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Article

Economic Experimentation under Authoritarian Closure: Urban and Social Transformation in North Korea's Rason SEZ

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Abstract

This study examines how the Rason Special Economic Zone (SEZ), an experimental initiative in highly closed North Korean society, has affected urban space and everyday life, and identifies the factors driving these changes. Drawing on satellite data on nighttime illumination from 1992 to 2023 and building density from 1990 to 2020 for 68 districts in Rason, we combined statistical analyses with in-depth interviews. The results show that nighttime illumination increased rapidly between 2009 and 2013, primarily in downtown Rason, while building density continued to rise in the city center and its surrounding areas. Regression analysis indicates that trade volume, targeted sanctions on specific goods, and the COVID-19 pandemic significantly influenced the SEZ's development, with trade with China exerting the most substantial effect. The interview findings corroborate the satellite data and highlight concrete spatial changes. Methodologically, this study demonstrates the potential of mixed approaches for researching highly closed regions, and substantively, it also contributes to strategic debates on North Korea's SEZs, investment potential, and the effectiveness of international sanctions.

Keywords

North Korea, Rason, special economic zone, satellite data, spatial change, social change

Introduction

Recent geopolitical developments have intensified tensions on the Korean Peninsula. Ongoing strategic competition between the United States and China, North Korea's involvement in the

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Russia–Ukraine conflict, and its reactions to South Korean drone surveillance and balloon incidents all contribute to growing instability (H. Kim, 2024). Against this backdrop, discussions among Russia, China, and North Korea have focused on the potential joint development of the lower Tumen River, a border region shared by the three countries (Lee, 2024). If the lower Tumen River is jointly developed, China will secure a route to the Pacific Ocean in the Northeast, and Russia, China, and North Korea will strengthen their political and economic cooperation. The Rason SEZ is located in the key area of trilateral cooperation along the lower Tumen River. Examining the evolution of Rason as a special economic zone over the past three decades provides critical insights into North Korea's economic trajectory and its broader regional dynamics in Northeast Asia.

The Rason SEZ represents one of the few areas in North Korea where market-oriented institutions have been relatively more developed, with comparatively fewer restrictions on foreign investment and external access. Established in the early 1990s during a period of economic crisis, the zone was intended to generate foreign currency and attract external capital. North Korea subsequently introduced the Foreign Investment Law in 1992, which created a more favorable institutional framework by offering legal protections, tax incentives, long-term land leases, and improved access to financial services (Woo, 2019). Further institutional adjustments in 1997 expanded the use of foreign currency and permitted limited forms of self-employment within the zone. However, despite these reforms, Rason failed to meet its initial investment target of $350 million, reflecting a combination of international sanctions, infrastructure constraints, limited local autonomy, and persistent investment risks (Woo, 2019).

The North Korean regime selected Rason for the SEZ for several geopolitical reasons. First, the internal reason is that the city's location is the farthest from the capital, Pyongyang, where key power players are concentrated, which is favorable for political stabilization (Mun & Kim, 2015). One key external factor lies in Rason's strategic position at the intersection of North Korea, China, and Russia, which enhances its potential to attract foreign investment. China sought to use Rason to address the limitations of its northeastern region, which did not have access to the sea, and to open up Pacific trade routes to Japan, Russia, and the Americas through the Rajin port located in Rason (S. Choi, 2010). Russia hoped to connect the Trans-Siberian Railway (TSR) to the Pacific trade route through the ice-free, all-season port of Rajin. Chinese and Russian investments did occur, with China agreeing to develop Rajin Port in 2005, building the Hunchun-Rajin highway, and securing a 50-year concession to operate Rajin Port No. 1 in 2009. Russia also agreed to build a rail link between Rajin and Khasan in 2007, and in 2014, North Korea and Russia jointly renovated and officially opened Pier 3 of Rajin Port's cargo terminal (Y. Choi, 2018).

Although constrained by structural limitations, the Rason SEZ demonstrated a degree of economic vitality prior to the tightening of sanctions in 2017. Between 2010 and 2015, approximately 70 firms entered the zone, accompanied by expanding tourism infrastructure, active coal exports to China, and increasing diversity in market goods (Y. Lee, 2016). Together with the gradual introduction of market mechanisms after 2002, SEZs have contributed to incremental changes within North Korea's otherwise tightly regulated economic system (Jung, 2015; Kwak & Moon, 2017; S.-H. Lee, 2016; Lim, 2016).

Special economic zones have emerged as key instruments for mobilizing foreign direct investment (FDI), leveraging geographic advantages alongside flexible regulatory and legal arrangements (Bach, 2011). SEZs were mainly developed in industrial nations until the 1970s, and then expanded in East Asia and Latin America, especially in Chinese cities with globalization. An economic zone is a small area that is not permitted to encompass the whole country and has been granted various government-led economic development opportunities

(Ong, 2004). Specifically, to attract businesses, governments have offered legally low labor law standards, bans on unionization and strikes, low environmental standards, low wages, cheap land, and easy administrative permitting (Easerling, 2016). Many governments are using SEZs as a mechanism for spatial capital accumulation and as a place for international rather than domestic cooperation. The main policy objectives that governments pursue through SEZs are to 1) attract foreign direct investment, 2) utilize idle labor, including the unemployed, and create jobs, 3) attempt broader national economic reforms, and 4) experiment with new economic institutions to be scaled nationwide (Akinci & Crittle, 2008; Bach, 2011).

Within post-socialist urban transitions, FDI has been a key driver of changes in spatial organization and everyday life (Szelényi, 1996). This dynamic is reflected in the Hualing International Special Economic Zone (HISEZ) in Tbilisi, where increased foreign investment has been accompanied by urban sprawl and the emergence of privately enclosed forms of development (Gogishvili & Harris-Brandts, 2019). Night-time light (NTL) analysis of the Xiamen Special Economic Zone in China showed that the city expanded by 79.44% between 2005 and 2020, after its designation as an SEZ (Chai et al., 2022). Since its designation as a special economic zone, Shenzhen has demonstrated significant economic and demographic expansion. Over a three-decade period, its per capita GDP increased by nearly two orders of magnitude, while its population reached approximately 14 million. As a connecting city between China and Hong Kong, the Shenzhen SEZ has served as a gateway for foreign capital and technology to enter China and for manufactured goods to go abroad, and the constant influx of immigrants has led to the city's continued expansion (J. S. Yoon, 2016; M. Park et al., 2015). SEZs have led to urban expansion and development in developed, developing, and late socialist countries.

