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on Transport, Trade Logistics and
Trade Facilitation
8th Session

# Climate Change Adaptation for Seaports in Support of the 2030 Agenda for Sustainable Development

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# Actual Adaptation to Sea Level Rise in Ports: Learning from Land Subsidence in Japan and Indonesia

Presentation by

**Mr. Miguel Esteban**
Professor
Waseda University
Japan


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## Acknowledgements

- The work being presented here is part of a number of different collaborations. In many cases I'm not the leading author of some of the work, so it is important to emphasize I'm presenting this on behalf of various teams (I hope I didn't forget anybody…)


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## Land subsidence: a peak into the future

- **We can look at cases of land subsidence around the planet to understand how adaptation to SLR will actually work**
  - ***Cities (residential and commercial areas inside dykes)***
    - **Case study of Jakarta** **(Takagi et al., 2015, 2016)**
    - **Case study of Tokyo** **(Esteban et al., 2017, Hoshino et al., 2015)**
    - **Phases of adaptation in cities** **(Esteban et al., 2017)**
    - **The cost of adaptation** **(Hoshino et al., 2015)**
  - ***Ports (outside dykes)***
    - **Case Study of Jakarta** **(Esteban et al. 2019)**
    - **Case Study of Tohoku** **(Esteban et al. 2016)**
  - ***Small Islands:***
    - **Case Study in Philippines** **(Jamero et al. 2016, 2017)**

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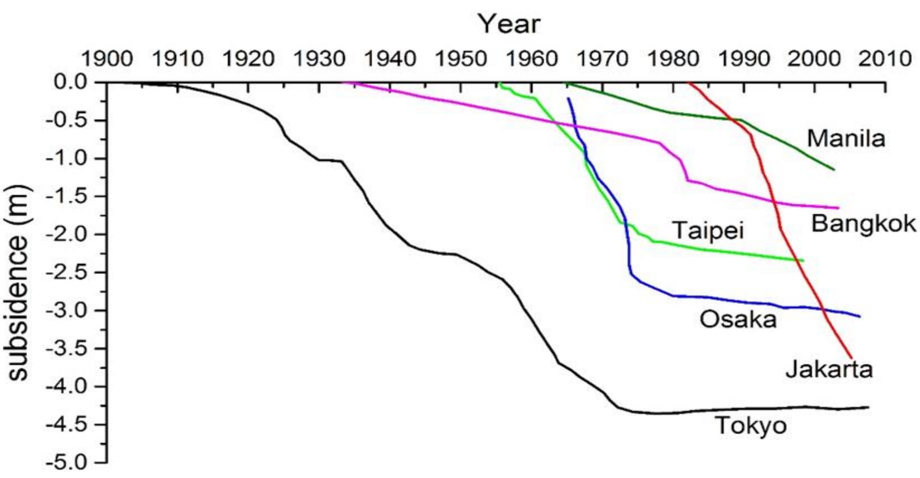
## Using land subsidence as a proxy to study SLR




**No, this is not a mistake, it really is 20cm per year for Jakarta!*

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## Cost to adapt to future SLR and typhoon storm surges in port areas of Tokyo Bay

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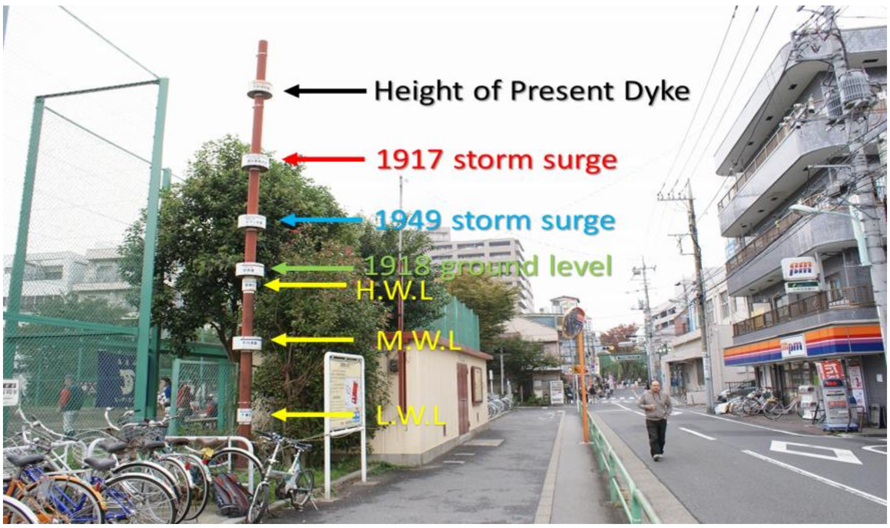
## Land subsidence caused by groundwater extraction in the 20th century

