An ABS Consulting Research Report:

Earthquake Property and Business Continuity Risk Affecting Japanese Industries

November 2007

ABS Consulting

Executive Summary

A devastating earthquake hit the Southern Hyogo Prefecture of Japan on 17 January 1995 resulting in damage to or the destruction of more than 100,000 buildings and 6,400 deaths in Kobe City. Direct damage to businesses has been estimated to be about 2.4 Trillion JPY (not including business interruption or loss of production). Another earthquake of 6.8 magnitude hit the Niigata Prefecture causing Niigata SANYO Electronic in Ojiya City to suffer damage to business estimated to be 42.3 billion JPY in direct impact and 31 billion JPY in business interruption. Most recently, after the Niigataken Chuetsu-oki Earthquake, the automobile industry suffered a production drop of about 120,000 units due to damage to a critical supplier's facility that manufactured piston rings. The Ministry of Economy, Trade and Industry estimated that this earthquake caused industrial production to shrink by 0.4%. (Japan Times, 1 September 2007). It is clear that earthquakes can not only impact business revenues and profits, but also result in extensive property damage and loss of life.

In response to these events, and the recent updated seismic risk studies sponsored by the Japanese Government, ABS Consulting has completed a research study that quantifies the earthquake risk for direct and indirect damage for a list of 32 select corporations in eight industries. The industries included in the study were steel (three enterprises), nonferrous metals (three enterprises), chemical (four enterprises), automobiles (four enterprises), oil (three enterprises), precision machines (three enterprises), electronics (nine enterprises), and pharmaceuticals (three enterprises).

The top five industries suffering the most potential earning loss are shown in the table below. The earnings impact losses are calculated as a percent of quarterly pre-tax earnings, assuming a 500-year return period event.

Industries suffering the largest potential impact on earnings

Industry Group	Earnings Impact Loss
Chemical	**930%**
Precision Machinery	**429%**
Petroleum	**411%**
Steel	399%
Nonferrous	330%

The study used ABS Consulting's highly advanced probabilistic EQECAT JapanQuake™ earthquake model, to simulate the ground motions from earthquake events and to estimate the resulting damage in each of the eight industry groups. The model incorporates the most recent Japanese Government findings of heightened risk in parts of Japan, including the probability of a magnitude M8.0+ earthquake caused by a rupture in the Tonankai deep sea ocean trenches. Such an event is estimated to have a probability of 60-70% of occurring during the next 30 years. It is evident that in Japan, where 20% of the world's earthquakes occur on 0.25% of the world's landmass, the chemical, precision machines and petroleum industries may suffer potentially devastating impacts to their quarterly earnings, exceeding 400% (or the equivalent of one year of pre-tax earnings) in the aftermath of such an earthquake. It can be extrapolated further that since all the industries in Japan depend upon one another for raw material input, or are related in the supply chain in the renowned, efficient Just-in-time (JIT) manufacturing method, additional business interruption losses could add to the reported estimates. It is important to note that this study does not represent all Japanese industrial companies, but demonstrates that the earnings impact for many industries can be very substantial.

In summary, CEOs, CFOs and chief risk officers of all companies in Japan should undertake a study to fully understand their earthquake exposure and if warranted, implement an active mitigation strategy for earthquake risk. Though mankind cannot prevent earthquakes, it must be said that business owners can protect themselves from much of the adverse financial impact, by having prudent risk transfer and mitigation strategies in place. Direct mitigation measures could include strengthening property structures, anchoring critical equipment and using earthquake isolation systems to reduce overall vulnerability to earthquake damage. Indirect mitigation measures could include strengthening the supply chain to minimize business interruption risk. Risk can be also mitigated by the use of traditional insurance products or alternative risk transfer (ART) instruments such as cat bonds and derivatives.

Securitization of earthquake risk has been successfully implemented by several leading organizations in Japan, including Tokyo Disneyland and most recently, The East Japan Railway. These organizations utilized risk analysis studies by ABS Consulting to support the cat bond issues. ABS Consulting has the expertise and experience to help businesses assess and mitigate earthquake property risk, minimize business interruption risk through supply chain strengthening and also transferring risk by insurance or via ART such as cat bonds.

Purpose of this White Paper

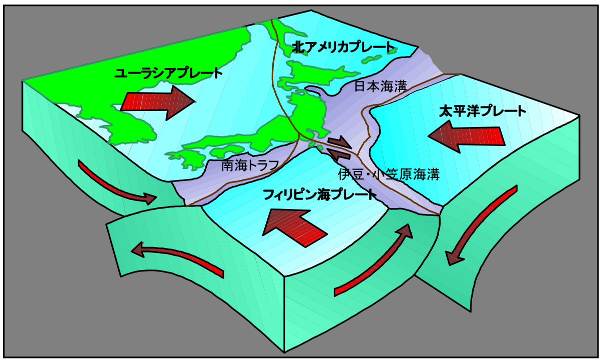
Following the recent series of earthquakes, as well as the Japanese Government's impetus to understand the risk of earthquake and its potential consequences, this white paper has been written to quantify the damages that might be suffered by the Japanese industries. In this study, the physical property damages from the shaking of earthquakes are classified as direct loss damages, while business interruption losses are classified as indirect loss damages.

The advanced probability earthquake model, EQECAT JapanQuake™, is used for the evaluation of these losses. This study presents these results and considers various earthquake risk mitigation measures.

Earthquake Hazards in Japan

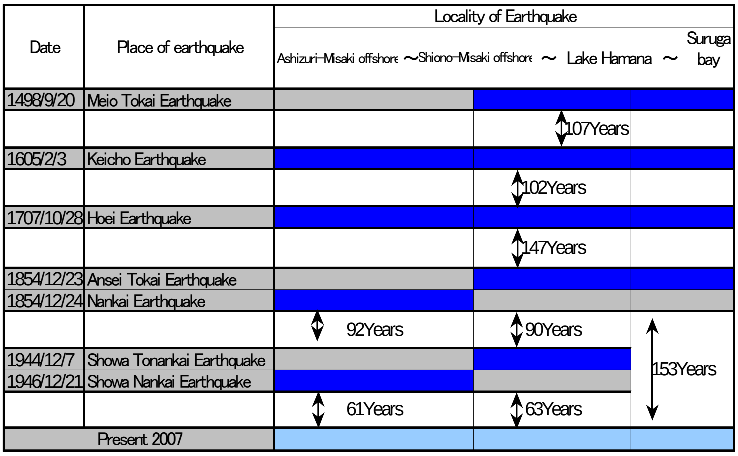
According to statistics, about 20% of the world's earthquakes occur within the vicinity of the land of Japan.[1] While Japan makes up only about 0.25% of the world's landmass, it has been called the "Land of Earthquakes-Japan."

