Study on Application of Floating Structure Technology in Indonesia

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Abstract: As the climate and global weather conditions change, the human environment also changes. Rising sea levels and higher rainfall are driving people to find safer shelter. The increase in population causes the lack of residential land that can be used as a residence. These problems also occur in Indonesia, the country with the 4th largest population globally and has waters covering 70% of the total area. One potential technology that can be used to reduce the impact of the problems that have been conveyed is the use of floating structures. With a large area of water and the number of residential lands is decreasing, this technology offers alternative solutions to these problems. Floating structures are defined as structures that rely on water's buoyancy force to support the structure's weight. Some floating technologies that can be utilized for development in Indonesia include floating houses, floating breakwaters, floating bridges, floating docks, and other infrastructure facilities. In this research, we will see the advisability of the floating structure technology application in overcoming some of the problems that occur in Indonesia using comparative analysis. Several literature reviews were carried out to study the various applications of floating structures in Indonesia. The study results show that this technology is very likely to be applied and can solve several problems that occur in Indonesia.

1 INTRODUCTION

Infrastructure development in Indonesia continues to grow to be able to encourage high economic growth. The increasing level of international trade and the needs of the maritime industry is promoting sea reclamation. Without proper implementation and planning, reclamation can have a negative impact. Adverse impacts such as the destruction of animals' living places and coastal plants can cause the balance of nature to be disturbed. Besides, the seawater hydrological system on the coast will change from its natural state.

Maritime infrastructure development is mostly done conventionally, using land as a foundation that supports the structure's weight above it. In certain sea areas, the seabed is very deep, so a deep foundation is needed. In this condition, water buoyancy can be utilized to support the weight of the existing structure. Thus, infrastructure development in areas with deep seabed can be more effective.

One potential technology that can be used to reduce the impact of the problems that have been conveyed is the use of floating structures. Floating structures are defined as structures that rely on water's buoyancy force to support the structure's weight. Under broader conditions, structures that rest on the soft seabed and use the buoyancy force to reduce the reaction forces that occur can be categorized as floating structures (Wang and Wang, 2015).

There have been many studies on the use of floating structures in solving problems in the world. Anderson (Anderson, 2014) examined amphibious architecture, Drieman (Drieman, 2011) also researched the use of A Floating Breakwater To Protect a New Artificial Beach In Balchik, Bulgaria. Research on the use of floating buildings has also been carried out by Boyke (Boyke et al., 2019) with a conceptual design of floating houses for disaster response purposes.

With many uses of this floating technology, this research seeks to identify what floating technologies can be used to solve some of the problems that occur in Indonesia. In this study, floating structures are all structures that float on water with specific dimensions that are static and have no movers. Therefore, boats and ships are not included in the definition in this study. This study's potential use of floating buildings is a floating house, road, bridge, breakwaters, jetty, and other possible functions.

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2 FLOATING STRUCTURE

In the development of floating technology, many types of materials have been used for this structure. In offshore buildings, steel structures have been widely used as the primary material for aggressive environments. For smaller-scale applications, such as housing and marinas, concrete floating objects are used more. The floating structure can be made from several types of materials, including:

1. Caisson Concrete
2. Concrete tray
3. Steel structure
4. Concrete - EPS

From these various materials, diverse floating technologies have been developed with several functions: floating houses, floating bridges, floating dock, and other public facilities.

2.1 Floating Structure Materials

2.1.1 Caisson Concrete

The term Caisson is French which means large box, which refers to the Caisson form. The Caisson structure has been widely used in Civil Engineering works as pillars of bridges, docks, and tunnels. This structure can float on water to be carried easily to the installation location by the sea. After arriving at the installation location, this structure will be submerged to build a foundation. At present, the Caisson concrete system is the most widely used structural system as a base for floating buildings.

Closed space that contains the air inside the caisson is the cause of the large caisson buoyancy. Caisson is made of hefty, reinforced concrete, so this type of structure has an extensive draft and is suitable for deep seabed areas.

Advantages:

- has been widely used, so that a lot of experience regarding the design and implementation.
- has excellent stability because of its weight.
- has an internal space that can be utilized
- relatively inexpensive compared to steel
- has good durability, with low maintenance costs.

