

Just-in-Time Inventory: Effects on Earthquake Recovery



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Executive Summary

How long could your business survive without replenishing inventory? It's an important question if you're in earthquake country. This paper uses the Seattle area as a case study of how crucial it is to understand inventory and supply chain practices as part of earthquake preparation.

Geologists say a magnitude 6.7 earthquake could strike along the Seattle fault that runs through King County. The earthquake could kill or injure thousands of people and disrupt the economy of the region. It could badly damage homes, office buildings, manufacturing plants, schools, port facilities, utilities, and transportation routes from the south end of downtown Seattle east through Bellevue and throughout river valleys north and south of the cities. Other earthquake dangers are a magnitude 9.0 Cascadia subduction zone quake, which could disrupt the economy of the entire Pacific Northwest, and deep earthquakes like the 2001 Nisqually quake.

A rarely discussed problem that could stall the recovery of our area is the widespread practice of Just-in-Time (JIT) inventory. JIT can help local businesses compete in global markets when it saves warehousing costs. After a major earthquake, however, it could lead to shortages along supply chains for many industries and services.

Many businesses in the Puget Sound area use warehousing or distribution facilities in the Kent or Duwamish Valleys. These areas have soils in that are prone to liquefying during ground shaking. When soil liquefies, it loses cohesion and may be unable to



Figure 1. Road damage like that from the 1965 Olympia earthquake could make it difficult to resupply many businesses throughout Puget Sound.

support structures, causing serious building damage. In addition, many warehouses are tilt-ups, which perform poorly in quakes.

Making it worse, roadways and bridges disrupted by shaking or blocked by debris may stop or slow transit for days, weeks, or even months (see Figure 1).

To help our community plan for this disaster, the Cascadia Region Earthquake Workgroup (CREW) invited a group of Puget Sound business representatives to discuss potential post-earthquake concerns.

They identified the following post-earthquake issues, listed in order of importance:

1. **Personal concerns** such as childcare, food, and shelter, including effects on businesses because of injuries or deaths to employees and customers.
2. **Loss of power** during and immediately following the event. Specific effects vary by industry
3. **Loss of surface transportation** — the ability to get employees and inventory to and from work, and access of emergency vehicles and repair equipment to damaged areas.
4. Questions of the **ability of businesses to communicate with customers**, from being open for business to the general loss of communication services during and after a disaster.
5. **Physical loss and damage** to business structures and facilities.
6. Questions of the **capacity of hospitals** and health care facilities to accommodate people injured by the earthquake, while continuing to provide care to people ailing from other causes.
7. Losses because of limited **Just in-Time inventories**.
8. **Potential for permanent loss** of businesses due to weeks or months of damaged infrastructure.

This paper focuses on inventories, but all factors are interrelated. It would be a mistake to focus only on inventories; equally it would be a mistake to ignore this critical component of business operation.

Without adequate inventories, immediate response such as emergency shelter, food, water, and medical treatment may be compromised. Longer term recovery cannot take place if businesses can't provide goods, services, and jobs.

Introduction

Could your business survive if you couldn't get inventory replenished for a couple of days? A week? A month? How quickly an area recovers after a major earthquake may depend on how well businesses are prepared for it. Families and neighborhoods cannot restart and rebuild their lives unless there are materials to use and jobs to provide income. The business sector is a critical part of any long-term recovery.

This report is a case study of potential problems with inventory after a major quake in Seattle. Other areas have similar potentials for quake-related damage, and business continuity planners from California to British Columbia can adapt the analyses and conclusions in this paper to their cities.

It is obvious that companies must plan for the safety of their staff and facilities. But history has shown that staff members cannot and will not attend to business responsibilities until they know their own families are safe. After the Nisqually earthquake, 60% of people left work to check on their families. So it is important for businesses to help employees prepare safety and response plans for family members. Workers simply cannot focus on business tasks until they know their loved ones are safe.

Recovery plans must also include strategies to retain customers and vendors, and a recognition that surface streets may be impassable for some time. A particular issue is that Just-in-Time (JIT) inventory practiced by many businesses may leave the area—or at least specific sectors—without adequate supplies, if warehouse facilities and transportation networks are damaged.

