The 1679 Sanhe-Pinggu Earthquake
Implications for the Modern-Day Beijing Region
ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Since 2000, Risk Management Solutions has been actively engaged in promoting the development of a world-class earthquake insurance market in China, establishing strong connections with the China Earthquake Administration (CEA) and the China Insurance Regulatory Commission (CIRC), as well as other leading authorities in the region. In 2004, RMS published a study on the issues and needs for the formation of a technically sound and commercially viable market for earthquake insurance in China. The study was based on papers presented in the symposium on Earthquake Insurance in China, co-organized by RMS in July 2004 in Beijing. In July 2006, in collaboration with the CEA’s Institute for Engineering Mechanics (IEM), RMS published a 30-year retrospective report on the 1976 Tangshan Earthquake, summarizing the key lessons from the event, including disaster response and reconstruction, the implications of changes in building codes, along with estimates of casualties and economic loss from a repeat of the event today.

This study represents the third report in the series, linking the emerging earthquake insurance market in China and the extraordinary growth of Beijing with estimates of loss from a repeat of the 1679 Sanhe-Pinggu Earthquake. This M8.0 earthquake is the largest historical earthquake in the vicinity of Beijing and one of the most significant events known in the densely populated North China region. Our objective with this study is not only to broaden the awareness of risk, but also to investigate the implications of a repeat of this event on the rapidly expanding insurance and mortgage markets in China.

Over the past decade, China has undergone spectacular economic development. According to the Ministry of Construction, between 2001 and 2005 the country built 2.7 billion square meters of new housing for urban residents along with equivalent amounts of commercial and industrial development. Older construction was also rebuilt or renovated over this same time period. The amount of new construction is equivalent to the total construction completed in the four previous decades. Today, the government is planning the development of satellite cities to service the accelerating urbanization of the Chinese population. In 2006, it was announced that eleven satellite cities are being planned for Beijing alone.

The recent building boom has completely outpaced the expansion of insurance systems to refund earthquake damages. While the CIRC is striving to establish a comprehensive catastrophe insurance system, there are currently only small quantities of industrial and commercial earthquake insurance purchased in China, while earthquake insurance in the residential sector is almost unknown. This lack of insurance take-up is disconcerting, given the dramatic switch from public rental to owner-occupied housing through the 1990s with an estimated 70% of the housing inventory already in private hands. Unfortunately, although a significant portion of this privatization has been funded by mortgage-lending, state owned banks currently do not require mortgaged properties to be insured against earthquake damages. In contrast to the property insurance sector, the life insurance market has expanded to keep pace with the growing economy.

Areas of rapid development in China have not encountered a major earthquake since the 1976 Tangshan Earthquake struck 140 km (87 mi) to the east of Beijing, killing more than 240,000 people and leveling around two million housing units. This potential intersection of development and risk reaches its culmination in the capital city of Beijing, home to nearly 15 million people, and located in a tectonically active sedimentary basin that is prone to ground motion amplification. Over the past several thousand years of recorded history in China, there have been several major earthquakes that caused damage in the city, including the 1679 M8.0 Sanhe-Pinggu Earthquake.

While building standards have improved significantly since 1976 and retrofitting of many of the most dangerous older masonry structures has been completed, a major earthquake close to the city will still cause catastrophic damage and significant casualties. With detailed modeling of ground motions and an understanding of the inventory of buildings across the Beijing municipality, it is estimated that over one half of the 800 billion RMB economic loss (US$100 billion) would occur in Beijing with expected fatalities between 35,000 and 75,000 across the region. Moreover, with the privatization of the housing market and the thriving Chinese life insurance sector, the liability of these losses would fall to a set of stakeholders, including banks, businesses, insurers, individuals, and the government.
THE 1679 SANHE-PINGGU EARTHQUAKE

The 1679 Sanhe-Pinggu Earthquake occurred the morning of Saturday, September 2, 1679 during the Qing Dynasty, which ruled China from 1644 through 1912. According to the historical calendar, 1679 was “the 18th year of the Kangxi Reign,” when the Kangxi Emperor was in power, having assumed the throne at age seven in 1662. In the *Annals of Jixian County*, it was recorded: “Just before noon, the violent earthquake occurred.” In the *Annals of Yutian County*, it was stated that “A great earthquake occurred in the period of the day from 9 am to 11 am.” Modern estimates of the earthquake’s magnitude and intensity have consistently been reported as M8.0, with maximum intensity over X at its epicenter in Hebei Province. Some references also indicate an intensity of VIII in Beijing, which lies approximately 50 km (31 mi) to the west of the epicenter.

The earthquake ruptured the Xiadian fault, a right-lateral strike-slip crustal fault in the North China plain. This fault is part of the Zhangjiakou-Bohai fault system, starting at its northern end in Beijing Province and trending to the southwest, passing close to Pinggu in Beijing Province and Sanhe in Hebei Province. As with other slow moving faults in this region, the recurrence interval of an earthquake of this size on the Xiadian fault is estimated on geological grounds to be around 6,500 years. As a result, while the Xiadian fault is able to produce a very large earthquake, there is a low probability of a repeat of this specific 1679 event in the immediate future. However, other major active faults with long recurrence intervals pass through the Beijing region, constituting additional sources of earthquake risk to Beijing.