Disadvantages:

- has a small buoyancy
- has a big draft
- easy to sink if it leaks

2.1.2 Concrete Tray/Open Caisson

A concrete tray or open caisson is a type of caisson that does not have a roof covering or is free. This type has similarities with a boat. This type is widely used for light construction such as houses.

2.1.3 Steel

The steel structure is a structural system that is widely used in offshore buildings and ship buildings. Steel structures can be made in various shapes. The box pontoon is the most common type used for floating installations. The steel structure has a thin wall thickness, so it has a lighter weight and great buoyancy. But with its lightweight, the steel structure is more unstable than concrete. But this can be overcome by using ballast water. The main disadvantage of steel structures is susceptibility to corrosion. Thus, routine maintenance is needed on steel structures, so this type is rarely used for light installations.

Advantages:

- it has been widely used, so that a lot of experience in designing and implementing it.
- has an internal space that can be utilized
- has a low draft
- has a small weight

Disadvantages:

- high maintenance costs
- relatively more expensive when compared to concrete
- easy to sink if it leaks
- can conduct heat and electricity.

2.1.4 Concrete - EPS

EPS (Expanded Poly Styrene) is a floating building first introduced by International Marine Floatation Systems Inc. (IMF) in 1980. This system consists of a core EPS layer covered by a concrete layer as an outer protector. EPS material has a specific gravity of 20 kg / m3, about 50 times lighter than water. With an EPS system, a floating building's weight can be much lighter compared to conventional Caisson systems. This is because the plate's dimensions can be thinner. After all, some EPS supports the inside. Besides, the inner plate is no longer needed because its function has been replaced with lightweight EPS. With the use of EPS, floating objects can have smaller drafts. Also, the risk of drowning due to leakage can be reduced because the concrete's cavities are no longer filled with air but instead contain EPS. The use of EPS certainly adds to the cost, but this can be compensated for by the reduced concrete volume and weight.

Advantages:

- EPS structure cannot sink
- lightweight, large buoyancy
- short draft
- cheap maintenance
- can be formed in various forms

Disadvantages:

- Has no internal space that can be utilized

2.2 Application of Floating Technology in the World

2.2.1 Floating Houses

The concept of floating housing is not a new thing or new technology in human life. Floating housing has become part of human history in the world. For example, countries that know the floating settlement culture are Cambodia, Vietnam, Indonesia, Thailand, China, Peru, and Bolivia. This settlement is used as a home for aquaculture and fisheries.

Figure 1: Floating city at Sedanau Island, Natuna (Masaul, 2013).

Indonesia itself has several floating villages in several provinces. The first floating village is in Torosiaje Village, Popayato District, Gorontalo. Then there is the Ayapo village located on Lake Sentani's shores, Jayapura, and the Bajo Village in Sulawesi. Besides, there are also villages on the Mahakam River banks, Kalimantan, and the City on Sedanau Island, Natuna. The towns are a form of local people's wisdom in adapting to nature where they live.

The more modern floating house was first introduced in the 80s. Then this concept is widely applied in several countries, especially those with large territorial waters. A company called International Marine Flotation Systems Inc. developed a floating house which later became a trend in several countries in Europe. The house was designed using concrete with EPS (Expanded Poly Styrene) as the filling (System, 2013). This system allows the concrete to have a lighter weight to be built in shallow water areas. This development then encouraged several companies to make similar innovations. In the Netherlands, modern floating homes have been developed as alternative housing for residents (Figure 2). These floating houses have good facilities and safety standards, so many people are interested in using them.

Several other studies on floating houses were carried out by Ambrica (Ambica, 2015), who developed house designs in areas with high water level fluctuations. Also, Muksin (Muchsin, Fachruddin Purwono and Amiuza, 2011) researched floating lodging for tourists in Indonesia.

Figure 2: Floating house at the Netherlands (System, 2013).

2.2.2 Floating Bridge

The floating bridge was first made from a series of boats bound by a wooden frame and anchored to the seabed. Floating bridges in the past were usually only used temporarily because they could not last long and were unable to support heavy loads. The first floating bridge recorded in history was built by the Persian King Xerses when he invaded Greece in 480 BC. This bridge was built in the Strait of Dardenelles, Turkey, to cross the war troops. This bridge consists of 300 boats tied and anchored at both ends with large vessels.

