to dried kiwis" (Lee, 2016). As the most prominent city in North Korea to be transformed by foreign capital and businesses, Rason has important academic and policy implications for studying the current situation and future changes in North Korea.

As a legacy, spatial disparities, as seen in post-socialist cities after the transition, are a persistent factor of influence even after the introduction of global markets (Szeleyi, 1996). Spatial inequality is a projection of the distribution of social structure within a particular neighborhood (Cassiers and Kesteloot, 2012), and the study of spatial disparities in the city of Rason is an approach that can identify the hierarchical structure of the city. This study aims to answer the following research questions.

1. What is the current state of urban spatial disparities in Rason?

2. How are urban spatial disparities affecting real lives?

3. Are the introduction of special zones and markets reinforcing urban spatial disparities?

To answer this question, the question of spatial disparity was analyzed using satellite data and deep learning methods of geographic information system (GIS). The impact of spatial disparity on life and the intensification of spatial disparity after the introduction of the market were confirmed through in-depth interviews with residents who escaped from Rason.

METHODS AND DATA COLLECTION

A. Study Area
Rason Special City (Economic and Trade Zone) is a coastal city on the northeastern tip of North Korea, bordering both Russia and China, as shown in Figure 1. This study selected 855.64 square kilometers of Rason's administrative area as the study area. The target area was subdivided into 68 districts according to regional characteristics to collect data. Rason City can be broadly divided into the urban center and the rural area, which is mostly composed of mountain and coastal villages. The target area can be broadly categorized into the urban center of Rajin and Sonbong, coastal villages, and rural areas (administrative region "Ri"). The researcher divided the 33 urban districts of Rajin, 22 urban districts of Sonbong, 6 coastal villages, and 7 rural districts.
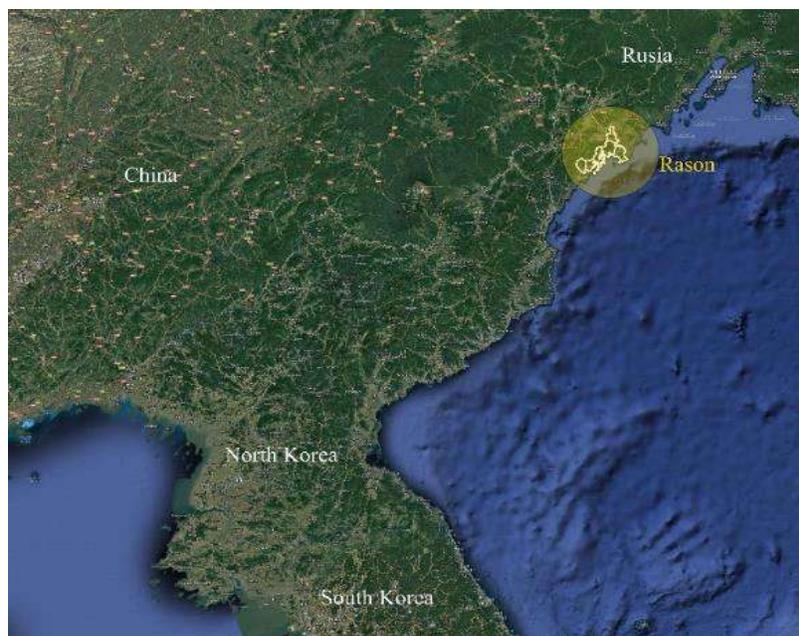

Figure 1: Location of Rason Special City

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B. Research Methods

For the spatial disparity analysis of Rason City, I went through the research process as shown in Figure 2. To extract spatial disparity variables, I analyzed North Korean urban space studies (Lee, 2020; Kim, 2019; Kwak and Moon, 2017; Lee et al., 2022) and machine-learning urban space studies (Brelsford et al., 2017; Andreoli et al., 2022; Hall et al., 2001; Wang et al., 2023). Based on this, four classifications for urban space analysis (residential environment, economic indicators, accessibility, and block activation) were established. Then, 15 variables were extracted from Remote Sensing, geographic information system (GIS), and Big data according to indicators.

