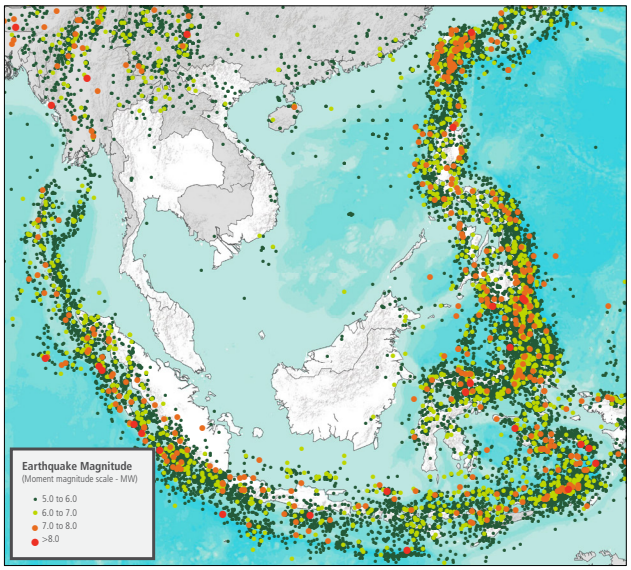
AIR Earthquake Models for Southeast Asia

Southeast Asia is located on and within some of the world's most active plate boundaries and has experienced some of the largest earthquakes ever recorded, including the 2004 M9.3 Boxing Day earthquake and tsunami. The AIR Earthquake Models for Southeast Asia incorporate the best available data and innovative modeling methods to support earthquake risk mitigation strategies in Brunei, Hong Kong, Indonesia, Macau, Malaysia, the Philippines, Singapore, Taiwan, Thailand, and Vietnam.

AIR

The Southeast Asia region has several of the fastest growing insurance markets in the world as well as growing concentrations of exposures in highly seismic areas. The AIR Earthquake Models for Southeast Asia serve as essential tools for seismic risk management, incorporating the latest high quality hazard data, innovative modeling procedures, and detailed exposure information to provide the most comprehensive view of earthquake risk available.



Historical seismicity (≥Mw5.0) in Southeast Asia.

Industry-Leading View of Seismic Hazard in Southeast Asia

The Southeast Asia region is one of the most complex seismic zones in the world; four major tectonic plates—the Pacific, Eurasian, Australian, and Philippine Sea plates—are converging toward or sliding past each other at rates ranging from 5 to 10 cm per year. Understanding the nature of these plate interfaces is key to modeling seismic risk, as subduction zones have the potential to produce immensely powerful earthquakes, such as the M9.3 Boxing Day earthquake in 2004.

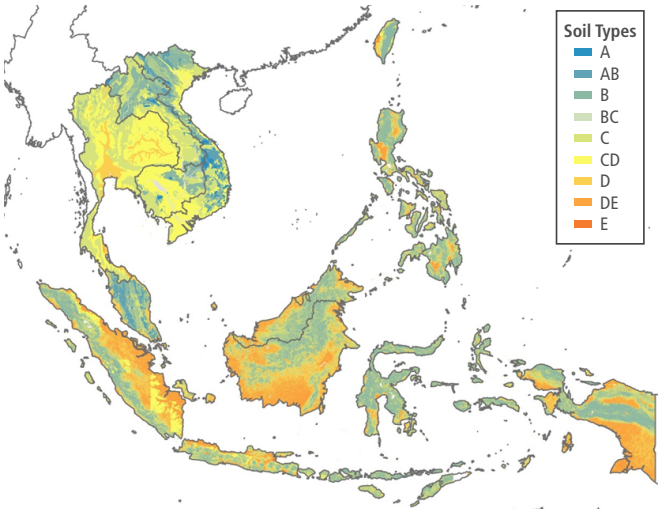
With the incorporation of the latest historical seismic data from both global and local sources, active fault and paleoseismological data, kinematic modeling of GPS data on crustal deformation, geotechnical data on soil, and damage survey data from recent earthquakes, the AIR Earthquake Models for Southeast Asia provide a comprehensive view of risk to exposures in Southeast Asia.