These were the conclusions of a group of Puget Sound-based business representatives that met at the request of the Cascadia Region Earthquake Workgroup (CREW). They identified and discussed

problems that could deter the rapid resumption of business operations following a major earthquake (see Figure 2). Their concerns were incorporated into a report titled *Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault*.¹

Representatives of hospitals, manufacturing, and retail sectors quickly realized that they had just a day or two of inventory and were supplied by vendors using surface streets. Many of the suppliers had their offices and warehousing in the Duwamish and Kent valleys. These valley soils lose strength and flow like a liquid during an earthquake but similar soils are found in other areas. Because of the geology of Puget Sound, if

a surface street in the Seattle area is long enough, there is a good chance it will intersect vulnerable soils (see Figure 3). The danger is not just that the roadway will break up, but that buildings along the streets will be damaged, blocking transportation routes with debris. Emergency vehicles could have trouble reaching those injured or trapped, and repair crews will not be able to get through.

Restoring business operations will depend on the recovery of individual supply chain resources. This in

turn depends on having intact surface streets and physical access to businesses and off-site warehousing facilities.

This document provides a three-part, general assessment of the risk to supply chains of King County businesses should the Duwamish and Kent Valleys be affected by an earthquake. To understand potential post-earthquakes problems, a review of the area's earthquake risk and current theories of business operation is offered. A list of the most important prospective problems identified by the Seattle business group is then included.



Figure 2. Many warehouse buildings are tilt-ups, which often don't fare well in earthquakes. The destruction of even one wall can cause injuries, leave inventory vulnerable, and create rubble on parking lots and streets that impedes rescue and recovery efforts.

Seattle Area Earthquake Risk (from the *Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault*)

The Puget Sound area has a long history of earthquakes. Most recently, the February 2001 Nisqually earthquake resulted in 700 injuries and losses estimated at between \$2 billion to \$4 billion (B), much of it in King County. Only \$350 million of the damage was covered by insurance.

That quake was centered 10 miles northeast of Olympia, more than 40 miles from Seattle. An earthquake centered on the Seattle Fault, which roughly coincides with I-90, could be considerably more damaging. A magnitude 6.7 earthquake on that fault could result in more than 1,500 deaths and 24,000 injuries, destroy almost 10,000 structures and restrict the use of another 180,000 buildings. Economic damages could reach \$33B.

Washington ranks second only to California among states susceptible to earthquake damage. Nationally, Seattle could incur the seventh highest largest dollar losses.

King, Snohomish, Pierce, and Kitsap counties are home to more than 60% of the state's population and much of its economic base, according to the 2000 census. Maintaining the integrity of supply chains is critical to sustaining this economic base.

The ground shaking in a Seattle Fault could be severe. Along the fault itself, the land could permanently rise or fall as much as six to seven feet. Ground failure includes landslides, which could number in the thousands after a major quake, and soil liquefaction (see Figure 3) which is a major cause of building, road, and bridge damage.

According to the Seattle Fault Scenario:

"The scenario earthquake badly damages homes, office buildings, manufacturing plants, schools, port facilities, utilities, and transportation routes from the south end of downtown Seattle east through Bellevue and throughout river valleys north and south of the cities. Collapsed structures and highway bridges kill or injure thousands of people. Communication links are swamped or broken, making communication difficult if not impossible throughout the region."

Many King County businesses rely on warehouses and distribution centers located in the Duwamish or Kent Valleys. These are both high-risk areas because of their proximity to the Seattle Fault and because their soil types make them especially susceptible to

earthquake damage. In addition, the building type of many warehouses doesn't fare well in medium to large quakes.

The Seattle fault is the latest potential earthquake site identified, but there are others. The 2001 Nisqually quake showed the danger of deep earthquakes, which can be generated more than 25 miles under

the Earth's surface. In addition, Cascadia subduction zone earthquakes can be as large as magnitude 9.0 and wreak havoc on the economy of the Pacific Northwest.

