Supply Chain Failures

A study of the nature, causes and complexity of supply chain disruptions

A report by Dr. Alan Punter on behalf of Airmic - Sponsored by Allianz Global Corporate & Specialty & Lockton

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About the Author

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Most companies depend on other companies to supply goods and services – many companies depend on hundreds of suppliers for thousands of parts. These suppliers in turn often have many sub-suppliers, and so on. Such supply chains are becoming increasingly more extended, more complex and more global. An event on one side of the world can stop production or delivery of a service on the other side of the world. The event may be a natural disaster (such as an earthquake or flood), or a man-made or other event (such as an explosion, a labour dispute, a company insolvency, an environmental protest). The event may be large or small, and the company experiencing it may be large or small, but if it disrupts the supply of a critical component or service, the consequences can be equally severe in terms of financial and/or reputational impact.

An event on one side of the world can stop production or delivery of a service on the other side of the world

The financial impact can be a near-term temporary drop in profits (because of increased costs and/or reduced sales) and shareholder value, and/or a longer-term more permanent loss of market share (as competitors take customers or a new product launch is delayed). The non-financial impact can be long-lasting damage to a company’s reputation or brands, if unethical behaviours within the supply chain become associated with the ‘front’ customer-facing company. Market share and reputation can both be very difficult to rebuild, particularly with fast-moving and fashionable products, such as cars, consumer electronics and clothing.

Such critical financial or reputational dependencies on tier-1, tier-2 or higher-tier suppliers are often not appreciated until after a disruption to the supply chain occurs. And as supply chains grow in complexity, the number of supply chain disruptions is increasing. So many consumer goods (such as cars, electronic products – computers, phones, cameras – and clothing) sold in the markets of North America and Europe are increasingly manufactured in whole or in part in the Far East.

These supply chains encompass multiple suppliers from countries such as Bangladesh and India, and on through to China, South Korea, Taiwan and Japan. In recent years, a number of catastrophes (earthquakes, tsunamis and floods) in countries such as Japan, China, Taiwan and Thailand have highlighted the extent and significance of these supply chain risks.

Supply chains can involve not just the physical production of parts, but also require access to utilities (such as power), the operation of IT, telecommunication and transport networks, and the provision of services such as back-office processing and operation of call centres – disruption to any of these can cause the supply chain to seize up.

This report examines the nature and growing importance of supply chain risk. For the purposes of this report, supply chain risk is taken to be any disruption to the quantity or quality of goods and/or services sourced from third parties. The risks introduced by the growing trend for outsourcing are compounded by other business developments such as offshoring and lean manufacturing – which have made supply chains more cost efficient but have increased risk and made them more fragile. Supply chain risks are often highly interconnected.

The Appendix to the report is a series of case studies of recent supply chain disruptions. The three main cases considered are the Japan earthquake and tsunami in March 2011, the Thai floods in July 2011 and the grounding of the Boeing 787 Dreamliner aircraft in January 2013. These are supplemented by 14 other case studies, covering disruptions due to a range of natural perils, and man-made, economic and other causes. Each case study briefly describes the event and then reviews the main business impacts on the affected companies.

Most of the supply chain disruptions examined in these case studies should not have been complete surprises to the companies involved. Earthquakes, tsunamis and floods usually only occur in regions known to be prone to such natural perils; and disruptions caused by man-made factors such as economic difficulties or labour unrest tend to develop over time, and are not sudden or accidental events. Hence, these case studies highlight some important widely applicable failings:

- Failure to anticipate the consequences of reasonably foreseeable events (e.g. earthquakes in well-known earthquake regions – see the Japan, Taiwan and Chile case studies; floods in well-known flood plains – see the Thai Chao Phraya case study) and to monitor early warning signs (e.g. labour problems – see the US West Coast port lockout, G4S, Nike, Apple and IKEA case studies).