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# Some wards would be completely flooded if dykes were breached

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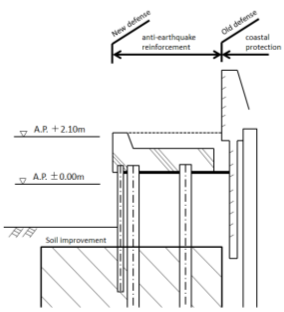
# Calculating the Cost of Adaptation (I): Rising and reinforcement of levees to cope with SLR

Order program of Naka-river protection works (2012)

| | | |
|---|---|---|
| **Levee protection works of Naka-river (at Katsushika)** | **Length** | **159.4 m** |
| | **Total Cost** | **7.06 (100 million yen)** |

includes the indirect cost




| | Tokyo | Kawasaki | Yokohama |
|---|---|---|---|
| Length | 22.0 km | 13.5 km | 21.4 km |
| Cost (Unit: 億円) | 974.3 | 597.9 | 947.8 |

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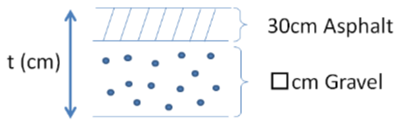
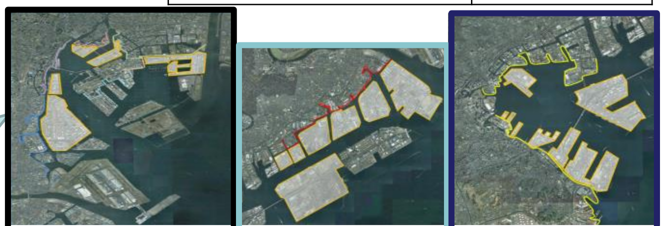
# Calculating the Cost of Adaptation (I): Raising the ground level outside the levees (including ports)




Unit cost Ministry of Land, Infrastructure, Transport and Tourism (2008)

| | |
|---|---|
| **Asphalt (30cm height)** | **5,194 yen/m²** |
| **Gravel (30cm height)** | **296 yen/m²** |

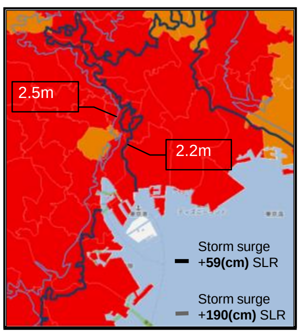
The areas that are selected according to the year of construction (before 1975)

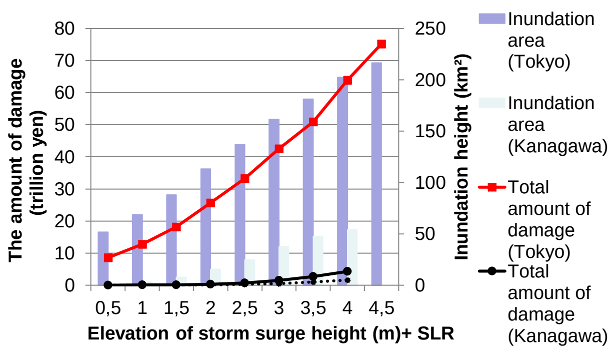


| | Tokyo | Kawasaki | Yokohama |
|---|---|---|---|
| Area | 11.9 km² | 17.6 km² | 8.5 km² |
| Height (T.P.) | 4.5 m | 4.0 m | 3.9 m |
| Cost (Unit: 億円) | 195.11 | 677.37 | 345.24 |



# Risks and costs to port areas of Tokyo Bay




Depending on SLR and storm surge scenarios, potentially between ~15-80 trillion yen of property could be affected in Tokyo and Kanagawa (~3-17% of GDP)

Cost of raising levees and land areas would be over 123 bn for Tokyo and 263 bn for Kanagawa (3.4bn USD, only including cost of materials, **NOT** cost of rebuilding all the buildings) 10