To analyze the urban spatial disparities in Rason, 15 variables extracted from 68 districts were subjected to a clustering process based on deep learning. First, the optimal number of clusters was determined through the 'Elbow method' to determine the optimal number of classes in the clustering process. Then, I used autoencoder, a deep learning-based clustering technique, to classify regions with similar features. An autoencoder is a neural network structure that encodes input data into a latent representation and then reconstructs it. The compressed representation in the middle represents the main characteristics of the data, which is used to cluster regions into groups with similar features. The hierarchy of the classified classes was confirmed by comparing satellite images.

The results of the quantitative analysis of the deep learning method were cross-checked with in-depth interviews with migrants from Rason. The interview process further confirmed the characteristics of spatial disparities and differences in daily life by class in Rason.
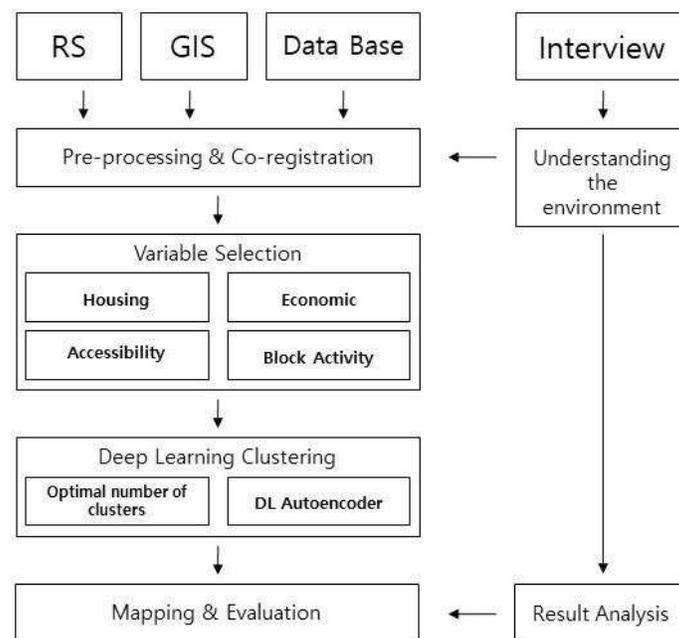

Figure 2: Progress of the Urban Disparity Study in Rason

C. Extracting Quantitative Data

Remote Sensing (RS), geographic information system (GIS), and Big data were extracted to analyze spatial disparities in 68 districts of Rason. The satellite (RS) data was extracted through Python coding on the Google Earth Engine platform, and the GIS data was extracted through data processing using the QGIS program. The 15 variables extracted are population, building density, average building area, average building floor, tree density, greenery density, agricultural land density, market accessibility, nighttime illumination, industrial facilities, main road density, residential road density, train station, educational facilities, and points of interest. The data collection was conducted for about two months from July 1, 2023, and the most recent data available was collected. The characteristics of the extracted variables are shown in Table 1.

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Table 1: Characteristics of variables

Categories	Data	Year	Methord of Data collection	Source
Residential Environment	Population	2018	RS	GHSL (f)
	Density of building	2018	GIS	NGII (a)
	Mean area of buildings	2018	GIS	NGII (a)
	Mean floor of buildings	2018	GIS	NGII (a)
	Area of Tree	2021	RS	ESA (g)
	Area of Grass	2021	RS	ESA (g)
	Area of Crop	2021	RS	ESA (g)
Economic Index	Official Market	2022	Document to GIS	Hong et. al., 2022
	Night Illuminate	2022	RS	VIIRS ©
	Industrial facilities	2023	Big Data to GIS	38North (b)
Accessibility	Main Road	2023	GIS	OSM (e)
	Residential Road	2023	GIS	OSM (e)
	Train stations	2023	GIS	OSM (e)
	Educational facilities	2023	Big Data to GIS	38North (b)
Block Activity	POIs (Point of Interesting)	2023	Big Data to GIS	38North (b)

