Reconditioning the resilience of Palu City within the natural disaster stories

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Abstract. In September 2018, the city of Palu was devastated by three natural disasters: an earthquake, a tsunami, and liquefaction. The disaster impacted most of the city, including the destruction of the city's coastal areas by the tsunami, and some places experienced 'moving land' or liquefaction. Both disasters were triggered by an earthquake with a magnitude of ±7M, which caused numerous buildings to collapse and thousands of casualties. Nevertheless, this series of tragedies force the city to adapt and rebuild a new life. Using the qualitative approach, this research seeks to understand how Palu's city life changes in terms of resilience, supported by the exploration of the city’s historical, natural, and urban morphology. This research was also done based on author's own first-hand experience of natural disasters in Palu. The finding revealed that the city of Palu has a long history of natural disasters, yet the people still desire to continue living in Palu. The government created new urban spaces and embraced adaptive design by enacting the ratification of new regulations regarding urban development planning that place greater attention on disaster issues. Finally, natural disasters let people and cities learn more about how to safely cope with living in natural disaster-prone cities.

Keywords: Natural Disaster, Palu City, Resilience, Urban Morphology

1. Introduction
Several cities, especially in Indonesia, are located in coastal areas; hence they are vulnerable to natural disasters [1]. Generally, cities that suffer from disasters will collapse and develop slowly. However, when a city faces a crisis, it must swiftly adapt and recover to continue to exist [2]. Natural disasters will force cities to be more cautious and resilient [3]. The development of equitable resilience in urban settings will improve the city's capacity to live in communities alongside the environment [4].

A city's resilience requires a detailed analysis so that adjustments to disaster recovery can align with the city's needs [5]. One of them is the morphological analysis to understand how cities form resilience. Urban morphology investigates cities based on their forms and the shape of blocks, streets, and buildings [3] that are responsible for their transformation process following their formal/non-formal activities (in terms of social, economic, political, and culture). It is critical to understand the city's identity and how it transformed before deciding on the future city development [6].

Palu is an Indonesian city that has been hit by 3 (three) natural disasters, resulting in the city's spatial pattern being altered and changed in people's lives. Several previous studies discussed the chronology of these catastrophic events, including the role of Palu's location within the coastal area [7]. Existing studies also discussed the three simultaneous disasters [8], the community reaction during the emergency response phase [9][10], tsunami mitigation analysis, impact survey, and background analysis.
of events a few days after the natural disaster [11]. The previous studies offer a more in-depth study of urban changes caused by disasters.

2. Research Method
This study aims to qualitatively evaluate the city of Palu in terms of coping with disasters and how the city attempts to better handle natural disasters and continue to exist the post-disaster. The study is based on the author's direct experience of natural disasters in Palu who also a resident born in Palu. The additional observations, maps, and interviews with the residents strengthened the author's first-hand description. The study also includes a review of the literature from numerous studies that explain the prior disasters in Palu.

3. Finding and Discussion
No one can oppose or avoid the occurrence of natural disasters. They have altered many aspects of city life, including ways of life, interpersonal relationships, and increased awareness of the causes and effects of disasters to move forward and build resilience [2]. Cities with a history of catastrophic situations will be more likely to experience similar disasters in the future, so cities must be prepared to ensure the sustainability of city lives. Understanding how cities build resilience also requires an examination of urban morphology.

3.1. Definition of Resilience
Natural disasters impact human welfare and health [5]. Cities that have experienced natural disasters will be more vulnerable and have more potential to experience them again in the future [4]. After the disaster, the city's priority is to recover in order to adapt to the new "normal" by developing resilience based on the capacity of the city's needs [2]. Resilience is a concept formed from the terms "fear" and "hope," or to be specific, "resilience is destroyed by fear" and "resilience is built on hope" [12]. Although the term has no universal definition, resilience is commonly associated with a city's ability to bounce back, adapt to, overcome, resist, and heal from disaster [4]. Activities related to resilience include social, political, governmental, and economic aspects in preparing the city to rise back after a disaster [12].