Examples of floating bridges in the modern era are the Bergsoysund Bridge with a span of 931 m and the Nordhorland Bridge with 1614 m in Norway. The largest steel frame floating bridge are located in Japan, the Yumemai Bridge (Figure 3). This bridge connects two reclamation islands, where underwater tunnels and conventional bridges are not feasible. There is also a floating concrete bridge in Dubai which was built in 2007. This bridge connects Bur Dubai and Deira.

Figure 3: Yumemai Bridge, Japan (Ltd, 2000).

2.2.3 Floating Piers

The floating pier was first used in World War II. At that time, the construction and repair of conventional ports became impractical because of the war. Therefore, it needs a pier that can be dismantled and moved quickly. Mulberry Harbour is an example of a type of floating pier that Britain developed in World War 2. This bridge consists of 3 parts, namely Breakwater, pier head, and walkway.

A modern floating pier design was built in Alaska and Japan. The first floating pier with a prestressed system was constructed in Valdez, Alaska (Figure 4). This pier opened in 1982 and serves container ships. This pier has many advantages because of its minimal maintenance and its ability to work in the deep sea and follow the tides. In Japan, the floating dock is located at Ujina Pier in Hiroshima, built-in 1993. This pier functions as a ferry pier. Because the location has a very high tidal difference of 4 m, a floating pier is used to overcome this condition.

2.2.4 Floating Breakwater

Figure 4: Floating Container Pier Valdez (Engineering, 2000).

Floating Breakwater is an innovation in coastal engineering. This structure is made of a concrete box with a hollow in the middle. (Biesheuvel, 2013) This concrete box is anchored to the seabed to maintain stability and effectiveness in breaking waves. This Breakwater is made up of several segments which are joined together and can be moved easily (Figure 5).

Figure 5: Ingemar Floating Breakwater (Engineering, 2000).

This type of Breakwater is suitable for deepwater areas because it is not limited to depth and can follow tides. This structure is not large and massive, so the manufacturing cost is relatively cheaper than other types. There are also no environmental problems such as erosion and sedimentation due to their floating shape. The upper part of the floating Breakwater can also be used for various facilities. Every breakwater segment are connected using special connection that allows all the units working together (Koekoek, 2013).

2.2.5 Floating Entertainment Facilities

As a supporting facility for residents, various entertainment facilities are also needed. To overcome the lack of land and provide a new experience, floating entertainment facilities have been developed. Examples are Jumbo Restaurant in Hong Kong and floating restaurants in Yokohama, Japan. A seven-story floating hotel has been built in Singapore to be towed to Australia and established there. The largest floating entertainment stage in the world is made at Singapore Marina Bay (Figure 6). This floating structure is designed as an entertainment stage. The floating island on the Han River, Korea, is an artificial floating island that is environmentally friendly.

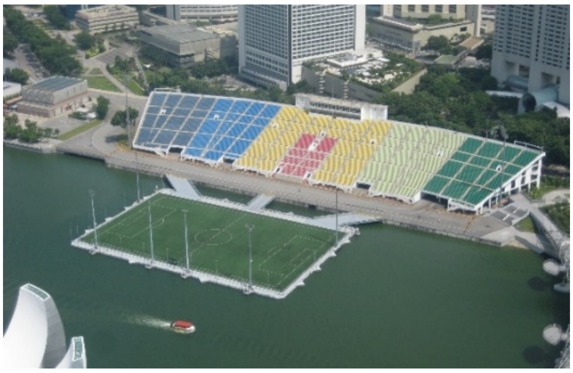

Figure 6: Marina Bay Floating Stage (Wang and Wang, 2015).

2.2.6 Large Floating Storage Facilities

Various structures with storage functions have been built using floating technology. An example is the construction of oil storage facilities in Kamigoto and Shirashima. This storage is intended as oil reserves when an emergency occurs. Shirashima oil storage consists of 8 floating steel structures measuring 397 x 82 x 25.4 m. One system can hold 7 million m3 of oil, equivalent to Japanese oil consumption in 1 day. Also, Japan has also made a floating solar power plant in Kagoshima Prefecture. This structure is the largest solar power plant in Japan.

3 STUDY OF APPLICATIONS IN INDONESIA

In this section, a comparative analysis between conventional technology and floating technology will be performed to overcome some of the problems. Floating technology that will be used includes floating houses, a floating pier, and floating breakwater.