## How small ports are adapting to subsidence

## >5.0m “rise” in Jakarta

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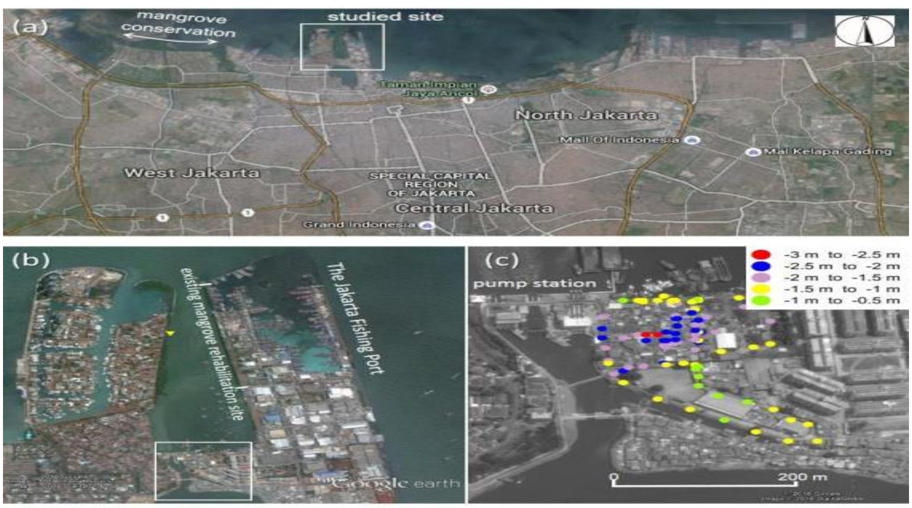
## Study site: Coastal Jakarta




Pluit District in norther Jakarta has been subsiding for a long time now, and is -0.5 to – 3 m below sea level)

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## Sunda Kelapa Port (I)

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## Sunda Kelapa Port (II)

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## Sunda Kelapa Port (III)

-Research Methodology: interviewed port officials

-Oldest port in Jakarta (52 ha of land area)

-~7-10cm subsidence per year

-**20% of their annual income spent on adaptation**

-**Section by section** the port elevates its wharfs (depending on the year)

-Adaptation measures do not consider earthquakes (Jakarta has low tsunami risk)

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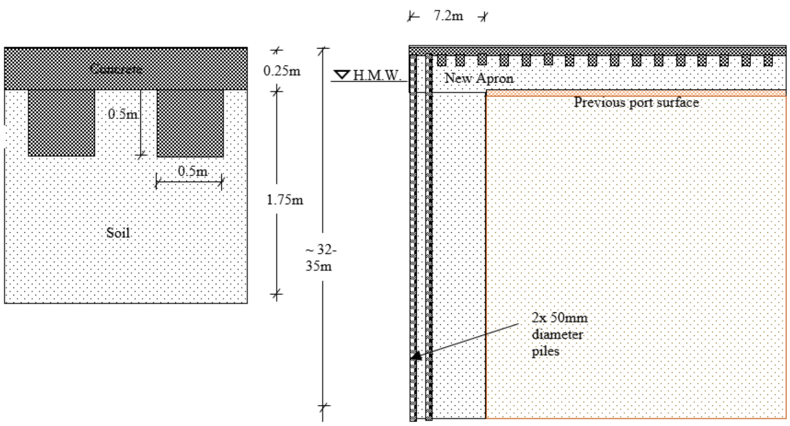
## Adapting to land subsidence (I)




Countermeasures: **piles** 7.2m to the water side, piled soil on top of old surface, placed concrete.

Cost: Ground raising ~100USD/m$^2$   Piling, 4,000 USD/m run

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# Adapting to land subsidence (II)

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# Barriers to Adaptation

-The port believes **there is no limit** to how far up they can go using the technology they are using (Table below is a self-assessment by port officials)

-If their costs increase they will simply increase tariffs. It is a heritage port, and there are plans to consolidate all passenger transit there

-**The government will ultimately have to pay**

-Might be increasingly difficult for water to drain to sea (solved through pumps etc)

| Sea Level Rise | Technological Limits | Cost-Benefit Limits | Financial Barriers | Social Conflict Barriers |
|---|---|---|---|---|
| + **0.5m** | | | | |
| + 0.51 - **1.0m** | | | | |
| + 1.01 - **2.0m** | | | | |
| + 2.01 - **4.0m** | | | | |
| + 4.01 - **8.0m** | | | | |