a https://www.ngii.go.kr/eng/content.do?sq=103

b https://38northdigitalatlas.org/

c https://eogdata.mines.edu/products/vnl/#monthly

d https://yceo.yale.edu/research/global-surface-uhi-explorer

e https://www.geofabrik.de/

f https://data.jrc.ec.europa.eu/dataset/2ff68a52-5b5b-4a22-8f40-c41da8332cfe

g https://zenodo.org/records/5571936

D. Collecting Qualitative Data

In-depth interviews were conducted with five people who have lived in Rason to examine the changes in urban space and daily life since the designation of the SEZ and to validate the results of the satellite imagery analysis. Three of them have been residents of Rason for more than 20 years since the early 1990s, one is a foreign investor, and one is a longtime visitor to Rason for business. The interviews were conducted between June 1 and October 20, 2022, and took place at the convenience of the participants, including in the research center's conference room, cafes, and online Zoom. The characteristics of the participants, whose personal information was minimized to protect their privacy, are shown in Table 2.

Table 2: In-depth interview participant characteristics

NO	Gender	Residence period in Rason	Job	Residence location
A	Man	1960s ~ 2010s	Fisherman	city center
B	Man	1990s ~ 2010s	Business	city center
C	Woman	1990s ~ 2010s	Trade	city center
D	Woman	1990s ~ 2010s	Trade	city center
E	Woman	1990s ~ 2010s	Pedlar	Outside of city

RESULT: SPATIAL DISPARITIES

Rason's city center is divided into Rajin and Sonbong, and the difference in density of individual variables by district is shown in Figure 3. Population density, building density, nighttime light, market access, and points of interest (POIs) are mostly higher in the city center, with some variation. In contrast, these variables decrease as you move out of the city center and into rural areas. Comparing the two urban centers, Rajin (south) and Sonbong (north), Rajin has a higher population, building density, and economic indicators such as nighttime light. This means that within the city, Rason is more developed than Sonbong. In contrast, the main roads are somewhat denser not only in the city center but also on the outskirts, which is due to the fact that roads connecting the city to China and Russia are built on the outskirts of the city.
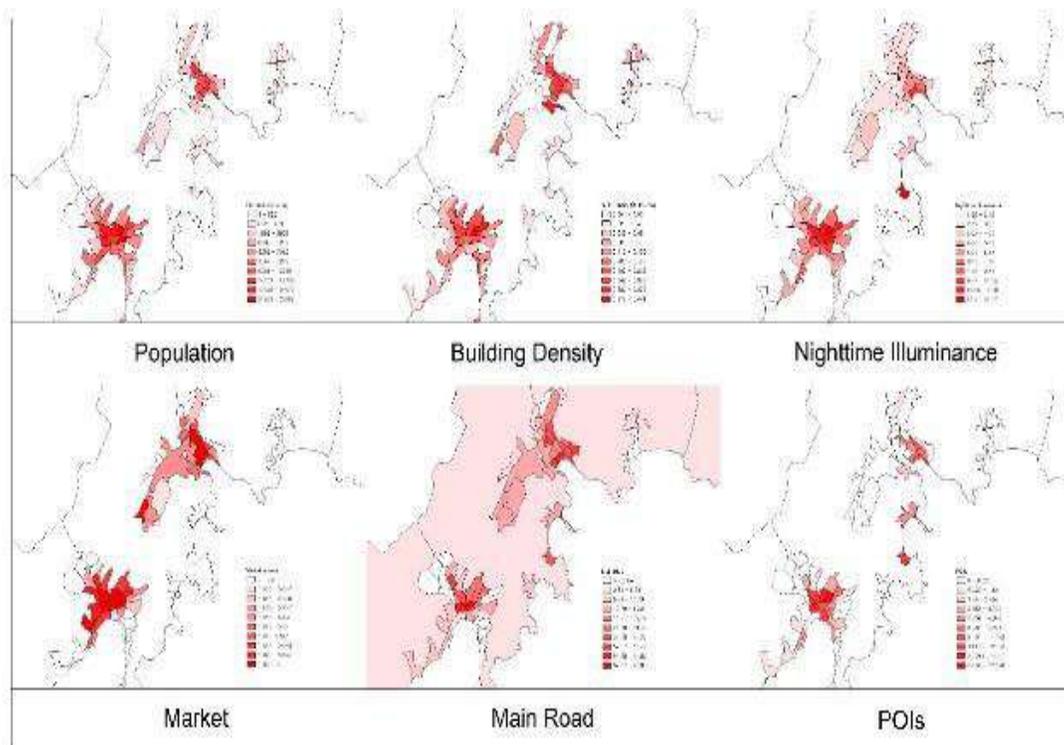