3.1 The Problem of Abrasion on the Nusa Dua Beach

Nusa Dua beach area with a beach length of ± 4 km is located in Nusa Dua, Bali. At present, the condition of the Nusa Dua beach is experiencing severe abrasion. This can be seen from the reduction in trees and the shrinking of beach sand eroded by abrasion. The beach condition, which is eroded by abrasion, damages Nusa Dua's image as an exclusive tourism area with golf course facilities, four and 5-star hotels, and other facilities with international standards.

A breakwater is planned to be built in this area to reduce the wave pressure that causes abrasion. Because the seabed in this area has been designated as a coral reef reserve, the construction of breakwaters must not damage the coral reefs. The alternative comparisons used are floating breakwaters and conventional breakwaters of mountain rocks or tetrapods.

In conducting a comparative analysis, the first step compares several criteria between alternatives 1 and 2, as listed in Table 1.

Table 1: Comparison between alternative breakwaters.

Evaluation Aspect	Alt.1 Conventional	Alt.2 Floating
Effectiveness of wave attenuation	Able to reduce waves> 2m with attenuation up to 100%	Able to reduce waves> 2m with attenuation of 50% - 80% depending on design requirements
Influence/impact on the Marine Environment	It was causing environmental impacts because dredging work is needed in coastal areas and Breakwater's development that can damage coral reefs	It does not cause environmental impacts because there is no need for dredging work, and the construction does not damage the seabed corals
Construction Permitting Process	Requires a special permitting process to carry out dredging and construction that damages coral reefs	Permitting is more comfortable because it does not require dredging and does not damage the coral reefs
The effective protected water area	Smaller, because it cannot be installed in deep waters	More extensive, because it can be installed in deep waters
Estimated Construction Costs	Rp. 68.803.377,-/ m	Rp.105.851.023, / m
Estimated completion time	Eight months	Ten months
Flexibility	Massive and permanent construction (not flexible to relocate)	Flexible and can be moved if needed
Value-added	Do not have the space that can provide added value	It has a void space that can be used as a fuel bunker/water, restaurant, mini hotel

Table 2: Comparison value between alternative breakwaters.

Evaluation Aspect	Alt.1 Conventional	Alt.2 Floating
Effectiveness of wave attenuation	100	80
Influence / impact on the Marine Environment	50	100
Construction Permitting Process	60	90
The effective protected water area	60	100
Estimated Construction Costs	95	100
Estimated completion time	100	85
Flexibility	60	100
Value-added	70	100
TOTAL	595	755

From several comparisons in Table 1, an assessment of each of the two alternative criteria can be made. The evaluation is carried out on a scale of 0-100. The results of the evaluation can be seen in Table 2.

From the results of the comparison in Table 2, it was found that the greatest benefit obtained from Alternative 2 (Floating) with a value of 755 is more significant than Alternative 1 with 595. The results of the comparison are illustrated in Figure 7.

3.2 Pier Elevation Problems in Port of Tanjung Emas Semarang

Semarang is one of the industrial cities in Indonesia, which has a high level of sea traffic. Tanjung Emas Harbor is the main gate of Semarang City from the sea. This Port has a typical land that continues to experience substantial settlement for each year. This is a significant problem for the Port of Tanjung Emas because the pier elevation decreases until it reaches sea level. One solution to the Port's concern is to elevate the pier elevation by adding a new structure above the existing structure. As an alternative solution to these problems, a floating pier can be made in front of the existing pier. The floating pier will always move to follow the water level and is not affected by land subsidence.

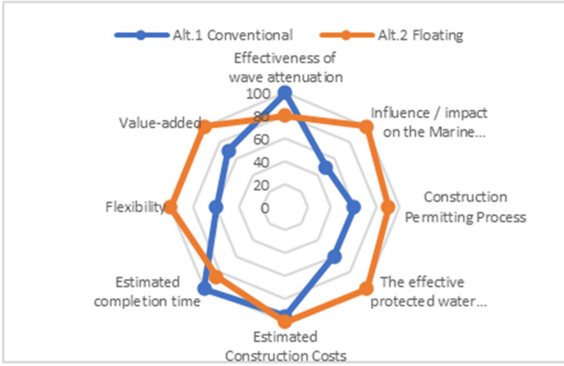

Figure 7: Comparison value between alternative breakwaters.