In the case of Rason, which has been designated as an SEZ for more than 30 years, has the city undergone development comparable to that of other post-socialist cities? Can SEZs be revitalized and lead to urban development in a totalitarian state, which Acemoglu and Robinson (2019) refer to as a "Despotic Leviathan"? This is a question that anticipates not only the current changes in North Korea but also potential transformations during a future period of opening under a totalitarian legacy. This study examines the following research questions.

1. Has the Rason SEZ resulted in urban spatial and economic development?
2. Has the Rason SEZ transformed the daily lives of urban residents?
3. What factors have influenced the Rason SEZ, and which countries have had an impact?

As a totalitarian state, regional studies of North Korea require specialized research methodologies and designs. North Korea has been in a state of 'statistical blackout' since the mid-1960s, when it stopped publishing official statistics (S. Lee & Kim, 2021; Son, 2021). Even the limited data submitted to the United Nations since the famine of the 1990s is highly restricted in terms of the period and subjects covered (DPRK, 2009; K. Kim, 2013). In recent studies of North Korea, satellite data have played an expanding role as alternative sources of information in the absence of reliable statistics and accessible fieldwork conditions. Examples of North Korean urban studies utilizing satellite data include the identification of poverty areas in Pyongyang, urban spatial disparities in Rason, and urban spatial change in Kaesong (S. Lee, 2024; S.-H. Lee, 2023; S.-H. Lee et al., 2024). Extending prior research, this study adopts a mixed-methods approach that combines satellite data analysis with in-depth interviews with North Korean defectors. This design provides a methodological contribution for studying empirically constrained and highly restricted environments.

Research Methodology

Study Area

This study examines Rason, a northeastern North Korean city positioned at the convergence of China and Russia. To study urban transformation in Rason, its 855.64 km² administrative area was subdivided into 68 districts based on spatial characteristics. The study area is divided into 33 Rajin urban centers, 22 Sonbong urban centers, 6 coastal villages, and 7 rural areas. Of the two urban centers in Rason City, Rajin is located in the south, while Sonbong is located in the north. The location and zoning of the Rason SEZ are shown in Figure 1.

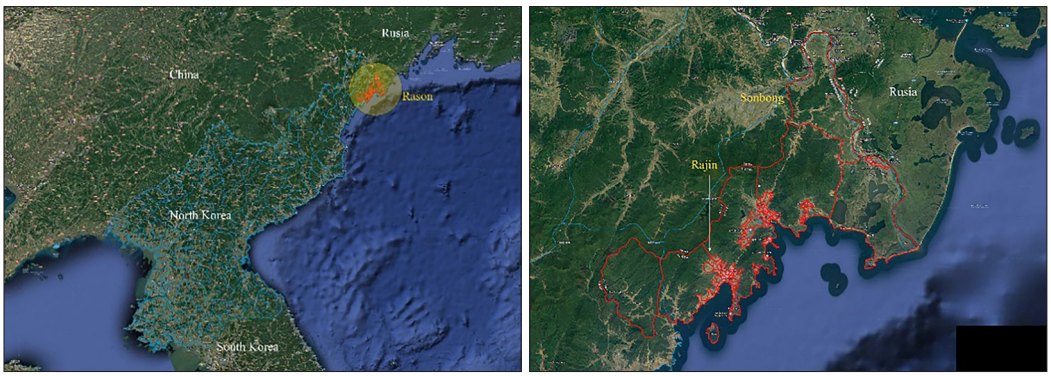

Figure 1. Location of the Rason SEZ and its 68 zoning distinctions

Research Progress

The analysis of changes in Rason City following the designation of the economic special zone followed the process outlined in Figure 2. In the first stage, satellite data on nighttime illumination and building density in the urban space of Rason City after the designation of the economic special zone were extracted to analyze trends over time and differences by district. Subsequently, the characteristics of Rason City's development were compared by comparing nighttime illumination and building density in North Korea as a whole during the same period. In the second stage, to analyze the factors influencing urban economic development, a regression analysis was conducted using nighttime illumination time series data from 1992 to 2023, dummy variables for specific periods such as famine, sanctions, and COVID-19, and time series variables for economic growth and trade volume. Additionally, to identify external influences on the development of the Rason Special Economic Zone, a multiple regression analysis was conducted using nighttime illumination data from Rason and time-series trade data from major regional economies, including China, Russia, Japan, the United States, and South Korea.

To strengthen the interpretation of the quantitative findings, this study incorporates in-depth interviews with former residents of Rason City. This process involved reviewing the quantitative research and examining changes in the daily lives and consciousness of Rason City residents, as well as the characteristics of the spatial environment in different areas, following the designation of the economic special zone.

