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Post-Tsunami Relocation Housing in Peri-Urban Transformation: Ribbon and Leapfrog Growth in Neuheun, Aceh, Indonesia

Azlan Shah[1]

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Abstract. *Post-disaster relocation housing is commonly assessed through shelter provision and hazard exposure reduction, yet its long-term role in shaping peri-urban spatial transformation remains insufficiently examined. This study investigated how post-tsunami relocation housing contributed to land-use change, building distribution, settlement densification, and spatial growth patterns in Neuheun, Aceh, Indonesia, between 2011 and 2021. Neuheun was selected because it accommodated seven relocation housing complexes after the 2004 Indian Ocean tsunami and later became part of the Beuramoe New Town relocation and development area. Using comparative spatial analysis, interpretation of Google Earth historical imagery, government statistical data, building-count analysis, and typomorphological reading, this study identified both quantitative and morphological changes in the area. The findings show that Neuheun retained a mixed rural-urban character, as agricultural land only slightly declined from 46.41% in 2011 to 45.29% in 2021. However, stronger transformation occurred through the expansion of trade and service activities and the gradual rise of settlement density from 3.24 to 3.45 buildings per hectare. Spatially, two dominant growth patterns emerged. Ribbon growth developed along Jalan Laksamana Malahayati, where the total number of buildings increased from 823 to 949, and trade and service buildings increased from 148 to 195 units. Leapfrog growth appeared within and around relocation housing clusters, where the total increased from 1,928 to 1,980, and trade and service buildings increased from 30 to 77 units. These results indicate broader building expansion along the established corridor but more concentrated commercial intensification within the relocation clusters.*

Keywords. *post-disaster relocation, peri-urban transformation, ribbon growth, leapfrog growth, spatial morphology.*

Introduction

Post-disaster relocation housing is intended to reduce the vulnerability of communities. After relocation is completed, it poses new demands on environmental knowledge and the pursuit of livelihoods in a new location, such as access to services, employment, and land (Nalau and Handmer, 2018). This study looked at the migration of disaster victims originally from Banda Aceh, an urban area, to Neuheun, a peri-urban area, which created new socioeconomic adjustments for the migrants.

[1]Department of Architecture, Faculty of Science and Technology, Universitas Islam Negeri (UIN) Ar-Raniry Banda Aceh, Jl. Syech Abdurrauf, Kopelma Darussalam, Kec. Syiah Kuala, Banda Aceh, Aceh 23111, Indonesia. *Corresponding author: azlan.shah@ar-raniry.ac.id

Peri-urban areas are transitional spaces between urban and rural systems. They are often characterized by mixed land uses, fragmented built-up areas, agricultural land conversion, low-density expansion, and changing relationships between settlement, infrastructure, and economic activity (Piorr et al., 2011; Shaw et al., 2020; Wolff et al., 2021). In Indonesian urban studies, peri-urban transformation is commonly associated with changes in land use, building function, settlement density, circulation systems, and the gradual shift from rural to urban characteristics (Yunus, 2008). Such transformation is rarely uniform. It may appear as linear development along transport corridors, scattered growth in isolated locations, or densification around new development nodes. These patterns are often described through concepts such as ribbon development and leapfrog growth (Yunus, 2008; Christiawan, 2019).

The findings from Shaw et al. (2020) in Europe show that peri-urbanization may manifest itself in many ways, including changes in land cover, land use, and land management, as well as changes in the planning status of an area, socioeconomic conditions, and the environment. Development in peri-urban areas appears to be attracted to pre-existing villages that already have basic levels of critical services (Wolff et al., 2021), a phenomenon known as the village magnet hypothesis. However, Dar es Salaam in Tanzania has also developed along highways and major roads as per the ribbon hypothesis. A study in Japan on centralized post-disaster urban planning (Kondo and Lizarralde, 2021) shows that maladaptation, urban fragmentation, and rapid changes in urban footprints emerged as consequences of centralized government-mandated planning and housing development. Tan et al. (2022) state that relocation impact predicts higher income but not better mental health or self-rated health. The evacuees who remained in the new locations eventually realized gains.

In the case of Aceh, the 2004 Indian Ocean tsunami generated one of the largest post-disaster reconstruction processes in the history of Indonesia. The reconstruction process was guided by institutional planning documents produced during the rehabilitation and reconstruction period. The Aceh-Nias rehabilitation and reconstruction master plan positioned housing, infrastructure, settlement recovery, and spatial planning as key components of post-tsunami recovery, while the final BRR report documented the broader reconstruction agenda after the disaster (Government of Indonesia, 2005; BRR Aceh-Nias, 2009). In this context, Neuheun became relevant not only as a relocation destination but also as part of a wider post-disaster settlement restructuring process. Local statistical records from Kecamatan Mesjid Raya further provide the demographic and administrative background needed to understand the area before and after the medium-term transformation period examined in this study (BPS Kabupaten Aceh Besar, 2011; BPS Kabupaten Aceh Besar, 2020).

Wulandari et al. (2020) revealed how land-use change occurred due to the construction of post-tsunami relocation housing environments and its impact on the patterns of daily economic activities of local communities in coastal hilly areas. The findings specifically show that relocation housing hinders the movement of existing people and livestock. Meilianda et al. (2019), on the other hand, found an increase in built-environment expansion towards the coastline in Banda Aceh. The same thing is stated by Murao et al. (2025), who also found that 29% of the Banda Aceh population still resides in high-risk zones. Benazir et al. (2026) concluded that community acceptance appeared to be influenced by place attachment, livelihood dependence, and neighborhood cohesion. Jalan Laksamana Malahayati is approximately 500 meters from the coastline, highlighting persistent vulnerabilities.

The spatial consequences of relocation housing in peri-urban areas remain less discussed. Many post-tsunami studies in Aceh focus on coastal risk zones (Murao et al., 2025), coastal land-use

change (Meilianda et al., 2019), dwelling adaptation (Fithri et al., 2026), and community preparedness (Syamsidik et al., 2021). Wulandari et al. (2020) directly examined land-use change and daily economic activities in Neuheun but did not compare post-occupancy building footprints and functional changes between the pre-existing corridor settlement and the seven planned relocation clusters. Relocation settlements located outside the most devastated coastal areas have received comparatively less attention as a contributing factor to peri-urban transformation. This research gap is important because relocation housing may create new demands, attract commercial activities, stimulate road-based development, and transform rural-urban interfaces. In this sense, post-disaster relocation can contribute to peri-urbanization by increasing the local population rather than merely being a response to disaster displacement.