- Failure to appreciate the dependence on single-source suppliers (see the Evonik explosion case study), or a cluster of suppliers all in the same geographic region and hence all suppliers’
exposure to the same peril (see the Japan and Taiwan earthquakes, the Thai Chao Phraya flood and Buncefield explosion case studies). Even if a decision is made to dual source a critical component from two tier-1 suppliers, they may both depend on a common tier-2 supplier.

- Failure to appreciate the exposure to utilities and communication and transport infrastructures around suppliers (see the Japan, Taiwan and Chile earthquake case studies).

- Failure to understand the implications of the extension of supply chains to tier-2, tier-3, etc. suppliers, and the loss of control over quantity and quality.

- Failure to monitor and inability to maintain risk management standards consistently throughout the supply chain. The overriding concerns are usually the cost and quality of goods and services provided by the direct supplier, with less focus on the compliance with health & safety standards and good employment practices throughout the supply chain (see the Nike, Apple and Mattel case studies).

- Failure to understand potential reputation consequences, not just the financial cost, of supply chain disruptions.

- Failure to fully appreciate the speed and power of social media in spreading news or concerns about issues in the supply chain.

Supply chain risk is an enterprise-wide risk. Decisions made in the product design and development stage, decisions made about locating production facilities, decisions made about manufacturing technologies, decisions made about purchasing components and the choice of suppliers, decisions made about outsourcing functions and services, decisions made about marketing and distribution strategy, and many other strategic and operational decisions, can all have an impact on the ultimate level of supply chain risk.

A 2008 survey by McKinsey found that 57% of those asked said that reducing costs was the biggest strategic goal for the supply chain. This overriding desire of the procurement, manufacturing, finance and other departments to reduce costs will almost invariably increase the frequency and severity of supply chain disruptions – leading to potential tension, particularly between the procurement and risk management functions. There is an obvious danger that companies do not achieve the required clear and integrated ownership of supply chain risk management.
2. Introduction

The main objective of this report is to provide details of some recent supply chain disruptions to illustrate the range of events that can cause such disruptions and the scale of impacts such disruptions can cause to the companies involved, both directly and indirectly. The report was compiled from desk research and analysis of the many articles and reports published on this topic.

Firstly, two definitions of what constitutes a supply chain:

- All the processes involved in manufacturing, distributing, storing or servicing goods, from the basic raw material produced through to the final customer.

- The network of organisations that are involved, through upstream and downstream relationships, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer.

One definition of supply chain management is:

The design, planning, execution control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply with demand and measuring performance globally.

What makes managing supply chain risk particularly challenging is that there are many potential points and causes of disruption from the start to the end of the chain. The supply chain for a single product or service can easily include hundreds of companies in tens of countries across the world. A relatively small local disruption can have a large global impact or multiple consequences. For example: the entire fleet of the new Boeing 787 Dreamliner airplanes was grounded in January 2013 because of suspected problems with the lithium-ion batteries supplied by a company in Japan (see Boeing case study).

To assemble the 787 Dreamliner aircraft in Everett, Washington, Boeing uses thousands of parts from hundreds of suppliers around the world, but problems with just this one component had impacts on both Boeing (holding up the production of new aircraft) and its clients (the grounding of aircraft hit the profits of eight different airlines, ironically including Japan Airlines and All Nippon Airlines, both based in Japan, where the lithium-ion batteries came from). It also impacted many of Boeing’s suppliers that are on risk-sharing contracts and are not paid until planes are delivered.

The definition of supply chain risk used in this report is:

- Supply chain risk is any disruption to the quantity or quality of goods and/or services sourced from another supplying organisation, internal or external.

The supplying organisation may be internal, i.e. another part of the parental group, or more often, external, i.e. owned by a third party – a disruption in either case can be critical. This report focusses on the easier to observe disruptions caused by problems from third party suppliers. Also note that for the purposes of this report we interpret a supply chain disruption to mean that the final product or service is either not delivered in a timely manner or to an unacceptable standard - and so we include several cases of what may also be labelled product recall.