1.1 HISTORICAL ACCOUNTS OF DAMAGE

Historical accounts of the impact of the earthquake are limited to the annals of the various counties in the region – Jixian, Sanhe, Tongzhou, Yutian, and Zunhua counties. The official records of the Qing Dynasty stated: “An earthquake occurred in the capital and damage was especially serious in Guan, Baodi, Sanhe, Pinggu, Xianghe,
The Bodhisattva pavilion of the Dule Temple in Jixian County, constructed in 984, was undamaged in the 1679 earthquake (Huixian et al., 2002).

While the annals of the various counties do not generally give estimates on the number of fatalities, historical accounts indicate the extent of casualties. It was recorded that buildings collapsed in Jixian County “killing a huge number of people and livestock.” Official records also note that “numerous officials and common citizens were killed and some families were even completely killed by the earthquake.” In Pinggu, it was observed that “besides those killed by the collapses of the houses, no more than 30 to 40% [of the people] were left.” There was an attempt to learn from the earthquake, however, by recording practical suggestions on how to avoid injury. In the Annals of Sanhe County, it was noted that “if people hide themselves under beds and tables or stand by the side of door or window, they would survive a sudden quake, otherwise, a broken head or cut body would be inevitable.”

1.2 Damage to Ancient Buildings

Separate accounts exist concerning the impacts of the earthquake on palaces, temples, and pagodas. For example, Bai Ta (‘White Pagoda’), built in the 1650s during the Qing Dynasty and located in Beihai Park, an imperial garden northwest of the Forbidden City in Beijing, was damaged in the 1679 event and rehabilitated after the earthquake. Also in Beijing, the arrow tower of Deshengmen Gate (‘Gate of Virtuous Triumph’), first built in 1436 and one of the few surviving city gates, was demolished in the Sanhe-Pinggu Earthquake and was rebuilt following the event. In Jixian County, the Bodhisattva pavilion of Dule Temple, which was built in 984, was one of the few buildings to survive the earthquake undamaged: it was stated that “…since the quake strongly struck, no official buildings and residential houses survived and only the Bodhisattva pavilion of Dule Temple stood rock firm.”

![The Bodhisattva pavilion of the Dule Temple in Jixian County, constructed in 984, was undamaged in the 1679 earthquake](image)

Wuqing, Tongzhou, and Jixian.” In addition, it was noted that “buildings in Beijing were seriously damaged.” Surface fault rupturing and liquefaction were recorded in Sanhe and Pinggu. In Sanhe, “the ground split in many places and dark water flooded everywhere” while in Pinggu, “the split in the ground was about 3 meters wide, dark water rushed out from the gap.” In Pinggu, the mountains were observed to move, where they “staggered loosely like the teeth of a saw… Some peaks were even cut in the middle and the collapsed rocks dashed into the earth quite deeply.” Cracks in the ground were also witnessed in Jixian County, where “ground fissures appeared everywhere and black water was spouting fiercely with foul smell.” From the Annals of Sanhe County, one observer noted the sounds of the coming earthquake: “In the morning, I had just finished my official business and retreated to my western sitting room for a rest… when I was dozing, a sudden sound, like a fired cannon, came up underneath the ground, then followed with a thousand of cannon firing and earth-sounds came from all around, somewhat like being attacked by thousands of army soldiers and galloping horses. I was suddenly aware of an arriving earthquake and immediately jumped out…” Similarly, from the Annals of Jixian County, it was observed: “the thunder-like cracks burst in the sky and rumbles like thousands of running carts underground were heard. During the instantaneous disaster the whole cosmos appeared to have turned over and a murky sky covered the dark earth.” Damage in the form of building collapse and fires following the earthquake was recorded as well. In Sanhe County, “many houses collapsed and the remaining fire in kitchen ranges spread underneath the ruins.” In the city of Sanhe, “city walls and houses were almost completely destroyed.” In Jixian County, “countless buildings and structures suddenly collapsed; aftershocks occurred successively; people dared not return to their rooms.” In Tongzhou County, “fire occurred at many places in the city.” Additionally, although farther from the epicenter, in the Annals of Zunhua County, it was recorded that: “an earthquake with thunder-like sound came from the northwest direction and the ground swung like a boat, and a great number of official and residential buildings were destroyed.” Interestingly, in the Annals of Yutian County, it was observed that “temples, buildings, and city walls east of the capital were almost totally collapsed and that only buildings in Yutian were intact.” This historical account supports the theory that Yutian was an area of lower intensity as a result of improved site conditions. The existence of areas of reduced ground shaking amidst a region of high levels of damage was also observed during the 1976 Tangshan Earthquake (Huixian et al., 2002).
Throughout the history of China, numerous catastrophic earthquake events have impacted the mainland. Official figures from the Chinese government show that 550,000 people have died from earthquakes since 1900. If one considers the 2,000 years of chronicled history, total earthquake fatalities are around four times this number. Historical records also report the lessons concerning earthquake hazards learned by the people over the centuries to protect themselves against earthquake hazards. In more recent years, the Chinese government has formalized this management of risk through the establishment of the Chinese Earthquake Administration (CEA) and seismic design codes for building structures. As China looks to the future and the establishment of a robust insurance market, catastrophe models will play a key role in managing this risk.

