Identification of Unique Events Induced by a Combination of Seismic and Tsunami Impacts for Developing a Multi-Hazard Probabilistic Risk Assessment Method

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Abstract: Fukushima-Daiichi Nuclear Power Plant accident in March 2011 revealed the risk of the combinational hazards of earthquake and tsunami at nuclear power plants (NPPs). For evaluation and improvement of the safety of NPPs against seismic and tsunami hazards, probabilistic risk assessment (PRA) methods have been developed for each hazard. Through PRA, we can identify important accident scenarios that need to be mitigated to reduce the risk at NPPs. However, the methods for each hazard focus on the target single-hazard and does not consider the impacts of the combination of earthquake and tsunami. For a precise risk assessment of the combination of the two hazards, a new PRA method needs to be developed that considers not only the impact of each hazard but also the impacts of their combination. For developing the PRA method, this study identifies in general what kind of events can be induced by the combination of seismic and tsunami impacts at a typical NPP site faced on a coast. These events are classified based on their causes and occurring locations. How each event can be considered in PRA is briefly described.

1. INTRODUCTION

If only one of the two hazards, the earthquake and the tsunami, had struck Fukushima-Daiichi Nuclear Power Plant (hereinafter “1F”), the 1F accident could have proceeded differently and reached different consequences. In reality, all the off-site power lines were shut down because of seismic impact, and most of the facilities for on-site power were failed by tsunami damage. The 1F accident revealed the risk of the superposition of earthquake and tsunami at nuclear power plants (hereinafter "NPPs").

For improving the safety of NPPs, probabilistic risk assessment (PRA) has been developed. PRA is an essential tool for assessing the safety of a nuclear power plant for various potential initiating events possibly caused by random component failure, human error, internal hazards, and external hazards. However, few PRA study has focused on the superposition of seismic and tsunami hazards. The method for assessing the risk of the superposition of the two hazards has not yet been established.

The Nuclear Risk Research Center (NRRC), Japan, has started a preliminary study for the PRA for the superposition of seismic and tsunami hazards in 2018, followed by a project funded by Agency for Natural Resources and Energy, Ministry of Economy, Trade, and Industry, Japan, since 2021. In the early stages of the project, scenarios for human behavior and plant conditions, including transient changes in conditions, under seismic and tsunami impacts have been comprehensively organized and analyzed to the extent possible.

This study identifies, in general, what kind of events can be induced by the combination of seismic and tsunami impacts at a typical NPP site faced on a coast. These events are classified based on their characteristics, such as locations of damaged SSCs and types of influencing hazard impacts. Then, we propose how each event can be considered in PRA.

2. CONCEPT OF IDENTIFYING SUPERPOSITION EVENTS

This section explains the concept of identifying superposition events induced by the combination of seismic and tsunami impacts on human behavior and plant conditions.

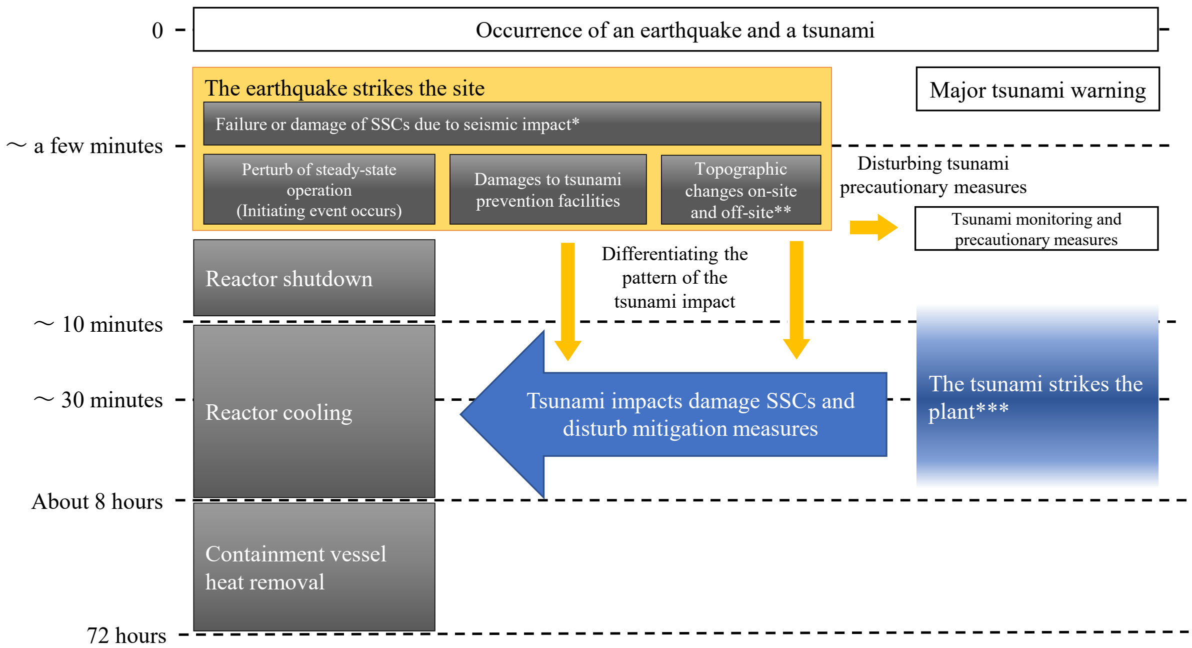
2.1. Preconditions for Identifying Superposition Events