Through a time-dependent approach, the models account for the impact of recent earthquake ruptures and the potential for partial rupture of subduction zones. When considering seismic risk from subduction zones, of particular interest is the Indonesian island of Java, home to Indonesia's largest exposure concentrations. Recent kinematic modeling of GPS data has suggested higher coupling between the Australian and Eurasian plates along the Java Trench than previously thought—a condition with the precursor ingredients for a tsunamigenic megathrust earthquake. Recently mapped crustal faults in Java are also significant drivers of risk on the island.

> "Selections of input parameters are based upon comprehensive data, references, in-depth consideration, and strong justification. We have previously reviewed seismic hazard studies for Indonesia… and we consider AIR's study to be the most impressive one."
>
> Professor Masyhur Irsyam
> Chairman, National Team for Revision of
> Seismic Hazard Maps of Indonesia

High-Resolution Soil Maps Capture Potential for Amplified Ground Shaking

Using the most detailed surficial geological maps that are available, together with digital elevation model (DEM) data and seismic microzonation studies for Jakarta, Manila, and Taipei, the AIR models account for variations in soil type that can significantly alter the intensity and nature of ground shaking.



Composite Southeast Asia regional soil map.

Ground motion prediction equations that are appropriate to each of the region's seismic settings—which include subduction, stable continental, and shallow active crustal zones—are used in a logic-tree approach to model the ground shaking at each affected site.

Probabilistic Tsunami Modeling for Indonesia, Taiwan, and the Philippines

The 2004 Boxing Day M9.3 earthquake in the Indian Ocean demonstrated the devastation that can be brought about by tsunamis. The waves were as high as 30 meters in places and damage was massive, with some coastal areas reshaped, subsided, or removed altogether.

Modeled tsunami height in northern Sumatra, Indonesia, following the 2004 M9.3 Boxing Day earthquake.

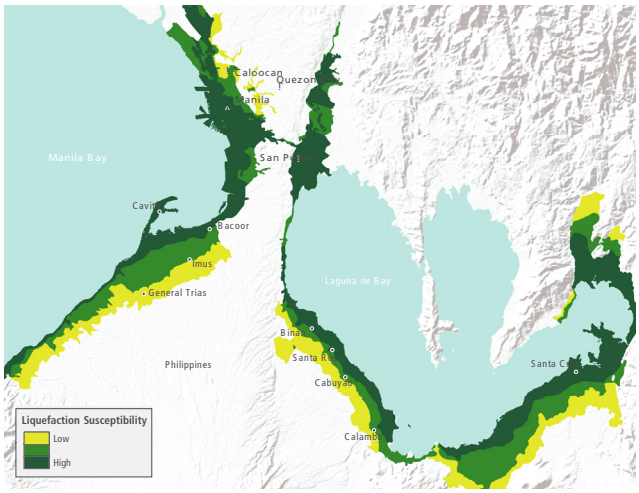
The AIR earthquake models include a probabilisitic tsunami model for Indonesia, the Philippines, and Taiwan that explicitly captures the effects on properties of inundation depth, wave velocity, and debris borne by tsunami waves. Coastal areas around major ports are characterized as light, moderate, or heavy debris zones determined by their annual cargo tonnage. AIR's tsunami model has been extensively validated against reported inundation depths, damage observations, and economic losses from historical tsunamis, with a particular focus on the 2004 Boxing Day earthquake.

Explicit Modeling of Liquefaction

When violent ground shaking causes water-saturated soils to lose their strength, ground settlement and/or lateral spreading may occur, causing buildings to tilt or topple, highways to crack and subside, and underground utility pipelines to break.

Because liquefaction is strongly correlated with soil type and the groundwater table, detailed soil and groundwater data are required to produce a comprehensive picture of liquefaction risk. Liquefaction risk is explicitly captured in the AIR Earthquake Models for Southeast Asia where high-resolution soil and groundwater depth data are available.

Moreover, the liquefaction susceptibility maps of the National Center for Research on Earthquake Engineering (NCREE, Taiwan) and the Philippine Institute of Volcanology and Seismology (PHIVOLCS) are incorporated in the AIR Southeast Asia earthquake models.



Liquefaction risk in the Greater Manila Area.