![Figure 1](image)

Figure 1. Principal of creating resilience [4][9].

Disasters provide insight into how resilience is built for future life (Figure 1). According to the UNDRR (United Nations of Disaster Risk Reduction), the disaster response in developing resilience is a step toward the goal of a good civilization. Disaster risk governance, at its core; is all about prevention, response, and recovery since the disaster risk reduction strategy between cities and communities is the repeating cycle of 1) disaster, 2) response, and 3) recovery [2]. After the city has developed resilience, the city’s ability to recover from natural disasters can reduce the burden [13]. The city can also strengthen people’s or communities’ ability to learn about habits, skills, values, or preferences before and after a disaster [4].
3.2. Principal of urban morphology
The city is a human-inhabited area. Many scientists and experts agree that "the city can be read" [3]. Structural and non-structural aspects of a city are measured through its economy, social, health, and culture, which both are crucial in forming resilience for a person, community, and environment [2]. It is also very important to know about how a city grows after a disaster because they help us understand how to build resilience.

Until now, Kevin Lynch famous book the Image of The City (1960) has inspired planners around the world to propose legibility to build more meaningful environments in contemporary society. Legibility is an understanding of the city gained through experience or what is seen in order to build a more intense depiction of the potential, structure, and meaning of the city. Understanding the city is not only through the shape of a city but also through community activities and the areas where people gather for activities. Nature, history, and design are three aspects of morphology that show the physical and non-physical forms of the city [14]. People who move through the city need to be able to recognize and organize urban elements into a coherent pattern. Understanding the city through urban morphology produces information about the community's requirements to adapt when disaster occurs in the city. It leads to restructuring the city to develop resilience and new social networks and finally produce a new economic activity based on its ability to bounce back [13].

3.3. The natural disaster stories in Palu City
3.3.1. The City of Palu and Its Disaster History

Figure 2. Palu City regional context.

Palu, one of Indonesia's coastal cities, is the capital of Central Sulawesi and has a population of 372,113 people living in an area of 395.06 square kilometers. Palu is one of Indonesia's coastal cities and is the capital of Central Sulawesi. This city is surrounded by five different landforms: mountains, valleys, rivers, bays, and oceans; it is also spanned by 0° latitude, which is also known as the equator [15]. Palu's geographic location and topography result in a high air temperature and a diverse variety of natural potentials that are extremely helpful to both the people who live there and the city as a whole [1]. As a result, the morphology of Palu City has changed dramatically from one year to the next. In addition, the distribution of structures in Palu began to shift from west to east as a result of the restrictions placed on hills that ran along the coastal area, which became the city's trade and service center as well as leisure places, and the city's population began to grow. Another problem is that a river separates two parts of the city of Palu. This meant that a bridge had to be built to connect the western and eastern parts of the city and encourage inter-provincial activity on the island of Sulawesi (Figure 3).
Prof. Katili, an Indonesian geologist, prophesied a natural calamity in 2018. He claimed in 1970 that Palu would never be the provincial capital due to the region's potential vulnerability to disasters. It is caused by the "Palu-Koro" fault, which is the active plate of Sulawesi or Celebes into Palu [16] [17]. The origin of the name Palu is derived from the word "Topalu'e" in the language of ethnic Kaili, which means "elevated land." Palu's original tribes lived in mountainous terrain or highlands, as evidenced by local knowledge and collective memory regarding disasters. From 1927 to 2012, 9 (nine) earthquakes caused 4 (four) tsunamis in Palu and its environs, killing 4 people. The worst was in 1938 in Donggala, when a 6 M earthquake triggered a tsunami up to 8–10 meters high, killing hundreds. However, the latest disaster in 2018 escalated the previous ones in the term of the victim.

On September 18, 2018, at 18:02 Palu time, an earthquake of 7 M destroyed large parts of the city. The earthquake triggered a tsunami in the coastline area and liquefaction, causing the city of Palu to suffer 3 (three) natural disasters simultaneously [8][7][11]. The disaster drew not only national but also international attention. The city's devastations were overwhelming. To name a few were the destruction of the city's proud landmarks of the Floating Mosque Arqam Baburahman and the Ponulele Bridge. In addition, the earthquake cut off the connection between Palu's east and west areas, damaged and collapsed buildings and city infrastructure (Figure 4). The disaster was so great that it ended up making the city lose its physical structure.