2.1 Lessons in Earthquake Resilience

Throughout the historical record of China, knowledge concerning the struggle against earthquake hazards has been passed down from generation to generation. In particular, historical records document ways to survive the ground shaking from an intense earthquake, as well as observations on the earthquake-resistance of certain materials and ancient building structures. Following the 1556 Huaxian Earthquake in Shaanxi Province, one survivor wrote: “...if possible residents are encouraged to build a wood framework with a plank ceiling and employ a large wood bed with strong foot-columns in a room for the seismic season. In case a sudden quake strikes and there is no time to run out, it is best to hide under the bed and then wait until tranquility returns. Even if the house collapses, people could still be safe where they had chosen to remain in the open space outside beforehand for protection.” After the 1668 Tancheng Earthquake in Shandong Province, “the local people built their temporary shelters out of reed mats in order to prevent them from being killed by falling structures.” Many lived in temporary shelter for months following the event.

Throughout history, accumulated observations indicate that traditional Chinese timber frame structures resist strong ground shaking. For example, a 60 m (197 ft) tall pagoda built of wood in Yingxian County of Shaanxi Province was erected in 1056 and survived strong earthquakes in 1303, 1368, 1626, and 1976. In the Annals of Yingxian County, it was written: “The wood pagoda experienced quite a number of quakes.

However, it stands majestic and firm.” After 1949, as large scale urbanization led to the construction of unreinforced masonry or concrete multi-family dwellings, new strategies were needed for these massive buildings to develop resistance to earthquake damages.

2.2 Risk Management in Modern China

One significant element of risk management requires preparation for the occurrence of an earthquake, so as to minimize the human and economic losses as well as accelerate the reconstruction process. Since the founding of the People’s Republic of China in 1949, the Chinese government has been concerned about the potential consequences of devastating earthquakes, particularly in the densely populated and earthquake affected regions of North China, including the cities of Beijing, Tianjin, and Tangshan. The monitoring and prediction of earthquakes, as well as funding for disaster prevention efforts, intensified following the 1966 Xingtai earthquakes in Hebei Province, which marked the beginning of a period of high seismic activity (the “fourth high activity time period”) in North China (See RMS, 2006).

In 1971, the Chinese Earthquake Administration (then known as the State Seismological Bureau) was established to manage earthquake risk in China. At the Chinese Earthquake Administration (CEA), there are three main areas of work: earthquake monitoring and prediction, earthquake preparedness, and emergency response. While methods to monitor earthquakes are important, it is earthquake preparedness, both in terms of seismic design and training, which most directly reduces human and economic losses. The Chinese gov-
ernment has invested significant effort in reducing the vulnerability of the older masonry building stock with a wide scale strengthening program, as well as with the enforcement of seismic design codes, first published in 1955. The government also strives to educate Chinese citizens on ways to prepare, prevent, and reduce the impacts from an earthquake disaster.

2.3 The Role of Catastrophe Modeling

One key tool in both evaluating earthquake risk and in managing catastrophes is a fast and accurate method for loss estimation. The RMS® China Earthquake Model meets this need by estimating losses from a comprehensive set of earthquake events which could impact the region, informed by years of historical earthquake activity throughout China. Output from the model can be employed to determine the extent of an earthquake’s impact, or to explore the overall technical risk costs at a location, measured in terms of an average annual loss (AAL) for a single property or a portfolio of properties.

While the principal use of catastrophe models has been in the insurance sector, increasingly finance and government sectors are making use of catastrophe model outputs. The model can be employed to provide the technical foundation of any system of risk sharing, as well as for identifying the most cost-effective means of mitigating the losses from natural catastrophes. For example, a scenario analysis, similar to the study presented in this report on a repeat of the 1679 Sanhe-Pinggu Earthquake, can be utilized to implement disaster plans in response to a catastrophic event. A probabilistic analysis can also be completed to determine the appropriate framework for a catastrophe insurance pool.
Mainland China is the most seismically active continental region on Earth, lying within a broad zone of intraplate seismicity that fans out from the Himalayan collision zone towards the Korean peninsula. Many of the principal cities in China lie within zones of active tectonics, including the urban area of Beijing which contains the cities of Beijing, Tianjin, and Tangshan. In this region, there have been 160 earthquakes over M5.0 recorded in history and thirteen strong earthquakes M7.0 or higher. These include the 1626 Lingqu Earthquake, the 1679 Sanhe-Pinggu Earthquake, and the 1976 Tangshan Earthquake, as well as the aftershock north-east of Tangshan. These events, if they were to recur today, have the potential to impact large concentrations of population and exposure in the fault bounded plain.

3.1 Hazard

From the set of historical events impacting the Beijing region, the M8.0 1679 Sanhe-Pinggu Earthquake is chosen for analysis purposes as it is the most significant event in the historical record in the vicinity of Beijing. Consistent with the historical event, this analysis assumed an M8.0 earthquake on the Xiaodian fault, centered at 40.0°N and 117.0°E, situated 50 km (30 mi) to the east of Beijing. It should be noted that the earthquake modeled in this study is not the earthquake with the highest occurrence probability in this region.