Building damage observed in Taiwan following the 1999 Chi-Chi earthquake. (Source: AIR)

Damage Functions Provide a Robust Multi-Peril View of Vulnerability

To estimate losses from ground shaking, AIR has developed a uniform vulnerability framework that explicitly accounts for both the strength and ductility of buildings. Spatial and temporal variation of buildings' vulnerability are delineated in AIR models through comprehensive studies of building codes throughout Southeast Asia and collaboration with local experts to gain further insight into code enforcement and local construction practices.

AIR damage functions employ nonlinear dynamic analyses and component-level fragility curves. The models support loss estimation for 116 construction classes, 116 occupancy classes, and four height bands, including one for "tall" buildings of 21 or more stories.

Exposures of unknown construction, unknown occupancy, unknown age, and/or unknown height widely exist in many industry accounts. In AIR's earthquake models for Southeast Asia, for buildings with unknown attributes—such as height or construction—region-specific damage functions are calculated as a weighted average of the damage functions for buildings of known attributes.

Damage functions for infrastructure, builder's risk, marine hull, marine cargo, automobiles, two-wheeled vehicles, and warehouses are included for the shake, tsunami, and liquefaction perils, and for large industrial facilities for the shake and tsunami perils.

Leveraging AIR's Detailed Industry Exposure Databases for Southeast Asia

AIR's industry exposure databases (IEDs) for Southeast Asia* feature a 1-km grid resolution and are based on the latest available information on risk counts, building characteristics, and construction costs from a wide variety of local sources. The benefits and uses of AIR's IEDs are numerous; they provide a foundation for all modeled industry loss estimates. Risk transfer solutions, such as industry loss warranties that pay out based on industry losses, rely on the IEDs. Using Touchstone®, companies can also leverage the IEDs to disaggregate the exposure data in their own portfolios to a highly detailed level for improved loss estimates.

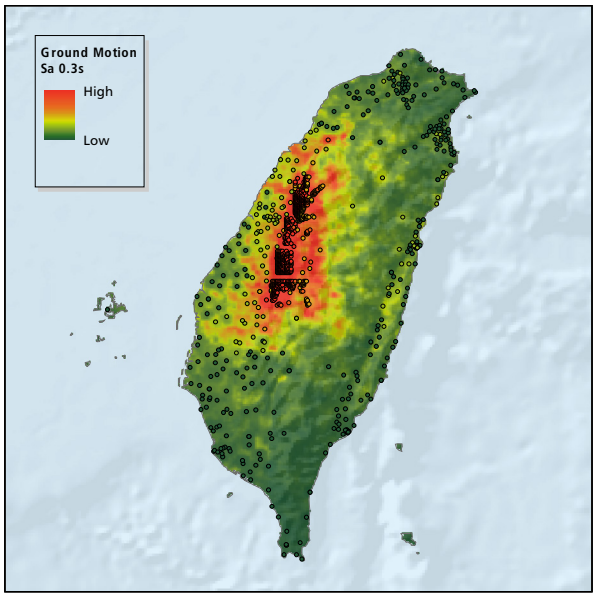
Comprehensive Validation of Model Components and Loss Estimates

To ensure the most robust and scientifically rigorous results possible, the AIR models have been built from the ground up, with each model component independently validated against multiple sources and data from historical events. The magnitude–frequency distributions of events in the stochastic

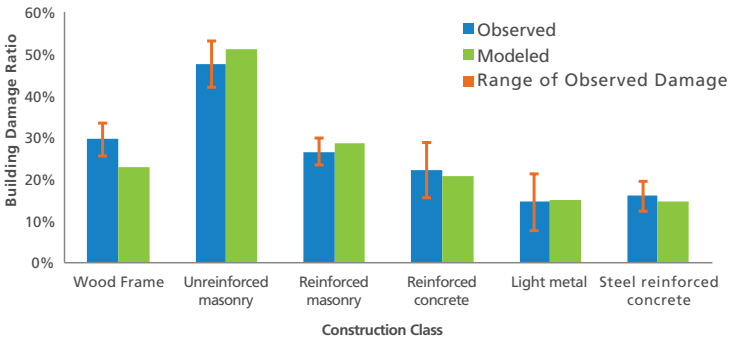
*Brunei, Malaysia, and Thailand are not supported in the industry exposure database for Southeast Asia and are available for risk analysis in Touchstone only.

catalog have been validated against historical earthquake rates. In addition, modeled ground motion agrees well with recorded or observed ground motion intensity fields for earthquakes.