**Figure 4.** Various news about incidents of tsunami, earthquake, and liquefaction in Palu – Indonesia.
3.3.2. Natural Change Due and After Disasters

Disasters have a huge impact on city life, especially on structural and non-structural patterns. (Figure 5) A disaster disrupts Palu's natural and built environments because of the Palu-Koro Fault. The city was vulnerable. It ruined structures and eroded coastlines. Some areas of the city were also experiencing liquefaction and damaging densely populated areas. In the Kaili language, "nalodo" means liquefied soil that has been sucked up by mud, which means liquefaction. Moving land (at Petobo) and landslides are both liquefaction in Palu (occurred in Perumnas, or the national housing area of Balaroa). Many scientists feel that constant shaking weakens soil and causes it to become liquid. For example, liquefaction-induced soil failure comprises loss of soil carrying capacity, oscillatory movement of the ground surface, lateral spreading as the ground surface's slope steepens, and flow-type soil movement with a moderate to the extremely steep slope (flow slide/failure) [18]. Palu has class 1 and 4 liquefaction.

The earthquake occurred on September 18, 2018 at 15.00 PM. However, it was still under control, and most citizens were unaffected and quickly returned to their activities. However, during aftershocks, the shaking became stronger. At around 18.00 a tsunami unexpectedly struck the coastal area. This time, the disaster killed many people who hung around the area. They attended FPPN (Festival Pesona Palu Nomomi) or the annual festival to mark the city's anniversary. Most were employees of the Palu city government, others were vendors and merchants. They were busy preparing their stalls and were ready to welcome the spectators who would visit and enjoy the venue. Three huge tsunami waves crashed onto the shore. They took many visitors who had fallen into a panicked confusion of earthquake. They struggled to overcome the suction of the waves but failed, and many lives were lost. The tsunami also demolished the Ponulele Bridge, a secondary arterial road, and the city landmark. The waves flattened houses and buildings, and the powerful shocks destroyed the roads.

Because the tsunami generated panic and uncertainty, many tried to flee the damaged city by rushing to the highlands. Unfortunately, most people were not aware of liquefaction. The soil moves and collapses into a thick porridge. Surface-level solid items, including houses and buildings, move and are crushed, drawing into the porridge. As a result, many of them are buried and liquefied. Seismologists liken it to a spring that sways left and right. Figure 6 shows the impact of the devastation on the natural
shape. Coastal erosion has changed the city administration, roads, and faults that damage Palu's ecosystem. The disaster killed 4340 people.

3.3.3. Adaptive Designs for Palu to Bounce Back

Natural catastrophes have a negative and beneficial impact on Palu that create changes in the layout and design of the city. The city and its citizens had lived through disasters. Restructuring the city in the post-disaster should be considered the historical and natural changes that occurred throughout the city formation process. In this way, the city can strike a balance that meets its needs [6]. In urban spatial formation, people are the most important factor [3]. The community must work with local agencies to establish a "new normal" or habit through rapid adaptation [7]. After a natural disaster, urban reconstruction can be drawn from knowledge and responses to change to achieve the city's needs [14]. Recovery from natural disasters needs a new policy, mitigation, and development agents. It is critical to creating new urban adaptations that determine resilience to disaster.

The local government puts some effort into responding the city to bounce back from the loss of the inhabitant’s spirit caused by natural disasters. “Palu Bangkit” and “Palu Mantap Bergerak” are the government’s motto for city recovery. This motto aims to give new power, hope, and resilience to city life and society in order to survive and recover, as well as boost the spirit of civic solidarity to help each other rebuild city life. Those elements are vital for the post-disaster communal spirit [19]. Why does the community want to stay in Palu? The main reasons are their fear of losing their livelihood and their attachment to Palu. The strong determination allowed urban residents to survive even though they knew Palu was a disaster-prone city.