The ground motion from the event is calculated using the RMS® China Earthquake Model, which uses region-specific attenuation functions to calculate the expected peak ground acceleration (pga) and spectral acceleration (Sa) at a given location. Overall, this event would be felt in the provinces of Beijing, Hebei, Liaoning, Shandong, Shanxi, and Tianjin, as well as in Inner Mongolia. The highest ground motions would be in the immediate vicinity of the fault rupture in the cities of Pinggu and Sanhe, as well as parts of Hebei and Beijing provinces.

In order to calculate accurate ground motion estimates, special consideration was given to the amplification of ground motion due to the surficial geology. The proprietary RMS geographic indexing system known as the variable resolution grid (VRG) was used to store information about soil classifications and their potential for liquefaction throughout China. Softer, sandy soils have lower shear wave velocities, which give rise to larger ground motions than harder, rocky soils. As shown in the 1985 Guerrero-Michoacan (Mexico City) Earthquake, long period ground motions from large earthquakes at great distances (i.e., magnitudes > 7.0 at distances > 50 km) can adversely impact buildings over ten stories. These effects are of particular concern for mid and high-rise structures in the parts of Beijing that are further away from the fault rupture of the 1679 event.

In addition, liquefaction occurs when strong ground shaking causes loosely packed soil particles to become more tightly packed, raising soil water pressures and causing the material to lose its strength. When the soil liquefies, the overlying buildings can sink into the ground, causing extensive and often irreparable damage. The highest potential for liquefaction is on alluvial soils in floodplains, which are widespread in the North China plain. As noted in the historical record, there was major liquefaction reported in the 1679 Sanhe-Pinggu Earthquake, and widespread liquefaction could be expected in a repeat of the event.

3.2 Exposure

In this scenario, the strongest ground shaking would impact both Beijing and Hebei. This analysis, however, is principally focused on the 18 administrative subdivi-
sions (districts and counties) of Beijing Province, which has grown considerably in population and building inventory over the past ten years. In 1996, Beijing contained 10 districts and 8 counties with 12.5 million people, including permanent residents and transient population. In 2005, there were 16 districts and 2 counties administered by Beijing with close to 15 million permanent and temporary residents. The designation change from county to district is significant, as districts are traditionally subdivisions of urban areas with built-up areas only. The province is further subdivided into 273 townships and contains 1.1% of the total population of China. The value of the building inventory in the 18 administrative subdivisions of the Beijing municipality, including structures and their contents, is estimated at over 570 billion RMB (US$75 billion) for residential properties and 920 billion RMB (US$120 billion) for commercial and industrial properties (based on NBS, 2005).

3.2.1 History of Beijing

Beijing (‘Northern Capital’) has a long history and over time has had many names. It was first established as a town named Ji in the Yan State two thousand years ago. As time went on, it became an important city in North China during the Jin, Liao, and Yuan dynasties. Numerous ancient buildings, such as palaces, pagodas, temples, and tombs, have been built in Beijing. During the Ming Dynasty from 1368 through 1644, Beijing began to resemble its current configuration when the Beijing city wall, the Forbidden City, and the Temple of Heaven were constructed. The Forbidden City was the Imperial Palace of both the Ming Dynasty and the Qing Dynasty, which ruled from 1644 until 1912, when Emperor Puyi abdicated his throne in February of 1912 following the Xinhai Revolution.

From 1912 through 1949, various factions fought over control of the region. In 1928, and again in 1945, Beijing’s name was changed to Beiping (‘Northern Peace’) to indicate that it was not the true capital of China, as the national capital was Nanjing. In 1949, following the Chinese Civil War, the Communist Party of China changed the city’s name back to Beijing when it established the People’s Republic of China with the city as its capital.

Since 1949, there have been five national censuses conducted in China: in the years 1953, 1964, 1982,
1990, and 2000. According to the National Bureau of Statistics (NBS) of China, the total population of China grew from under 600 million in 1953 to 1.3 billion in 2000. Yearly growth rates were at their maximum in the 1960s at over 3 percent but started to fall in the 1970s and have fallen to under 1 percent in recent years (NBS, 2001). Population has been projected to have a zero growth rate over the coming decades, primarily due to the government-led policy of one child per family. During this same time, however, the population of Beijing has grown, particularly since the 1970s primarily due to migration and administrative border expansion. In the 1990s, it became more pronounced due to the rapid economic growth in the capital.

3.2.2 Growth of Beijing

The growth of Beijing from the 1950s to 2007 is unique. Cities in the United States often have skyscrapers in the center with other commercial mid-rise structures encircling the downtown central business district (CBD). As one moves out from the city center, low-rise residential structures become more prominent. Beijing, in contrast, has low-rise historical buildings at its center (i.e., in the Forbidden City) and is surrounded by commercial skyscrapers and residential towers. Within 250 m (820 ft) of the Forbidden City, no structures over three stories tall are allowed to be built. In addition, within the 2nd Ring Road, buildings are restricted to 10 stories or less. Modern single-family dwellings are rarely seen in Beijing.