This article addresses that research gap by showing that relocation housing in Neuheun was associated with two simultaneous spatial processes: accessibility-driven ribbon growth along the main road corridor and settlement-node-driven leapfrog growth within and around relocation housing clusters. This dual reading offers a more precise explanation of how post-disaster recovery landscapes evolve after the immediate reconstruction phase.

The case of Neuheun is analytically important because it reveals a dual process of post-disaster peri-urban transformation. While agricultural land remained substantial, trade and service activities expanded along the main road corridor and within selected relocation housing clusters. This indicates that the most significant transformation was not simply agricultural land conversion but the emergence of new economic and morphological patterns within a mixed rural-urban setting. This study argues that post-tsunami relocation housing in Neuheun contributed to the emergence of two simultaneous growth patterns: corridor-based ribbon growth along Jalan Laksamana Malahayati and cluster-based leapfrog growth within and around relocation housing areas.

Based on this background, this article examines how post-tsunami relocation housing contributed to peri-urban spatial transformation in Neuheun between 2011 and 2021. Specifically, it addresses two questions: first, how did the physical characteristics of Neuheun change after the occupation of relocation housing? Second, how did ribbon and leapfrog growth patterns emerge in relation to relocation housing and transport corridors?

By answering these questions, the study contributes to post-disaster planning and peri-urban studies in three ways. First, it extends the discussion of relocation housing from shelter provision to long-term spatial transformation. Second, it shows how planned relocation can generate differentiated growth patterns within peri-urban areas. Third, it provides empirical evidence from Aceh that post-disaster recovery landscapes need to be evaluated not only through risk reduction but also through their impacts on land use, settlement morphology, accessibility, and local economic change.

Literature Review

Post-disaster resettlement as housing recovery and spatial restructuring

Post-disaster resettlement is commonly understood as a recovery strategy to move affected communities from hazardous areas to safer locations. However, relocation is not only the physical movement of households. It also involves land acquisition, housing provision, infrastructure, livelihood restoration, access to services, social integration, and long-term governance. Planned relocation is widely recognized as a disaster risk reduction and climate

adaptation strategy, but it may create new social, economic, spatial, and governance challenges when it is not integrated with local development systems (UNHCR, Brookings Institution, and Georgetown University, 2014; Nalau and Handmer, 2018).

Post-tsunami relocation housing is treated as both a recovery instrument and a spatial intervention. After occupation, relocation complexes may become new settlement nodes that influence land use, building growth, circulation, and local economic activity. This perspective is important because the relocation housing areas were followed by changes in land use, trade and service growth, and differentiated development among housing clusters.

Peri-urban growth in Southeast Asia and developing Asian contexts

Peri-urbanization is a major feature of urban growth in developing Asian countries. It often occurs through the expansion of built-up areas into rural landscapes, agricultural land conversion, and the growth of mixed residential, commercial, and infrastructural functions. A systematic review of peri-urbanization in China, India, and Indonesia describes this process as a double-edged sword because it may create economic opportunities while disrupting peri-urban livelihoods when physical expansion outpaces population growth, infrastructure provision, and livelihood adaptation (Christiawan and Nguyen, 2024).

Recent Indonesian peri-urban studies also show the importance of land-use proportion, building density, facility distribution, road networks, and distance from urban centers in explaining spatial transformation (Firmansyah et al., 2024). Muladica et al. (2018) found that planned housing development in Wonolopo was followed by changes in surrounding settlements.

Urban morphology, land-use change, and spatial growth patterns

Urban morphology provides a useful approach for understanding how settlements change physically over time. In peri-urban areas, transformation may appear through fragmented development, roadside commercialization, settlement infill, and scattered growth nodes. Land-use and built-up changes therefore need to be read spatially, not only statistically (Mosammam et al., 2017). Yunus (2005) identifies developer initiatives as one of six factors influencing centrifugal spatial development.

The concepts of ribbon development and leapfrog growth are especially relevant to this study. Ribbon development refers to linear growth along major roads or transport corridors, while leapfrog growth refers to discontinuous development that appears away from the existing built-up core (Yunus, 2008; Christiawan, 2019).

Aceh post-tsunami recovery and the spatial question of relocation

Aceh provides an important case for understanding the long-term spatial consequences of post-disaster reconstruction. The 2004 Indian Ocean tsunami triggered massive housing reconstruction, infrastructure rebuilding, risk reduction, and institutional reforms. Previous studies have examined long-term recovery, mitigation, preparedness, coastal land-use change, population redistribution, and evacuation risk after the tsunami (Syamsidik et al., 2021; Meilianda et al., 2019; Murao et al., 2025). These studies show that post-tsunami recovery involved not only rebuilding damaged areas but also changes in settlement locations, land-use patterns, and risk distribution over time.

More directly related to this article, Wulandari et al. (2020) examined how tsunami relocation housing changed land use and daily economic activities in Aceh's coastal mountain area. However, the present study develops this discussion further by reading Neuheun's transformation through peri-urban morphology, particularly the simultaneous emergence of ribbon and leapfrog growth.

Positioning Neuheun within the literature

The literature reviewed above suggests that post-disaster relocation should be understood as a long-term spatial process rather than a one-time housing delivery program. Planned relocation can reduce exposure to coastal hazards, but it may also redistribute population, create new settlement nodes, attract economic activities, and generate new development pressures in peri-urban areas. In Aceh, previous studies have examined tsunami recovery, coastal land-use change, disaster preparedness, and the socio-economic consequences of relocation housing. However, the morphological pathways through which relocation housing reshapes peri-urban areas remain less explicitly discussed.

This study addressed that gap by positioning post-tsunami relocation housing in Neuheun as a contributing factor of peri-urban transformation. The article argues that relocation housing did not only provide shelter after the tsunami. It also introduced new spatial nodes that later interacted with road access, land availability, local economic demand, infrastructure quality, and topographic constraints. As a result, Neuheun experienced a dual spatial transformation: ribbon growth along Jalan Laksamana Malahayati and leapfrog growth within and around relocation housing clusters.

The contribution of this study is therefore both empirical and conceptual. Empirically, it provides evidence from Neuheun using data on land-use, building, settlement, and circulation from 2011 to 2021. Conceptually, it connects post-disaster resettlement research with peri-urban morphology by showing that relocation housing can stimulate fragmented and corridor-based growth in the urban fringe.

Methods

Research design

This study used a comparative spatial case study approach to examine the long-term peri-urban transformation associated with post-tsunami relocation housing in Neuheun, Aceh, Indonesia. The research combined diachronic land-use comparison, building-count analysis, settlement-density analysis, circulation analysis, and typomorphological interpretation. This approach was selected because the study aimed to identify not only the amount of physical change between 2011 and 2021, but also the spatial pattern through which relocation housing reshaped the peri-urban morphology of Neuheun.