The island chain of Japan lies within one of the most complex tectonic regions of the world, where the Philippine, Pacific, Eurasian and the North American crustal plates converge. The island chain owes its origin to the tectonic and volcanic processes active at this plate boundary zone, the same processes that result in high seismic hazard throughout the region. This region is tectonically complex due to the interaction of these crustal plates and has been the subject of scientific study by both Japanese and foreign researchers for over 130 years.



[1] Estimated from 1994 to 2003 period for earthquakes with magnitudes above M6.0. (Cabinet Central Disaster Prevention Committee)

North of Tokyo, the Pacific plate is being subducted by the North American plate along the Japan Trench ("JT") subduction zone at about 10cm a year, and the Philippine Sea plate is also being subducted by the North American plate along the Sagami Trough ("ST") subduction zone. South of Tokyo, the Philippine Sea plate is being subducted by the Eurasian plate along the Nankai Trough ("NT") subduction zone at about 4cm a year. Some of the earthquakes having a large impact on Yokohama and Tokyo were caused by the movements of the Sagami Trough subduction zone. Earthquakes that occur at the Nankai Trough are worrying due to their probability of occurrence and magnitude. The earthquakes of Nankai Trough are classified as Tokai Earthquake, Tonankai Earthquake and Nankai Earthquake depending upon the rupture zone. These earthquakes tend to occur at a certain constant cycle of about 100 to 150 years. Instances include the Meio Tokai Earthquake in 1498, the Keicho Earthquake in 1605, the Hoei Earthquake in 1707, the Ansei Tokai and Nankai Earthquake in 1854, the Showa Tonankai Earthquake in 1944, and the Showa Nankai Earthquake in 1946. One hundred and fifty-three years have passed since the Tokai Earthquake, whose epicentral area lies between the coast of Hamana Lake and Suruga Bay. Scientists said that it was no wonder that the Tokai Earthquake happened then. The probability of an earthquake occurring within the next 30 years of earthquakes along the Nankai Trough is 87% for Tokai Earthquake, about 50% for a Tonankai Earthquake, and about 60% to 70% for a Nankai Earthquake[3]. The magnitude of these earthquakes is in the range of 8.0 for occurrence alone of Tokai to 8.5 for simultaneous occurrence of Tokai, Tonankai and Nankai. There is a concern that these earthquakes would exert a huge impact on the Japanese industries because the magnitudes are large and Japanese industry is concentrated along the Pacific Belt Zone, which lies parallel to the Nankai Trough.



Quaternary faults are another source of seismic hazard and many of these exist in Japan. These are on-land faults that have ruptured during the last two million years. They are generally

3 Centre for Earthquake Research Promotion: Accurate as of 1 January 2007.

considered to be active faults because the stresses in them are still active. The highest concentration of quaternary (active) faults occurs in central Honshu, about 200 km southwest of Tokyo. In northeastern Honshu, the faults are of the reverse type. In central Honshu, faults are of the strike-slip type. On the island of Shikoku, the strike-slip style of faulting also occurs. The Median Tectonic Line is an example of a Quaternary fault that runs through northern Shikoku. An extension of this fault through Awaji Island ruptured in the 1995 Kobe Earthquake.

There are some earthquakes that cannot be associated with any of the known active faults. Recent examples are the earthquake (M7.3) that occurred in the western part of the Tottori prefecture in October 2000, the Fukuoka prefecture western offshore earthquakes (M7.0) that occurred in March 2005 and the Noto Hanto Earthquake (M6.9) that occurred in March 2007. Earthquakes can occur from unknown faults other than the ones already specified by the Headquarters for Earthquake Research Promotion.

Ancient literature contains references to recorded earthquakes and bears testament to such an earthquake prone country as Japan. Earthquakes constantly occur in the Tokai, Tonankai, Nankai areas. The concept of understanding and predicting the next big earthquake in these areas has been actively conducted in order to take preventive measures.

The Japan Meteorological Agency (JMA) set up an earthquake early warning system on 1 October 2007 which will disseminate early earthquake warning to residents in the affected location. Further information can be found at the following website: (http://www.seisvol.kishou.go.jp/eq/EEW/kaisetsu/index.html).

This system uses the detection of the primary wave or P-wave to issue an early warning before the secondary wave or S-wave would strike the affected location, effectively giving the affected residents seconds to react to protect themselves. It is hoped that this early information system will be able to provide residents precious time to seek shelter quickly and it is also hoped that it will be useful to prevent secondary damage such as fire after the earthquake by allowing the shutting down of dangerous processes in the factories and gas systems at homes before the earthquake occurs.

Examples of Governmental Earthquake Mitigation Activities

Central Disaster Management Council of the Cabinet Office:

One of the key policy of the Japanese Cabinet Office is the creation of the Central Committee for Disaster Prevention. (http://www.bousai.go.jp/chubou/chubou.html). This Committee is part of the Prime Minister's office and is composed of serving ministers in the Government as well as individuals from academic, public and private sectors. They meet regularly to design the master plan for disaster prevention and to consider various disaster prevention related matters.

The Central Disaster Management Council carefully considers the risk of the earthquake-prone region in the Nankai Trough as a probable trigger of a major Tokai Earthquake or Tonankai-Nankai Earthquake. The Committee estimates the damage in such scenarios and suggests appropriate earthquake emergency response plans and disaster prevention promotion activities aimed at reducing the consequence after such a large earthquake.

Headquarters for Earthquake Research Promotion:

The Headquarters for Earthquake Research Promotion（http://www.jishin.go.jp/main/index.html）is a Governmental initiative for the research activities directly involving earthquakes. It is a special Governmental organization set up by the Ministry of Education, Culture, Sports, Science and Technology (then the Prime Minister's Office). Its purpose is to improve earthquake disaster measures, especially to promote earthquake research in the development of mitigation measures against earthquake damage. It has issued earthquake forecast maps, evaluated probable seismic magnitude and occurrence probabilities for major active seismic faults and ocean trench earthquake sources.

National Research Institute for Earth Science and Disaster Prevention:

The National Research Institute for Earth Science and Disaster Prevention（http://www.bosai.go.jp/）offers a much broader research scope regarding earthquakes. Generally, the evaluation of the earth's crustal activities is done using earthquake movement forecasts, advanced earthquake hazard evaluations, and earthquake sensor data. Moreover, after the 1995 Southern Hyogo Prefecture Earthquake, the seismic observation data network has been expanded to the entire country. The research headquarters operates the "Earthquake Hazard Station" or commonly known as J-SHIS（http://www.j-shis.bosai.go.jp/, which makes possible the download of earthquake movement forecast charts for the whole of Japan.

