# Estimating the Risk of Future Plastic Marine Debris Resulting from the Urban Coastal Built Environment

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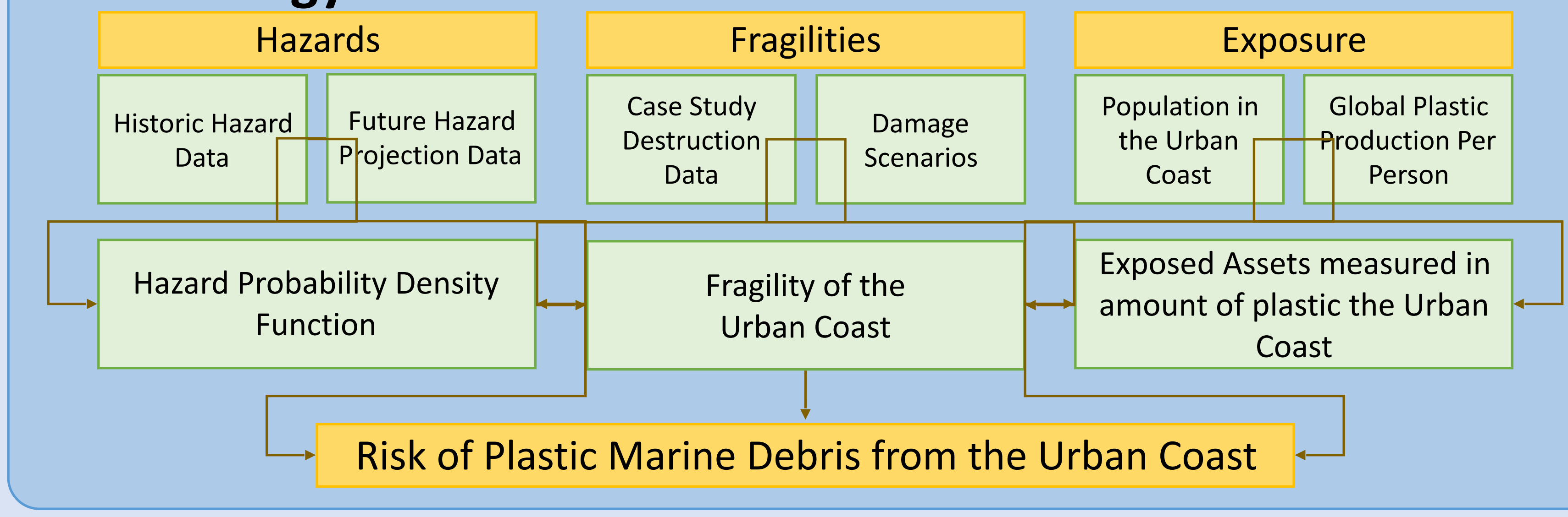
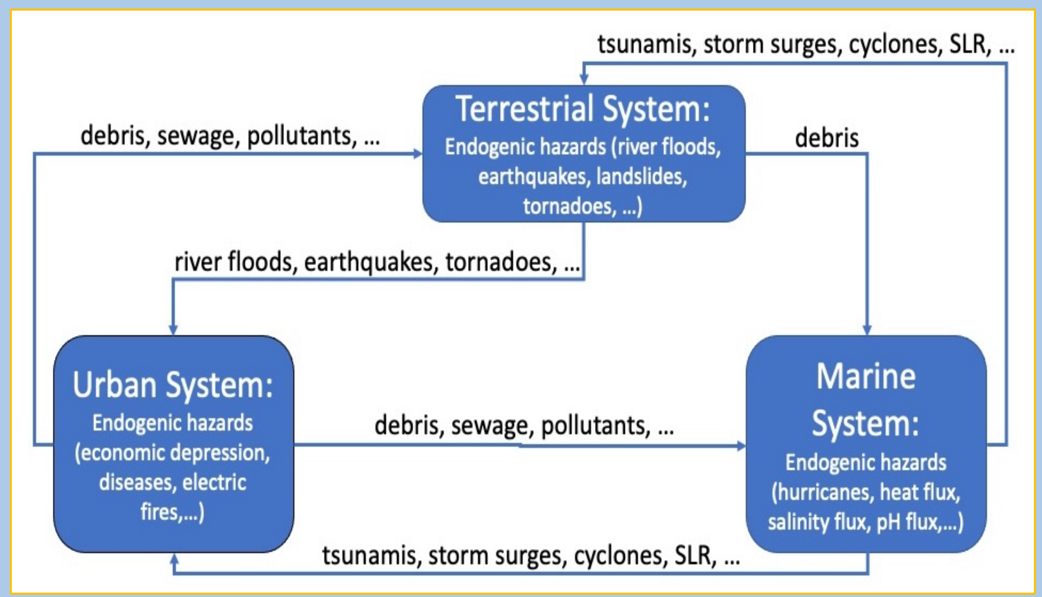
## Introduction