In the 1950s, housing was built by the government in Beijing but little was built in the coming decades until the late 1970s. At this time, many individuals returned to the city seeking jobs following the events of the Cultural Revolution, and many younger couples began looking for their own housing apart from their families. By 1979, the housing market was oversaturated and an overdue housing boom began. It is estimated that over 95% of the current residential exposure in the urban area of Beijing has been built since this time. As for commercial and industrial construction, in the 1980s, low-rise industrial plants were moved to outlying areas of the city and in the 1990s through today, mid and high-rise commercial
buildings were built throughout the city. Census data shows that two-thirds of the commercial building stock has been built since 1990. The CBD, which is currently under enormous development, is primarily located on the eastern edge of the urban area between the 3rd Ring Road and the 4th Ring Road. In the Guomao area, there are a number of regional corporate headquarters and retail shopping areas, including the famous Wangfujing Street, housing many high-end shopping stores.

Due to the change in patterns of daily movement of people within the urban areas of Beijing (i.e., living and working in separate parts of the city), the transportation network has grown over the past few decades, as has traffic with it. The transportation network in and out of Beijing is dominated by concentric ring roads, starting with the 2nd Ring Road, built in the 1980s and encircling the four districts of Dongcheng, Xicheng, Chongwen, and Xuanwu. The 3rd Ring Road, the next concentric ring, was completed in the 1990s and is a major highway in the region that goes through the CBD. It also connects to the major highways in the area, including the expressway to the airport. It is elevated for much of its length and as a result, is vulnerable to collapse in a large earthquake event. The 4th Ring Road and the 5th Ring Road are 8 km (5 mi) and 10 km (6 mi) respectively from the city center and connect the suburban areas of Beijing. The 6th Ring Road is the last road encircling the city, linking Beijing with the districts of Shunyi, Tongzhou, Changping, and Daxing.

Moreover, in 2007 Beijing is a major transportation hub for the region and the Beijing Capital International Airport is the busiest airport in China. In 2008, Beijing will host the Olympic Summer Games. Construction for the event is especially intense to the north of the city center, where the Olympic stadiums and village are being built.

3.3 Building Vulnerability

The RMS spectral response methodology provides advanced modeling of the vulnerability of property risks. The methodology uses an objective measure of ground motion intensity (spectral acceleration) to directly correlate ground motion to building performance based upon building height, construction material, and ground motion propagation. Individual vulnerability curves are
used for predominant construction types in the Beijing area (e.g., reinforced concrete and masonry) for buildings of various heights and years of construction. As there has not been a major earthquake in the vicinity of a large Chinese urban area in recent years, empirical evidence regarding the vulnerability of the modern buildings in Beijing was derived from other regions with comparable building styles and standards (e.g., the 1999 Chi-Chi Earthquake). In addition, the seismic zonation map of China was used to determine capacity parameters for the predominant construction types, as the construction in Beijing is designed to withstand intensity VIII.

Since 1990, reinforced concrete has been the primary building material used for residential and commercial construction in Beijing, comprising two-thirds of the building stock. Additionally, a significant percentage of the residential and commercial construction is over 15 stories tall. Industrial structures, however, are primarily low-rise masonry construction in the form of confined masonry and some unreinforced masonry. Wood frame construction is present in buildings constructed before 1979; however, these are minimal throughout the region since wood frame buildings are more predominant in rural areas.

The buildings most susceptible to collapse are unreinforced masonry buildings, as clearly demonstrated during the 1976 Tangshan Earthquake. However, only a small percentage of residential and commercial buildings in Beijing are constructed using unreinforced masonry walls, with a slightly higher percentage of industrial structures built with unreinforced walls. The majority of the building stock (comprised of reinforced concrete and reinforced masonry buildings) are susceptible to cracking and partial or full collapse in an earthquake. Fortunately, the majority of the modern mid and high-rise buildings built with reinforced concrete in the Beijing region are designed with seismic resistance, either through a moment resisting frame or a shear wall. A significant portion of the damage to multi-story buildings will be the non-structural masonry infill walls and the façade materials. Comparatively heavy damage to residual, commercial, and industrial properties would also occur in areas with poor soil conditions subject to liquefaction, as is the case in the Beijing region.

### 3.4 Casualty Vulnerability

Based on the latest population information available from the National Bureau of Statistics of China (NBS, 2005), the population density of Beijing Province is close to 890 people per km² (2,280 people per mi²). The urban population contained within the 6th Ring Road is 7.5 million. This urban center has a density of 6,000 people per km² (15,400 people per mi²). If one considers the entire region impacted by a repeat of the 1679 Sanhe-Pinggu Earthquake, an estimated 45 million people are at risk.

Building collapses are the primary cause of casualties from earthquakes, with the number of people killed rising with the total number of collapsed structures. The residential occupancy level is a major factor affecting the number of people killed in an earthquake.