Past Earthquakes and Damage:

The first record of a JMA intensity seven earthquake in Japan was in 1995 in the southern part of the Hyogo prefecture, known as the South Hyogo Prefecture (Kobe) Earthquake. After the Kobe Earthquake, there were 26 earthquakes including aftershocks that registered JMA intensity 6- or higher. Recently, the Niigataken Chuetsu-oki Earthquake (M 6.8) which occurred on 16 July 2007 and the Noto Hanto Earthquake (M 6.9) which occurred on 25 March 2007, registered JMA intensity 6+.

Earthquake	Date	M_{JMA}	JMA Intensity
South Hyogo Prefecture (Kobe) Earthquake	1995/1/17	7.3	7
Western Tottori Prefecture Earthquake	2000/10/6	7.3	6+
Geiyo Earthquake	2001/3/24	6.7	6-
Miyagi Prefecture Offshore Earthquake	2003/5/26	7.1	6-
Northern Miyagi Prefecture Consecutive Earthquake	2003/7/26	6.2	6+
Tokachi-Oki Earthquake	2003/9/26	8.0	6-
Mid Niigata Prefecture Earthquake	2004/10/23	6.8	7
Fukuoka Prefecture Western Offshore Earthquake	2005/3/20	7.0	6-
Miyagi Prefecture Offshore Earthquake	2005/8/16	7.2	6-
Noto Hanto Earthquake	2007/3/25	6.9	6+
Niigataken Chuetsu-Oki Earthquake	2007/7/16	6.8	6+

In the event of a large earthquake, various damages may occur. On 17 January 1995, at 5:46 A.M, a powerful and intense shake that lasted 20 seconds hit Southern Hyogo Prefecture. After the earthquake, 294 fires occurred in the area. These fires continued and burned 6,814 houses in Kobe City, affecting over an area of more than 600,000 m^2. In addition, liquefaction effects affected reclaimed areas along the coasts, Port Island and Rokko Island. The shaking caused by the earthquake and the fires in Kobe City resulted in around 6,400 casualties and about 100,000 houses were destroyed, making it one of the greatest disasters ever to occur.

According to Hyogo Prefecture's estimates, damages to the industry and buildings were estimated to be 1.77 trillion yen, while damages to machines and facilities were in the range of 630 billion yen. This is direct damage, i.e. physical damage caused during the shake and the fire following the earthquake. Manufacturing and related industries that suffered direct damage such as damaged buildings and machinery had to repair or replace building and equipment, to purchase new equipment and to commission tests in order to start production again. During this period of time, disruption to the manufacturing process caused business interruption losses to the industry.

The Mid Niigata Prefecture Earthquake in 2004 caused a 6+ JMA intensity to strike the semiconductor manufacturing factory Niigata SANYO Electronic in Ojiya City causing extensive damage. SANYO Electric Co. Ltd. reported the loss related to equipment damage, so called direct loss, was 42.3 billion yen in the earthquake, while the opportunity loss due to business interruption was estimated to be about 31 billion yen according to the annual report in 2005. Although the factory's building, which had been designed under the current earthquake-resistant regulations, was not damaged severely, the machines suffered heavy damage because they had been secured to endure JMA intensity 5. Also, leaked gas and toxic liquids in the clean room could not be cleaned immediately due to the disruption of the lifeline services resulting in a shortage of water. Large intermittent aftershocks following the main earthquake on 23 October made full recovery efforts difficult. One part of the production line did not open for production for two months and the whole recovery effort took more than five months[5].

In the Niigataken Chuetsu-Oki Earthquake that occurred on 16 July 2007, the factory owned by Riken Corporation (having a share of 50% of the domestic market for the piston rings required by automobile manufacturers) was damaged. More than one week went by before the factory resumed production, and the overall recovery effort took two weeks. Major automobile manufacturers such as Toyota adopted the just-in-time (JIT) production method. Subsequently all the major automobile manufacturers halted their production due to the disrupted supply of piston rings from Riken. Overall, automobile production dropped by about 120,000 or more for that period of time. This earthquake highlighted the vulnerability and exposed the weakness of the JIT production method, which has been used by many businesses as a demonstration of an excellent supply chain management[7].

[5] Nikkei Business 17 January 2005, Nikkei MicroDevice Nov 2005 Edn

[7] Nikkei Net (News 2 August 2007).

When a large-scale earthquake occurs, extensive damage could occur for public utility lifelines, the railway, roadways harbor facilities, etc. In the Kobe Earthquake, ground subsidence caused by liquefaction in harbor areas and the seaside region resulted in major damage to underground installations.

Since the Kobe Earthquake, many earthquakes that have caused damage in Japan have been magnitude 7-type earthquakes occurring inland and while the damage has been significant, they affected a limited area. There is a concern as to the potential impact of a major subduction zone earthquake that can affect a much larger and economically developed area of Japan, inflicting potentially much higher losses.

Damage prediction result by the Central Disaster Management Council

	Tonankai, Nankai Earthquake	Tokai, Tonankai, Nankai earthquake	Tokai earthquake
Direct damage （Personal property, industrial facilities, lifelines, etc）	about 29～43Trillion JPY	about 40～60 Trillion JPY	about 19～26 Trillion JPY
Indirect damage	about 9～14 Trillion JPY	about 13～21Trillion JPY	about 7～11Trillion JPY
Loss of production	about 4～5Trillion JPY	about 5～8Trillion JPY	about 3Trillion JPY
Major transportation system disruption	about 0.3～1Trillion JPY	about 0.5～2Trillion JPY	about 0.5～2Trillion JPY
Impact on other areas	about 5～8Trillion JPY	about 7～11Trillion JPY	about 4～6Trillion JPY
Total	about 38～57Trillion JPY	about 53～81Trillion JPY	about 26～37Trillion JPY

The Central Disaster Management Council of the Cabinet Office has commissioned a report concerning the Tokai as well as the Tonankai and Nankai Earthquakes. The report envisioned that a simultaneous earthquake ocurring on Tonankai and Nankai would cause damages (to personal properties, business facilities and lifelines, etc.) in the amount of 29 to 43 Trillion JPY and business interruption totaling 4 to 5 Trillion JPY.

A portfolio of property risks is defined by location, replacement cost, age and type of construction. This portfolio is input into the model, which then calculates the probability of ground shaking and damage from all potential earthquake sources affecting each site. The model then combines the damage and loss for each event and each site to estimate average annual loss and PML levels for selected return periods, such as 50, 100, 250 or 500 years. Major model components required to perform the calculations are described below.