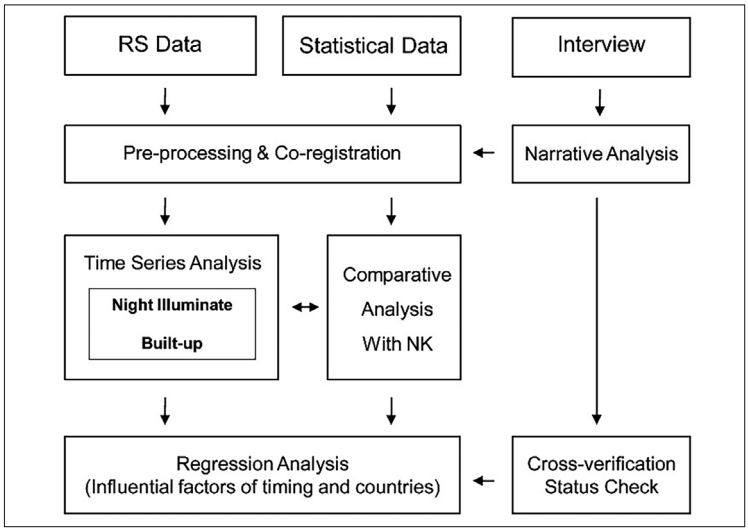

Figure 2. Research process

Data Assembly

The analysis of urban spatial change in Rason City was conducted by extracting time series satellite data of night illumination (1992-2023) and building density (1990-2020) acrooss 68 zones. Nighttime illumination is a representative variable that reflects the economic conditions of a city (Putri et al., 2023; Puttanapong et al., 2022). Within the North Korean context, nighttime illumination has been adopted as an indirect measure of economic activity and political centralization, while also capturing variations in nighttime intensity and their relationship to welfare and poverty (Crespo Cuaresma et al., 2020; K. Kim, 2022; S.-H. Lee et al., 2024). This study extracted two types of nighttime light satellite data to analyze a 32-year time series. Nighttime illumination from 1992 to 2013 was extracted from DMSP OLS data (resolution of 927.67 meters) provided by NOAA's National Geophysical Data Center (https://eogdata.mines.edu/products/dmsp/). VIIRS-based nighttime illumination data for the period 2014-2022, corresponding to the Kim Jong Un era, were utilized at a spatial resolution of 463.83 meters, with data accessed via the Earth Observation Group (EOG). Building density is an indicator that reflects the physical development and social change of a city (Nicholas & Patrick, 2015; Wu, 2002). The analysis of building density in Rason City draws on the GHSL dataset at a 1 km spatial resolution. Data processing was performed using Python in the Google Earth Engine environment, and visualization was conducted in QGIS.

For both nighttime illumination satellite data, a fitting process is required for time series analysis. Prior research has applied both linear and non-linear regression models to DMSP-OLS and NPP-VIIRS nighttime illumination data, selecting the model with the strongest explanatory performance (Liu et al., 2022; Meng et al., 2023). In this study, the researchers also conducted various regression analyses on the 2012 and 2013 data, which overlap (see Table 1). The analysis showed that power regression had the highest reliability and explanatory power (R-squared), and the model was applied to adjust the two nighttime illumination datasets.

To complement the quantitative findings, this study incorporates qualitative evidence based on in-depth interviews with individuals connected to Rason. The interviews were designed to

Table 1. DMSP-OLS and NPP-VIIRS calibration parameters, 2012-2013 (per-unit-area values)

Model	Formula	a	b	Pr (>t)	R^2
Linear	y = ax + b	1.5022	8.2375	0.000***	0.4408
Power	$y=ax^{\wedge}b$	9.3843	0.3211	0.000***	0.5107
Index	$y=ae^{\wedge}bx$	8.0176	0.1131	0.000***	0.3938

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2. Characteristics of interview participants in Rason

ID	Type	Duration of residence	Nationality	Job	Location of residence
A	Residence	1960s ~ 2010s	N. Korean	fisherman	Sonbong and Rajin
B	Regular visit	1990s ~ 2010s	N. Korean	merchant	Nearby Rason
C	Residence	2000s ~ 2010s	Foreigner	businessman	Sonbong and Rajin
D	Residence	1990s ~ 2010s	N. Korean	office worker	Rajin downtown
E	Residence	1990s ~ 2010s	N. Korean	office worker	Rajin downtown
F	Residence	2010s (4 years)	Foreigner	businessman	Rajin downtown
G	Construction	1960s ~ 2000s	N. Korean	Bureaucrat	Pyongyang

capture changes in the city's spatial structure and everyday life following the establishment of the SEZ. A total of seven participants were included: long-term residents of Rason (with more than two decades of experience since the early 1990s), foreign investors engaged in business activities in the zone, a North Korean defector with regular business visits to the area, and a senior official involved in construction-related policy. Interviews were carried out between June and October 2022 in settings selected for participant accessibility, including in-person meetings and online sessions. To ensure confidentiality, identifying information was minimized, and participant characteristics are summarized in Table 2.

Result

Nighttime Illumination Changes

The analysis of economic change in Rason after SEZ establishment draws on nighttime light data covering 68 districts over the period 1992-2023. Figure 3 shows the changes in nighttime illumination in the main city center, spearhead city center, coastal towns, and rural areas after the designation of the SEZ. Overall, nighttime illuminance increased from the mid-1990s to the end of 1990, then decreased until 2007. From 2009 to 2013, it increased sharply, and since then, it has shown a steady upward trend with fluctuations. Regionally, nighttime illumination has risen sharply, especially in the city center of Rajin.

To further examine the trends in nighttime illumination in Rason, the researcher categorized six periods based on political and economic events in Rason (see Table 3). The selected reference years correspond to major institutional and economic turning points: SEZ designation in 1992, administrative elevation in 1998, a decline in nighttime illumination in 2007, a subsequent

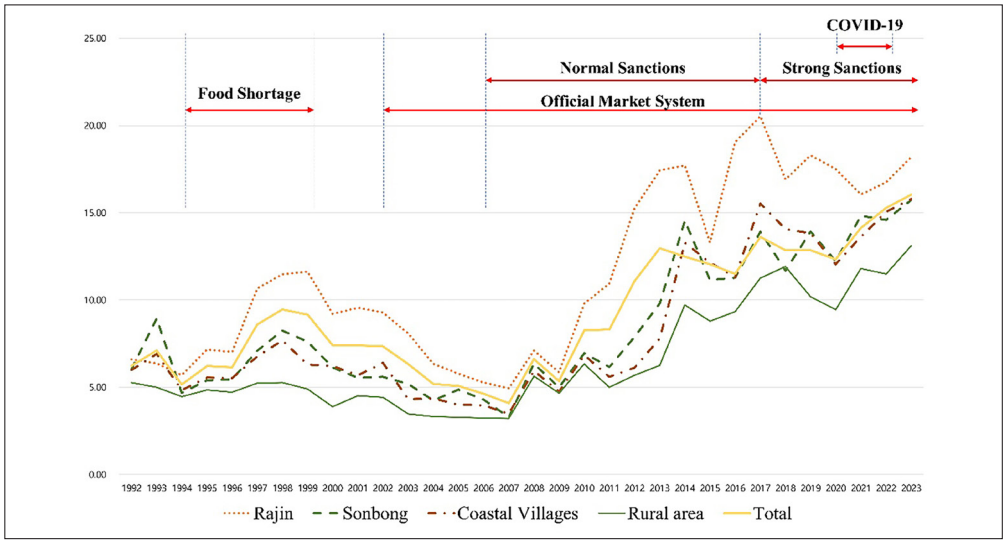

Figure 3. Changes in nighttime illumination by region in Rason (1992-2023, unit: nanoWatts/sr/mm^2)