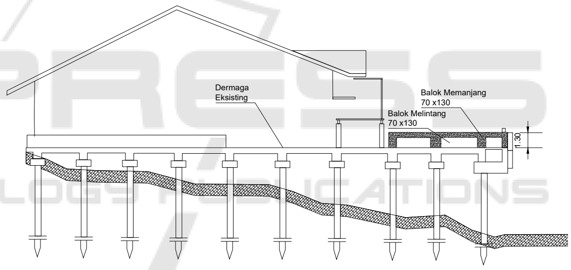

Figure 8: Alternative 1 (new construction above existing pier).

In conducting a comparative analysis, the first step compares several criteria between alternatives 1

Table 3: Comparison between alternative pier.

Evaluation Aspect	Alt.1 Conventional	Alt.2 Floating
Effectiveness in overcoming sea level rise	Ineffective, because it is static, it cannot keep up with rising water levels.	Practical because the height of the floating pier can always change according to sea level.
Influence/impact on Existing Pier	Significant impact, adding additional burden to the existing pier. This can cause a decrease in strength at the existing Port in the long run.	No impact because it was built in front of the existing pier, so it does not directly burden the existing pier structure.
The Pier area can be used	10x 100 m2	2 x 10x 100 m2
Estimated Construction Costs	Rp. 50.000.000, - / m	Rp. 150.000.000, -/ m
Estimated completion time	Nine months	12 months
Flexibility	Massive and permanent construction (not flexible to relocate).	Flexible and can be moved if needed.

and 2, as listed in Table 3. And the second step is to make a scoring of each of the two options. The assessment is carried out on a scale of 0-100. The evaluation result can be seen in Table 4.

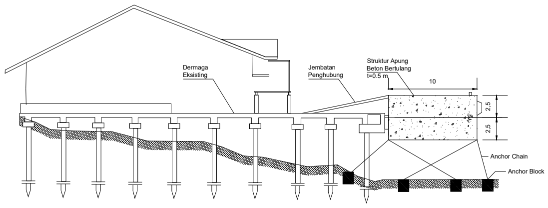

Figure 9: Alternative 2 (new construction of floating structure in front of the existing pier).

Table 4: Comparison value between alternative pier.

Evaluation Aspect	Alt.1 Conventional	Alt.2 Floating
Effectiveness in overcoming sea level rise	60	100
Influence / impact on Existing Pier	70	100
The Pier area can be used	100	100
Estimated construction costs	100	30
Estimated completion time	90	100
Flexibility	60	100
TOTAL	480	530

From the scoring that has been done in Table 4, it can be concluded that Alternative 1 (Conventional) and Alternative 2 (Floating) can both be used at Tanjung Emas Pier. From the assessment results, it was found that the most significant benefit obtained from Alternative 2 (Floating) with a value of 530 is more significant than Alternative 1 with 480. The results of the comparison are illustrated in Figure 10.

3.3 Temporary Shelters for Earthquake Victim

When the earthquake strikes, thousands of residents affected by the earthquake are forced to live in refugee camps with emergency tents as temporary shelters. Due to the immensity of the affected area and the number of damaged roads, the aid that came can be slow and insufficient. If this happens, refugees are forced to live in makeshift tents that they made themselves. Many of these tents are uncomfortable to live in, causing refugees' physical and mental conditions to decline. To help disaster victims with such situations, there must be a temporary shelter that

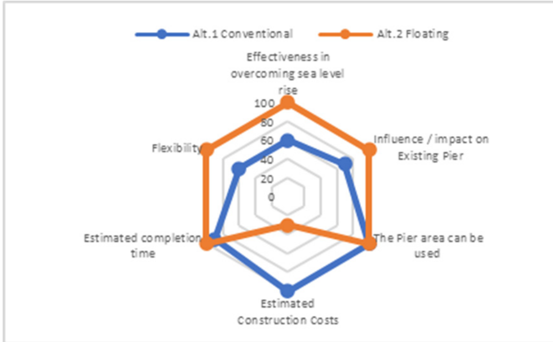

Figure 10: Comparison between alternative piers.

is habitable, safe, comfortable, and delivery is not affected by road damage. The floating house can be used as an alternative solution. A floating home can be placed on the coast, where most of the affected victims live. Floating houses can be deployed by sea; therefore, mobilization is not affected by road damage. With this floating emergency house, refugees are expected to live with better quality housing.