To identify the unique events induced by a combination of seismic and tsunami impacts (hereinafter "superposition events"), which are candidates to be modeled in a PRA process, we first set the following preconditions for clarifying the situation we consider:

(a). The earthquake striking the plant induces the tsunami attacking the plant.
(b). For each hazard, earthquake or tsunami, we consider the most significant impact on the plant. Thus, we do not consider aftershocks or multiple waves of earthquakes and tsunamis.
(c). A tsunami reaches the plant after the earthquake as it induces the tsunami.
(d). We ignore the internal hazards, fire, and flooding, induced by the earthquake for focusing on the combination of earthquake and tsunami.
(e). We do not consider the impact of the deterioration of SSCs on the possibility of core damage.

Note that as we focus on the events induced by the combination of seismic and tsunami impacts, from the classification, we exclude the events that can be induced by a single hazard, earthquake or tsunami, which have been already identified and summarized in [1] and [2].

Based on the above preconditions, Figure 1 summarizes a timeline outlining what happens when an earthquake and subsequent tsunami strike a plant. It shows how each hazard can interact with mitigation and precautionary measures for each hazard and subsequent events. The arrows in the figure represent the possible superposition events, which will be discussed in this section.



* ：This term refers to phenomena that can affect civil structures and SSCs, such as seismic motion, inclination, and collapse of slopes.

** ：This term refers to phenomena that change the inundation pattern of surging waves around and within the site due to topographic changes such as ground subsidence/uplift, the collapse of slopes, etc.

*** ：After the seismic impact strikes the plant, the tsunami arrives at the site with a time lag.

Figure 1: Image of a Timeline of How an Earthquake and a Subsequent Tsunami Strike a Plant

The following is the timeline. An earthquake and a tsunami occur at the epicenter, and the earthquake precedes the plant within a short period of time. The arriving seismic motion causes topographic deformation and functional degradation/damage to the SSCs, resulting in causing initiating events, interfering with mitigation measures, and disturbing precautionary measures for the subsequent tsunami. Based on the observed seismic motions, a warning against tsunami strikes is issued, and operators conduct tsunami monitoring and preventive measures. At this time, the consequences of the earthquake on the plant can interfere with this tsunami monitoring and precautionary measures. When a tsunami strikes during the mitigation measures to a seismic-induced initiating event, it damages previously well-functioning systems, restricts mitigation action, etc. The tsunami striking the plant is affected by the seismic impacts, such as topographical changes and damage to tsunami prevention facilities. As a result, the inflow path, flow volume, and other aspects of the tsunami can change.

2.2 Characteristics of the Superposition Events

2.2.1 Review of Fukushima Daiichi Nuclear Accident

First, we review the 1F accident, the only accident where seismic and tsunami hazards stroke the plants. From the accident, we can know examples of superposition events that occurred at sites and ones that would have happened if the situation had been different. Figure 2 summarizes the chronology of the accident [3].