increase in 2013, and intensified international sanctions in 2017. The results show that between 1992 and 2007, when Kim Jong Il was mainly in command, the nighttime light level in Rason increased in the mid-1990s, but overall, it was lower than the level before the designation of the special zone. Since 2007, after the agreement to develop the North Korea-China Rajin Port (2005) and the North Korea-Russia railroad connection (Rajin- Khasan), nighttime light levels have been increasing. The tightening of international sanctions after 2017 has altered Rason's development trajectory, constraining trade in agricultural and marine products and affecting seafood processing activities connected to joint ventures with China. The sharp drop in nighttime illumination in 2017 was related to the downturn of joint ventures between North Korea and China that processed seafood, as agricultural and marine products were added to the sanctions against North Korea. What was not expected was that the economic indicator, nighttime illumination, continued to increase after 2017, even with the strengthening of sanctions and COVID-19. This suggests that there may be an undisclosed factor that allows the Rason SEZ to sustain its economic performance despite sanctions and border closures.

Since its designation as a special economic zone in 1991, nighttime illumination in Rason has changed dramatically. A comparative analysis of nighttime illumination between Rason

Table 3. Changes in Nighttime Illumination in Rason (1992-2023, unit: nanoWatts/sr/mm^2)

Region	1992 (a)	1998	2007 (b)	Gap (b-a)	2013	2017	2023 (c)	Gap (c-b)	Times (c/b)
Rajin	6.60	11.47	4.93	-1.67	17.43	20.53	18.18	13.25	3.69
Sonbong	6.05	8.25	3.29	-2.76	9.81	13.93	15.73	12.44	4.79
Coast. Vill.	5.99	7.68	3.49	-2.51	7.80	15.53	15.79	12.30	4.53
Rural area	5.26	5.27	3.21	-2.05	6.25	11.25	13.12	9.91	4.09
Total	6.23	9.46	4.09	-2.13	12.97	13.61	16.04	11.94	3.92

Note: DMSP data for 1992-2013, VIIRS satellite data for 2014-2022

and North Korea as a whole is employed to assess whether the observed pattern reflects SEZ-specific dynamics or broader changes associated with market introduction. To test this question, the researchers compared nighttime light levels in Rason with data for the whole of North Korea between 2002 and 2022, during which the official market was established. The analysis utilized raw, unprocessed data. Table 4 presents the results.

The analysis shows that the change in nighttime illumination between 2002 and 2013 was slightly (0.1 times) higher in Rason than in all North Korean cities, but this difference was not statistically significant. In rural areas, North Korea as a whole experienced a larger increase than Rason. This suggests that the economic development of Rason may not have been unique compared to the overall market development in North Korea during this period. On the other hand, from 2014 to 2022, nighttime illumination in the city center of Rason declined while nighttime illumination in North Korea as a whole increased. The findings indicate that external constraints, including tightened sanctions and COVID-19-related border restrictions, exerted a stronger influence on the Rason SEZ than on North Korea as a whole.

Table 4. Comparison of nighttime illumination in Rason and North Korea (2002~2022)

	Rason		N. Korea		Variation (b/a)		Rason		N. Korea		Variation (d/c)	
	2002 (a)	2013 (b)	2002	2013	Rason	N.K.	2014 (c)	2022 (d)	2014	2022	Rason	N.K.
Urban	7.81	14.38	14.52	24.87	1.8	1.7	8.55	5.80	1.72	3.13	0.7	1.8
Rural	5.33	6.97	11.95	20.18	1.3	1.7	2.75	3.53	0.99	2.01	1.3	2.0
Total	7.34	12.97	12.27	20.77	1.8	1.7	7.44	5.37	1.10	2.18	0.7	2.0