Figure 3: Variable densities by districts in Rason

The result of the deep learning-based clustered urban map of Rajin's urban area by class is shown in Figure 4. The upper-class (class 5) residential areas of Rajin are identified as the historic downtown area with the plaza and Kim Il Sung Square. The upper-middle class (class 5) is located between the city center and Rajin Port. The middle-class (class 1) neighborhoods are the dense residential areas on the outskirts of the city. These areas include many neighborhoods that have been built by foreign capital since the designation of the Rason Special Economic Zone. Class 2, identified as middle and lower class residential areas, are residential areas slightly away from the city center, such as Changpyeong-dong near Rajin Port and areas with a high concentration of old residences. Class 3, which is considered to be inhabited by the lower class, is an area on the outskirts of the city adjacent to rural or forested areas.
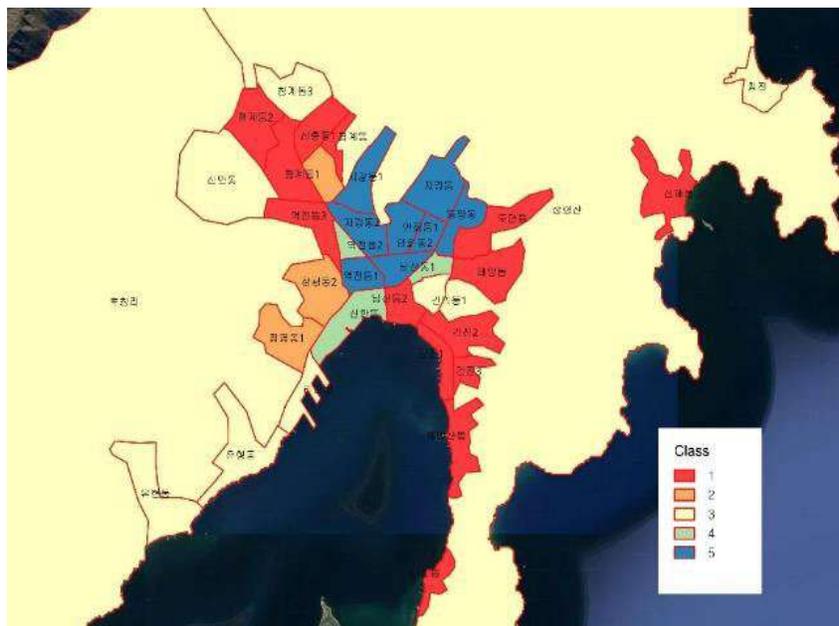
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Figure 4: Spatial Disparity Map of Rajin urban area