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**Estimated economic loss to the commercial, industrial, and residential lines of business in the Beijing municipality from a repeat of the 1679 Sanhe-Pinggu Earthquake**

![Graph showing estimated losses in various districts of Beijing](image)
In Beijing, with high population and building density, the fatality levels are generally higher than other less dense regions, as the earthquake impacts more buildings and kills more people per collapse. Buildings in the urban area of Beijing accommodate large numbers of occupants, where commercial office buildings and residential towers can contain thousands of people at a time. While these tend to be built more recently under more stringent design codes, and thus less likely to collapse, if any of these highly populated structures do fail, the loss of life could be considerable.

The time of day an earthquake occurs can also affect the number of people killed and injured. Variations are based on the locations of the population at a particular time and the relative vulnerability of the residential and commercial building stock. Casualties from earthquakes in the early morning hours (between midnight and 6 am), when most people are asleep, are determined by the vulnerability of residential buildings and are higher overall. Losses from an earthquake that occurs during work hours primarily depend on the performance of commercial buildings and have lower overall casualty levels, as commercial buildings are generally built to more stringent earthquake resistant design codes.

3.5 Social and Economic Losses

In the RMS study completed here to determine the impact of a repeat of the 1679 Sanhe-Pinggu Earthquake on the 18 districts of Beijing Province, the highest ground motions and mean damage ratios (defined as the ratio of the expected monetary damage to total exposure value) would occur in the districts of Pinggu, Tongzhou, and Shunyi on the eastern side of the province closest to the epicenter. The highest overall loss numbers, however, are expected in the two districts containing over 30% of the total exposure value: Chaoyang and Haidian. Total economic damages from ground shaking are estimated at approximately 445 billion RMB (US$57 billion), with 265 billion RMB (US$34 billion) in commercial and industrial damage to structures and their contents and 180 billion RMB (US$23 billion) in residential damage to structures and their contents. It should be emphasized that the property losses estimated in this study include residential, commercial, and industrial property and contents losses only. No losses were explicitly calculated for the cost associated with business interruption (BI) or displaced households. Additionally, no estimates of loss due to fire following the earthquake or loss associated with infrastructure damage (e.g., transportation or power networks) were calculated.

In order to estimate the casualties from this event, it is important to know the time of day and day of the week. Historically, the 1679 Sanhe-Pinggu Earthquake occurred on a Saturday in the mid-morning hours (between 9 am and noon). However, if this event were to recur, it could happen on any day at any time. As a result, it is more appropriate to consider a range of values when estimating casualties. RMS estimates that the total number of casualties across the entire impacted region (i.e., parts of Beijing, Hebei, Tianjin provinces), including fatalities and injuries, would be between 200,000 and 300,000. Casualties alone are expected to be between 35,000 and 75,000. Of these total estimates, over one-half would occur in Beijing Province.

Some implications of this analysis merit highlighting, including the magnitude of the loss and the major loss component. Based on the total exposure value for the residential, commercial, and industrial lines of business, the total mean damage ratio for Beijing Province is close to 30% (i.e., ratio of 445 billion RMB to 1.49 trillion RMB). Historically, this would be the largest economic loss to the North China region with the largest component of loss from commercial property damage. Damage to commercial buildings would certainly impede economic growth in the region for many years. Moreover, while there have been historical earthquake events in China with larger losses of life, thousands of individuals dying as a result of a repeat of the 1679 earthquake would constitute a major catastrophe.
In the changing economic landscape of the Beijing region, there are significant implications for the various stakeholders in recovering from an event such as the 1679 Sanhe-Pinggu Earthquake. In the past, disaster recovery has been supported mainly by Chinese government funds and social donations since housing was state-owned and there was a lack of a comprehensive catastrophe insurance system. In the future, as the middle class grows in China and the housing market continues to be driven by private capital, the burden of loss will fall to individuals and recovery will be provided through other mechanisms, including insurance.

The purpose of insurance is to provide a significant component of the costs of restoring properties after a catastrophic event. It is useful to explore the role of insurance in China, and in particular in Beijing, both as it is at present and how it could develop, in order to assess how Beijing would recover both socially and economically after an earthquake such as that of 1679. In addition, while the insurance industry inherently accepts the concept of catastrophe loss, other sectors of the economy, such as the property mortgage industry, might not be aware of the impact of an event of this magnitude on their financial solvency.

4.1 IMPACT ON PROPERTY INSURANCE INDUSTRY

The property insurance market has experienced sustained growth, especially since joining the World Trade Organization (WTO) in 2001. In the successive four years, non-life insurance premiums grew on average by 15.3% per year. In parallel with increased trade, the number of fully licensed insurance companies has risen to more than 90 with the People’s Insurance Company of China (PICC) continuing to dominate the market. However despite this rapid economic expansion, there are currently only a small number of industrial and commercial earthquake insurance policies purchased in China, while residential earthquake insurance is almost unknown. Insurance growth is mostly concentrated in an increased take-up in motor policies.

In 2007, non-life insurance take-up in China is only around 0.7% of GDP, compared to 3.75% of GDP in the United States. Property insurance policies in China do not generally include automatic coverage from earthquake damage—the coverage is available but must be purchased separately. Most Chinese consumers still do not buy the earthquake insurance extension, as household insurance is not a requirement for purchasing a mortgage. In the commercial property market, earthquake coverage is not widely purchased with the exception of foreign companies and for facilities developed with international investment.