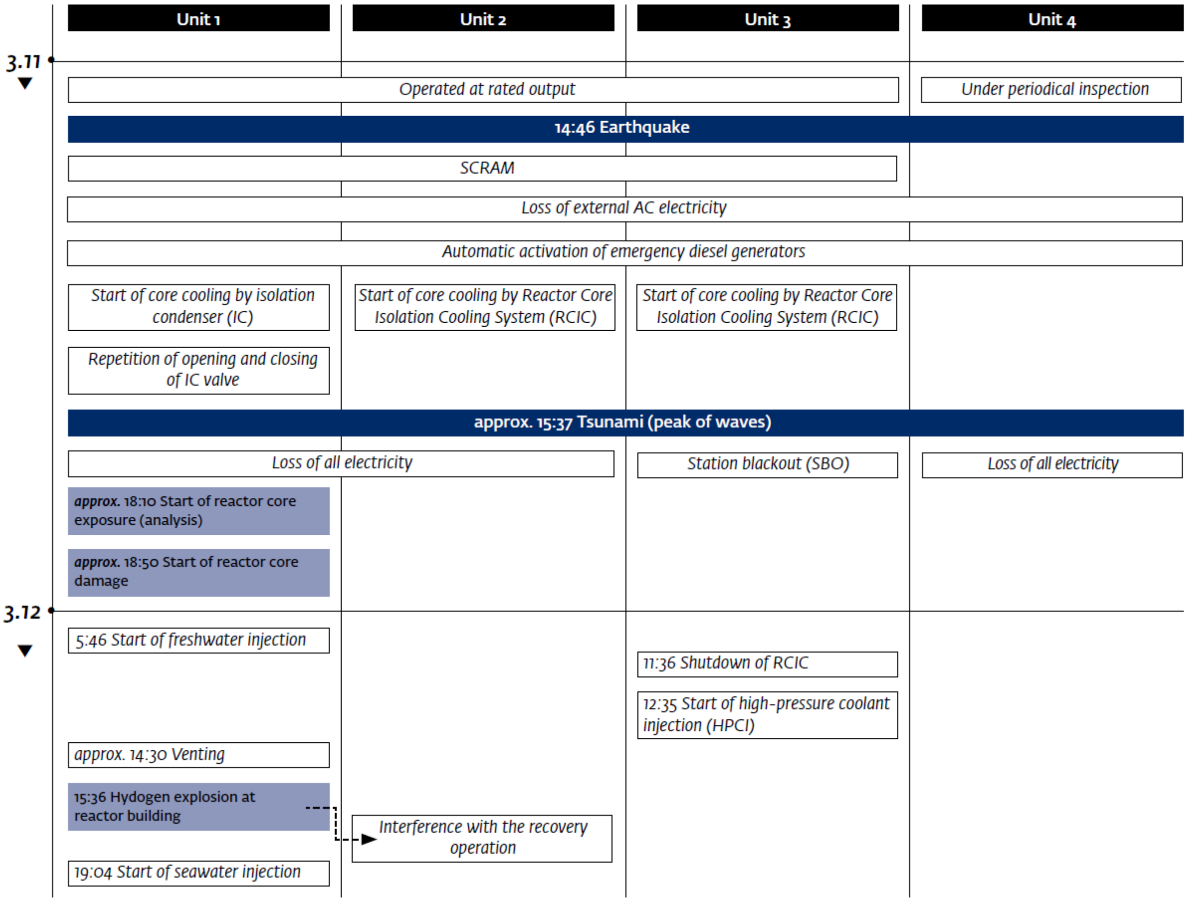


Figure 2: Timeline of Fukushima Daiichi Nuclear Accident (Excerpted from [3])

On March 11, 2011, off the Pacific Coast of Tohoku area, Japan, an earthquake occurred, followed by tsunamis. The reactors at the 1F site successfully shut down all the operating reactors, though the ground motion at several units exceeded the design basis seismic ground motion, widely called "Ss." The loss of off-site power happened, but the emergency diesel generators were initiated and working as planned. About 50 minutes after the earthquake, the highest tsunami wave reached the site and ruined all the AC power, most DC power, and many other support systems. The loss of these support systems finally resulted in the reactor core damage in Units 1, 2, and 3.

During the accidents, several superposition events happened. The examples of the superposition events are as follows:

- The tsunami ruined all the AC power, most DC power, and many other support systems that were to be used for responding to the loss of off-site power induced by the earthquake.
- Two operators perished in the tsunami, checking the status of the plant system after the earthquake.
- A pure water tank buckled because of the ground motion. If a tsunami had been to hit a tank that had lost its strength due to the earthquake, the tank might have lost its function or turned into drifted material.

At the Onagawa site, located about 110 km north of the Fukushima Daiichi site, as a result of the one-meter subsidence of the area, the site's elevation became 13.8 meters from the reference sea level, which was close to the tsunami height, about 13 meters (at the Onagawa site).

2.2.2 Review of Previous Studies

The Atomic Energy Society of Japan, AESJ, points out the categories of the superposition scenarios in its tsunami PRA standard [2]. Though they are trying to comprehensively review the unique scenarios under the superposition of earthquake and tsunami with respect to three categories, the rationale for the categories is not clearly explained, and how each category is related to others and needs to be combined is not clear.