Note: DMSP data for 1992-2013, VIIRS satellite data for 2014-2022

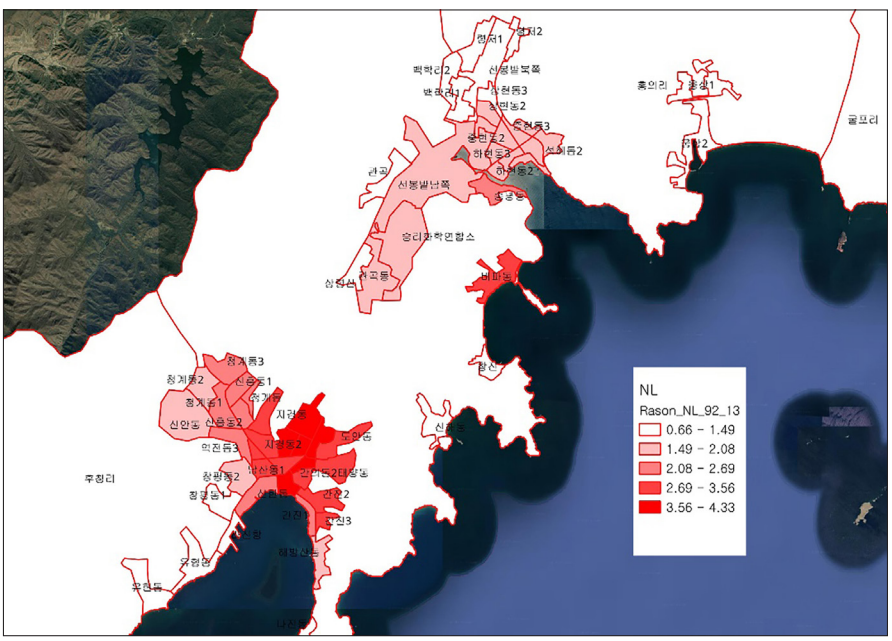

Figure 4. Changes in nighttime illumination in Rason from 1992 to 2013

The changes in nighttime illumination in Rason after the designation of the SEZ were visually checked using the QGIS program. As shown in Figure 4, the change in nighttime illumination between 1992 and 2013 was higher in Rajin city center, Sonbong city center, coastal towns, and rural areas. However, even in the same urban area, there were differences by district, and in the case of Rajin city center, the nighttime illumination increased significantly in the central and northeast districts. These areas are home to the city's bureaucratic class and Chinese-funded seafood processing plants. In Sonbong city center, the increase was smaller than in Rajin city center, and nighttime light levels increased in the coastal area, the city center, and near chemical plants. Of the coastal towns, Bipa-dong, between Rajin and Sonbong, showed the highest increase, as it is home to the Imperial Hotel and Casino, a five-star hotel built with Hong Kong capital in 2000, after the area was designated as a special economic zone.

As shown in Figure 5, between 2014 and 2022, which includes the period of North Korean sanctions and COVID-19, nighttime illumination in the city center of Rason declined. The areas that experienced the sharpest decline in nighttime illumination (shown in blue) are mostly urban centers, roughly corresponding to the areas that experienced the sharpest increase in the previous period (1992-2013). Bipa-dong, a coastal town with a high concentration of foreign capital outside the city, also experienced a sharp decline in nighttime light levels. These results show that Rason, as a special economic zone, is highly dependent on external factors affecting investment, and that the effects are concentrated in the city center and certain areas where foreign investment is concentrated.

Building Density Changes

The GHSL dataset, a satellite dataset capturing building density changes in Rason, provides data in five-year increments. This study extracted five-yearly data from 1990 to 2020 to analyze trends

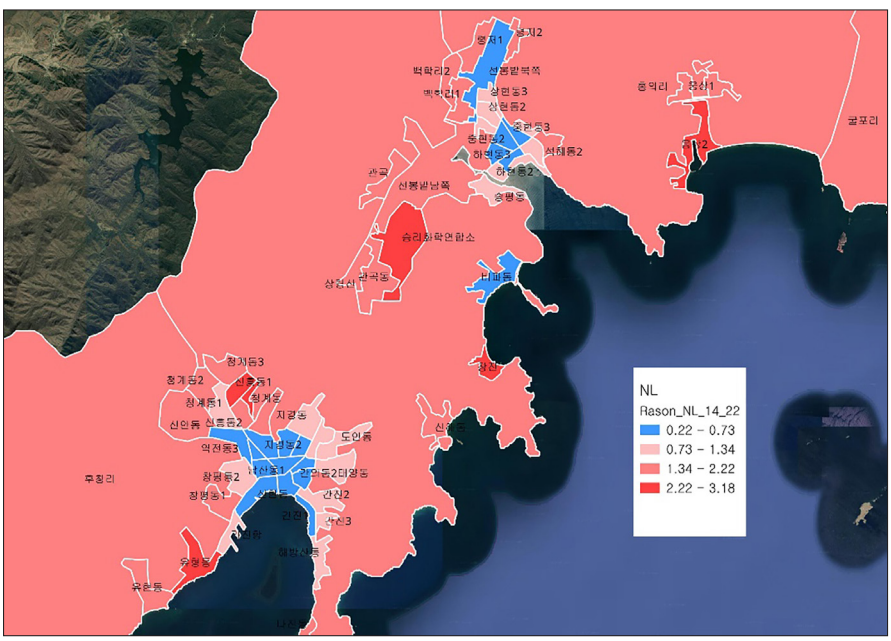

Figure 5. Changes in nighttime illumination in Rason from 2014 to 2022

before and after the designation of the Rason SEZ. The ratio of building area by district in Rason City from 1990 to 2020, starting two years before the designation of Rason SEZ, is shown in Table 5. During this period, the quantitative increase in building density (b-a) was higher in Rajin city center, Sonbong city center, coastal villages, and rural areas. This result shows a difference when comparing the percentage increase from 1990 to 2020. This means that after the designation of the SEZ, the total increase in construction in Rason was higher in the urban center, and the percentage increase was higher in rural areas.

To determine whether the change in building density in Rason is due to the revitalization of the Rason SEZ or other factors, this study compared the change in building density in Rason with the change in building density in North Korea as a whole. As shown in Table 6, there is no significant difference when comparing the change in building density between Rason and North Korea as a whole between 2000, which is two years before the official market was established in North Korea, and 2020. The urban areas show the same growth rate as North Korea as a whole, while the rural areas show a larger increase in building density than North Korea as a whole. This finding shows that the main factor in the urban development of Rason may not be the SEZ designation, but other factors such as general market development.

Figure 6 shows a visual analysis of the differences in building density among the 68 districts after the designation of the SEZ. The results show that the areas that experienced rapid construction after the designation of the SEZ were located slightly outside the city center rather than in the downtown core. For example, in Rajin, the neighborhood of Jagyeong-dong, northeast of the city center, where housing complexes were built, and the area of northeastern Sonbong, experienced rapid construction. On the outskirts of the city, the coastal town of Bipa-dong, with its casino hotels, has seen a high rate of building density growth.

Table 5. Changes in Building Density Ratio by Region in Rason (1990-2020)

	1990 (a)	2000	2010	2020 (b)	Variation	
					(b-a)	%
Rajin	0.1140	0.1584	0.1801	0.2118	0.0978	185.7%
Sonbong	0.1224	0.1338	0.1370	0.1750	0.0526	142.9%
Coastal villages	0.0342	0.0473	0.0532	0.0674	0.0332	197.0%
Rural area	0.0009	0.0013	0.0014	0.0023	0.0014	256.5%
Total	0.0981	0.1245	0.1365	0.1656	0.0674	168.9%

Table 6. Comparison of building density changes between Rason and North Korea (2000-2020)

	Rason			North Korea		
	2000	2020	Variation (times)	2000	2020	Variation (times)
Urban area	0.15	0.20	1.33	0.94	1.25	1.33
Rural area	0.02	0.03	1.44	0.12	0.18	1.49
Total	0.12	0.17	1.33	0.22	0.31	1.41