Seismotectonic Model. The seismotectonic model consists of three components:

1. **Seismic Source Model**. The earthquake zonation model for Japan is composed of an explicit representation of the known subduction zones, Wadati-Benioff zones and major active faults. These source zones are modeled as three-dimensional fault planes. Earthquakes that cannot be associated with any of these sources are assumed to occur as diffuse seismicity. Modeled subduction interface sources include the Nankai Trough, the Sagami Trough and the Japan Trench subduction zones. These interface zones are modeled as one or more dipping planes to a depth of 30 to 60 kilometers, the maximum depth of interplate earthquakes. The Wadati-Benioff zones are also modeled as dipping fault planes that extend from a depth of around 40 kilometers near the eastern coast of Japan to a maximum depth of around 150 kilometers further inland.

2. **Magnitude-Frequency Relationship**. The average recurrence frequency of earthquakes of a specific magnitude or greater for each seismic source is modeled using a magnitude-frequency relationship. In the EQECAT model, earthquake frequency is modeled using two distinct magnitude-frequency distributions depending upon the earthquake source. The largest earthquakes on the Nankai and Sagami Trough subduction zones, the Japan Trench subduction zone, and the active faults are modeled as characteristic earthquakes, the magnitudes of which are distributed within a relatively narrow range of values defined by a truncated Gaussian probability distribution. All other earthquakes are modeled using the Gutenberg Richter log-linear relationship.

3. **Time-Dependent Recurrence Model**. If the magnitude, recurrence time, elapsed time since the previous earthquake, and a periodicity of the characteristic earthquake on a fault zone were known to an acceptable level of reliability, EQECAT adjusted the long-term recurrence frequency to account for time dependency. Time-dependent recurrence frequencies were calculated based on a Brownian Passage Time (BPT) probability distribution, consistent with the methodology used by the NIED and Earthquake Research Committee and other published studies that EQECAT believed to be credible. When the elapsed time since the last earthquake is longer than about two-thirds of the time-independent mean recurrence interval, the fault is said to be late in its seismic cycle and the calculated time-dependent recurrence frequency is higher than the time-independent (Poisson) recurrence frequency. Conversely, when the elapsed time is shorter than about two-thirds of the

time-independent mean recurrence interval, the fault is said to be early in its seismic cycle and the calculated time-dependent recurrence frequency is lower than the Poisson recurrence frequency.

The Sagami Trough subduction zone is considered to be early in its seismic cycle due to the occurrence of the Great Kanto Earthquake in 1923. However, most of the Nankai subduction zone is considered to be late in its seismic cycle. There is a general consensus among Japanese researchers that the Tokai Gap section of the Nankai Trough subduction zone is expected to rupture in the near future, thus posing an immediate and significant hazard to the coastal region lying approximately midway between Tokyo and Nagoya. Taking this consensus opinion into account, the modeled time-dependent recurrence frequency for the entire Nankai Trough subduction zone is higher than the time-independent frequency because of the relatively long elapsed time since the last known rupture of the Tokai Gap in 1854 and because, in EQECAT's opinion, there is a high likelihood that the Tokai Gap will rupture together with the adjacent two segments of the Nankai Trough when it does rupture in the future.

The Ground-shaking and Hazard Model. The ground-shaking and hazard model consists of the following three components:

1. **Attenuation Relationship**. An attenuation relationship is used to estimate strong-motion intensity from magnitude, source-to-site distance and other seismological parameters. In the EQECAT model, an attenuation relationship developed by Japanese scientists was used to estimate the expected value of Peak Ground Velocity (PGV). This attenuation relationship accounted for differences in regional geological and tectonic environment, including differences between shallow seismic sources (faults and shallow background seismicity), Wadati-Benioff earthquakes, and interplate earthquakes on the subduction zones. EQECAT used statistical variability associated with the strong-motion intensity estimated from each relationship in its seismic hazard analysis.

2. **Soil Amplification Model**. Soil amplification factors were used to adjust the estimated values of strong-motion intensity from the attenuation relationship to account for the local soil conditions at the site. In the EQECAT model, soil amplification factors for PGV were defined in terms of site categories based on geomorphologic and geologic data from the Digital National Land Information database (a Japanese Government source of geologic information) and correlations of these data with the average shear-wave velocity in the top 30 meters of the site profile (30-meter velocity).

3. **Hazard Probability Distribution**. The hazard probability distribution is the probability distribution of strong-motion intensity. In the EQECAT model, development of the hazard probability distribution was based on the seismotectonic model. Each seismic source in the seismotectonic model was characterized by its location, depth, geometry, fault area,

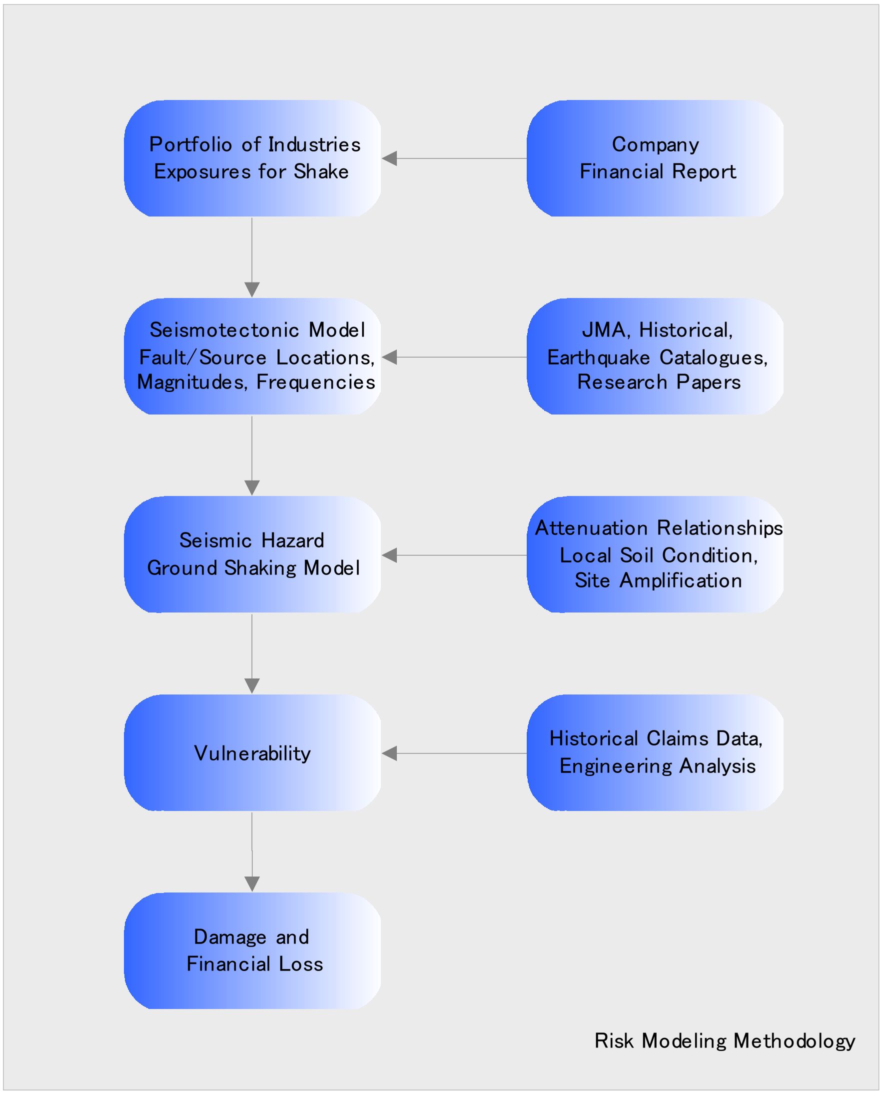
magnitude-frequency relationship and minimum and maximum magnitudes. A stochastic event set was developed from the seismotectonic model accounting for the geometry of the seismic sources, the magnitude-frequency relationship, the uncertainty of the ructure area and rupture location.