There are a number of crucial components that go into a business earthquake response and recovery plan, but one of them must be a look at supply chains. Without adequate inventory, neither individual business owners and workers nor the region as a whole can adequately respond to a major earthquake.



Figure 3. This road was destroyed by liquefaction, when soil turned to liquid during the shaking of the ground. Many soils in the Seattle area can liquefy, including those in the Kent and Duwamish Valleys.

Supply Chain and Just-in-Time (JIT) Management

Managing supply chains and on-site inventories are important components of business efficiency. Reducing the cost of supplies can increase profitability and competitiveness.

In *Strategic Management Theory*, Charles Hill and Gareth Jones explain:

“For the average manufacturing enterprise, the materials and transportation costs account for 50-70% of revenues. Even a small reduction in these costs can have a substantial impact on profitability. According to one estimate, for a company with revenues of \$1 million, a Return on Investment of 5% and materials costs that amount to 50% of sales revenue, increasing profits by \$15,000 would require either a 30% increase in sales revenues or a 3% reduction in materials costs. In a saturated market, it would be much easier to reduce materials costs by 3% than to increase sales revenues by 30%.”²

To reduce costs, a company’s production system may include Just-in-Time (JIT) delivery of materials, supplies, and even services. JIT saves space and simplifies production scheduling because items are scheduled to arrive just when they are needed rather than sitting on the shop floor waiting to be used. But there are potential problems with JIT. According to Hill and Jones:

“The drawback of JIT is that it leaves a firm without buffer stock of inventory, which although expensive to store, can help tide a firm over shortages and disruptions.”²

Ford’s switch to JIT systems in the early 1980s reportedly brought the firm a huge one-time savings of \$3B. Inventory turned over six times a year, rather than five, and holding costs were reduced by 33%. Using JIT, the production process can be seen as a continuous flow. Continuous flow production processes can reduce factory floor space by 50% or more as inventory space is eliminated. In the book *Lean Thinking*, Chihiro Nakao, President of Shingijutsu Ltd., de-



Figure 4. Hospitals must keep critical items in stock. Inventory, such as in this typical hospital central services department, can be supplemented several times a day. Without this replacement stream, they may be quickly overwhelmed after a major earthquake.

scribes a visit to the Porsche manufacturing facility where he told the company’s executives that their first goal was to clear away the entire inventory stacks so the actual production line could be visualized.³ At Jacobs Vehicle Equipment Company, unused space was first converted to staff break areas and later to basketball courts, according to George Koenigsaecker, President of Lean Investments.

Hill and Jones describe the importance of inventory systems (see Table 1):

“A key decision in manufacturing, retail and some service industries is how much inventory to keep on hand. Once inventory levels are established they become an important input to the budgeting system. Inventory decisions involve a delicate balance between three classes of costs: ordering costs, holding costs, and shortage costs. The aim is to minimize cost of production and avoid loss of sales, and there is an increasing emphasis on customer satisfaction.”²

Hospitals and service industries have different demands. They must maintain critical items in inventory to anticipate emergency situations or significant

swings in demand (see Figure 4). As a result they use a minimal on-site inventory, called “par level,” supplemented with multiple deliveries throughout the day. To meet this continual demand, the supply chain now includes an industry sector of large medical and other industry material distribution and warehousing companies. They use a system of regionally interdependent warehousing and trucking resources. It is this

Table 1. Inventory systems must balance a number of costs.

Ordering Costs	Holding Costs	Shortage Costs
Labor to do orders	Storage space	Disruption of production
Time spent finding vendors	Security	Idle workers
Transportation	Deterioration, theft	Lost sales
Receiving	Spoilage	Dissatisfied customers
Inspection	Obsolescence	Lost customer base
	Insurance	Extra set-ups



Figure 5. Suppliers can bundle and package materials as specified by the end user business. After a disaster, shortages of raw materials and labor could increase the cost of comparable supplies — or make them completely unobtainable.

type of large regional facility that is often located in the Duwamish and Kent Valleys.