Another research group, Japan Association for Earthquake Engineering, JAEE, working closely together with AESJ, has summarized how the superposition hazards impact plants differently from the single hazards, earthquake and tsunami, in their report for developing tsunami resistant engineering basis [4]. The report identifies the factors that can affect the accident scenarios caused by the combination of earthquakes and tsunamis as follows:

- Correlation of seismic hazard and tsunami hazard
- Correlation of SSCs' fragilities against seismic and tsunami hazards
- Uplift or subsidence of the site and surrounding ground due to ground deformation
- The time lag between the impacts of the main earthquake and tsunami
- Time lag among tsunamis induced by the main earthquake and aftershocks

Note that the first and last points are out of the scope of our classification, as shown in Subsection 2.1.

2.2.3 Categories for Identifying Superposition Events

We propose to classify the superposition "events" first, before considering the "scenario." We organize each superposition event into categories, representing types of superposition impacts on a site. The identified superposition events become elements to build superposition "scenarios."

Here we propose three categories as shown in Table 1. The first category is for the events in which the pattern of tsunami behavior can change as a result of the failure of tsunami prevention facilities due to seismic or superposition impacts of earthquake and tsunami. The events in this category can be further classified based on the subcategories: the combination of the seismic and tsunami impacts and the location where the event occurs.

The second category is the superposition impacts on the failure of SSCs. SSCs that do not fail due to single hazards can fail due to superposed impacts of earthquake and tsunami if these SSCs' capacity against tsunami impacts are reduced by seismic damages. In such cases, new events can occur which have not been considered in single hazard PRAs. The events in this category can be further organized based on the locations of the affected SSCs.

Table 1: Categories of Superposition Events

#	Category	Subcategory
(1)	Superposition impacts on tsunami impacts	• Type of seismic impact • Type of tsunami impact • Location of the SSC
(2)	Superposition impacts on the failure of SSCs	• Location of the SSC
(3)	Superposition impacts on precautionary measures and mitigation measures	• Related characteristics of the superposition impact: "Time lag of the two hazards" or "Simultaneous responses to two hazards' impacts" • "tsunami precautionary measures" or "mitigation measures"

The third category is for the events related to precautionary measures for tsunami or mitigation measures for seismic-induced initiating events. The seismic impacts interfere with the tsunami precautionary measures by damaging the SSCs, access route, and the work site for the measures. On the other hand, the tsunami impacts affect the mitigation measures for the seismic-induced initiating events and their consequences. The characteristics of the events can be considered based on how the two hazard's impacts make the situation: the need for the simultaneous response for each hazard's impact or the time lag between the two hazards affect the plant.

Figure 3 shows the image of how possible scenarios under seismic impacts, tsunami impacts, and their superposition impacts on a plant can be identified by using the event flow diagram. It illustrates how each possible scenario is identified as a combination of superposition events.