The analysis focused on two observation years, 2011 and 2021. The year 2011 was selected to represent the condition after the initial post-tsunami relocation and reconstruction phase had stabilized, while 2021 was selected to observe medium-term spatial transformation after approximately one decade of settlement development. The comparison between these two years allowed the study to examine changes in land use, building function, settlement density, and spatial growth patterns after the relocation housing complexes became embedded within the wider peri-urban structure.

The main analytical emphasis was placed on spatial comparison and typomorphological reading. This emphasis is appropriate because the objective of the article is to explain how ribbon and leapfrog growth emerged after the establishment of relocation housing, rather than to produce predictive statistical modelling.

Study area

The study area was Gampong Neuheun, Kecamatan Mesjid Raya, Kabupaten Aceh Besar, Aceh, Indonesia. The observed area was limited to the administrative and spatial extent of Neuheun, from the southern river boundary to the northern area near Ujong Batee. Neuheun is located between 5°36'21" and 5°39'00" North Latitude and 95°24'03" and 95°26'12" East Longitude.

Neuheun was selected for three reasons. First, it accommodated seven post-tsunami relocation housing complexes after the 2004 Indian Ocean tsunami. Second, it was part of the broader Beuramoe New Town relocation and development area. Third, it provides a clear case for examining peri-urban transformation because relocation housing, arterial road access, hilly terrain, agricultural land, and emerging commercial activities coexist within the same village area.

The main spatial elements observed in this study were: 1) post-tsunami relocation housing clusters; 2) Jalan Laksamana Malahayati as the main road corridor; 3) agricultural and non-agricultural land uses; 4) residential and commercial-service buildings; and 5) classified land-use density and circulation patterns.

Data sources

The study used secondary and primary spatial data. The secondary data consisted of government data, village and district statistical information, land-use maps, satellite imagery, and planning-related documents. Statistical data from Kecamatan Mesjid Raya were used to support the demographic and administrative background of the study area, while BRR documents were used to understand the broader post-tsunami rehabilitation, reconstruction, and settlement planning context (BPS Kabupaten Aceh Besar, 2011; BPS Kabupaten Aceh Besar, 2020; Government of Indonesia, 2005; BRR Aceh-Nias, 2009). The primary data consisted of field observation, visual documentation, and direct checking of selected physical conditions in Neuheun.

Google Earth historical imagery was used as the main visual base for spatial interpretation. The imagery was interpreted through manual on-screen digitizing rather than automated or supervised image classification. This approach was selected because the study required detailed identification of building distribution, building function, road-based development, and relocation housing clusters at the village scale. The spatial resolution of Google Earth imagery varies by image provider and acquisition date; therefore, the imagery was used as a high-resolution visual interpretation source rather than as a standardized remote-sensing dataset with a single fixed spatial resolution.

Land-use categories were identified through visual interpretation of Google Earth imagery, existing spatial maps, and field observation. The classification focused on categories relevant to peri-urban transformation, including agricultural and livestock land, housing, trade and services, public facilities, fisheries, and unused/open land or other non-classified areas. The classification was conducted manually by comparing spatial patterns, building forms, road access, and

observed land-use functions. No supervised or automated land-use classification was applied in this study.

Table 1. Data sources used in the study

Data group	Data used	Purpose
Land-use data	Google Earth historical imagery (March 2, 2011 and June 10, 2021), Google Maps imagery, administrative boundary reference, and field-verified land-use interpretation for 2021	To identify land-use change and rural-urban transition
Building data	Manual building counts from Google Earth interpretation and building-by-building field verification	To identify changes in residential, trade, and service buildings
Settlement data	Built-up area and settlement density	To measure densification and settlement expansion
Circulation data	Road hierarchy and road-access maps	To examine the relationship between accessibility and spatial growth

Source: Author's analysis

Several supporting spatial references were also consulted, including administrative boundary references, road network interpretation, land-use interpretation maps, and field documentation. These materials were used to support spatial interpretation, while Google Earth historical imagery and field verification served as the primary basis for building-count and land-use analysis.

Field verification was conducted in 2021 and was used only to confirm the dominant function of buildings observed in the 2021 dataset. It was not used to verify building functions in 2011. Building footprints were compared between the 2011 and 2021 images. A building was classified as an addition when no footprint was visible in the 2011 imagery but a footprint was visible in the 2021 imagery. Field verification conducted in 2021 was then used to identify the dominant function of these buildings in 2021.

Land-use percentages were calculated using the classified peri-urban land-use area as the denominator. Unused/open land and other non-classified areas were retained in Table 3 to maintain consistency with the total mapped area, but they were excluded from the percentage interpretation of agricultural, housing, trade-service, public facility, and fisheries categories. This distinction was applied to avoid overstating rural-urban conversion while still presenting the full mapped area transparently.

Variables and indicators

The analysis was structured around four physical indicators of peri-urban transformation: land use, building characteristics, settlement characteristics, and circulation. These indicators follow the peri-urban morphology framework commonly used to describe physical characteristics of

peri-urban areas, particularly land-use composition, building density, residential land area, and circulation character (Yunus, 2008). The variables used in this article are summarized below.

Table 2. Research variables and indicators

Indicator	Variable	Measurement/observation
Land use	Agricultural land, residential land, trade and service land	Area and percentage change between 2011 and 2021
Building characteristics	Residential, trade, and service buildings	Number and distribution of buildings
Settlement characteristics	Built-up area and settlement density	Buildings per hectare and settlement proportion
Circulation	Road hierarchy and road access	Relationship between road access and building growth
Spatial growth pattern	Ribbon and leapfrog growth	Typomorphological interpretation of spatial distribution

Source: Author's analysis

This structure allowed the study to compare two different spatial mechanisms. Ribbon growth was identified through the concentration of trade and service buildings along Jalan Laksamana Malahayati. Leapfrog growth was identified through discontinuous development within and around the relocation housing clusters.

Data analysis

The analysis was conducted in five stages. First, the study identified the spatial boundary of Neuheun and mapped the location of post-tsunami relocation housing clusters. This step was necessary to distinguish between growth associated with the main road corridor and growth associated with relocation housing clusters.