Each combination of magnitude, rupture area, rupture location and expected occurrence frequency was used to represent a stochastic event. The collection of all such stochastic events from all seismic sources was used to define the stochastic event set.

The ground-motion model (attenuation relationship, soil amplification factors and their associated variability) was used to calculate a distribution of PGV values for each risk location and stochastic event. These distributions were combined with the frequencies of the stochastic events to derive a hazard probability distribution, from which a Japan earthquake modeled loss exceedance distribution was calculated.

Vulnerability Model: Vulnerability of property (buildings and building content) is measured in terms of the damage ratio and is dependent upon structure type, age and other construction characteristics. The vulnerability database used in the EQECAT model includes earthquake vulnerability functions (for building and contents) for various types of structures categorized by their age and seismic zone. Losses from business interruption are estimated based upon the amount of damage to buildings and the annual financial exposures for each facility. Development of the vulnerability functions in the EQECAT model was based upon the experience damage data collected by the ABS Consulting structural engineering staff from over 70 earthquakes worldwide as well as on experience with building codes and construction practices.

Financial Loss Model. The financial loss calculation involves estimating the portfolio loss. Financial loss at a site is a function of the replacement value and the damage ratio. Portfolio loss is calculated by aggregating financial losses over the sites in the portfolio. Stochastic aggregation accounts for the correlation in vulnerabilities between sites.



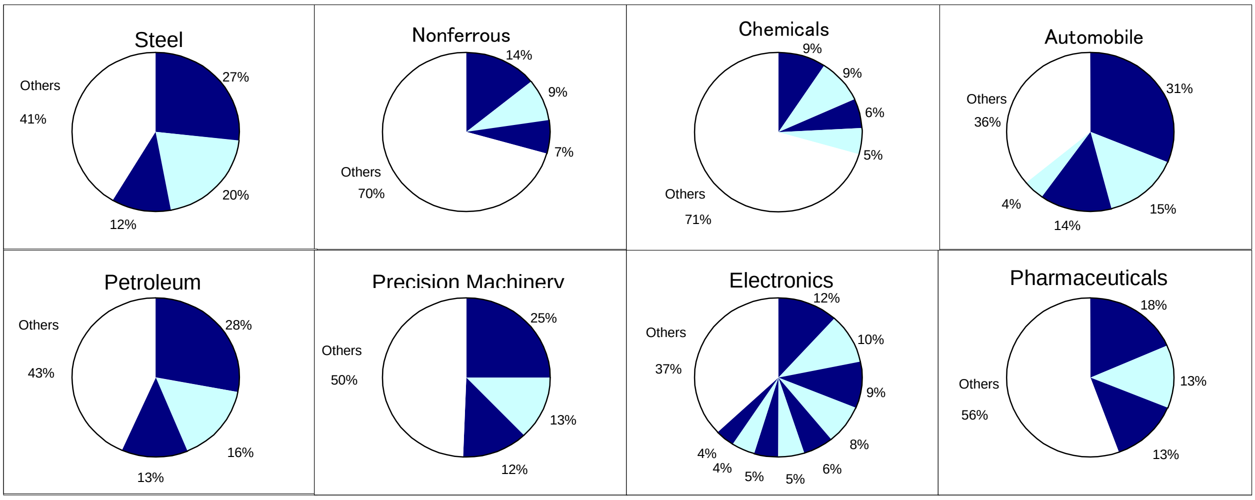
Japan Earthquake Modeling Methodology

Target Industries in the Investigation

In this white paper, the following industries were examined: domestic steel companies (three enterprises), nonferrous metals (three enterprises), chemical (four enterprises), automobiles (four enterprises), oil (three enterprises), precision machines (three enterprises), electronics (nine enterprises) and pharmaceuticals (three enterprises).

Target industries information

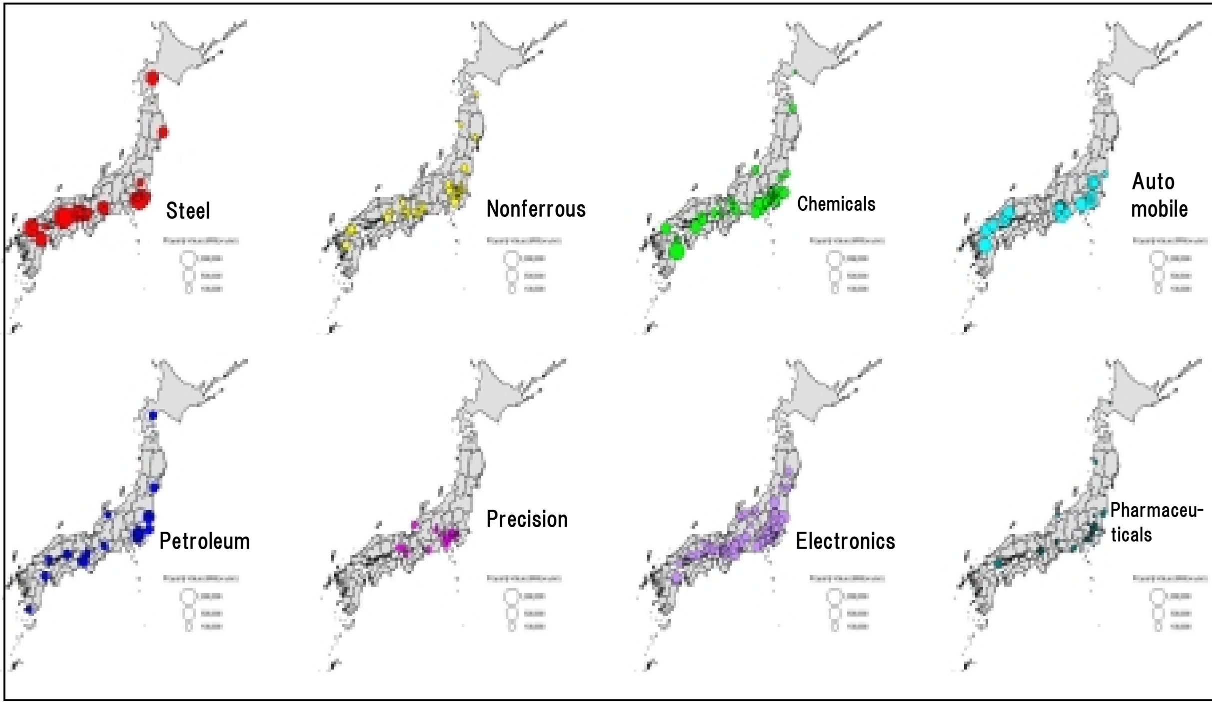
Target Industries	Market Share	Market Capitalization	Comments
Steel	58.71%	16,135,916	Top 48 businesses
Nonferrous	29.37%	16,891,897	Top 100 businesses
Chemicals	29.47%	29,929,480	Top 100 businesses
Automobile	63.91%	76,276,000	Top 66 businesses
Petroleum	56.54%	23,887,299	Top 11 businesses
Precision Machinery	50.44%	8,244,364	Top 46 businesses
Electronics	62.67%	88,815,604	Top 100 businesses
Pharmaceuticals	44.47%	7,095,701	Top 41 businesses