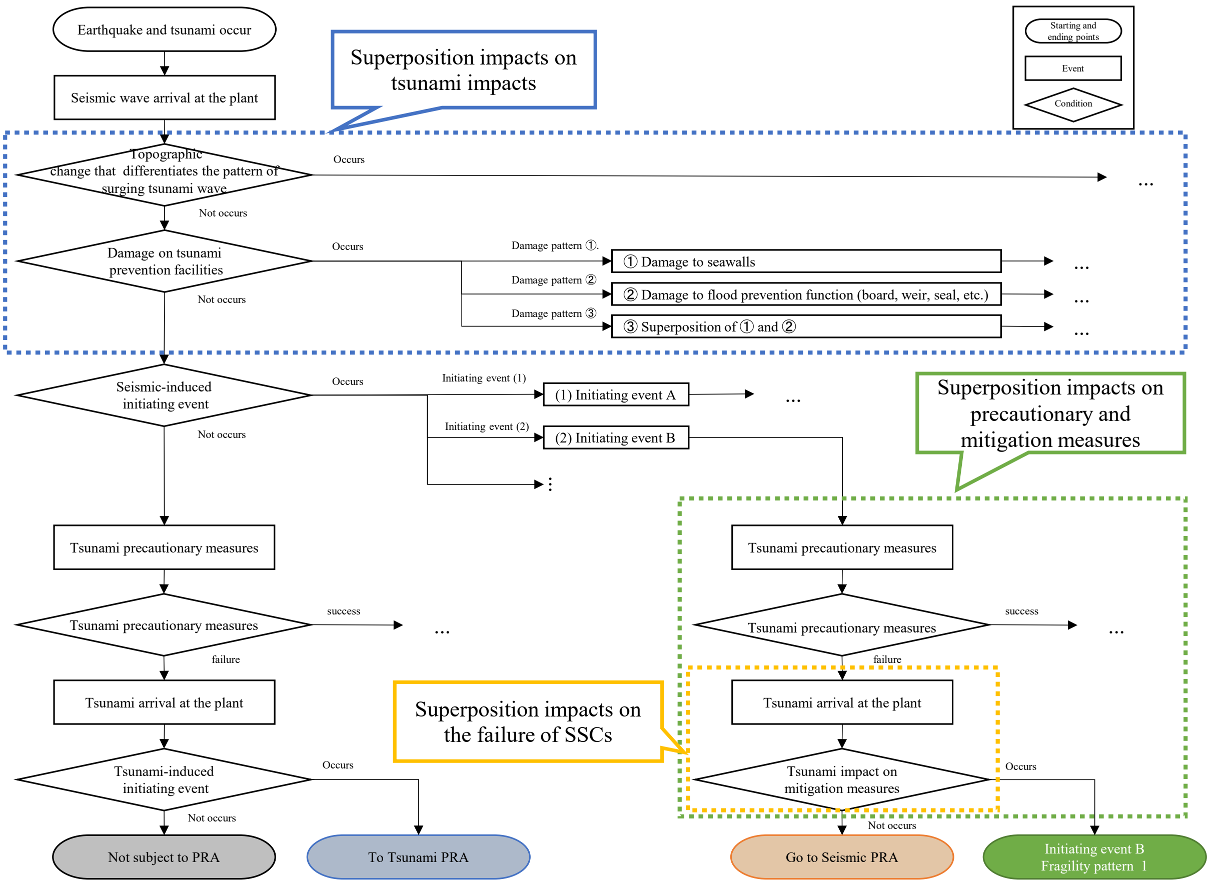


Figure 3: Image of Superposition Scenario Description by an Event Flow Diagram

The events in the three categories can be considered in a branch with the condition that differentiates each sequence. The variations of the scenarios can be further considered based on how much more informative results the differentiation of the patterns of the scenario provides. Note that the end node at the bottom-left represents the case where no plant disturbances that could result in core damage due to earthquakes and/or tsunamis occur and are therefore outside the scope of the PRA.

3. IDENTIFIED SUPERPOSITION EVENTS

Based on the preconditions in Section 2, we have extracted the superposition events caused by the combination of seismic and tsunami impact on the plant [5]. Table 2 shows the overview of the extracted events. Each event will be described in this section according to the categories presented in Table 1.

Table 2: List of Superposition Events (Referred from [5], Modified and Translated by the Authors)

#	Superposition event
1	Change in the route of tsunami arrival at the site due to seismic damage to civil engineering structures around the site
2	Variation in tsunami impact due to ground deformation (uplift/subsidence) over the entire site
3	Damage to tsunami prevention structures due to rock slope collapse caused by seismic motion
4	Variation of site inundation conditions due to seismic or superposed damage to tsunami prevention structures
5	Change in tsunami propagation path due to topographical change in the site (landslide, etc.)
6	Damage to outdoor SSCs by superposition impacts
7	Lowering of water level due to seismically caused sloshing in intake tanks or lowering of water level caused by tsunamis impair water intake
8	Damage to equipment to ensure water intake when the water level drops due to earthquake or superposition impact
9	Drifting of outdoor SSCs damaged by seismic impact (or superposed impact)
10	Damage to SSCs on the building boundary or building itself by superposition impact
11	Variation of inundation into buildings and/or propagation of tsunami between buildings due to seismic or superposed damage to tsunami inundation protection equipment
12	Variation of tsunami inlet due to seismic or superposed damage to the building structural frame
13	Variation of tsunami propagation path due to seismic or superposed damage to overflow propagation prevention equipment inside the building
14	Damage to indoor SSCs by superposition impacts
15	Tsunami inundation into the system and/or containment vessel due to seismic or superposed damage to storage tanks, piping, and containment, or creation of new flooding routes due to flooding through bypass caused by damage to equipment
16	Seismic impact on tsunami precautionary measures
17	Response and/or route changes on post-earthquake evacuation, which may cause new tsunami inlet paths
18	Restoration of work sites, access routes, etc. that are newly created or become more complicated due to the impact of superposed hazards than when they were single hazards
19	Different operation of severe accident mitigation systems from that for a single hazard due to an impact of the superposed hazard
20	Lack of resources (equipment, personnel, time available) when responding to the earthquake impact and tsunami impact on the site simultaneously
21	Interruption of accident response and/or damage to mitigation functions in operation due to tsunami during the response to an accident caused by an earthquake (earthquake and tsunami arrival time lag)