For the building-count analysis, Neuheun was divided into two mutually exclusive analytical zones. The corridor zone comprised the pre-existing Neuheun settlement organized along Jalan Laksamana Malahayati, as delineated in Figure 2, while the cluster zone comprised the seven planned post-tsunami relocation housing complexes. The corridor zone followed the mapped extent of the original Neuheun settlement. The boundaries of the seven relocation clusters were excluded from the corridor zone and every identified building within the village boundary was assigned to one of the two zones. Consequently, the 2011 corridor count of 823 buildings and cluster count of 1,928 buildings add up to a village total of 2,751 buildings. The corresponding 2021 counts of 949 and 1,980 buildings add up to a total of 2,929 buildings.

Second, land-use data from 2011 and 2021 were compared to identify changes in agricultural land, residential land, and trade-service areas. This comparison was used to determine whether Neuheun experienced a strong shift from rural to urban land use or retained a mixed rural-urban character.

Third, building-count analysis was used to identify changes in building number and dominant function within the administrative boundary of Neuheun. The results were then interpreted through two spatial mechanisms: corridor-based growth along Jalan Laksamana Malahayati and cluster-based growth within and around post-tsunami relocation housing areas.

Fourth, settlement density was calculated using the number of buildings per hectare. This analysis was used to identify whether physical transformation occurred through settlement densification, land-use conversion, or functional change.

Fifth, typomorphological analysis was used to interpret the spatial pattern of change. This step examined maps, building distribution, road hierarchy, contour conditions, and field observations to explain why some areas developed more rapidly than others. Typomorphological analysis was used to reveal spatial transformation in each relocation housing area and to explain how different physical conditions shaped different development outcomes.

Data checking and interpretation reliability

To improve the reliability of the spatial interpretation, the analysis used data triangulation across Google Earth historical imagery, existing land-use maps, building-count data, road hierarchy maps, field observation, and visual documentation. Google Earth imagery was used as the main visual base for identifying building distribution, land-use patterns, road-based development, and relocation housing clusters. The interpretation was conducted manually through visual reading and on-screen digitizing rather than through automated or supervised image classification.

Building-count analysis was conducted through manual interpretation of Google Earth imagery and direct field verification. Each identified building within the administrative boundary of Neuheun was checked against field conditions to confirm its dominant function. The verification was conducted building by building rather than through sample points. Therefore, this study did not rely on a sampling-based accuracy assessment but on a census-style field verification of identifiable buildings within the administrative boundary of Neuheun.

Building functions were classified based on their dominant visible use at the time of observation. Trade and service buildings included shops, stalls, small commercial premises, and local service facilities serving daily needs. Residential buildings were classified based on their dominant housing function, while public facilities included education, worship, health, and community facilities. This procedure was used to reduce misclassification between purely residential buildings and residential buildings with emerging commercial or service functions.

The identification of ribbon and leapfrog growth was not based only on numerical change but also on spatial configuration. Ribbon growth was interpreted when new or intensified trade-service activities followed the main road corridor in a linear pattern. Leapfrog growth was interpreted when development appeared as separated pockets within or around relocation housing clusters, without continuous expansion from the main road corridor or the older settlement core. This combined numerical and morphological reading was used to avoid overinterpreting building counts without considering spatial form.

Identification of ribbon and leapfrog growth

The identification of ribbon and leapfrog growth was based on spatial distribution and relationship to infrastructure. Ribbon growth was defined as linear development concentrated along the main road corridor. In this study, Jalan Laksamana Malahayati was treated as the primary corridor because it functions as the main access route through Neuheun and connects the area with broader regional movement. Growth along this corridor was observed through the increase and concentration of trade and service buildings.

Leapfrog growth was defined as discontinuous development occurring within or around relocation housing clusters. This pattern was identified when new buildings and economic activities appeared in separate pockets rather than through continuous expansion from the main road or existing built-up area. In Neuheun, this pattern was associated with relocation housing clusters that introduced new settlement nodes into the peri-urban landscape.

The use of these two categories helped clarify that Neuheun's transformation was not a single linear process. Instead, it consisted of two simultaneous spatial processes: road-based commercial growth and cluster-based settlement growth.

Research limitations

This study had four limitations. First, the analysis focused only on Gampong Neuheun and did not compare Neuheun with other relocation areas in Aceh Besar. Second, the temporal comparison used 2011 and 2021 as the main observation years, so the study explains medium-term spatial change rather than continuous annual change. Third, the study relied mainly on comparative spatial analysis, building-count interpretation, and typomorphological reading rather than predictive statistical modelling. Fourth, field verification was conducted only in 2021; consequently, the retrospective 2011 building-function classification is less reliable than the field-verified 2021 inventory. Therefore, the strength of this article lies in explaining spatial patterns and morphological change rather than producing a generalized predictive model.

Despite these limitations, the Neuheun case provides a useful empirical basis for understanding how post-disaster relocation housing can become a contributing factor of peri-urban transformation. The case shows how planned relocation may generate new spatial patterns after the immediate recovery phase, particularly when relocation housing interacts with arterial road access, local economic activity, land availability, and topographic constraints.

Results and Discussion

Neuheun's peri-urban character between rural persistence and urban transition

The spatial transformation of Neuheun between 2011 and 2021 shows that the area did not experience a complete conversion from rural to urban land use. Instead, Neuheun remained a mixed rural-urban area where agricultural land, residential areas, public facilities, and trade-service activities coexist. Based on the land-use comparison, agricultural and livestock land decreased from 1,879,939 m² in 2011 to 1,844,093 m² in 2021, representing a decline of 1.91%. In percentage terms, agricultural land changed from 46.41% to 45.29%. Following the urban and peri-urban classification framework used in Indonesian urban studies, this proportion places Neuheun within the mixed city-village category rather than a fully urban or fully rural category (Yunus, 2005).

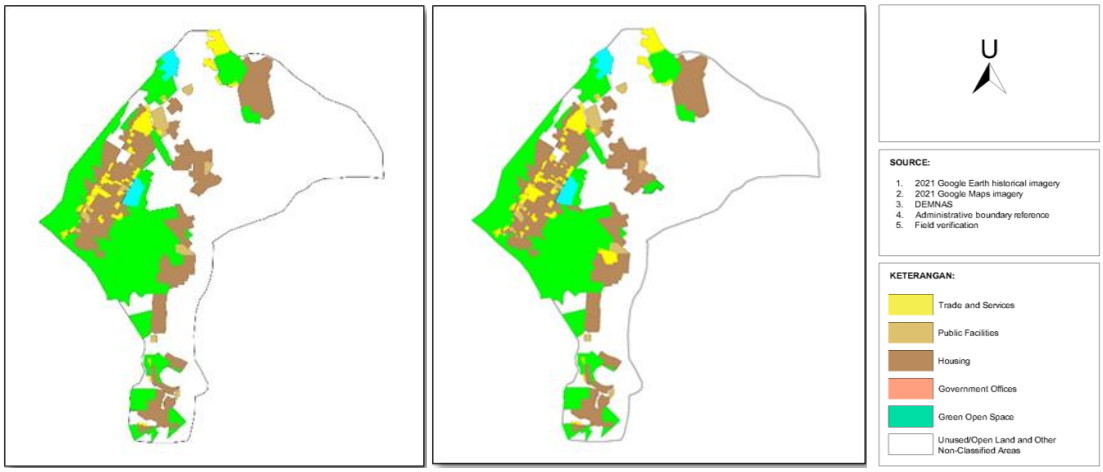

Figure 1. Land-use comparison of Neuheun in 2011 and 2021.
(Source: Author's manual land-use interpretation based on Google Earth historical imagery, Google Maps imagery, administrative boundary reference, and field verification)