**Table colour key:**

Green: No barrier

Yellow: Some barriers

Red: Impossible to adapt

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## PPS Nizam Zahman Port (I)



## PPS Nizam Zahman Port (II)

-Founded in 1984, largest fishing port in Indonesia

-52 ha of land area

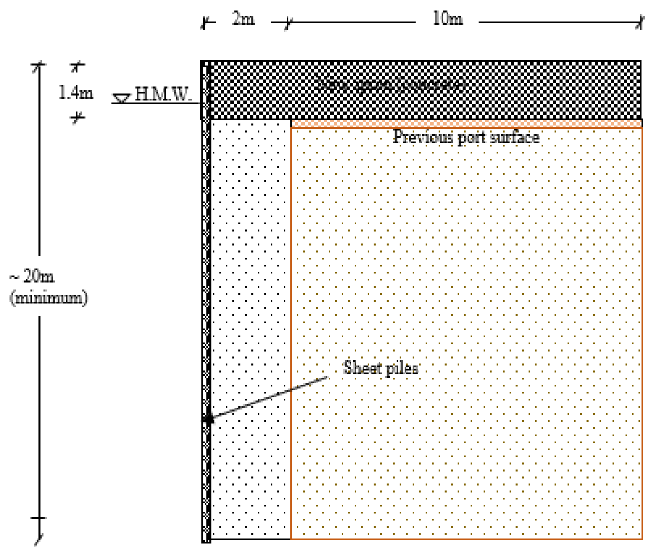
-~7-12cm subsidence per year

-Port was raised in 2002 and then in 2012 (last time by +1.4m)

-**Raising is done sequentially**, first one part of the port, then the others

-Funding for raising was provided by JICA

# Adapting to land subsidence (I)




-Port was raised by using **sheet piles** 2.0m from edge of old port, and then pouring 1.4m of concrete on top of existing port structure

-Thinking of moving to floating port?

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# Barriers to Adaptation

-The port believes **there is no limit** to how far up they can go using the technology they are using

-However, **might be cost-effective to move to a floating port**

-The **government will ultimately have to pay** (giving multiplier effects to economy)

-Nearby communities are happy to know that the ports are being raised.

| Sea Level Rise | Technological Limits | Cost-Benefit Limits | Financial Barriers | Social Conflict Barriers |
|---|---|---|---|---|
| + **0.5m** | | Floating port better? | | |
| + 0.51 - **1.0m** | | | | |
| + 1.01 - **2.0m** | | | | |
| + 2.01 - **4.0m** | | | | |
| + 4.01 - **8.0m** | | | | |

**Table colour key:**

Green: No barrier

Yellow: Some barriers

Red: Impossible to adapt

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## Muara Angke Port (I)

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## Muara Angke Port (II)

-Fishing port

-Founded in 1977

-64 ha of land area

-~7cm subsidence per year (Water Resource Agency of Indonesia)

-**Port was raised three times** (2006, 2011 and 2014, about 40-50cm each time)

-Breakwaters also being submerged by the subsiding land

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# Muara Angke Port (III)

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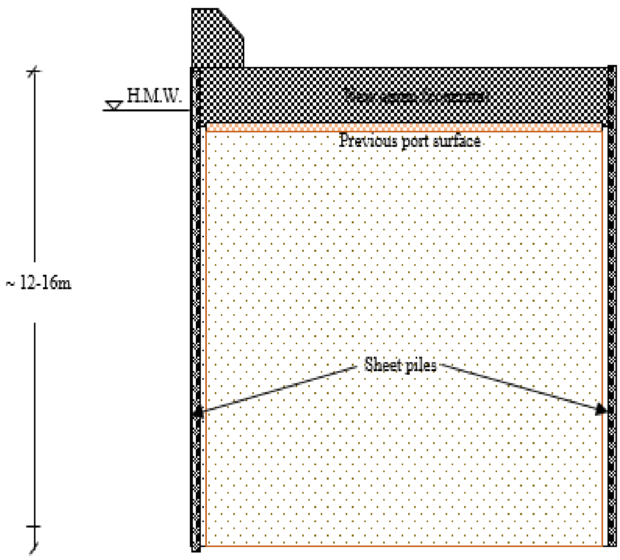
# Muara Angke Port (I)




-Port was raised by using **sheet piles** right at the edge, and then pouring 0.4-0.5m of concrete on top of existing port structure

-Thinking of moving to floating port?