Target Industries by Market Share(% by Sales)

NIKKEI NET(http://markets.nikkei.co.jp/ranking/keiei/uriage.cfm)Based on Sales Revenue ranking for companies listed nationwide

The total amount of the tangible asset surveyed is 49.2 Trillion JPY in original cost, total revenues is 76.6 Trillion JPY in Domestic Revenue Base, and makes up 8.9% and 13.9% of the real GDP in 2006 (preliminary figures)respectively. In order to develop a database for the research, financial reports in the year ending March 2006 were used. The tangible asset data include domestically owned buildings and structures as well as machinery and equipment which were used as the original price base. The tangible asset was allocated to major production sites depending on their size in order to calculate property losses. Also, gross profit sales were allocated to major production sites in order to calculate business interruption losses.



Property by Industries Distribution Map

Domestically owned buildings and structures as well as machinery and equipment in original base cost allocated to major production sites of the target industries.

The main production locations of each industry tend to gather in a so-called ‘Pacific Belt’ zone, and are arranged in the regions coinciding with the Tokai, Tonankai and the Nankai earthquake-prone areas. Moreover, the steel, chemical and oil industries have their main production base located along the coast line, where seismic hazards are generally higher due to soft soil conditions, and it can be inferred that many of their properties have a high risk of exposure to earthquakes.

Research Study Results

EQECAT, Inc., (a subsidiary of ABSG Consulting Inc.) uses a probabilistic risk analysis model incorporated into proprietary earthquake risk analysis software called EQECAT JapanQuake^{TM} to calculate the losses stemming from direct and indirect damages. In this risk analysis, all possible earthquake scenario which may occur are appropriately considered and modeled. The earthquake model contains about 80,000 earthquake events from all over Japan, and it is used to simulate and predict the potential damages in the above described earthquake scenarios.

Direct Damage/Loss:

In this research study, the direct loss has been calculated as the cost to restore the damaged buildings and machinery, caused by the earthquake shaking, to their original condition. The replacement cost is assumed to be greater than a property's original cost by 15% taking into consideration factors, such as an increase in price and technological advancement since the acquisition of the property. In addition, when a large-scale earthquake occurs, the demand for restoration services will peak causing the cost of restoration and rebuilding to increase suddenly as a result otherwise known as the demand surge. In this report, the demand surge factor has been assumed to take a value of 10% for a return period of 50 years and below, and 15% for return periods of 100 years or more. In calculating the direct loss, the loss from the fires caused by earthquakes and the loss caused by a tsunami has not been included.

Return Period vs Property Loss（Unit: One billion yen）

Return Period/ yr	Steel	Non ferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
100	512	71	452	657	227	101	435	32
500	1,100	141	856	1,239	443	215	918	59
Annual Expected Loss	98.73	3.45	20.03	22.72	14.20	3.90	24.16	1.79
Total Assets	15,387	2,175	9,151	9,873	5,024	1,193	12,935	792

Return Period vs Property Loss (Property Loss/Total Assets)

Return Period/ yr	Steel	Non ferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
100	3.3 %	3.3 %	4.9 %	6.7 %	4.5 %	8.4 %	3.4 %	4.1 %
500	7.1 %	6.5 %	9.4 %	12.5 %	8.8 %	18.0 %	7.1 %	7.5 %
Annual Expected Loss	0.64 %	0.16 %	0.22 %	0.23 %	0.28 %	0.33 %	0.19 %	0.23 %

Indirect Damage/Loss:

In this research study, the indirect loss has been defined as a business interruption loss due to the property damage calculated in the section above. An indirect loss is defined as a loss of gross profit on sales. In the calculating the indirect loss, the loss from contingent business interruption, such as a disruption to the supply chain, seen in the Niigataken Chuetsu-Oki Earthquake, is not included.

Return Period vs Business Interruption Loss（Unit：One Billion yen）

Return Period/ yr	Steel	Non ferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
100	58	18	86	687	42	55	202	55
500	125	42	184	1,304	105	112	499	130
Annual Expected Loss	3.34	0.99	4.27	23.32	3.46	1.95	15.64	3.74
Gross Margin	1,398	447	1,380	4,255	941	899	5,556	1,414

Return Period vs Business Interruption (BI) Loss (BI Loss/Total Sales Revenue)

Return Period/ yr	Steel	Non ferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
100	4.1 %	4.1 %	6.2 %	16.1 %	4.5 %	6.1 %	3.6 %	3.9 %
500	8.9 %	9.5 %	13.3 %	30.7 %	11.2 %	12.5 %	9.0 %	9.2 %
Annual Expected Loss	0.24 %	0.22 %	0.31 %	0.55 %	0.37 %	0.22 %	0.28 %	0.26 %

Earnings Impact Loss

To evaluate the potential impact of a large earthquake on the Japanese industry, the earnings impact loss index was used. This index is expressed as a percentage of the sum of both the direct and indirect loss in a 500 year return period event against the quarterly pre-tax earnings. The pre-tax earnings are the consolidated income before income tax and other costs.

$$\textbf{Earning Impact Loss} = \frac{\text{500 RP Direct loss damage} + \text{500 RP Indirect loss}}{\text{Quarterly Pre-tax earnings(Consolidated Income before income tax and}} \times 100$$

The results show that the highest damage is in the chemical, the precision machinery, petroleum, and steel industries. The loss on assets and the business interruption loss due to the earthquake show that there is a possibility of earnings impact lasting more than two years to the chemical industry. The earthquake loss to the equipment, petroleum, and steel industry could last about one year or more.