This finding is important because the most visible transformation in Neuheun was not the large-scale loss of agricultural land. The decline in agricultural land was relatively modest. However, the internal structure of the area changed through the expansion of trade and service activities, the increase of built-up functions, and the growing role of road-based economic development. This confirms that peri-urban transformation may occur through functional and morphological change even when the overall land-use composition remains mixed.

Table 3. Land-use change in Neuheun, 2011–2021

Land-use category	2011 (m²)	2021 (m²)	Relative change (%)
Trade and services	332,807	381,832	+14.73
Public facilities	167,319	168,946	+0.97
Housing	1,522,638	1,528,342	+0.37
Agriculture and livestock	1,879,939	1,844,093	-1.91
Fisheries	147,710	147,710	0.00
Unused/open land and other non-classified areas	4,448,418	4,427,908	-0.46

Source: Author's analysis
Note: Relative change was calculated within category as [(area in 2021 − area in 2011) / area in 2011] × 100. The category "Unused/open land and other non-classified areas" is presented to maintain consistency with the total mapped area.

The strongest land-use change occurred in trade and services, which increased by 14.73% between 2011 and 2021. This increase indicates that the post-tsunami relocation housing areas did not only absorb population but also generated demand for local services, shops, small-scale commerce, and new economic activities. The growth of trade and services can therefore be interpreted as a spatial response to increased local demand generated by new settlement concentrations created by relocation housing.

Settlement densification and the gradual strengthening of urban functions

Building growth also indicates a gradual intensification of Neuheun's peri-urban character. The total number of observed buildings within the administrative boundary of Neuheun increased from 2,751 units in 2011 to 2,929 units in 2021. These buildings were then interpreted through two main spatial mechanisms: corridor-based growth along Jalan Laksamana Malahayati and cluster-based growth within and around post-tsunami relocation housing areas. As a result, settlement density increased from 3.24 buildings per hectare to 3.45 buildings per hectare. Although this increase was not drastic, it confirms that Neuheun experienced incremental densification during the ten-year observation period.

Table 4. Land-use coverage and building density change

Indicator	2011	2021
Total observed buildings	2,751	2,929
Total observed area	849 ha	849 ha
Building density	3.24 buildings/ha	3.45 buildings/ha
Classified land-use area	47.66%	47.90%

Source: Author's analysis

Note: Classified land-use coverage refers to the combined area of trade and services, public facilities, housing, agriculture and livestock, and fisheries as a proportion of the total mapped administrative area. It was calculated by dividing the combined area of these five categories by the total mapped area and multiplying the result by 100%. Unused/open land and other non-classified areas were excluded.

The proportion of classified land-use increased from 47.66% in 2011 to 47.90% in 2021. This proportion indicates a medium level of classified land-use coverage. In morphological terms, Neuheun remained neither fully rural, nor fully urban. Its spatial image was formed by the interaction between village-like land uses and emerging urban functions. This pattern shows that Neuheun's transformation occurred less through large-scale land conversion than through the strengthening of urban functions within a mixed peri-urban setting.

Ribbon growth along Jalan Laksamana Malahayati

The first major growth pattern identified in Neuheun was ribbon development along Jalan Laksamana Malahayati. This road corridor functioned as the main spatial attractor for trade and service activities. The strategic role of Jalan Laksamana Malahayati also strengthened its function as a corridor of peri-urban transformation. In local spatial planning, this corridor is associated with wider transport and regional service functions, including its connection to the Malahayati Port system and its role as a primary arterial route. These planning and accessibility characteristics help explain why trade and service activities tended to concentrate along the corridor rather than being distributed evenly across Neuheun (Pemerintah Kabupaten Aceh Besar, 2013). The Jalan Laksamana Malahayati corridor formed the original Neuheun settlement axis before the seven relocation housing complexes were developed and continued to function as the village's principal road during the post-occupancy period.

The number of trade and service buildings along the main road increased from 148 units in 2011 to 195 units in 2021. Public service buildings increased from 49 to 61 units, while residential buildings increased from 580 to 622 units. Overall, the total number of buildings along the main road increased from 823 to 949 units.

Table 5. Building change along Jalan Laksamana Malahayati

Building function	2011	2021	Change
Trade and services	148	195	+47
Public facilities	49	61	+12
Housing	580	622	+42
Government offices	46	71	+25
Total	823	949	+126

Source: Author's analysis

Note: Government institutional building counts refer to individual mapped building footprints rather than the number of government agencies or offices.

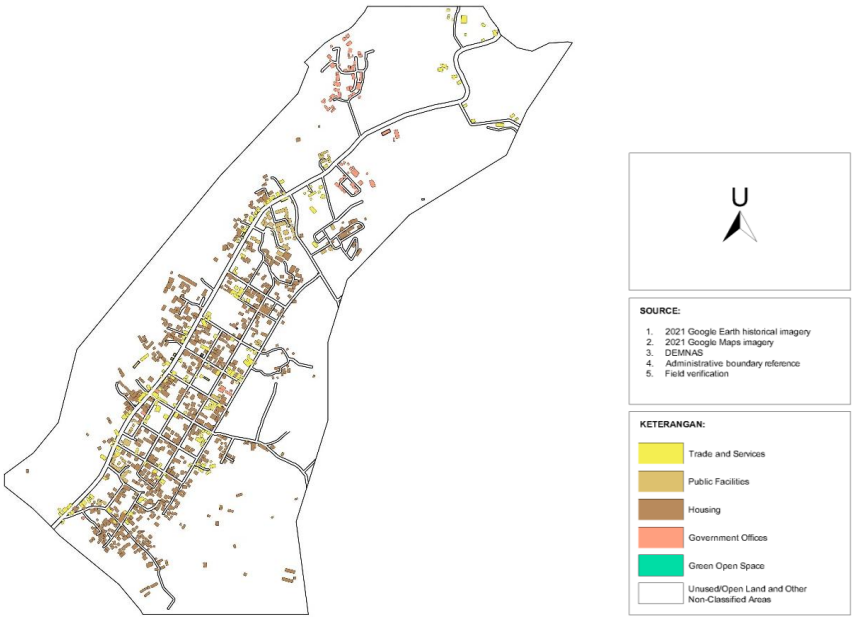

Figure 2. Building functions along Jalan Laksamana Malahayati as evidence of ribbon growth. (Source: Author's manual building-function classification based on Google Earth historical imagery, Google Maps imagery, and building-by-building field verification)