* Upper: Class 5 / UM: Class 4 / Middle: Class 1 / LM: Class 2 / Low: Class 3

The results of the clustered urban map by class in Sonbong urban areas are shown in Figure 5. The upper class (class 5) residences in the spearhead area are located in the historically downtown Junghyeon-dong neighborhood and the pier area. The upper-middle class (class 4) neighborhoods are Sanghyun-dong and Haahyeon-dong, which are dense urban neighborhoods near the upper class neighborhoods. The middle class, class 1, lived in dense residential areas outside the city center, near chemical factories. The lower-middle class (class 2) residences in Sonbong are located in rural areas with low building density and a high percentage of agricultural land. The lower class, class 3, is located between the city center and the chemical plant, which is mostly composed of rice paddies and fields. The coastal towns east of Sonbong are analyzed as middle-class residential class 1, which includes labor districts, medium-sized residential clusters, docks, factories, and train stations.
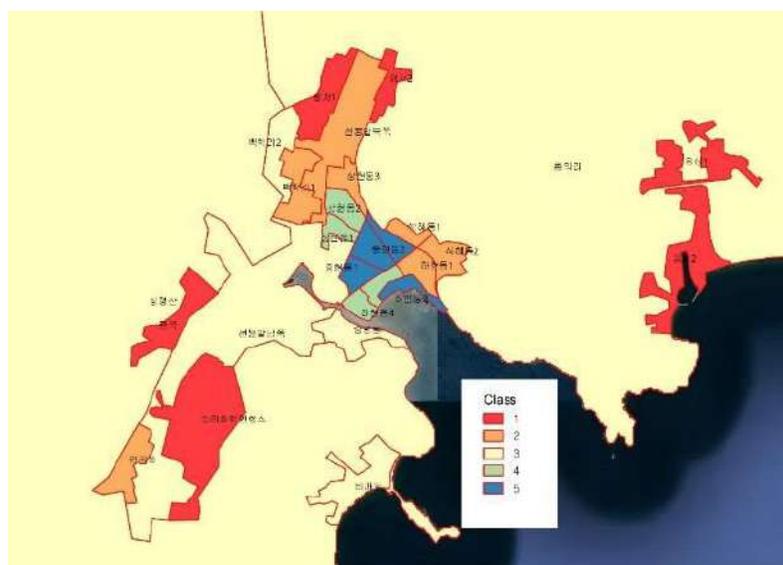

Figure 5: Spatial Disparity Map of Sonbong urban area

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* Upper: Class 5 / UM: Class 4 / Middle: Class 1 / LM: Class 2 / Low: Class 3

The residential hierarchy by class was determined by analyzing satellite images and conducting in-depth interviews. Figure 5 shows the results of the satellite imagery analysis: Class 5, the highest class of residence, is characterized by tall buildings that serve as city squares, hotels, and shops. Many of the buildings are in relatively good condition and contain large areas of green space, including grassy sports fields and street trees. The spatial character of the upper-middle class (class 4) neighborhoods was a mix of older low-rise housing and high-rise apartments in the city center. The middle class (class 1) spatial environment on the outskirts of the city was characterized by the planned construction of dense residential complexes built after the designation of the SEZ. The lower-middle class (class 2) spatial environment is characterized by a concentration of older low-rise housing on the outskirts of the city. Lower class (class 3) housing is characterized by low-density, older low-rise housing on the outskirts of the city in the form of villages between rice paddies and fields. There were no shops, playgrounds, schools, or large structures in the neighborhood other than residential facilities.

Figure 5: Reviewing satellite imagery by class

DISCUSSION: CROSS-REVIEW WITH IN-DEPTH INTERVIEWS

The results of the deep learning spatial disparity analysis were cross-checked with in-depth interviews. We conducted in-depth interviews with A, C, and D, who lived in Rason for more than 25 years and moved out relatively recently (around the end of 2010), B, who did business in Rason as a foreign investor, and E, who lived near Rason and moved to the city center of Rajin to do business. They testified that the deep learning result that the city center is home to higher-end residents is generally correct. According to their testimonies, the city center has seen a rise in real estate prices during recent development, and party members and officials have lived in the city center from the past to the present. However, a phenomenon that has emerged since the designation of the SEZs is that Chinese businessmen and wealthy North Koreans who have made money live in high-rise apartments with elevators that have been recently built, rather than location.