The coastal urban built environment (UBE) is rapidly expanding. Not only is the global population growing, an increasing fraction of this population is migrating into the UBE. For the construction of the UBE, anthropogenic materials including plastics are increasingly replacing the natural materials. Additionally, the coastal UBE is exposed to a changing spectrum of hazards. As a consequence, the coastal UBE poses the risk of future plastic marine debris entering the ocean. Risk is the possibility of consequences where the outcome is uncertain (Pinto & Garvey, 2012), and here the consequence is additional plastic marine debris entering the ocean. To quantify this risk, the product of hazard probability, fragility of the urban coast, and the exposed assets, measured in the amount of plastic, is used.

## Methodology




## Hazard to the Urban Coast




Sea Level: Global Mean Sea Level (GMSL) has risen 17.8 cm - 20.3 cm since the beginning of the 20th century, but more than half of this change has occurred in the past 25 years (Wuebbles et al., 2017).

Flooding: Extreme precipitation is expected to increase in frequency and intensity (Tabari, 2020), with extreme precipitation events increasing and GMSL rising (IPCC, 2007), compound flooding is more likely.

Cyclones: Tropical cyclones are expected to increase in intensity with climate changes (e.g., Holland & Bruyére, 2014).

Tsunami Waves: Climate change does not impact the occurrence of tsunamis, but sea level rise will exacerbate tsunami impacts.

**These hazards may exploit the fragilities of the exposed urban coast.**

## Fragilities of the Urban Coast

Case Study Analysis:

- Fragilities of the Urban Coast in general include:
  - Building and infrastructure destruction,
  - Deterioration from erosion and economic loss preventing upkeep,
  - Changes in building codes, rules and regulations for businesses and health.
- Assessment of fragilities in case studies is used to determine the fragilities of selected urban areas to specific hazards.

Case studies:

- The **2019 cyclone, Hurricane Dorian** impact on the Bahamian Islands is a case where the probability of the hazard as well ass the level of exposure was increasing. This resulted in a catastrophe to the human and nonhuman systems.
- In the case of the **2011 tsunami in Japan** only the exposure was changing, not the probability of the hazard. The population is increasing and so is the UBE, changing the risk through increased exposure to the exogenic hazard.
- The **city of Jakarta** is an example of high-probability hazards (sea level rise due to land subsidence and river floods) presently occurring resulting in a retreat out of the city.

**Fragilities indicate how much of the urban built environment might becomes plastic marine debris**

## Amount of Exposed Assets

The amount of exposed assets is expressed in tons of plastic.

A **Proxy Approach** is used to estimate the amount of plastic $V_A(t)$ in the urban coast.

- The model equations to estimate $V_A(t)$ are:

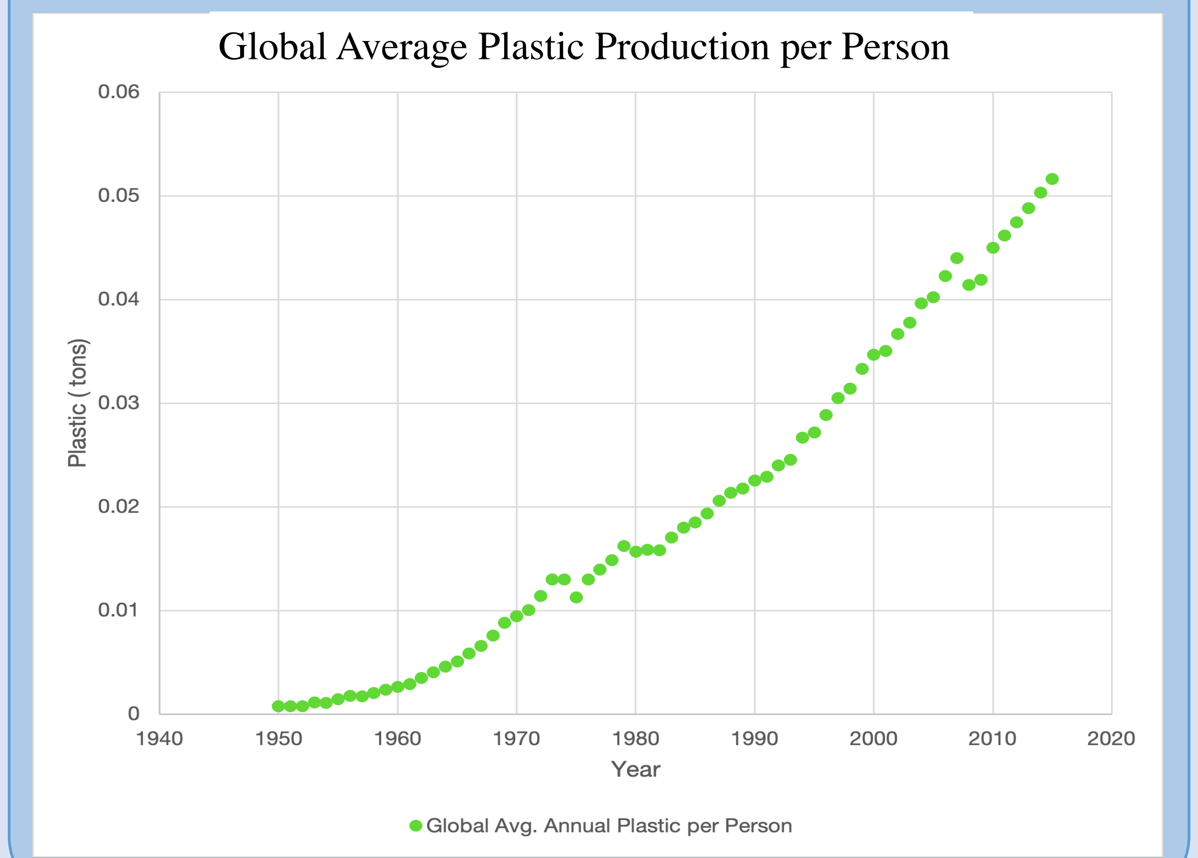
$$V_A(t) = N(t) \times A_N(t)$$

$N(t)$: Number of people in the Urban Coast
$A_N(t)$: Amount of plastic per person

$$A_N(t) = P_a(t)/N_G(t)$$

$P_a(t)$: Global Annual Plastic Production (Geyer et al., 2017)
$N_G(t)$; Global Population (UNPD, 2019)

- Note that the exposure is expressed in tons of plastic in a specific urban coast at time $t$ instead of monetary value.




## Risk

Risk Equation, $R(H) = P(H) \times F_A(H) \times V_A$

$R(H)$: Risk associated with hazard $H$

$P(H)$: Probability of hazard $H$

$F_A(H)$: Fragility of asset $A$ to relative to hazard $H$

$V_A$: Amount of asset $A$ expressed in tons of plastic

The risk assessment:

- The risk of the largest Tsunami in Japan by 2100 is around 730,000 tons of plastic.
- The risk of the large Hurricane in the Bahamas by 2100 ranges between 2,000 and 8,500 tons of plastic.
- The risk of only 20% material left behind in Jakarta is 1,300,000 tons of plastic.

Quantifying the risk of plastic marine debris originating in the urban coastal zone is critical for understanding the risk this hazard poses to the marine biosphere. Ignoring the input of plastics from the coastal zone leads to underestimating the risk to the marine biosphere and human health. The way we build currently in the coastal zone increases the risk of plastic marine debris for current and future generations.

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