Allianz Global Corporate & Specialty estimate that Business Interruption (BI) and Contingent Business Interruption (CBI) losses typically account for 50% to 70% of catastrophe losses. There are a small number of ‘classic’ supply chain case studies in the risk management literature, where the original ‘physical damage’ is exceeded many times by the consequent ‘business interruption’; these include the Phillips Albuquerque, New Mexico fire and explosion, 17 March 2000, and the impact on the fortunes of Nokia compared to Ericsson, and the Perrier water recall incident of 1990.

The point that small disruptions can give rise to severe consequences is captured in the folk rhyme (probably referring to King Richard III of England at the Battle of Bosworth Field, 1485):

For want of a nail the shoe was lost,  
for want of a shoe the horse was lost,  
for want of a horse the King was lost,  
for want of a King the battle was lost,  
for want of a battle the kingdom was lost.

A smaller, more recent example is that Porsche was forced to suspend production for two weeks in 2009 when the manufacturer of the thread used in its seat belts went bankrupt. The scale of the consequences for Boeing, Ericsson, Perrier, King Richard III and Porsche, as illustrated in the above examples, shows the relative importance for risk management of focussing on the impact(s) rather than just the cause(s) of events – and applies particularly to the management of supply chain risk.

†, ‡ - see page 48
3. The importance of supply chain risk

Supply chains are important, if not critical. Slone et al suggest that 60% to 70% of the cost structure of many companies is embedded in its supply chain. Hendricks and Singhal quote a survey by FM Global of more than 600 financial executives that found that supply chain risks posed the most significant threat to profitability, and that a survey by Accenture of 151 supply chain executives found that 73% had indicated that their firms had experienced supply chain disruptions in the previous five years.

An Oracle survey of large organisations in the EMEA region found that 63% of businesses had reported that they had seen disruption to their value chain beyond their control, such as economic disruption (24%), adverse weather (19%) and bankruptcy of suppliers (16%) – and that it took an average of 63 days to get back to normal operations.

The events of 2011 (particularly in Japan and Thailand) reinforced the significance of supply chain risk. The Allianz Risk Barometer 2013, based on the responses from 529 experts across 28 countries, ranked business interruption and supply chain risk as the top risk concern of businesses globally. The second-highest concern was natural catastrophes (such as storm, flood and earthquake), which have also increased in recent years – and are often the main cause behind business interruptions. In the 10th annual Excellence in Risk Management survey published in 2013 by RIMS and Marsh, business interruption jumped from number 6 in the list of top risks in 2012 to number 1 in 2013.

Supply chain disruption most clearly features in the manufacturing and retail sectors, but can also impact many others. Various studies have attempted to measure the impact of supply chain disruptions on companies, including:

- Hendricks and Singhal tracked the impact of 885 operational supply chain disruptions on publicly traded companies from 1992 to 1999: operating income dropped by 107%, return on sales by 115% and return on assets by 92%.
- Hendricks and Singhal further studied 519 operational supply chain disruptions over the period 1989 to 2000 and reported a decrease in shareholder value of 10.28%.
- Singhal and Sheffi estimated that supply chain business interruptions caused roughly 10% lower sales and 11% higher costs, leading to an average 25% share price decline (compared to industry peers).
- PricewaterhouseCoopers compared the performance of 600 US public companies that announced supply chain disruptions from 1998 to 2007 with that of benchmark groups, and found that, on average, the affected companies’ share prices dropped 9% behind the benchmark group immediately upon announcement of disruption and continued to underperform those of their peers for some years. Over a two-year period, their average stock return was almost 9% lower and share price volatility was greater for the majority of affected companies. Profitability was also impacted, with average return on assets down 5% and average return on sales down 4%.
- The 17th Annual Logistics Study estimated that economic losses from supply chain disruptions increased 465% between 2009 and 2011.
- The Business Continuity Institute reported that of the 559 companies surveyed across 62 countries, 85% recorded at least one supply chain disruption in 2011. In the 2012 survey, 73% of the respondents experienced at least one disruption, with an average of five disruptions.
- Accenture reported that companies that are hit by significant supply chain disruptions suffer an average share price loss of 7%.
One worrying feature is that various surveys also report that supply chain risk management appears to be somewhat deficient:

- Slone et al suggest that 90% of the firms they studied “do not consider risk when outsourcing production”\(^2\).
- ESI International (2010) conducted a survey of 615 supply chains executives and found that only half of the organisations had a structured approach to supply chain risk management in place\(^2\).
- The Business Continuity Institute Supply Chain Resilience Survey 2011 of 559 respondents from 62 countries reported that only 8% of respondents could confirm that all key suppliers had Business Continuity programmes in place to deal with disruptions. Further, it reported that 19% of respondents were not strongly confident that they could identify their key suppliers\(^2\).
- A Deloitte survey of 600 global supply chain executives reported that only 55% believed that their risk management programmes were effective or very effective; 45% felt that their risk management programmes were only somewhat effective or not effective at all\(^3\).
- The Airmic Property Damage and Business Interruption Benchmarking Report of 2012 included the question: Have you conducted a supply chain risk review? The response was that 35% performed a review using internal / in-house resources plus 6% using external resources, but that 59% had not performed a supply chain review at all\(^4\).
- With regard to potential issues concerning quality and unethical activity, and hence risk to reputation, research carried out by Ernst & Young’s Fraud Investigation & Dispute Services team (covering UK companies operating across a range of sectors and countries) found that only 48% of UK firms carry out due diligence in their supply chain, with a further 30% never doing any checks. The survey of procurement managers and directors also revealed that only 6% have ever been made aware of unethical activity in their supply chain\(^5\).
According to the Business Continuity Institute's 4th annual Survey of Supply Chain Resilience (published in November 2012), the main cause of supply chain disruptions was unplanned outages of IT and telecommunications at suppliers, with adverse weather in second place and outsourcer failure to provide services in third place.

### Table 1: Top causes of supply chain disruptions for various business sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Top causes of high impact disruptions</th>
<th>Sector</th>
<th>Top causes of high impact disruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Services</td>
<td>IT &amp; Telecoms 45%</td>
<td>Professional Services</td>
<td>Adverse weather 11%</td>
</tr>
<tr>
<td></td>
<td>Data breach 13%</td>
<td></td>
<td>London 2012 7%</td>
</tr>
<tr>
<td></td>
<td>Outsourcer 11%</td>
<td></td>
<td>Olympics 4%</td>
</tr>
<tr>
<td></td>
<td>Adverse weather 11%</td>
<td></td>
<td>IT &amp; Telecoms 4%</td>
</tr>
<tr>
<td></td>
<td>Cyber-attack 11%</td>
<td></td>
<td>Outsourcer failure 4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>New law / regulations 4%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Currency volatility 15%</td>
<td>IT &amp; Communications</td>
<td>IT &amp; Telecoms 41%</td>
</tr>
<tr>
<td></td>
<td>Energy scarcity 15%</td>
<td></td>
<td>Adverse weather 18%</td>
</tr>
<tr>
<td></td>
<td>Adverse weather 9%</td>
<td></td>
<td>Outsourcer failure 18%</td>
</tr>
<tr>
<td></td>
<td>Product quality 9%</td>
<td></td>
<td>New law / regulations 18%</td>
</tr>
<tr>
<td></td>
<td>Transport network 9%</td>
<td></td>
<td>Energy scarcity 18%</td>
</tr>
<tr>
<td>Retail and wholesale</td>
<td>IT &amp; Telecoms 13%</td>
<td>Energy &amp; Utility</td>
<td>Adverse weather 25%</td>
</tr>
<tr>
<td></td>
<td>Fire 13%</td>
<td></td>
<td>Fire 25%</td>
</tr>
<tr>
<td></td>
<td>Outsourcer failure 13%</td>
<td></td>
<td>Health &amp; Safety event 13%</td>
</tr>
<tr>
<td></td>
<td>Civil unrest / conflict 13%</td>
<td></td>
<td>Outsourcer failure 13%</td>
</tr>
<tr>
<td></td>
<td>Adverse weather 6%</td>
<td></td>
<td>Earthquake / tsunami 3%</td>
</tr>
<tr>
<td>Public Administration</td>
<td>IT &amp; Telecoms 22%</td>
<td>Health &amp; Social Care</td>
<td>IT &amp; Telecoms 19%</td>
</tr>
<tr>
<td></td>
<td>Adverse weather 17%</td>
<td></td>
<td>Adverse weather 11%</td>
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<tr>
<td></td>
<td>Outsourcer failure 11%</td>
<td></td>
<td>Outsourcer failure 11%</td>
</tr>
<tr>
<td></td>
<td>Insolvency 6%</td>
<td></td>
<td>Earthquake / tsunami 11%</td>
</tr>
<tr>
<td></td>
<td>Loss of talent / skills 6%</td>
<td></td>
<td>Product quality 6%</td>
</tr>
<tr>
<td>Engineering &amp; Construction</td>
<td>Insolvency 22%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of credit 22%</td>
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<tr>
<td></td>
<td>Loss of talent / skills 11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outsourcer failure 11%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the main cause of supply chain disruptions was unplanned outages of IT and telecommunications at suppliers