"The city center is a bit expensive. Namsan-dong (Class 5, High class) is a high class neighborhood close to the city center... It's not a rich neighborhood, but the buildings are expensive because they were recently built, and the heating is good. (C)"

Rason residents do not move to better neighborhoods even when they accumulate money. This is because there is no official freedom of residence, and they prefer to stay where they grew up. In addition, Rajin is not a very large city, and the vanguard does not have to travel far to get to wherever they are. Those who have accumulated capital often choose to demolish and rebuild their old homes rather than move.

"We don't move much. We don't rent a house and then move like in South Korea. In North Korea, we don't have that idea. Most people live from the time they are born until they die. I don't think many people move (D). So even the rich people are scattered all over the place. It's not really a state matter. (C)"

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"Rason is a small city, it's close anyway, you can take a taxi and be there in 10 or 20 minutes, and the workers have accommodation where they work, so it doesn't really matter where you live, because it's a small city, so if you want to go home from work, you just go there. (C)"

As a special economic zone, Rason is strictly off-limits to outsiders. Since most workers from outside the country live in company-provided housing, they are not subject to location "preferences," so most residents of Rason stay in the same place for a long time. The exception to this is when a North Korean businessman who has accumulated capital buys additional housing. In this case, the capitalist prefers a high-rise apartment with an elevator in the center of Rason.

"There's this guy, he made a lot of money by running several boats on the beach. He wanted to buy an expensive apartment, so he recently bought an apartment for 400,000 Chinese yuan. He's got a lot of money, so he bought another nice house. (C)"

Since the designation of the SEZ, Rason's downtown area has seen the addition of luxury hotels, casinos, foreign pubs, a gym with cultural facilities that can be accessed for a fee, an outdoor swimming pool, and large TVs in the square donated by Chinese investors (C, D). This has driven up real estate prices in the city center and changed the tone of the urban space. These changes in the environment have made it more attractive for young people to live in the city center.

"The gyms are all new, like after 2010, so I mean, I've been living in the city center since I've been at work... I feel like the streets are cool... You can pay for the gym and you can go and play ping pong, you can play hockey, you can play volleyball, people play a lot of volleyball there, you can use the entertainment center, you can do all kinds of things. (C)"

Cross-checking with in-depth interviews, we found that the deep learning spatial environment disparity analysis is valid considering real estate prices, the phenomenon of high-class urbanization, and the concentration of cultural facilities in the city center. Unlike other cities in transition countries, residents of Rason do not have freedom of residence mobility and have strong attachment to their place of birth, so spatial mobility based on wealth is not severe. However, this phenomenon is changing with the rise in real estate prices and the expansion of cultural facilities in the city center, which are centered on capitalists and young people.

CONCLUSION
This study empirically demonstrates the existence of class-based spatial segregation in Rason through a mixed methods study. The results show that the upper class in Rason is mostly located in the city center, the middle class is located near the city center, along the waterfront, in new building complexes, and the lower class is located on the outskirts of the city or under the mountain behind the docks. Cross-checking with in-depth interviews confirms that the quantitative results are valid, and that there is a phenomenon of higher land prices in the city center and longer residency by the upper class.

This research has also revealed that Rason exhibits unique spatial disparities and undergoes distinct changes compared to cities undergoing transition. Residents of Rason are characterized by a lack of residential mobility and an unwillingness to leave the neighborhoods where they were born. Although there is a phenomenon of emerging capitalists moving into some high-end apartments and residences, this research found that residents who have accumulated capital tend to build new residences in their existing residences rather than move. As a result, unlike the special economic zones in transition countries, where the phenomenon of class mobility due to the accumulation of capital was prominent, Rason found that the phenomenon of residential mobility due to the rise of the emerging capital class was weak.

This study is also a novel methodological attempt to push the boundaries of North Korea research, where data is severely lacking and field access is impossible. It will be of academic significance as a preliminary study for future research on this under-documented and heavily closed region.

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