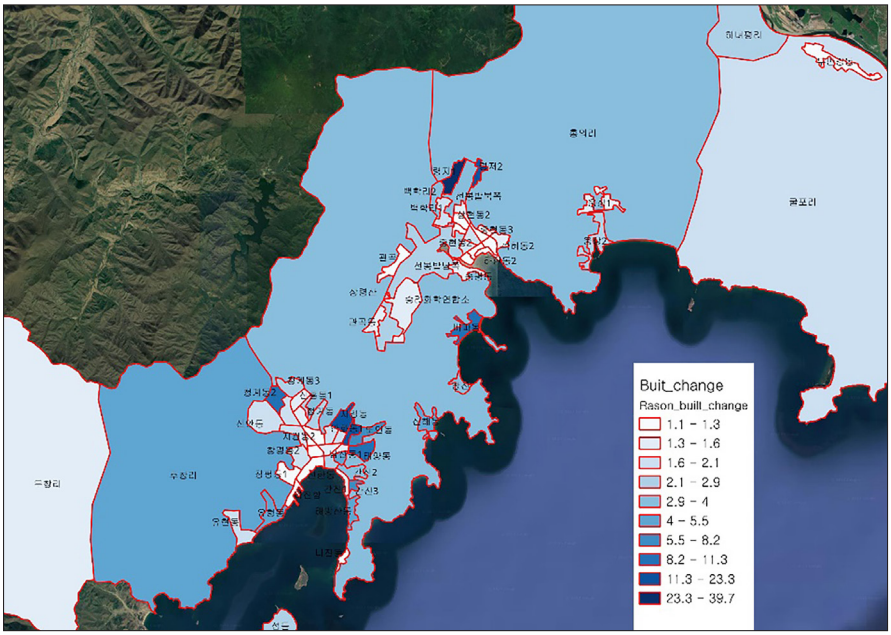

Figure 6. Change in built-up area in 68 districts of Rason (1990-2020)

Analysis of Factors Affecting the Local Economy (Nighttime Illumination)

Influencing Factors

We estimated a regression model for nighttime illumination and various influencing factors from 1992 to 2023 to analyze the economic influencing factors in the Rason region after its designation as a special economic zone. In the initial analysis, we examined various specifications including GDP (real) and economic growth rate. However, GDP and growth rate variables were not statistically significant in all models, and instability was observed, such as negative (-) coefficients in some cases. These results reflect the limitations in the reliability of North Korean GDP estimates and the difficulty of national-level indicators in explaining regional variability. The trade-only specification is retained based on its superior explanatory performance and consistency. The main results are presented in Table 7, while alternative model specifications are reported in the Appendix.

The analysis results confirmed that trade volume (log_Trade) was a major factor explaining fluctuations in nighttime illumination in Rason. This shows that, as Rason is a hub for foreign trade, the scale of cross-border trade was directly reflected in local economic activity, electricity consumption, and city lights. Strong sanctions and COVID-19 also affected nighttime illumination in Rason, showing that strong sanctions and border closures had a clear impact on investment, production, and the local economy in the Rason SEZ. On the other hand, factors such as famine, official market activities, and general sanctions, which affected the entire country, were not statistically significant. This suggests that the factors influencing economic activities in the Rason SEZ may differ from those affecting the rest of North Korea.

The results indicate that intensified sanctions exerted a stronger effect on the Rason Special

Table 7. Determinants of Nighttime Lights in Rason (1992-2023)

Variable	Coef.	Std. Err.
Intercept	-58.916***	(18.823)
Famine	1.502	(1.301)
Official Market	-1.528	(1.392)
Sanctions	-0.044	(1.413)
Strong Sanctions	6.598***	(1.431)
COVID-19	5.681**	(2.189)
log_Trade	4.496***	(1.282)
Adjusted R^2	0.683	
N	32	

Note: Standard errors in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$
Source: Author's calculations.

Economic Zone, whereas the broader sanctions framework established since 2006 had relatively limited influence. This suggests that the 2017 sanctions targeting the seafood processing industry, which was the primary investment sector for Chinese capital in Rason, had a strong impact, particularly the ban on seafood imports and exports. Therefore, the Rason Special Economic Zone is more significantly affected by external trade volumes and stringent sanctions on specific goods rather than general sanctions. This demonstrates that alternative indicators are more suitable for analyzing the economic situation in the Rason region than North Korea's economic growth rate or changes in market institutions.

Differential Effects of Trade by Country

As shown in Table 7, if trade volume has a strong influence on the Rason SEZ, which countries' trade have a great impact? To answer this question, we conducted a multiple linear regression analysis (OLS) using trade volume by country as the independent variable and nighttime illumination in Rason (NL_Rason) as the dependent variable. The study examines major partner economies, including China, Russia, Japan, the United States, and South Korea, characterized by strong trade linkages and close geopolitical proximity to North Korea. All data used in this analysis were time-series data collected from 2000 to 2023.

The estimates in Table 8 show that China has a positive and statistically significant coefficient ($p = 0.004$), pointing to a strong association between trade with China and economic activity in the Rason SEZ. Russia had a statistically significant negative coefficient ($p < 0.001$), suggesting that increased trade is associated with a decrease in nighttime illumination. Japan ($p = 0.086$) and South Korea ($p = 0.005$) also exhibited statistically significant negative coefficients. In contrast, trade with the United States did not show a statistically significant effect ($p = 0.929$).