3.1. Superposition Impacts on Tsunami Impacts

This category includes events that can change the pattern of tsunami impacts as a result of the failure of tsunami prevention facilities due to seismic impact or superposition impact of earthquake and tsunami. Note that the failure due to superposition impact occurs when the capacity against tsunami impact is reduced by seismic impact. The seismic impact is the influencing impact that damages the SSCs, and the tsunami impact is the influenced one. The events can be classified based on the combinations of the types of seismic and tsunami impacts, as shown in Table 3.

The pattern of the surging waves can change due to seismic and superposed damage to tsunami prevention facilities. The different inundation patterns can change the affecting SSCs and their tsunami fragility. Table 4 describes what kind of tsunami facilities can change the route of the tsunami by the locations of each tsunami prevention facility.

Table 3: Combinations of the Seismic and Tsunami Impacts and Descriptions of How the Seismic Impacts influence the Tsunami Impacts

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Type of seismic impact
(Influencing impact)</td></tr>
<tr><td>Seismic motion</td><td>Others (Landslide/Rock slope collapse/Ground deformation)</td></tr>
<tr><td rowspan="3">Type of tsunami impact
(Influenced impact)</td><td>Surging wave (inundation, immersion, wave power)</td><td colspan="2">• Changes in the route of tsunami due to damage to tsunami prevention structures (Details are shown in Table 4)
➢ Patterns of tsunami inlet to the site
➢ Patterns of tsunami behavior on the site
➢ Inundation behavior in buildings.</td></tr>
<tr><td>Collision of drifting particles</td><td colspan="2">• New drifting particles due to superposition impact on the failure of SSCs (outdoor SSCs)</td></tr>
<tr><td>Pulling wave</td><td>• Lowering of water level due to seismically caused sloshing in intake tanks
• Damage to equipment to ensure water intake when the water level drops</td><td>• Reduction of water intake function due to buried water intake facilities
• Reduction of water intake function due to ground deformation</td></tr>
</table>

Table 4: Variation of Tsunami Prevention SSCs That can Change Surging Wave (Inundation, Immersion, Wave Power) Patterns

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Types of seismic impact
(Influencing impact)</td></tr>
<tr><td>Seismic motion</td><td>Others (Landslide/Rock slope collapse/Ground deformation)</td></tr>
<tr><td rowspan="5">Location of the SSC</td><td>Off-site/entire site</td><td>• Damage to civil engineering structures around the site</td><td>• Damage to civil engineering structures around the site
• River blockage</td></tr>
<tr><td>Site boundary*</td><td>• Damage to tsunami prevention structures</td><td>• Damage to tsunami prevention structures</td></tr>
<tr><td>On-site (outside buildings)</td><td>• Damage to tsunami prevention structures</td><td>• Topographical change in the site</td></tr>
<tr><td>Building boundary /building itself</td><td>• Damage to the building structure
• Damage to tsunami inundation protection equipment between buildings</td><td>• Damage to the building structure</td></tr>
<tr><td>Inside building</td><td>• Damage to overflow propagation prevention equipment
• Damage to the structural frame inside the building</td><td>—</td></tr>
</table>

* The division between inside and outside of the site here is defined as whether the area is protected from tsunami inundation or not. In other words, all the facilities outside seawall are considered to be outside of the site.

For the collision of drifting particles, the fragility of each SSC can also change as new drifting particles can be created due to seismic or superposed impacts. For pulling waves, the amount of water stored in the intake facility can be reduced by seismic or superposed impacts. Table 5 describes the superposition events belonging to this category.

Each pattern of the influenced tsunami impacts needs to be simulated for the fragility analysis as an input for obtaining the fragility curve for each SSC. When the number of superposition events is too large to deal with, we may need to reduce and group the scenarios by setting criteria or assumptions.