Figure 11: Makeshift tents built by refugees.

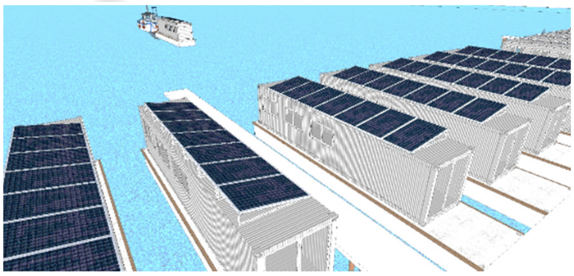

Figure 12: Emergency floating house.

In conducting a comparative analysis, the first step compares several criteria between alternatives 1 and 2, as listed in Table 5. And the second step is to make a scoring of each of the two options. The assessment is carried out on a scale of 0-100. The results of the evaluation can be seen in Table 6.

Table 5: Comparison between alternative temporary shelters.

Evaluation Aspect	Alt.1 Tents	Alt.2 Floating House
Safety and comfort of temporary shelters	Unsafe and uncomfortable for refugees if evacuated for an extended period.	Safer and more comfortable to live in the long term because there are more complete supporting facilities.
Supporting facilities	Has limited supporting facilities.	Have more complete supporting facilities.
Estimated Development Cost per unit	Rp.10.000.000, - per unit.	Rp.100.000.000, - per unit.
Estimated Installation Time	1 hour.	8 hours.
Durability	It has low durability, can be damaged at one-time use only.	Very durable, can be used many times during the building period of 50 years.
Capacity and Flexibility of Use	It can accommodate many refugees and can be demolished/disposed of when not in use.	Accommodate fewer refugees. After not being used, it must be brought back to the place of origin to be stored.
Delivery and installation when land infrastructure is damaged	Difficult to do because construction and delivery are mostly done on land.	Can be sent by sea and installed at sea/beach.

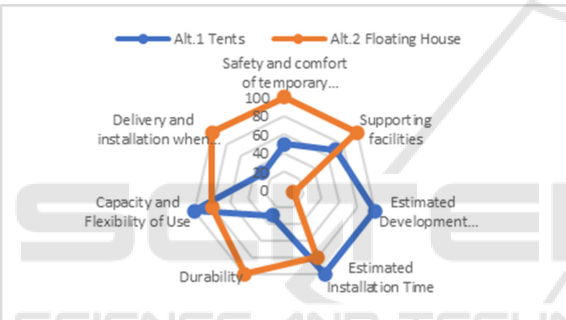

Figure 13: Comparison Between Alternative Temporary Shelters.

From the assessment conducted in Table 5, it can be concluded that Type 1 (Conventional Emergency Tents) and Type 2 (Floating Houses) can both be used as temporary shelters after an earthquake. From the evaluation of several criteria in Table 6, it was found that the most significant benefit was obtained from Type 2 with a value of 570, more significant than Type 1 with 480. The results of the comparison are illustrated in Figure 13.

4 CONCLUSIONS

Some problems in Indonesia require alternative solutions in the form of the application of floating technology. Issues that occur include sea-level rise, land subsidence, increased urbanization to cities, and a large seabed depth. Applications of floating technology that can be implemented in Indonesia include floating breakwaters, floating docks, floating bridges, floating houses, and other infrastructure that may be needed. Examples of applying floating technologies suitable for Indonesia's application are Floating Breakwater, with a sample of Bali's Nusa Dua beach; Floating Pier, for example, Pier at Tanjung Emas Semarang and Floating Houses, with examples of post-earthquake emergency shelters. More detailed research is needed to apply the conceptual design that has been made to be applicable following existing field conditions in Indonesia.

Table 6: Comparison value between alternative temporary shelters.

Evaluation Aspect	Alt.1 Tents	Alt.2 Floating House
Safety and comfort of temporary shelters	50	100
Supporting facilities	70	100
Estimated Development Cost per unit	100	10
Estimated Installation Time	100	80
Durability	30	100
Capacity and Flexibility of Use	100	80
Delivery and installation when land infrastructure is damaged	30	100
TOTAL	480	570

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