The results point to an asymmetric structure among trading partners in the development of the Rason Special Economic Zone. Trade with China, in particular, is strongly linked to production and consumption patterns and functions as a central driver of economic activity in the region. On the other hand, Russia and South Korea showed negative influence. In the case of Russia, this is because its investment is limited to resources and infrastructure, while in the case of South Korea, it is because it invests in cities in the south, such as Kaesong, which is adjacent to the DMZ, rather than in the north of North Korea, and is greatly affected by domestic and foreign political

Table 8. Impact of Nighttime Illumination based on trade volume by country (2000-2023)

Variable	Coef.	Std. Err.	t-value	p-value
Intercept	12.39***	0.958	12.937	1.49e-10
China	7.623e-07**	2.345e-07	3.251	0.004436
Russia	-3.061e-05***	6.863e-06	-4.460	0.000303
Japan	-5.383e-06 ·	2.959e-06	-1.819	0.085590
USA	2.934e-06	3.233e-05	0.091	0.928686
South Korea	-1.846e-06**	5.859e-07	-3.151	0.005532
Adjusted R^2	0.780			
N	24			

Note: Dependent variable is NL_Rason (nighttime illumination in Rason). Coefficients are estimated using OLS. Standard errors, t-values, and p-values are reported. Significance codes: *** $p<0.001$, ** $p<0.01$, * $p<0.05$, · $p<0.1$.
Source: Author's calculations.

influences. The negligible influence of the United States and Japan seems to reflect the political isolation and trade disruption that have continued since the sanctions against North Korea.

Discussion: Cross-Review with In-Depth Interviews

Cross-Reviewing Nighttime Light Results

This study incorporates interviews with migrant residents of Rason to complement satellite-based analysis and to capture changes in spatial structure and everyday life. According to the interviews, the increase in the time series of nighttime light levels since 2010 is due to the increase in Chinese investment. The revitalization of the Rason SEZ occurred around the time of China's 50-year lease of Rajin Port in 2009 and the opening of the Hunchun-Rajin Port Road in October 2012. At that time, construction of roads and port facilities was actively underway in Rason, and slogans such as "Let's earn foreign currency" were posted on buildings (W. Choi, 2012).

> "The development of Rajin started when China built a 56-kilometer road from Hunchun to Rajin Port between 2011 and 2012. After the road was completed, a lot of outside capital came in strating in 2013, when a lot of Chinese developers came in (Interview with C)."

Enterprises in the Rason SEZ can be broadly categorized into three types: "state-owned companies" run by the North Korean regime, "joint companies" run by North Korean and foreign companies, and "independent companies" run by foreign companies on their own (D, E). In the mid-2010s, there were about 500 foreign companies in Rason, most of them Chinese (D, E). Even for Chinese investors, investing in Rason was risky, but low labor costs, the ability to start a business after signing a contract for 10% of the total investment, and the potential for high returns encouraged Chinese capital to invest (C). At the time, Hong Kong newspapers described Rason as a "golden land" and attracted not only Chinese investors but also Hong Kong investors (C). Many Chinese language schools sprang up in Rason, and residents began to learn the language to get jobs in Chinese companies (D, E). Chinese investors moved in, putting dollars into subleases, and began building high-rise apartments in Rason (C). In 2012, the railroad between Khasan, Russia,

and the port of Rajin was completed; many restaurants, warehouses, shops, and living quarters were built; and a surge in tourists filled 600 accommodations (Chosunsinbo, 2012). The reason why Chinese companies have continued to invest in Rason, unlike other foreign companies, despite the various investment risks, is not only because of its geographical advantages, but also because the investment threats have prevented the entry of large international companies and given Chinese companies the opportunity to put down roots in the region.

> "Chinese investors want things to be like they are now. Places like this, where there's a lot of potential for ongoing conflict, are categorized as risky areas, so big international companies don't come in, and they can rely on their networks and relationships. There are Chinese companies that have dominated trade in Rason. The biggest trading company in Rason is a Chinese-owned trading company called B. They have a lot of power. Rason residents call Rason "B City." That's how powerful the Chinese companies are there. (Interview with C)"

The trend of nighttime illumination in Rason shows a sharp increase from 2016 to 2017, before sanctions were tightened against North Korea. In 2017, the nighttime light density in Rason was 9.83, which is 6.2 times higher than the average nighttime light density in North Korea (1.58) during the same period. D, who had the opportunity to visit various parts of North Korea in 2016, testifies that Rason had a much better economic and electrical supply situation than other cities in North Korea.

> "At the time, Rajin had electricity for 23 hours a day. Rason would lose power for 30 minutes to an hour a day. Hamhung had 30 minutes of power a day. When I traveled, I had to charge my phone, and that was the real battle. Hamhung had really bad electricity, and Wonsan in Gangwon Province had about 17 hours of electricity. That was in 2016 (Interview with D)."

Since 2017, when sanctions were tightened against North Korea due to its nuclear test, nighttime illumination in Rason has shown a sharp decline. The situation in Rason has not recovered since the 2019 North Korea-U.S. summit collapse and the COVID-19 border closure (C). This situation is consistent with the trend of nighttime illumination in Rason. The reason why the 2017 sanctions on North Korea had a major impact on Rason's economy is that the "prohibition on importing North Korean fish" was among the sanctions. Most of the Chinese enterprises in the Rason SEZ were factories that processed North Korean fish and imported them into China. Official fish exports from North Korea to China declined sharply following the imposition of UN Security Council sanctions in 2017. Since then, North Korean seafood has been distributed to China through smuggling, but the volume has sharply decreased, which has affected investment and the economy of Rason (S. Yoon, 2019).

> "Not only fish caught near Rason, but also fish caught nationwide are brought to Rason. Fish caught in Wonsan, Hamhung, and Chongjin are transported by land in containers to Rason. Live seafood is sold wholesale to Chinese merchants along the way. Containers loaded with fish sometimes enter China at the border and then return to Rason. This is because labor costs in North Korea are cheaper than in China, so the fish is processed there (Interview with F)."

Cross-Reviewing Building Density Results

The results of building density changes in Rason show that since the designation of the SEZ, the entire city of Rason has grown steadily, mainly in the city center and coastal villages, with more

construction activity in the city center than in rural areas. Interviewees who had lived in Rason from the 1990s to the end of the 2010s testified that the same phenomenon observed in the spatial density satellite data occurred in Rason. According to them, construction changes in Rason have been continuous since the designation of the SEZ, especially in the city center of Rajin and some coastal areas. Construction activity following SEZ designation was primarily concentrated in the areas surrounding Rajin port (A, D, E). Although the North Korean regime has lumped Rajin and Sonbong together as the Rason SEZ, the two areas are in subtle competition with each other, and residents of Rajin often distinguish themselves from Sonbong.