A third strategy of inventory management which takes advantage of optimizing all inventory costs with the needs of the end user is economic order quantity (EOQ), described by Ronald Hilton in *Managerial Accounting* (see Table 2):

“The Economic Order Quantity (EOQ) decision model is a mathematical tool for determining the quantity that minimizes the cost of ordering and holding inventory. It focuses on the optimal timing of orders to balance its costs with optimal production and customer satisfaction.”⁴

Risk assessment in inventory management

Risks lurk all along the supply chain — political instability, exchange rates, carriage capacity, shelf life, and customer demand, to name a few.⁵ There are several factors specifically affected by earthquakes.

City streets and interstate freeways can be temporarily closed by earthquake damage or by debris falling and making them impassable. Other transportation corridors can also be affected. After the Nisqually quake, Sea-Tac was closed until the control tower

could be repaired. At the best of times, there are sometimes long distances and traffic congestion that slow distribution. After a major earthquake, these problems can increase exponentially. The relationship of carrying costs to transportation costs may not be linear.⁶

Allied to transportation corridors are hazardous material shipments. The widespread use of JIT practices means large quantities of inventory constantly in route and highly regulated hazardous materials are being transported more often. Multiple transfers significantly increases the risk of spills. If highways, ports, or rail lines that provide access out of the area are temporarily closed, an earthquake could trap a mobile inventory of hazardous materials in the Puget Sound region.⁷

In our society, paper has been replaced by computers. Large regional warehouse and distribution systems are fundamentally linked to the growth and sophistication of information management systems. Purchase orders and invoices are now commonly exchanged electronically. Suppliers have robust databases of their customers’ needs, as well as buying histories and preferences. Reconfiguring a supply chain from other regional warehouses or primary suppliers will be easier to reconstruct from computer files than from a paper-based system — as long as the original databases are still intact.

Another risk relates to inventory. Suppliers often deliver bundled, pre-packaged units that are ready to be placed on the customers’ inventory “shelves” (see Figure 5). These “shelves” can be widely dispersed throughout the end user’s facilities rather than being stored at one central location. This eliminates the labor cost to unpack, repackage and distribute the supplies at the consumer business. If these pre-packaged units are not be available after a disaster, the cost of labor to construct these bundled units will be high. If available labor is scarce because of competing needs, the cost will be even higher.

Table 2. There are many theories of inventory management, each emphasizing different costs and benefits.

Just-in-Time (JIT)	Economic Order Quantity (EOQ)
Minimize or eliminate inventory	Some inventory is needed
Holding costs are higher due to waste	Balance ordering costs with holding costs
Order size varies depending on need	Order size is constant

Because of their unique responsibilities, hospitals must have redundant supply chain resources. It is common practice for them to maintain a safety stock or develop relationships with other facilities for cross-borrowing. Other in-

dustries might consider expanding their safety stock (see Figure 6). Hill and Jones explain:

“As a practical matter, some safety stock is required due to supply chain shutdowns without immediate resolution. Safety stock is extra inventory consumed during periods of above average usage in a setting with fluctuating demand. Although a safety stock will increase inventory holding costs, it will minimize the potential costs caused by shortages (disruptions, failures).”²

Some supply chains are anchored in the global economy, making them vulnerable to interruptions from other countries’ political turmoil. The benefit of the global reach of supply resources, however, could be a faster recovery after a Seattle disaster. In an article for *Slate*, Duncan Watts addresses this issue with the example of a 1997 catastrophic fire of a key Toyota factory:

“The key to recovery was not that there was anticipated built up emergency problem solving capacities or the ability to implement these capacities in response to the particular disaster that struck. Rather the collective ability of firms and individuals alike to react quickly and flexibly was a result of unintentional capabilities, based on informal and often accidental networks that they had developed over years of socializing together and collaborating on unrelated and routine – even trivial – problems.

“The solution to this potentially devastating and completely unforeseeable combination of circumstances was astonishing, not because it required any technical wizardry or imposing leadership, but because it did not.”⁸

After the events of 9/11, researchers from the Massachusetts Institute of Technology (MIT) Center for Transportation and Logistics in 2003 studied the im-



Figure 6. Supply chains are key to business operations, but may be disrupted by natural disasters or terrorism. In this warehouse there is little evidence of earthquake mitigation like active or passive restraints. Inventory might be destroyed or trapped after a large quake.