Table 2: Main consequences of supply chain disruptions

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loss of productivity</td>
<td>57%</td>
</tr>
<tr>
<td>2</td>
<td>Increased cost of working</td>
<td>44%</td>
</tr>
<tr>
<td>3</td>
<td>Service outcome impaired</td>
<td>36%</td>
</tr>
<tr>
<td>4</td>
<td>Loss of revenue</td>
<td>35%</td>
</tr>
<tr>
<td>5</td>
<td>Customer complaints received</td>
<td>35%</td>
</tr>
<tr>
<td>6</td>
<td>Product release delay</td>
<td>26%</td>
</tr>
<tr>
<td>7</td>
<td>Delayed cash flows</td>
<td>24%</td>
</tr>
<tr>
<td>8</td>
<td>Damage to brand reputation / image</td>
<td>24%</td>
</tr>
<tr>
<td>9</td>
<td>Stakeholder / shareholder concern</td>
<td>20%</td>
</tr>
<tr>
<td>10</td>
<td>Expected increase in regulatory scrutiny</td>
<td>12%</td>
</tr>
<tr>
<td>11</td>
<td>Product recall / withdrawal</td>
<td>11%</td>
</tr>
<tr>
<td>12</td>
<td>Payment of service credits</td>
<td>9%</td>
</tr>
<tr>
<td>13</td>
<td>Fines by regulator for non-compliance</td>
<td>7%</td>
</tr>
<tr>
<td>14</td>
<td>Share price fall</td>
<td>4%</td>
</tr>
</tbody>
</table>

More than 20% of the 532 respondents from 68 countries to this survey reported suffering a supply chain disruption of more than €1 million.
Supply chain risk is not only a concern for large companies, but increasingly, mid-sized companies are also exposed to it – in fact, smaller companies may suffer disproportionately more from supply chain disruptions.

To aid the identification of the potential causes and impacts of supply chain risk, the following classification may be useful:

**Potential causes of supply chain disruptions:**

1. At source (no or reduced production at supplier):
   - Natural causes – earthquake, flood, wind, snow / freeze, etc.
   - Man-made – fire, labour strike, civil unrest, terrorism, utility failure
   - Economic – insolvency, trade credit, loss of patent, non-performance of sub-supplier.