> "Rajin and Sonbong were merged into the SEZ. Rajin was a little better, with fish processing plants and stuff, but Sonbong had nothing like that. Sonbong was less livable than Rajin. Rajin and Sonbong had a rivalry in the past. Before the SEZ, Sonbong was much better off, and when Rajin officials asked Sonbong officials for something, they didn't give it to them. After the two areas merged, the Rajin people didn't appoint the Sonbong cadres, so it's a local dispute (Interview with A)."

> "There was such a thing, like a guy in the same company who lived in Rajin and Sonbong, and once it was designated as a special economic zone, he was like, 'You're from there, I'm from there (D).' (Laughs) Yeah, I think it's everywhere, I'm from Rajin. (E). I think it's stronger when we're younger, when we're immature (D)."

Satellite data between 1990 and 2020 shows that the area of Rajin city center with the highest increase in building density is Dongmyeong-dong in the northeast, where building density increased by 9.4 times during this period. According to D and E, the terrace-style apartment buildings on the hill were built by the North Korean government. However, the source of the construction funds could also be Chinese companies, as Chinese investors sometimes build housing as donations to attract investment from the North Korean regime (D, E). According to Google satellite imagery as shown in Figure 7, the construction period of the apartment complexes was between 2014 and 2015.

According to the testimony of G, a former high-ranking North Korean official, it is important to consider that the economic profits from the Rason SEZ may not directly translate into construction in Rason. Unlike in capitalist societies where decentralization is established, construction activities in North Korea reflect special policies centered on the party. Despite

Figure 7. Satellite image of changes in Dongmyeong-dong (left: September 2013, right: September 2022)

various changes such as the introduction of market mechanisms, North Korea's totalitarian power remains intact and continues to be a "classical socialism" as mentioned by Kornai (1992). Therefore, the income generated through the Rason SEZ is more likely to be used for the party's political purposes rather than for the development of Rason City.

> "From a common-sense perspective, when an economic zone develops, the surrounding area also develops. However, in North Korea's system, the development of an economic zone does not necessarily lead to the development of the city. The money generated there goes to the government. Ultimately, construction cannot be led by individuals or companies. This is related to national policy and national initiatives. A portion of the income from economic special zones is allocated to the residents of the city. However, these reflections are not sufficient to fund large-scale apartment construction or architectural revolutions (Interview with G)."

Conclusion

This study examines how the SEZ designation has affected spatial change in Rason city through a cross-examination of time series satellite data and in-depth interviews. The analysis of nighttime illumination, an economic indicator, showed that the city's nighttime illumination rose sharply from 2009 to 2013, and has continued to rise since then, even under sanctions. Nighttime illumination is higher in urban areas than in rural areas, and within urban areas, Rajin is higher than Sonbong. Comparative analysis of nighttime illumination between Rason and North Korea as a whole points to a strong association between SEZ designation and urban economic change, particularly in downtown Rason. Satellite analysis of building density in Rason shows that since the designation of the SEZ, the city center of Rason has seen the most construction activity, especially in urban areas, near the city center and in certain coastal villages that have attracted foreign investment and luxury hotels. The analysis of building density in North Korea as a whole and in Rason found no evidence that the SEZ had a particular impact on urban construction in Rason. Statistically significant factors influencing economic activity (nighttime illumination) in the Rason Special Economic Zone were trade volume, strong sanctions against North Korea, and COVID-19. The results highlight cross-country variation, with trade with China exhibiting a stronger association with the development of the Rason Special Economic Zone than trade with Russia, Japan, the United States, or South Korea.

Interview-based evidence supports the satellite analysis of economic and construction dynamics in the city. It further highlights changes in urban space and everyday life following SEZ designation, including the growing involvement of Chinese firms and their influence on Rason. In conclusion, while Rason has made progress in the city's economy and daily life since its designation as an SEZ, it has been modest compared to post-socialist countries, and it is not significantly different from the changes in North Korea as a whole, pointing to a limited overall influence of SEZs within North Korea

This study advances research on North Korea by integrating satellite-based analysis with in-depth interviews in a context of limited data availability and restricted field access. The proposed mixed-methods design offers a transferable framework for empirical research in similarly constrained environments. In addition, the results of this study on North Korean SEZs and urban transformation will help to identify the future direction of North Korean SEZs, the spillover effects of China-Russia-North Korea economic cooperation, and the potential for foreign direct investment in North Korea. This study also revealed that sanctions targeting specific items are more effective than general sanctions in terms of their effectiveness on North Korea. The findings

provide policy-relevant insights into responses to international sanctions associated with North Korea's nuclear development.

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Conflict of Interest

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Appendix

Table A-1. Robustness Checks (Side-by-Side Models)

Variable	Model 1: GDP+Trade	Model 2: GDP only	Model 3: Trade only	Model 4: GDP w/o GR	Model 5: Trade w/o GR
Intercept	116.292 (88.588)	-17.679 (116.618)	-62.279*** (17.047)	24.289 (118.373)	-58.916*** (18.823)
Str. Sanctions	7.658*** (1.258)	8.605*** (1.723)	7.471*** (1.336)	7.914*** (1.739)	6.598*** (1.431)
log_Trade	5.988*** (1.244)		4.762*** (1.162)		4.496*** (1.282)
Famine	0.495 (1.222)	0.606 (1.695)	1.571 (1.175)	0.307 (1.750)	1.502 (1.301)
Growth Rate	0.248** (0.108)	0.257* (0.150)	0.291** (0.113)		
Sanctions	0.438 (1.207)	3.154** (1.479)	0.260 (1.282)	2.959* (1.531)	-0.044 (1.413)
Official Market	-2.613** (1.263)	-2.107 (1.745)	-2.744* (1.342)	-1.040 (1.692)	-1.528 (1.392)
log_GDP	-18.968* (9.255)	2.430 (11.255)		-1.665 (11.419)	
COVID-19	6.707*** (1.883)	0.349 (1.861)	6.180*** (1.986)	-0.010 (1.919)	5.681** (2.189)
Adjusted R^2	0.772	0.561	0.742	0.527	0.683
N	32	32	32	32	32

Note: Standard errors in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$