Table 3. Values for truck shipments in the Puget Sound area were estimated.¹¹

City	Daily value (in millions)
Seattle	\$110
Tacoma	\$113
Everett	\$32 (outbound only)

pact of terrorism on supply chains and commerce. Terrorism-related risk is similar to that from natural disasters, like the 1999 Taiwan earthquake, or the 2001 episode of Mad Cow disease in Europe:

“Single events impact the entire chain. There is a need to protect the chain and for organizational resilience, to bounce back.”⁹

In *Revisiting the JIT Paradigm*, Michael Gorman explains:

“Earthquakes, floods, hurricanes and blizzards have regularly hampered deliveries. Prolonged strikes, supplier bankruptcies, mergers, have stopped pipelines. Wars, coups, terrorist events, changes in trade policy and border-crossing restrictions have made delivery of goods and services problematic.

“For an example, Ford and GM had to shut down plants, losing thousands of units of production, as their supply chain was disrupted by 9/11. Conversely, Harley-Davidson had stockpiled critical parts to avoid \$56,000 per hour assembly line outages.”¹⁰

Seattle area commodity flow (from Peterson and others’ study of Washington highways)¹¹

The daily value of truck shipments into and out of Seattle, Tacoma, and Everett (see Table 3) was estimated from the Strategic Freight Transportation Analysis.¹¹ Information included types of cargo and trip destinations. Approximately 38% of all outgoing truck shipments leave from a warehousing or distribution center and 37% of inbound truck shipments have a final destination at a warehousing or distribution center (see Figure 7).

Table 4 shows estimates of the daily tonnage of commodities shipped from 18 counties in Western Washington. From the limited set of raw data, the most likely commodities located in warehouse/distribution centers are food and kindred products, paper products, furniture (outbound), meats and fish, lumber and wood, steel and metals, petroleum products, machinery, and some electrical supplies.



Figure 7. More than a third of truck trips in the Puget Sound area are to or from warehouses and distribution centers. This leaves Seattle vulnerable if freeways and surface streets are impassable.

The top three destinations for goods leaving Washington are Oregon, Canada, and California. Disruption in Puget Sound transportation corridors means these areas could also experience economic losses. They may not be able to get supplies from Seattle, and they may not be able to ship their commodities to western Washington.

Post-earthquake business relocation (from Sandia National Laboratories analysis)¹²

Most businesses survive natural disasters, but some fail and others relocate. Firms that choose to leave the region will avoid the risk of future losses from earthquakes, but will incur relocation expenses. The earthquake-related economic loss of the region is only from those closing or leaving because of the quake.

Supply chains can be a major factor in the decision to move out after an earthquake. Earthquakes may produce dislocations even in economic sectors that aren't directly or physically damaged. All businesses rely on regional suppliers to provide their inputs, and rely on regional customers to purchase their output. Because of this, linked business activities are vulnerable to indirect damages. For example, when a damaged facility can't ship a critical ingredient to another factory, the production disruptions in the second factory are an indirect loss.

These potential losses are not limited to immediate customers or suppliers of damaged businesses.

All of the successive rounds of customers of customers and suppliers of suppliers can be affected. In this way, even limited damage causes a chain reaction that is transmitted throughout the economy. The extent of indirect losses depends on factors such as the availability of alternative supply sources, alternative markets for products, the length of the production disturbance, and the ability of factories to postpone production.

The first round of indirect losses occurs because damaged production facilities and inventories cause shortages of inputs at other firms that need those supplies to produce their goods. Secondly, damaged facilities may reduce their demand from suppliers. Thirdly, the reduced availability of goods and services may diminish regional, national, and export demand.

If a factory is unable to locate alternative sources for inputs unavailable because of quake damage somewhere in their supply chain, it can be crippled. The business is left with only four options: import additional supplies from outside the region; identify factories with excess capacity; use existing inventories; or seek unused stock of the needed input. The end result may be that management decides to move the factory.