Industries suffering the largest potential impact on earnings

Target Industries	Steel	Nonferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
Earning Impact Loss	**399%**	330%	**930%**	266%	**411%**	**429%**	241%	91%
*Foreign Sales Ratio	**26.9%**	**22.4%**	**35.0%**	74.8%	**10.0%**	60.5%	46.4%	40.9%
*Tangible Fixed Asset Turnover	**0.65**	**2.22**	**0.98**	5.04	**2.80**	3.82	4.65	4.38

* Foreign Sales Ratio: Foreign sales divided by total sales

* Tangible Fixed Asset Turnover: Total sales divided by the property value surveyed

The high earning impact loss calculated for the chemical, petroleum and steel industry could be due to the following reasons:

- Expensive and large scale equipment required for the process industry, i.e. small tangible fixed asset turnover.
- The foreign to domestic sales ratio is low.
- The main production base is located in the coastal area where the earthquake hazard is highest.

As far as the precision instrument industry is concerned, the main production sites of the companies surveyed are concentrated in the Kanto area and the “portfolio effect” shrinks, it is thought that, as a result, earning impact loss rose.

For other four industries, the earnings impact tends to be lower for several reasons: 1) the major production sites are located inland, e.g. nonferrous industry; 2) the foreign sales ratio is high, e.g. automobile and precision machinery industries; and 3) the intangible fixed asset turnover is high, e.g. automobile, electronics and pharmaceuticals industries.

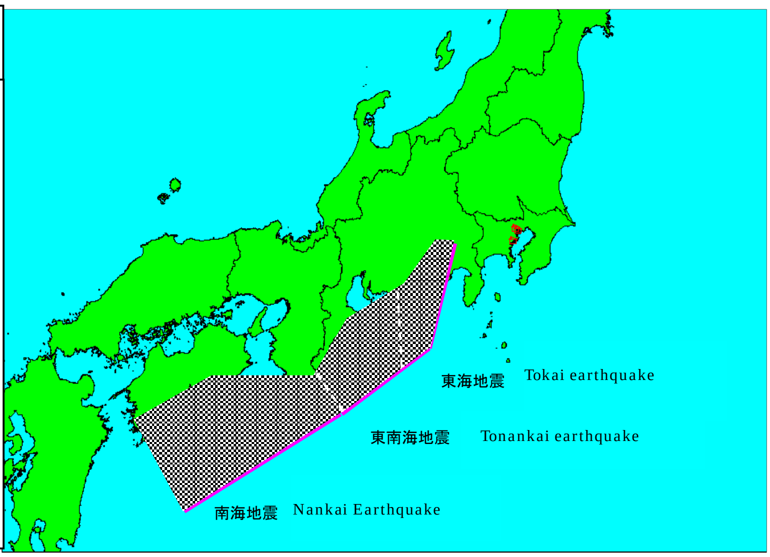
Return Period vs Earthquake Loss（Property Loss＋BI Loss）（Unit: One Billion yen）

Return Period/ yr	Steel	Nonferrous	Chemicals	Auto mobile	Petroleum	Precision Machinery	Electronics	Pharmaceuticals
100	570	89	538	1,344	269	156	637	87
500	1,224	183	1,041	2,543	548	326	1,417	189
Annual Expected Loss	102.08	4.44	24.30	46.04	17.66	5.85	39.80	5.53

Scenario Analysis

In this study, the most feared type of earthquake occurring in the Nankai deep sea trench has been simulated due to the high probability of its occurrence. There were six types of earthquake scenarios possible from the source in the Nankai deep sea trench as illustrated below. The results of the two most major events are presented in the tables below:

Earthquake Scenario	Magnitude
Nankai earthquake	8.4
Tonankai earthquake	8.1
Tokai earthquake	8
Tonankai, Nankai earthquake	8.5
Tokai, Tonankai earthquake	8.4
Tokai, Tonankai, Nankai earthquake	8.5



Tokai, Tonankai, Nankai Earthquake Combination （Magnitude M8.5）

Target Industries	Direct Damage				Indirect Damage				Direct + Indirect	
	Optimum Estimate		Worst Case		Optimum Estimate		Worst Case		Optimum	Worst Case
Steel	1,054	6.8%	1,787	11.6%	108	7.8%	188	13.4%	1,162	1,974
Nonferrous	146	6.7%	249	11.4%	43	9.6%	77	17.1%	189	325
Chemical	950	10.4%	1,534	16.8%	201	14.6%	340	24.6%	1,151	1,874
Automobile	1,098	11.1%	1,758	17.8%	1,122	26.4%	1,762	41.4%	2,220	3,520
Petroleum	345	6.9%	582	11.6%	66	7.0%	117	12.4%	411	699
Precision Machinery	190	15.9%	316	26.5%	129	14.3%	177	19.6%	319	492
Electronics	834	6.4%	1,379	10.7%	389	7.0%	668	12.0%	1,223	2,047
Pharmaceuticals	62	7.8%	103	13.0%	84	6.0%	147	10.4%	147	250

Tonankai, Nankai Earthquake Combination (Magnitude M8.5）

Target Industries	Direct Damage				Indirect Damage				Direct + Indirect	
	Optimum Estimate		Worst Case		Optimum Estimate		Worst Case		Optimum	Worst Case
Steel	807	5.2%	1,373	8.9%	91	6.5%	159	11.4%	897	1,532
Nonferrous	106	4.9%	183	8.4%	34	7.7%	62	13.9%	141	245
Chemical	430	4.7%	747	8.2%	86	6.2%	154	11.2%	515	901
Automobile	888	9.0%	1,431	14.5%	1,018	23.9%	1,599	37.6%	1,905	3,031
Petroleum	181	3.6%	313	6.2%	43	4.6%	79	8.4%	225	392
Precision Machinery	62	5.2%	107	9.0%	44	4.9%	66	7.4%	107	173
Electronics	412	3.2%	718	5.5%	181	3.2%	331	6.0%	593	1,049
Pharmaceuticals	34	4.4%	62	7.9%	38	2.7%	72	5.1%	73	135

What is Enterprise Risk Management?