Similarly, the model's damage functions have been validated against damage reports from field surveys for recent significant events such as the 1999 Chi-Chi earthquake in Taiwan.

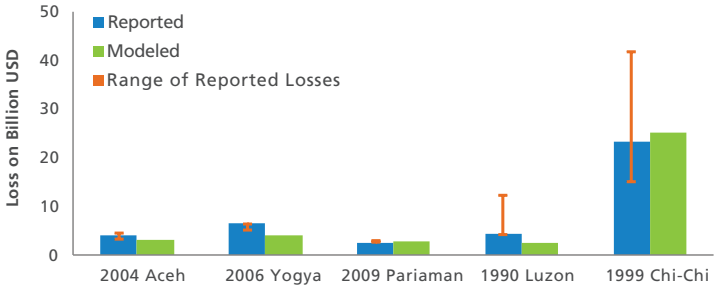


1999 Chi-Chi earthquake: Modeled ground motion intensity S_a 0.3s matches well with point observations. (Sources: AIR and the Central Weather Bureau of Taiwan)



Modeled versus observed building damage, 1999 Chi-Chi earthquake, Nantou County, Taiwan. (Sources: Chou et al. (2001) and AIR Worldwide)

Where detailed damage observation data is available, AIR damage functions are validated at a granular level, by construction type, which can be seen in the figure, and building height, and show good agreement.



AIR's Southeast Asia earthquake modeled ground-up losses show good agreement with trended reported ground-up losses for historical events. (Source: AIR)

> "Local construction practices and degree of code enforcement are solicited in order to capture both global and local perspectives in the structure's vulnerability assessment…"
>
> Professor Fernando J. Germar
> University of the Philippines - Diliman

> "AIR Engineers conducted a comprehensive study of Taiwan Seismic Building Codes, and their vulnerability assessment reasonably approximates requirement and evolution of seismic design codes and their enforcement in Taiwan."
>
> National Center for Research on Earthquake Engineering (NCREE, Taiwan)

Models at a Glance

Modeled Perils	Ground shaking, tsunami, and liquefaction
Model Domain	Brunei, Hong Kong, Indonesia, Macau, Malaysia, Philippines, Singapore, Taiwan, Thailand, Vietnam
Stochastic Catalogs	All 10 modeled countries share a 10,000-year stochastic catalog optimized from a 100,000-year catalog. The stochastic catalog is supplemented by a historical event set of 58 events and 11 Extreme Disaster Scenarios.
Supported Construction and Occupancy Classes	Touchstone supports 116 construction classes and 116 occupancy classes, including large industrial facilities (400-series)
Industry Exposure Database	— Contains risk counts, building characteristics, and construction costs, at a 1-km spatial resolution — Provides a foundation for all modeled industry loss estimates
Supported Policy Conditions	Touchstone supports a wide variety of location, policy, and reinsurance conditions that are specific to each modeled country.

Highlights of the Models

- Explicitly capture damage due to ground shaking, tsunami, and liquefaction
- Incorporate the best available analyses of historical seismicity in the Southeast Asia region through the integration of local, regional, and global earthquake catalogs
- Employ kinematic modeling of GPS data, active faults, and paleoseismological data to produce a comprehensive, time-dependent view of seismic hazard
- Use high resolution soil maps to assess the potential for liquefaction and local site amplification effects
- Feature a tsunami module that captures the propagation of a tsunami from its origin through the entire inundation period
- Feature validated peril-specific damage functions for shake, tsunami, and liquefaction
- Benefit from AIR's collaboration with local researchers during model development, and from thorough peer review of the hazard and vulnerability modules
- Support specialized risks, including infrastructure, large industrial facilities, builder's risk, warehouses, marine cargo, marine hull, automobiles, and two-wheeled vehicles
- Allow companies to analyze accumulations of exposure against the ground motion footprints of 58 historical events using the Geospatial Analysis Module in Touchstone

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber attacks, globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, please visit www.air-worldwide.com.

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