An example of this can be seen in Kobe, Japan. Before the 1995 earthquake that devastated the city, Kobe was the sixth busiest port in the world. It is now seventeenth. Firms that could not survive waiting for the port to reopen moved their business and many did not return when the Kobe port was fully functional again.¹

Business continuity planning

Business contingency planners in the Seattle area should determine their company's dependencies on potential supply chain interruptions resulting from warehousing and distribution sites in the Duwamish Valley and the Kent Valley.

Of particular concern are those supplies that will be in increased demand after an earthquake. For example, hospitals and clinics may place simultaneous demands for supplies if there are a large number of injuries. Disrupted transportation routes can also create pent-up supply demands.

On the positive side, supply chain vendors typically

Table 4. Commodity content for truck shipments leaving western Washington shows the diversity of the state's economy.¹¹

Commodity description	Average daily tons (in thousands)	Average daily value (in \$1,000s)
Live animals and fish	7	7,327
Cereal grains	1	140
Other agricultural	42	37,045
Animal feed and products of animal origin	11	4,819
Meat, fish, seafood, and their preparations	35	89,393
Milled grain products, preparations, and bakery products	17	23,861
Other prepared foodstuffs and fats and oils	65	88,015
Alcoholic beverages	18	63,788
Monumental or building stone	15	2,451
Natural sands	11	213
Gravel and crushed stone	16	104
Nonmetallic minerals	3	212
Metallic ores and concentrates	>1	119
Gasoline and aviation turbine fuel	41	9,467
Fuel oils	4	826
Coals and petroleum products	7	2,235
Basic chemicals	33	16,278
Pharmaceutical products	>1	5,906
Fertilizers	4	561
Chemical products and preparations	12	24,818
Plastics and rubber	18	43,874
Logs and other wood in the rough	128	14,353
Wood products	197	69,918
Pulp, newsprint, paper, and paperboard	71	58,554
Paper or paperboard articles	31	48,808
Printed products	20	73,714
Textiles, leather, and articles of textiles or leather	10	102,772
Nonmetallic mineral products	60	29,664
Base metal in primary or semifinished forms and in finished basic shapes	30	34,680
Articles of base metal	15	57,509
Machinery	32	288,486
Electronic, other electrical equipment components and office equipment	20	594,708
Motorized and other vehicles (including parts)	40	289,036
Transportation equipment	5	327,026
Precision instruments and apparatus	>1	17,856
Furniture, mattresses, lamps, lighting fittings, and illuminated signs	11	47,708
Miscellaneous manufactured products	51	147,456
Waste and scrap	43	7,938
Mixed freight	127	265,409
Commodity unknown	151	119,486
Total	1,404	\$3,016,539



Figure 8. After a major earthquake, the Strategic National Stockpile (SNS), an emergency medical supply for disasters, could help resupply hospitals and medical facilities.

have solid electronic databases of the needs of their customers. They may be able to change distribution centers to unaffected areas.

Hospitals and other health care delivery entities can also obtain relief for surge demand through the activation of the Strategic National Stockpile (SNS). The SNS is essentially a pre-positioned medical supply that is loaded on a wide-body aircraft and sent to a disaster area in 8-12 hours (see Figure 8). Local government emergency coordination centers working with the regional public health agency can initiate the request for the SNS.

There are other businesses that might have an upsurge in demand following a disaster. For example basic building materials, food, and water, may be in high demand at a time when the suppliers of these goods are adversely affected by their supply chain dependencies.

Vendors typically have *force majeure* clauses in their

Table 5. Sectors identified in the National Infrastructure Protection Plan can help continuity planners understand business interdependencies.¹³

Critical Sector
Agriculture and food
Banking and finance
Chemical and hazardous materials
Commercial Facilities
Defense Industry
Emergency Services
Energy
Government Facilities, Dams, and Nuclear Power Plants
Information Technology
National Monuments and Icons
Postal and Shipping
Public Health and Health Systems
Public Institutions
Telecommunications
Transportation
Water Supply

contracts to limit or nullify performance requirements after an emergency like an earthquake. Negotiating away such language is usually impractical. It might be possible, however, to get commitments to limit interruptions after a disaster, or to set up mutual assistance agreements between competing and alternate suppliers.