The mapped increase in government-related buildings along the corridor, from 46 units in 2011 to 71 units in 2021, was primarily concentrated within the BPBAP Location 2 compound. The additional 25 units represent separate building footprints within a single government institutional complex rather than 25 newly established government offices. This concentrated institutional development is spatially distinct from the more dispersed additions of residential and trade-service buildings along Jalan Laksamana Malahayati.

The linear distribution of additional trade and service buildings along the corridor reflects a typical ribbon development process. Trade and service activities concentrated along Jalan Laksamana Malahayati because the corridor offered accessibility, visibility, and economic opportunity. As relocation housing increased local demand for shops, food stalls, services, and daily facilities, many activities emerged along the more accessible road corridor rather than only

inside the housing clusters. This confirms that accessibility remained a dominant factor in shaping peri-urban growth.

Leapfrog growth within and around relocation housing clusters

The second growth pattern was leapfrog growth within and around the relocation housing clusters. Unlike ribbon growth, which followed the main road corridor, leapfrog growth appeared as discontinuous development in separate settlement pockets. These pockets were associated with post-tsunami relocation housing complexes that introduced new population concentrations into the peri-urban landscape.

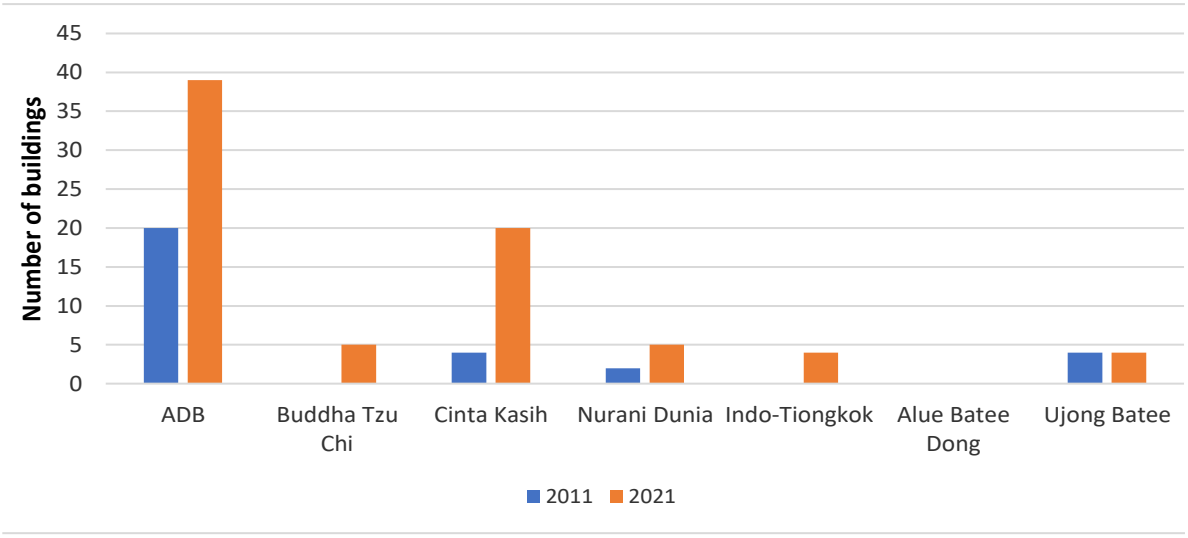

Figure 3. Distribution of additional trade and service buildings within and around relocation housing clusters.
(Source: Author's analysis based on manual building counts and building-by-building field verification in relocation housing clusters)

The number of trade and service buildings in the relocation housing clusters increased from 30 units in 2011 to 77 units in 2021. Public facilities increased from 32 to 37 units. The number of residential buildings remained stable at 1,866 units, indicating that the primary transformation within these clusters was not the addition of new houses but the conversion, adaptation, or addition of supporting economic and service functions.

Table 6. Building change in relocation housing clusters

Building function	2011	2021	Change
Trade and services	30	77	+47
Public facilities	32	37	+5
Housing	1,866	1,866	0
Government offices	0	0	0
Total	1,928	1,980	+52

Source: Author's analysis

This finding is significant because the increase in trade and service buildings in relocation housing clusters was numerically equal to the increase along the main road corridor: both increased by 47 units. However, the spatial meaning was different. Along the main road, trade-service growth formed a linear ribbon pattern. In the relocation clusters, growth appeared as separate nodes within planned housing areas. This is why the transformation of Neuheun cannot be explained by ribbon development alone.

The leapfrog pattern shows that relocation housing was associated with increased local demand. Once the housing clusters were occupied, they generated local demand and encouraged small-scale economic activities. These activities did not necessarily connect continuously with the existing built-up corridor. Instead, they emerged around specific relocation clusters, producing scattered growth pockets within the wider peri-urban area.

Uneven development among relocation housing clusters

Although trade and service activities increased across the relocation housing areas, the growth was uneven. The strongest increases occurred in Perumahan ADB and Perumahan Cinta Kasih. In Perumahan ADB, trade and service buildings increased from 20 to 39 units. In Perumahan Cinta Kasih, they increased from 4 to 20 units. Other relocation areas showed weaker growth: Nurani Dunia increased from 2 to 5 units, Indo-Tiongkok from 0 to 4 units, Buddha Tzu Chi from 0 to 5 units, while Alue Batee Dong and Ujong Batee showed no meaningful change in trade-service buildings.

Table 7. Distribution of trade and service buildings in relocation clusters

Relocation housing cluster	2011	2021	Change
ADB	20	39	+19
Buddha Tzu Chi	0	5	+5
Cinta Kasih	4	20	+16
Nurani Dunia	2	5	+3
Indo-Tiongkok	0	4	+4
Alue Batee Dong	0	0	0
Ujong Batee	4	4	0
Total	30	77	47

Source: Author's analysis

This uneven growth demonstrates that relocation housing did not automatically produce economic transformation. Its development effect depended on access, road quality, topography, proximity to Beuramoe New Town facilities, and connection to existing urban functions. The Beuramoe New Town relocation area included supporting facilities such as local economic facilities, water-supply infrastructure, roads and bridges, mosque facilities, playgrounds, shelters, and auxiliary health posts. These facilities helped create a basic service structure, but their benefits were uneven because physical access and terrain differed across clusters (BRR Aceh-Nias, 2009).