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# Barriers to Adaptation

-They can **only raise port another 2-3 times before they reach limit of sheet piles.** Then they have to move to something else (maybe deeper piles), or maybe **floating ports** (they are already experimenting with this)

-This will affect the cost of raising the ports (cost-benefit issues), but ultimately the government will have to pay.

-They noted how fishermen are not happy for ports to be elevated by too much each time, given that it is difficult to access ships.

| Sea Level Rise | Technological Limits | Cost-Benefit Limits | Financial Barriers | Social Conflict Barriers |
|---|---|---|---|---|
| **+ 0.5m** | | | | |
| + 0.51 - **1.0m** | Sheet piling limit | | | |
| + 1.01 - **2.0m** | Piles? Floating port | | | |
| + 2.01 - **4.0m** | Piles? Floating port | | | |
| + 4.01 - **8.0m** | Piles? Floating port | | | |

**Table colour key:**

Green: No barrier

Yellow: Some barriers

Red: Impossible to adapt

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# Floating ports

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**Tohoku and and port adaptation to land subsidence (0.5 to 1 m subsidence due to 2011 Earthquake)**

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## Effects of land subsidence (I)

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## Effects of land subsidence (II)

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## Adaptation on a pharaonic scale? (Tsunami Layer 2 Measures)

Esteban, M., Onuki, M., Ikeda, I and Akiyama, T. (2015) *"Reconstruction Following the 2011 Tohoku Earthquake Tsunami: Case Study of Otsuchi Town in Iwate Prefecture, Japan"* in Handbook of Coastal Disaster Mitigation for Engineers and Planners. Esteban, M., Takagi, H. and Shibayama, T. (eds.). Butterworth-Heinemann (Elsevier), Oxford, UK

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# Elevating entire towns and constructing huge coastal dykes

Huge investments are being made to elevate the level of towns and villages along **hundreds** of kilometres of coastline

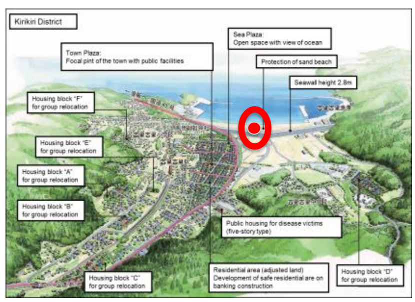
In some cases entire towns are being elevated by up to 15m!

Elevation depends on town and the results of tsunami inundation models

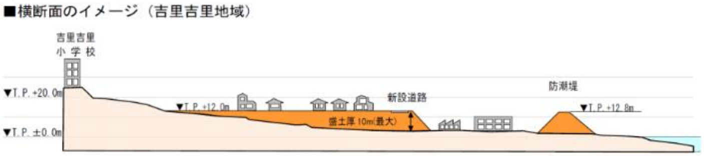
It is thus possible to get around problems of sea level rise by elevating land, provided that you have enough money!



# Kirikiri (Otsuchi Town): Elevated by 10m




■横断面のイメージ（吉里吉里地域）



# Ishinomaki Port

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# Ishinomaki Port (II)

-Industrial port

-Approx. 1.0m land subsidence as consequence of 2011 earthquake

-**Design considerations are dominated by tsunami hazard** in the area

-**Earthquake countermeasures** are very important (and costly).

-4,000 USD to elevate 1m$^2$ of port by one metre

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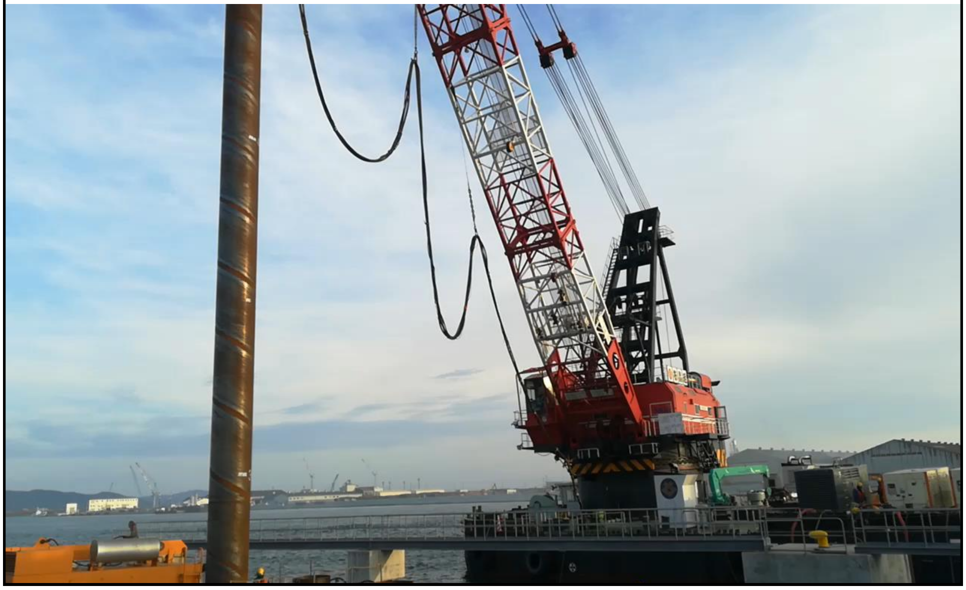
# Ishinomaki Port Raising of Port Levels (II)