In order to estimate the insured losses from a repeat of the 1679 Sanhe-Pinggu Earthquake, it is necessary to know the nature of the building stock at risk, including its values and vulnerabilities, along with the typical policy conditions. No central agency collects details of the total value of insured property exposure in Beijing. For the purposes of this study, exposure values have therefore been developed for the residential, commercial, and industrial property lines based on a range of available datasets.

According to the Yearbook of China’s Insurance 2006 (CIRC, 2006), the annual property premium in Beijing is 533 million RMB (US$69 million). Assuming the proportion of premium associated with policies which cover earthquake damage is 15%, this translates to 80 million RMB (US$10.3 million) of premium charged annually for earthquake coverage. Average rates for earthquake insurance can range between 0.02% and 0.1% of the value of the property, with commercial coverage at the lower and industrial coverage at the higher end. Deductibles are commonly 10% of the loss with limits of 80% of the total insured value. Given the fact that the majority of earthquake coverage is for commercial and industrial lines of business, a rate of 0.08% was used to calculate the insured value of the property in the 18 administrative subdivisions of Beijing. At approximately 100 billion RMB (US$12.9 billion), the insured value constitutes only 7% of the 1.49 trillion RMB (US$193 billion) economic exposure.

As in any country in which insurance penetration rates are low, the characteristics of the buildings that are insured is likely to differ from the average building stock that would be considered in the total economic inventory. The vast majority of insured buildings are of very recent construction, since they represent those buildings that house the concentration of recent investment.
growth in the city. To capture the difference between the insured portfolio and the total building stock, losses to the estimated insured exposure have been calculated using a portfolio populated by buildings built between 1990 and 2006.

From these assumptions, RMS estimates that if the 1679 Sanhe-Pinggu Earthquake were to recur in 2007, only 20 billion RMB (US$2.6 billion) or approximately 4.5% of Beijing’s total economic damage of 445 billion RMB (US$57 billion) would be covered by earthquake insurance. This indicates a lower damage ratio as compared to the general building stock, reflecting the way in which modern construction is more likely to withstand strong earthquake ground motion.

4.2 Impact on Mortgage Industry

Starting in 1988, residential properties in China that were previously government-owned have been sold at subsidized rates to their occupants. As the housing market emerged and the availability of subsidized housing dried up, housing reforms were implemented in 1998, fueling a vigorous real estate market. In 2007, property ownership has become mainstream and trading up to larger more modern apartments is a key feature of city life. An estimated 70% of the housing inventory is in private hands; in the urban regions of China, such as Beijing, this estimate is even higher at over 85%.

While part of the residential building stock is owned outright by former workers of the state through subsidized housing programs, there is a significant subset of residential property that is mortgaged. The newly developed residential building stock and the commercial building stock built in Beijing since 1990 comprise the majority of the mortgaged property. While mortgages are a relatively new feature in China, the mortgage market has grown considerably over the last ten years from 13 billion RMB (US$1.7 billion) in 1997 to over 1.5 trillion RMB (US$194 billion) in 2005.

To get a mortgage in China, it is necessary to purchase income protection but property insurance or an earthquake extension are not required. As a consequence, earthquake coverage for mortgaged residential properties is very unusual. In the absence of insurance, there is a rapidly growing liability to the banking sector in the form of loss of mortgage repayments in the event of an earthquake, as borrowers might default their repayments if a property is severely damaged or destroyed in an earthquake. In the event of a catastrophic earthquake, banks would also experience financial loss from collapsed or badly damaged buildings, for which the borrower would be unable to fund the repairs. Also, starved of rental income, many building owners would be unable to service the loans taken out to fund the development of a multi-story office or apartment complex.

At the end of 2005, the total market value of mortgages in Beijing was 441 billion RMB or US$57 billion (Liu, 2006). These loans are spread between the residential and the commercial sector and, in both sectors, the mortgaged building stock is assumed to be of similar building inventory types and ages to the insured exposure, almost all concentrated among more recent construction. In order to estimate the loss from a repeat of the 1679 earthquake to this sector, it is necessary to determine the replacement value of the building stock as it differs from the market value. The average replacement cost for residential and commercial construction in Beijing is 2,160 RMB per square meter (NBS, 2005) but the market value is 6,770 RMB per square meter, translating to a difference of 3.13. Based on this scaling factor, the corresponding replacement value for the mortgages in Beijing is 140 billion RMB (US$18 billion) and the expected loss from a repeat of the 1679 earthquake is 37 billion RMB (US$4.8 billion).

It should be emphasized, however, that the liability of the lenders lies in the market value, which includes buildings and the land on which they are built. Moreover, if the greatest risk to the lenders is considered to be the inability of the borrowers to meet mortgage repayment schedules, the loss is more faithfully modeled by estimating the total number of mortgage agreements that could default.