At a minimum, the business continuity development process must include a thorough documentation of the key supply chain dependencies, since disasters anywhere in the global economy — not just the Seattle region — have the potential to cripple a business.

The first priority of emergency response services following a significant earthquake will be saving lives and restoring essential services. Continuity of government will also be a high priority. The plight of interrupted businesses as the economic engine of the region will become noticeable only after the loss of the complex interdependencies between such sectors as energy, banking and finance, water, food chain and transportation, to name a few, becomes evident. According to David Stauffer in *Harvard Business Week*:

“Severe events can lead to insolvency whereas low severity events seldom do; hence the need for insurance or other methods for transferring or mitigating catastrophic risks.

“The appropriate response when a critical supplier may be put out of commission by such an event is to identify an alternate supplier. But such steps double back on the very measures implemented to remove supply chain costs. Insurance carriers, which made huge payouts to cover losses related to 9/11, have reexamined the risks implicit in today’s leaner supply chain.”⁵

We suggest that the common denominator of the competing needs of businesses, government, and other essential services will be the restoration of surface streets and utility lifelines.

The Department of Homeland Security defined attributes of 17 infrastructure industries to help continuity planners understand primary interdependencies between industries that may affect their own businesses (see Table 5)¹³. Whether emergencies are from natural disasters or terrorism makes no difference in how they affect a region. Understanding how companies are protecting their supply chains from security breaches can help make a business more resilient after a quake.

Seattle Business Group

Seattle area business representatives brought together by CREW identified the following earthquake effects as potential business problems, listed in order of importance:

1. **Personal concerns** such as childcare, food and shelter, including the immediate effects on businesses because of injuries or deaths to employees and customers.
2. **Loss of power** during and immediately following the event. Specific effects vary by industry
3. **Loss of surface transportation** — the ability to get employees and inventories to and from work, and access of emergency vehicles and repair equipment to damaged areas.
4. Questions of the **ability of businesses to communicate with customers**, from being open for business to the general loss of communication services during and after a disaster.
5. **Physical loss and damage** to business structures and facilities (see Figure 9).
6. Questions of the **capacity of hospitals** and health care facilities to accommodate people injured by the earthquake, while continuing to provide care to people ailing from other causes.
7. Losses resulting from limited **Just in-Time inventories** (as described in this report).
8. **Potential for permanent loss** of businesses due to weeks or months of damaged infrastructure.



Figure 9. Vulnerable buildings can be surveyed, counted, and retrofitted as one way to reduce future losses from earthquakes.

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For more about earthquakes or information to help prepare your business, contact CREW.

Conclusions

Every few decades the Seattle area is hit by an earthquake large enough to cause injuries and damage. In a Cascadia subduction zone earthquake or a deep quake like the 2001 Nisqually event, damage can be regional, even international. Future events may dwarf those felt so far.

Using Seattle as a case study but applicable to Cascadia as a whole, this paper looked at just one facet of what could happen after a major quake with hundreds of fatalities, thousands of buildings damaged beyond repair, and dozens of bridges out.

This paper focused specifically on potential losses from limited Just-in-Time inventories. This supply chain strategy may help businesses remain profitable and competitive in the current global economy, but may cause problems after a major earthquake.



After the 1989 Loma Prieta earthquake, debris trapped people in buildings and blocked roads in Santa Cruz. After a large earthquake in Seattle, it could take days, even months, to reopen freeways and surface streets. Keeping businesses open during that time will be a challenge.

As with all disasters, every area affected interrelates with all others. Each item on the list compiled by the Seattle business leaders can have an effect on supply lines and general business operations.

It would be a mistake to assume all earthquake-related risk to the supply chain is because of soft-soil and vulnerable building conditions in the region's major warehousing and distribution center. Still, it is a component that can be addressed.

Contingency planners, business leaders, and elected

officials should develop short- and long-term strategies to mitigate this vulnerability. A multifaceted approach is needed. Public policies such as land use and tax incentives can work hand in hand with pre-disaster mutual aid agreements and transportation corridor upgrades. Everyone has a stake in ensuring an economic engine continues to run, especially after a disaster.