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# Barriers to Adaptation

-**No technological limits, though re-design would be necessary to adapt the design** (new piles?) if going above an extra 1m of raise. Raising ground by another half a metre would be maybe x10 more expensive, and a further metre could be x100 more expensive (**earthquake measures**)

-No cost-benefit assessments were conducted, but government would ultimately spend the money. However, over 4m would be make no sense from cost-benefit point of view.

-After 4.0m local residents might be happier to retreat

| Sea Level Rise | Technological Limits | Cost-Benefit Limits | Financial Barriers | Social Conflict Barriers |
|---|---|---|---|---|
| **+ 0.5m** | | | | |
| + 0.51 - **1.0m** | | | | |
| + 1.01 - **2.0m** | | | | |
| + 2.01 - **4.0m** | | | | |
| + 4.01 - **8.0m** | | | | |

**Table colour key:**

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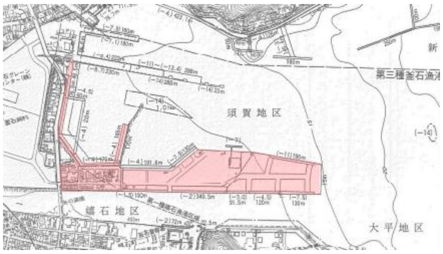
# Kamaishi Port (I)

-Industrial port

-Approx. 1.0m land subsidence as consequence of 2011 earthquake

-Design considerations are dominated by tsunami hazard in the area

-360 USD to elevate $1m^2$ of port by one metre (looks like unit rates only)





# Summary of costs so far for ports?

| Source | Cost/$m^2$ for 1 m raise | Notes |
|---|---|---|
| Kamaishi Port | 360 USD | Does it include piling? |
| Ministry of Land, Infrastructure, Transport and Tourism | 80 USD | Unit rates only. Hoshino et al. (2013) |
| Ishinomaki Port | 4000 USD | Includes piling (for next 1m cost would be x 10!) |
| Sunda Kelapa | 100 USD (+4000 USD/m run) | 4000 USD/m run for piling, 100 USD/$m^2$ for ground elevation |

-Seems there is some disparity in costs

- Developing vs developed country
- Earthquake countermeasures
- Cost of materials to raise, vs inclusion of piling etc

## Conclusions

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## Conclusions (I)

- No significant barriers were identified by port authorities (at least for SLR <1.0m, and even for 2.0m)
- Technologies used to adapt are very simple, expect for ports in earthquake-prone areas
- Adaptation is sequential, with ports gradually adapting whenever they have money

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## Conclusions (I()

- **Ports are NOT going to be abandoned in the future*. No evidence can be found for a retreat strategy, even for subsidence of >5.0 m in a span of decades (much quicker than any scenario in the IPCC).**
- **This is all VERY EXPENSIVE! It will have a disproportionate effect on developing countries**

***At least not from those that are densely populated, marginal areas with little economic value will be abandoned. Note that *natural disasters* (typhoons, etc) are a different story!!**

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## Adaptation in small islands: "Racing the King Tide Documentary"

**The case of small islands in the Philippines that were affected by land subsidence (0.5-1.0m, so houses are now underwater at high tide)**

https://www.youtube.com/watch?v=gwaS9hlNv5M&t=13s&ab_channel=SustainabilityGPSS-GLI

**(please go to minute 3:30)**

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Thanks for listening!

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