4.3 Future Growth of Insurance and Mortgage Industries

China’s GDP is increasing by 9% year on year, and this increase in individual wealth indicates that at some point insurance penetration will expand faster than the current growth rates. Assuming a continuation of the increase in property insurance that has taken place over the past
Expected growth in earthquake insurance as a function of property exposure in Beijing through 2015

three years, by 2015 insured exposure can be projected to grow from 7% to 20% of the total exposure value in Beijing. In today’s money, insured losses from a repeat of the Sanhe-Pinggu Earthquake could increase from the currently estimated 20 billion RMB (US$2.6 billion) to 70 billion RMB (US$9 billion).

Today, mortgage loans in China hover above 10% of GDP; still significantly below the 26% and 50% seen in neighboring Korea and Hong Kong respectively. As a consequence, banks and other lenders will be increasingly exposed to the risk of catastrophic earthquake losses unless mortgage lenders demand, as in many developed countries, that property insurance also covering earthquake is sold in conjunction with the mortgage. This risk is one that should be considered at the board level in these financial institutions, as the occurrence of a catastrophic earthquake could seriously threaten their solvency.

This potential for the destabilization of the financial sector reinforces the need for regulatory and financial communities to embrace those risk management measures, including insurance, which would protect the economy from the severe setback that would follow a catastrophic earthquake.

4.4 Impact on Life Insurance Industry

The life insurance market in China has been growing rapidly over the past decade. While still not reaching the penetration rates seen in neighboring countries such as Japan, where life insurance take up rates can be over 70% of the population, a large earthquake would have a serious impact on the Chinese life insurance industry. Life insurance penetration in Beijing is approximately six times the average penetration rate in the country as a whole. A severe earthquake in Beijing that causes significant casualties would therefore have a disproportional impact on the life insurance market in China.

Based on information from the Yearbook on China’s Insurance 2006 (CIRC, 2006), it can be assumed that the average person with individual life insurance has a policy that covers them for about 1.2 million RMB (US$155,000). The average worker with group life insurance is covered for approximately 64,000 RMB (US$8,300). Assuming that only 20% of those killed in a repeat of the 1679 Sanhe-Pinggu Earthquake have individual life insurance, and a mean number of fatalities of 55,000, the individual life insurance industry would lose approximately 1.6 billion RMB (US$207 million). The group life industry would lose approximately 704 million RMB (US$91 million) using the same penetration rates. If one assumes a higher group life penetration rate of 50% of the population killed in the earthquake, the loss to the group life industry could be 1.8 billion RMB (US$233 million). Given that yearly premiums from both group and individual life insurance are approximately 47 billion RMB (US$6 billion) in Beijing, losses of this magnitude could represent anywhere from 40% to 80% of annual life insurance premium.

4.5 Conclusions

This study has set out to show the potential implications of a catastrophic earthquake in the vicinity of Beijing on the region’s building stock, infrastructure, and population, as well as the serious financial consequences for the insurance and banking sectors. To avoid accusations that the catastrophe under consideration is not credible, a well understood historical earthquake from 1679 has been chosen for the study. The earthquake was the most catastrophic in the region around Beijing, despite being located on the Xidian fault situated 50 km (30 mi) east of the city. However, given the relatively slow slip rate of this fault, the chance of the 1679 event recurring is remote and the next major earthquake is likely to be on one of the other faults to the north and west that pass close to the city. It may not be as large as the earthquake of 1679 but it could be much closer to the center of Beijing. It is important that Beijing’s earthquake risk is evaluated employing probabilistic catastrophe modeling capability that considers a full range of potential locations, sizes and probabilities of such earthquakes, as will the RMS® China Earthquake Model being released in mid-2007.

For those concerned with the well being of Beijing, the information provided in this study can guide planning for how the financial impact of the losses could best be managed, in particular through earthquake insurance. Beijing has grown far faster than the institutions of financial risk management that are required to sustain a major city through a disaster. A period of rapid growth in
insurance is now required to catch up with the extraordinary growth that has already taken place in the private property market. Today, if an uninsured property is lost, unless the government steps in, the average earner will need 20 years of accumulated earnings to repurchase a 50 m² (540 ft²) dwelling. Proper and effective financial risk management will require establishing a linked chain of institutions and protections. Insurance is required to support mortgages, while statewide catastrophe pools and reinsurance are required to ensure the solvency of insurance companies in the event of a major catastrophe in a principal city of China. To ensure the viability of all components of the financial risk management system in the aftermath of a catastrophe, both the insurance companies and the banks offering mortgages need regulation to ensure they have the appropriate levels of capital and risk management procedures in place.

The key question for China concerns whether it is possible to create a system that provides high-quality catastrophe insurance to as many people as possible without first experiencing a major earthquake in a large urban area. While there are many lessons to be learned from countries such as Turkey that have been able to create a universal catastrophe insurance system covering earthquake and flood risk (i.e., the Turkish Emergency Flood and Earthquake Recovery Program, or TEFER), this was only possible in the aftermath of the catastrophic earthquakes of 1999. Following the 1976 Tangshan Earthquake, major improvements were made to construction standards and building codes in China. With respect to 30 years ago, the building technology improvements embraced and implemented so thoroughly by China have already greatly reduced the loss of life and livelihood an earthquake would cause in urban Beijing. A similar level of initiative is now required to take forward the expansion of catastrophe insurance.