ADB and Cinta Kasih grew more strongly because they had better road access, flatter land, and closer links to built facilities. In contrast, Indo-Tiongkok, Alue Batee Dong, and Ujong Batee were located on hilly terrain, while Nurani Dunia and Buddha Tzu Chi were affected by poorer or damaged access-road conditions observed during fieldwork. Field observation also indicated

that the northern and eastern parts of Neuheun were more strongly influenced by hilly terrain, while the southern and western parts were relatively flatter. These site-specific conditions show that post-occupancy transformation was shaped by physical access, topography, and infrastructure quality.

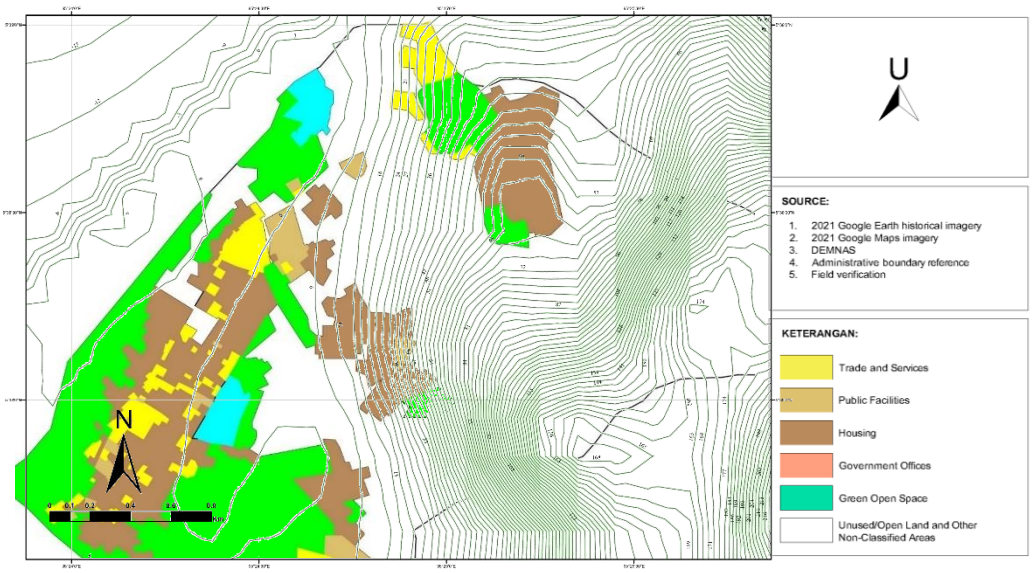

Figure 4. Land-use and contour conditions influencing uneven growth among relocation housing clusters.
(Source: Author's analysis based on Google Earth historical imagery, Google Maps imagery, elevation data, land-use interpretation, and field verification)

This finding supports the argument that post-disaster relocation outcomes are spatially differentiated. Relocation housing can contribute to peri-urban development, but its capacity to generate economic and morphological change depends on accessibility, terrain, infrastructure quality, and connection to wider urban systems.

Ribbon and leapfrog growth as a dual morphology of post-disaster peri-urbanization

The most important finding of this study is the coexistence of ribbon and leapfrog growth in Neuheun. The spatial analysis indicates that ribbon growth occurred along Jalan Laksamana Malahayati, while leapfrog growth occurred in the relocation housing areas. The growth of trade and service buildings in both locations confirms that post-tsunami relocation housing reshaped Neuheun through more than one spatial mechanism.

Table 8. Summary of trade and service growth by spatial pattern

Spatial pattern	Location	2011	2021	Change
Ribbon growth	Main road corridor	148	195	+47
Leapfrog growth	Relocation housing clusters	30	77	+47

Source: Author's analysis

The equal increase of trade and service buildings in both the road corridor and relocation housing clusters shows that Neuheun's transformation was not dominated by a single growth pattern. Instead, it developed through two parallel spatial logics: accessibility-driven growth along the main corridor and settlement-node-driven growth around planned relocation housing.

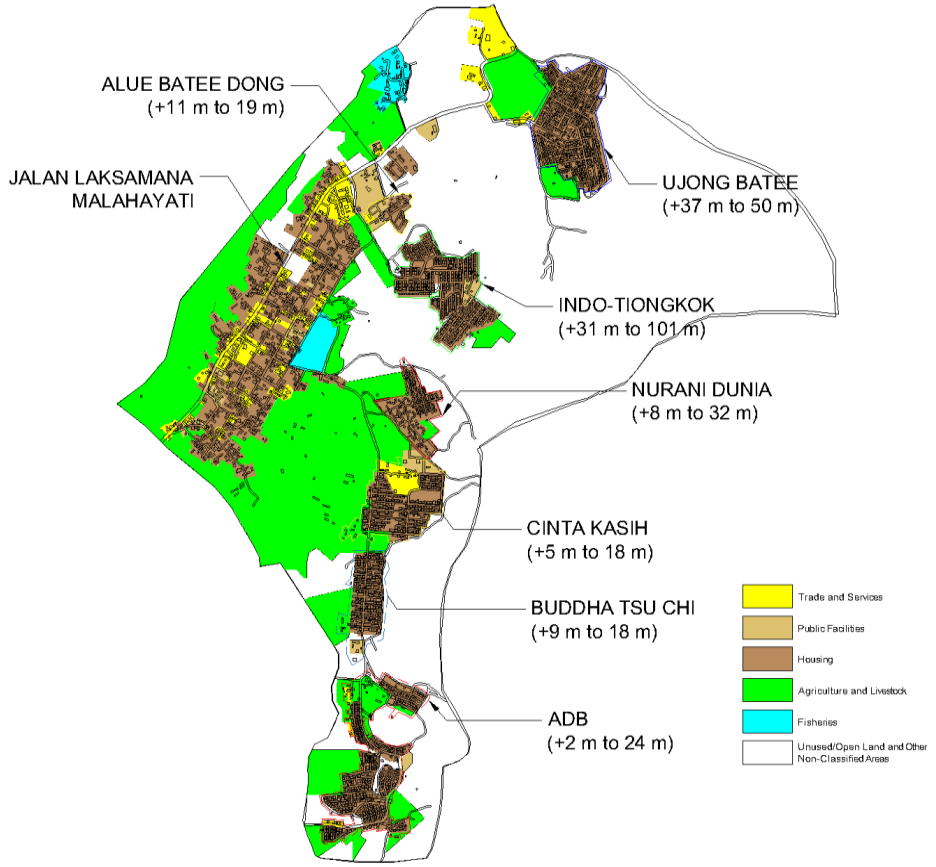

Figure 5. Spatial distribution of corridor-based ribbon growth and cluster-based leapfrog growth in Neuheun.
(Source: Author's typomorphological interpretation based on Google Earth historical imagery, Google Maps imagery, building-function classification, and field verification)