Table 5: Descriptions of the Events Classified as "Superposition Impacts on Tsunami Impacts"

#	Location of the SSC	Types of tsunami impact	Types of seismic impact	Descriptions
1	Off-site /entire site	Surging wave	Seismic motion/ Landslide/ Rock slope collapse/ Ground deformation	The tsunami strikes the site with a different inundation path and behavior from that of the tsunami alone due to the damage to seismic or the superposition of earthquake and tsunami impacts to civil structures outside the site, such as breakwaters and levees of surrounding rivers. Blockage of rivers due to landslides or falling rocks may become the causes of the events.
2			Ground deformation	The change in the site elevation due to seismic-induced ground uplift/subsidence causes different tsunami overflow behavior into the site than if there were no change in the site elevation, which in turn affects the inundation behavior.
3	Site boundary	Surging wave	Landslide/ Rock slope collapse	The seismic motion causes the rock slope to collapse, and the rock mass impacts the tsunami prevention facility, resulting in inadequate protection against the tsunami that strikes after the earthquake and inundation behavior that is not expected from the tsunami alone.
4			Seismic motion/ Ground deformation	Tsunami prevention facilities are damaged or lose their function due to seismic impacts (or superposed impacts), and site flooding, such as the amount of water flowing into the site and the maximum depth of flooding, behaves differently from when the tsunami alone strikes. The drainage system is damaged or loses its function due to seismic impacts (or superposed impacts), and the drainage rate and maximum depth of flooding behave differently from when the tsunami alone strikes
5	On-site (outside buildings)	Surging wave	Landslide/ Rock slope collapse/ Ground deformation	Topographic changes on the site result in different site inundation behavior than if no topographic changes occurred.
7		Pulling wave	Seismic motion	Water intake is disrupted due to the superposition of the water level drop caused by sloshing due to seismic motion and the tsunami pulling wave.
8			Seismic motion/ Landslide/ Rock slope collapse/ Ground deformation	Structures designed to ensure the intake of seawater system when the water level drops due to tsunami, such as storage weirs, are damaged by the earthquake or superposed action, resulting in loss of intake function.
9		Collision of drifting particles		Equipment whose supports are not damaged by the tsunami alone loses its support function due to seismic impacts (or superposed impacts) and becomes drifting particles when the tsunami inundates the site, damaging the SSCs on the site.

#	Location of the SSC	Types of tsunami impact	Types of seismic impact	Descriptions
11	Building boundary /building itself	Surging wave/ Collision of drifting particles	Seismic motion/ Landslide /Rock slope collapse	Tsunami prevention equipment loses its water sealing function due to seismic impacts (or superposed impacts), causing water to enter the building by a different inflow route than when the tsunami strikes. The tsunami prevention equipment includes watertight doors (hinges and seals), seals at pipe penetrations in the building wall, and waterproof sheets on the sides of the building wall.
12				Damage to the structural frames of the reactor buildings and other structures caused by seismic or superposition impacts results in tsunami inundation of the buildings.
13	Inside building	Surging wave	Seismic motion	The flooding prevention equipment in the building is damaged or loses its function due to seismic motion (or superposed impacts), resulting in tsunami inundation behavior in the building that is different from that of the tsunami alone.
15				SSCs that are not expected to be damaged by the tsunami alone are damaged by seismic (or superposed) action, and seawater floods into the system, causing not only damage to the SSCs but also secondary damage to other equipment in the system. Damage to the containment vessel is caused by seismic impacts (or superposed impacts), resulting in a penetration opening and tsunami inundation. Piping is damaged by seismic action (or superposed impact), becoming a bypass and creating a flooding path that differs from that of the tsunami alone.

3.2. Superposition Impacts on the Failure of SSCs

If SSCs that do not fail because of single hazards can fail because of superposed impact as their SSCs' capacity against tsunami impacts are reduced by seismic damages, new events can occur that have not been considered in single hazard PRAs. To identify these events, we need to first make a list of such SSCs and consider what kind of consequences may occur because of the failure of the SSCs.

Table 6 describes the events classified in this category by the location of the SSCs to fail. For example, let us assume that a building itself would not fail by single hazard impacts but could fail by the superposition impacts, such as that the seismic motion cause inelastic deformation of the building and the surging wave fails the building because of the reduced bearing capacity. The failure could change the possible sequences following the seismic-induced initiating events. Note that the failure modes of the seismic impacts vary depending on SSC types, and we need further study to identify them.

Table 6: Descriptions of the Events Classified as “Superposition Impacts on the Fragility of SSCs”

#	Location of the SSC	Description
6	Outside buildings	Outdoor SSCs that are not expected to be damaged by the earthquake alone or by the tsunami alone are damaged by the superposed impacts. The events include not only the case of multiple impacts on the SSCs themselves but also the case where the water sealing/waterproofing equipment (e.g., flood prevention boards) and drift protection equipment are damaged by seismic impacts (or superposed impacts), resulting in damage to the SSCs due to tsunami impacts.
10	Building itself	SSCs on the building boundary and/or building itself that are not expected to be damaged by the earthquake alone or by the tsunami alone are damaged by the superposed impacts.
14	Inside buildings	Indoor SSCs that are not expected to be damaged by the earthquake alone or by the tsunami alone are damaged by the superposed impacts.