Figure 7 shows Palu’s urban adaptation. The local government rebuilt numerous road infrastructures and urban settlements devastated by the disaster. The initiatives were overseen by the public works department as part of the KOTAKU (Kota Tanpa Kumuh, or city without a slum) program. The government decided to light up the area and beautify Talise beach. It effectively keeps crowds at bay. Small cafes are reclaiming the beach as a pleasant location, but they are still improvised buildings. Despite the hardships and traumatic memories, many choose to remain in Palu. Beach activities such as hanging out (especially for the young), running and swimming are only available from the morning to lunch. In any case, they provide life to the once-dead beach area. Late at night, the majority of public events shift away from the beach and toward the city center or the mountains. Cities can be revitalized by a new urban activity and entertainment sector.

The development of HUNTAP (Hunian Tetap) or permanent dwelling for individuals who have lost their homes reflects the modern design of disaster-resistant architecture. The original phase, which covered up to 70 hectares, created 200 dwellings with earthquake-resistant structures and full infrastructure facilities. To demonstrate fairness and human equality, the distribution of buildings was done based on lot’s ownership. Based on presidential directives set out in the KOTAKU program, the
PUPR (Ministry of Public Works) launched the project. Others are being constructed based on Arkom's "Building Homes Collectively for Better Habitat" project idea. It was accepted by the local government, and the survivors were actively involved in the design and construction of 38 earthquake-resistant homes. The project was a Bronze Award winner for the World Habitat Awards on December 16, 2021.

The government re-issued a new RTRW (Rencana Tata Ruang Wilayah or Urban Regional Planning) based on the improved version of the previous RTRW to avert future disasters (Figure 8). By adding additional sectors, the new RTRW pays greater attention to features of disaster management planning and more attention to disaster issues. This illustrates a more harmonious development between natural and economic components, which reflects Palu's urban design adaptation in the three years following the disaster. For instance, liquefaction-affected areas can be transformed into green open spaces and historical spots where the citizens and visitors will commemorate liquefaction incidents. The spot becomes a commemoration of both tangible and intangible that plays a substantial role in generating the collective and individual memories of a disaster event. The sign was erected at the gate to memorialize tragic events while the original landscape when the disaster occurred had been maintained. By considering how disasters tragically remake place, the commemoration would help to transform the grief of those connected to the tragedy into deeper meaning. In the liquefied-affected areas, housing development is restricted. Because the surrounding area has also become a low-methane zone, the government also imposed very severe control.
Figure 8. Map of RTRW Palu City 2021-2041 a) spatial structure plan, b) spatial plan, c) strategic plan.

4. Conclusion
The study shows an example of the city’s effort to recover, survive and bounce back in the post-disaster and build the urban inhabitants to become resilient to natural disasters. Natural disasters, including earthquakes, tsunamis, and liquefaction, have struck Palu simultaneously, causing many victims and devastating the city. In general, this catastrophic incident shows that, even though the level of destruction and the effect of the disaster was quite significant, the people's desire to continue living in Palu is evident. They still choose to remain in Palu, even though they still bear the strong awareness that the city is vulnerable to natural disasters. To comply with the reformed urban space, the residents are looking forward to the effort of the local government in ratifying the revised RTRW 2021–2041 with the vision of disaster-resilient cities.

On the other hand, since the earthquake altered people's lives in the affected areas and throughout the city, they gained new knowledge about disaster response and resilience, particularly in fault-line areas. Attitudes and adaptations have been formed as a result of experiencing a disaster. As life must go on, the better city of Palu should be developed by preserving the balance of urban development while at the same time ensuring the capacity for the city to be resilient.

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Acknowledgments

The authors wish to express their gratitude to the Palu government for providing data as well as the citizens who shared their disaster stories. This research is funded by the Ministry of Research and Technology/Research Agency and National Innovation or Kementrian Riset dan Teknologi/Badan Riset dan Inovasi Nasional 2022.