This dual morphology contributes to the literature on post-disaster relocation and peri-urban transformation. Post-disaster relocation is often discussed in terms of safety, shelter provision, livelihood recovery, or social adaptation. However, the Neuheun case shows that relocation housing can also reshape peri-urban morphology. It can generate new nodes of economic activity while simultaneously reinforcing existing transport corridors. In other words, relocation housing acts as both a population redistribution mechanism and a spatial growth factor.

Relocation housing beyond recovery

The Neuheun case shows that post-disaster relocation housing should not be evaluated only as a recovery output measured by the number of houses delivered or the reduction of exposure to coastal hazards. After occupation, relocation housing became embedded in a wider peri-urban system and was associated with long-term spatial consequences. It introduced new population

concentrations, generated local demand for trade and service activities, and influenced the distribution of buildings, circulation, and economic functions.

This interpretation is supported by local statistical indicators showing the growth of small-scale registered commercial activities in Neuheun. The number of food stalls increased from 4 units in 2009 to 30 units in 2014 and 31 units in 2019. Meanwhile, grocery shops increased from 8 units in 2009 to 30 units in 2014 and remained at 30 units in 2019. The recorded presence of a shop group also changed from none in 2009 to one in 2014 and 2019 (BPS Kabupaten Aceh Besar, 2011; BPS Kabupaten Aceh Besar, 2015; BPS Kabupaten Aceh Besar, 2020). These figures support the spatial finding that post-relocation settlement growth was accompanied by the strengthening of daily trade and service functions.

The coexistence of ribbon and leapfrog growth is the main morphological contribution of this study. Ribbon growth along Jalan Laksamana Malahayati demonstrates the role of accessibility, visibility, and road frontage in attracting trade and service activities. In contrast, leapfrog growth around relocation housing clusters demonstrates how planned housing nodes can stimulate discontinuous development pockets within the peri-urban landscape. These two patterns show that post-disaster relocation does not produce a single spatial trajectory. Instead, it can reinforce existing transport corridors while simultaneously contributing to new growth nodes away from the main corridor.

This finding also complicates the assumption that relocation to safer land automatically produces sustainable settlement outcomes. In Neuheun, relocation reduced direct exposure to coastal tsunami risk, but it also generated new planning challenges, including uneven economic development, dependence on road access, damaged local infrastructure, topographic constraints, and fragmented settlement growth. Some clusters, such as ADB and Cinta Kasih, developed stronger trade-service functions because they had better access, flatter terrain, and closer links to existing facilities. Other clusters developed more slowly due to hilly terrain, damaged access roads, and weaker connectivity.

Therefore, the long-term success of post-disaster relocation depends not only on physical safety but also on the integration of relocation sites with land-use planning, infrastructure investment, local economic development, and peri-urban governance. Without such integration, relocation housing may solve one form of risk while producing new spatial inequalities and fragmented growth patterns in the urban fringe.

Conclusion

This study examined how post-tsunami relocation housing contributed to peri-urban spatial transformation in Neuheun, Aceh, Indonesia, between 2011 and 2021. The findings show that Neuheun did not experience a complete conversion from rural to urban land use. Agricultural land remained substantial, decreasing only slightly from 46.41% in 2011 to 45.29% in 2021. However, stronger transformation occurred through the expansion of trade and service activities, settlement densification, and the strengthening of road-based development.

The main contribution of this study is the identification of two simultaneous spatial growth patterns. Ribbon growth developed along Jalan Laksamana Malahayati, where trade and service buildings increased from 148 to 195 units. Leapfrog growth appeared within and around relocation housing clusters, where trade and service buildings increased from 30 to 77 units. These two patterns demonstrate that post-tsunami relocation housing not only functioned as a

recovery instrument but also became a spatial instrument that reshaped peri-urban morphology, stimulated local economic activity, and was associated with new settlement nodes. The pre-existing Neuheun settlement experienced stronger overall building expansion and corridor-associated ribbon development. In contrast, the relocation clusters experienced limited physical expansion but substantial post-occupancy commercial intensification.

The transformation was uneven across relocation housing clusters. ADB and Cinta Kasih experienced stronger trade-service growth due to better access, flatter land, and closer links to existing facilities. Other clusters developed more slowly because of topographic constraints, damaged roads, and weaker connectivity. This finding shows that the spatial effects of relocation housing depend on its interaction with infrastructure, terrain, accessibility, and surrounding urban systems.

Overall, the Neuheun case contributes to post-disaster planning and peri-urban studies by showing that relocation housing should be evaluated beyond shelter provision and hazard reduction. Long-term evaluation needs to consider land use, infrastructure, accessibility, economic activity, settlement density, and spatial morphology. Planned relocation can reduce exposure to disaster risk, but it can also generate new peri-urban dynamics that require careful governance.

The findings have several planning implications. Post-disaster relocation areas should be monitored as long-term spatial systems rather than be treated as completed housing projects. Monitoring should include land-use change, building growth, infrastructure quality, road access, public facilities, and local economic activities. In Neuheun, ribbon development along Jalan Laksamana Malahayati requires corridor-based spatial management, particularly related to access control, pedestrian space, parking, drainage, frontage regulation, and mixed-use development.

Leapfrog growth around relocation housing clusters should also be integrated into the wider settlement system. Improved road connectivity, public transport access, drainage, open space, and access to education, health, worshipping, and economic facilities are needed, especially for clusters located on hilly terrain or with damaged access roads. Relocation housing policy should therefore combine hazard reduction with livelihood support, local economic planning, and infrastructure investment.

Future research should update the spatial analysis beyond 2021 and compare Neuheun with other post-tsunami relocation areas in Aceh Besar to determine whether the ribbon and leapfrog patterns are unique or part of a broader regional phenomenon. Household surveys, interviews, spatial metrics, network analysis, or remote sensing classification may also strengthen future evaluation of the effects of relocation housing on peri-urban transformation.

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