For PRA, the superposition events can be modeled by following the procedures. First, we need to define the failure mode of the superposition impact and identify the relationship between the SSC's response to seismic impact and the reduction of the SSC's capacity against tsunami impact. Then, we can make a list of SSCs that can be damaged by superposition impacts considering the consequences of the events. Following obtaining the data for response and capacity of the SSC for each hazard impact and fragilities of the SSC against each hazard, we can conduct the fragility analysis for the superposition impacts.

3.3. Superposition Impacts on Precautionary Measures and Mitigation Measures

Events in "Superposition impacts on precautionary measures and mitigation measures" are related to precautionary measures for the subsequent tsunami or mitigation measures for seismic-induced initiating events and their consequences. The events can be classified based on which type of measures are disturbed and what kind of superposition characteristic relates to the event. Table 7 shows the classification of the events. The uniquenesses of the superposition impacts on mitigation measures are (a)"there is a time lag between earthquake and tsunami impacts" and (b)"operators have to deal with the impacts of the two hazards simultaneously." The detailed descriptions of the superposition events are explained in Table 8.

Table 7: Types of Superposition on Each Hazard and Their Perspectives on Organizing Events

Superposition characteristics		Superposition events
Seismic impacts disturb tsunami precautionary measures	Time lag between earthquake and tsunami impacts	• Response and route changes on post-earthquake evacuation • Seismic impact on tsunami prevention response and/or measures
	Simultaneous responses to two hazards' impacts	• Lack of resources (equipment, personnel, time available) when responding to the earthquake impact and tsunami impact are superposed
Tsunami impacts disturb the measures for seismic-induced initiating events	Time lag between earthquake and tsunami impacts	• Interruption of accident response and/or damage to mitigation facilities in operation due to tsunami attack during the response to an accident caused by an earthquake
	Simultaneous responses to two hazards' impacts	• Restoration of work sites, access routes, etc. that are newly created or become more complicated due to the impact of superposed hazards than when they were single hazards • Different operation of severe accident mitigation systems from that for a single hazard • Lack of resources (equipment, personnel, time available) when responding to the earthquake impact and tsunami impact are superposed

4. CONCLUSION

This study has identified, in general, what kind of events can be induced by the combination of seismic and tsunami impacts at a typical NPP site faced on a coast. These events have been classified into three categories: superposition impacts on (i) tsunami impacts, (ii) failure of SSCs, and (iii) precautionary and mitigation measures. For each category, the events are organized based on their characteristics, combinations of influencing and influenced hazard impacts and the location of damaged SSCs for Category (i), location of damaged SSCs for Category (ii), and types of measures and related superposition characteristics for Category (iii). According to the classified categories, how the events in each category can be considered in PRA has been briefly described.

Acknowledgments

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Table 8: Descriptions of the Events Classified as "Superposition Impacts on Mitigation Measures"

#	Affected measures	Superposition characteristics	Description
16	Tsunami precautionary measures	Time lag between seismic and tsunami impacts	Tsunami precautionary measures and countermeasures such as sluice gate closures and seawater pump shutdowns become more difficult due to seismic impacts. Factors impeding the measures may include the followings: failure of tsunami warning and sea-level change indicators, reduced accessibility to monitoring and response sites, and disruption due to post-earthquake incident response.
17			Evacuation of people inside the reactor buildings, etc., takes a different route than under a single hazard event, which may become the tsunami's entry point.
18	Measures for seismic-induced initiating events	Simultaneous responses to two hazards' impacts	Under the situation where an earthquake and tsunami strike in succession, the restoration of worksites and access routes becomes more complex and challenging than that assumed for an earthquake alone or a tsunami alone.
19			The lineup for accident mitigation systems and startup operations differs from those assumed for an earthquake alone or a tsunami alone due to the superposition of an earthquake and a tsunami.
20		Simultaneous responses to two hazards' impacts	By responding to multiple hazard impacts, resources for mitigating events/accidents, such as equipment, personnel, and time available at the site for countermeasures against severe accidents, become insufficient.
21		Time lag between seismic and tsunami impacts	A tsunami arrives during the response to an accident caused by an earthquake, interrupts the accident mitigation measures, damages in-service facilities, and may cause more severe tsunami-induced initiating events than seismic-induced ones.

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