The underlying premise of enterprise risk management (ERM) is that every entity exists to provide value for its stakeholders. These entities all face uncertainty and the challenge for management is to determine how much risk it should accept as it increases stakeholder value. Uncertainty presents both risk and opportunity, with the potential to erode or enhance value of the enterprise. Enterprise risk management is a process, affected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise designed to identify potential events that may affect the entity and manage risk to be within its risk appetite to provide reasonable assurance regarding the achievement of entity objectives[9].

Enterprise risk management can be viewed from within its eight interrelated key components, which are integrated within the management process for each entity, but scaled and implemented given the nature of the business, risk environment, business goals and objectives, financial and other constraints. An effective enterprise risk management program will include some level of these key components:

- **Internal Environment -** encompasses the tone of an organization and sets the basis for how risk is viewed and addressed.
- **Objective Setting** - objectives must exist before management can identify potential events affecting their achievement; ERM assures that management has in place a process to set objectives and that the chosen objectives support and align with the entity's mission and are consistent with its risk appetite.
- **Event Identification -** internal and external events affecting achievement of an entity's objectives must be identified—distinguishing between risks and opportunities.
- **Risk Assessment** – risks need to be analyzed, considering likelihood and impact as a basis for determining how they should be managed.
- **Risk Response** - management selects risk responses including avoidance, acceptance (retention), reducing or sharing (transferring risk).
- **Control Activities -** policies and procedures are established and implemented to help ensure the risk responses are effectively carried out.
- **Information and Communication -** relevant information is identified, captured and communicated in a form and timeframe that enable people to carry out their responsibilities.
- **Monitoring -** the entirety of enterprise risk management is monitored and modifications made as necessary.

[9] Enterprise Risk Management – Integrated Framework, COSO, September 2004

This study has identified key risks to specific market sectors from the peril of earthquake ground shaking due to major seismic events creating physical damage to critical performing assets such as manufacturing plants, warehouses, processing facilities, etc. as well as expected losses which would result from these selected scenarios directly related to disruption of operations (BI), loss of continuity from vendors and suppliers (CBI) and impact to critical local infrastructure. This effort comprises the **Event Identification** and **Risk Assessment** components of the risk management process.

The **Event Identification** phase of the risk management process entails the identification and selection of key scenarios or “events” that can be expected to create loss to an entity’s portfolio of assets or disruption to operations and business continuity related to these events. In this study, both probabilistic and scenario analyses were conducted. The scenario analysis approach focuses upon a few selected scenarios that comprise both a frequency and severity component while the probabilistic approach utilizes a large stochastic set of individual events that are each described by multiple parameters selected randomly including location, frequency and other critical parameters that characterize the event severity. These events are combined statistically when analyzed against the portfolio of focus providing a robust method of pricing the risk to individual asset locations as well as aggregate losses to the portfolio in entirety. The scenario approach, while useful, will only provide a view of the expected risk impact from that particular event characteristic, without a view of other, less or more likely event occurrences. Sound risk management embodies both methodologies in the **Event Identification** phase.

In relation to natural and operational extreme events, the **Risk Assessment** phase of the process involves the use of site engineering reviews as well as detailed catastrophe modeling tools to identify key features of assets (i.e. construction type, secondary construction elements, age, condition, risk mitigation systems, loss prevention programs) that have a significant effect on the overall loss outcome given the event(s) analyzed or modeled. The result of this phase is the quantification of damage and/or losses due to these characteristic events, given both exacerbating and mitigating conditions present at or near the assets in the portfolio. This phase can and should include not only physical damage impact but most importantly, should also include the review of supporting assets such as key supplier facilities, critical local infrastructure (i.e. power, water, communications, etc.) and operational aspects of the plants and facilities in the portfolio to quantify more accurately the potential business continuity risk and supply chain impact from key risk events such as seismic, typhoon, flood and other extreme events.

Typically, the quantification developed within the **Risk Assessment** phase relates to physical damage and business interruption losses expressed in monetary terms, and also formulated into Probable Maximum Loss (PML) which describes an exceedance probability at some level of monetary losses for physical assets and business interruption. These losses can also be converted to other metrics, which are sometimes useful to other parties within the organization and can be related to key performance indicators to assist in better understanding the impact that extreme events can have on financial and operational aspects of the organization. In this study, the initial results included damage to physical assets and disruption to businesses through loss of revenue and then converted to their impact at varying return period frequencies on annual earnings within each of the businesses being considered and in each of the eight market sectors overall. Similarly, impact and losses developed in this study could also have been converted to operational measures related to production for certain product offerings or lines, number of days shut down, etc.

Once the potential damage and losses have been quantified, the next phase, **Risk Response**, can be implemented to assist management in deciding how to reduce, manage or transfer levels of risk that are identified as being intolerable to the business and its financial and operational goals and objectives. For example, this study identified that the earnings impact loss index for the chemical industry to the 500-year earthquake loss is 930% of the combined industry quarterly pre-tax earnings. This index is expressed as a percentage of the sum of both the direct and indirect loss in a 500 year return period event against the quarterly pre-tax earnings. Consider that a business entity operating in this sector had already developed its risk objectives and has established its risk appetite for extreme event impact on earnings at a maximum of 300% of pre-tax quarterly earnings. This particular study, which includes the **Event Identification** and **Risk Assessment** phases, would suggest to the chief risk officer that the risk from the 500-year earthquake loss is far and above the company's risk appetite, further advising that additional risk response and control measures are required.

In the **Risk Response** phase, risk management and operations personnel need to identify potential risk management measures or actions that could be employed to bring this excessive risk in line with management's objectives and risk appetite. With quantified risk results developed in the Risk Assessment phase, the organization can identify and analyze each plausible risk management activity, considering the cost to implement and the expected value of risk reduction achieved. In fact, many organizations would develop a "blended" approach to managing the identified risk to better optimize the risk management program given the firm's objectives and constraints.

Alternatives that can be considered would include:

- Consider that a business entity operating in this sector had already developed its risk objectives and has established its risk appetite for extreme event impact on earnings at a maximum of 300% of pre-tax quarterly earnings. This particular study, which includes the **Event Identification** and **Risk Assessment** phases, would suggest to the chief risk officer that the risk from the 500-year earthquake loss is far and above the company's risk appetite, further advising that additional risk response and control measures are required.

Each of these alternatives can be quantified in their effectiveness in reducing residual risk, which can then support a cost-benefit analysis to help optimize the risk management process and decision. In fact, these alternatives can be reviewed and “weighted” within the modeling analysis process to support a cost beneficial view of each approach prior to making any changes in a risk transfer or ART program and before conducting any physical improvements. From a business continuity standpoint, a supply chain simulation analysis can also be conducted to “weight” the benefit of each risk management approach prior to embarking upon changes in the supply chain, supplier/vendors or risk mitigation efforts with respect to owned assets.