2. In transit (late or non-delivery) – transportation & logistics (including infrastructure failure – roads, railways, airports, bridges, tunnels, fuel shortages):
   - Natural causes – earthquake, flood, wind, snow / freeze, volcanic activity, etc.
   - Man-made – terrorism, piracy, dock strikes, political (e.g. embargoes), pandemic / quarantine.

3. At destination (delivery quality):
   - Defective component (product or food)

4. Plus corporate-level risks:
   - Reputation issues – patent infringement / expiry, slave / child labour, environmental practices.
   - Cost / exchange rate issues
   - IT system failure (virus, cyber, etc.)
   - Social media.

All the above can be caused by similar issues at a supplier’s supplier, etc.

**Potential impacts of supply chain disruptions:**

a. Increased costs (extra expenses)
b. Reduced sales
c. Loss of market share (e.g. delayed / missed new model launch)
d. Fines (e.g. health & safety, product or food recall)
e. Damage to brand, risk to reputation.

And all causes and costs can be experienced as part of an internal (not just an external) supply chain – and do not just have to do with ownership (although companies have more control over owned facilities). However, outsourcing business processes to third parties does mean that the company no longer owns its own means of production, knowledge creation and/or servicing of their clients. Plus, causes can be local or global, and impacts can be local or global.
“I guess the question I’m asked most often is: ‘When you were sitting in that capsule listening to the count-down, how did you feel?’ Well, the answer to that is easy. I felt exactly how you would feel if you were getting ready to launch and knew you were sitting on top of two million parts – all built by the lowest bidder on a government contract.”

John Glenn, the first American to orbit the earth and third American in space.
5. Reasons for the growing frequency, severity and complexity of supply chain disruptions:

The growing significance of supply chain disruptions is identified from analysis of the case studies as being due to several reasons (each of which is described in more detail below):

1. Changing business models – outsourcing
2. Offshoring
3. Competition and cost pressures – lean sourcing
4. Production methods
5. Geographic clustering / local specialisation
6. Size and complexity, criticality and vulnerability
7. Modern communications.

1. Changing business models (especially outsourcing): The basic structure of much manufacturing industry has been changing over recent decades. The trend in the 20th century was for manufacturing companies to become ‘vertically integrated’, i.e. to own and operate many of the stages of the production processes that led up to the final manufacture of their finished products. For instance, in the 1920s, the Ford Motor Company completed the Ford Rouge Complex in Dearborn, Michigan, with its own docks, electricity plant and iron ore processing facility (coke ovens and foundry) to manufacture steel (rather than buy it from suppliers) for use in Ford products: in the 1930s and 1940s, Ford Motor Company also established plantations, Fordlandia and Belterra, in Brazil to supply rubber for use in its car making. Ford owned its own glassworks, forests for timber and railway lines.

The trend in the 20th century was for manufacturing companies to become ‘vertically integrated’

However, more recently, this trend has been reversed, with many manufacturing companies moving to a more ‘horizontally integrated’ mode of operation, i.e. leveraging their specialist expertise in one or more particular stages of the production process, whilst subcontracting or outsourcing the other stages to other specialist companies, thus increasing expertise and economy of operation but also their dependence on these other, non-owned, companies. Companies nowadays are less often manufacturers in the old sense of the word, but more assemblers or ‘integrators’. Nike is the largest shoe company in the world, but it does not actually make any shoes. It is essentially just a design and marketing operation, all manufacturing is subcontracted.

Even Ford Motor Company started to go down this route – in the days of the “New Economy”. When Jacques Nasser became CEO of Ford in 1999, it was the world’s most profitable automaker, with profits of $7.2 billion on sales of $163 billion. However, he proclaimed that he would transform Ford “from a boring old car maker whose shares achieve a price-earnings ratio of only 10, into a consumer-products and services company commanding a multiple of more like thirty”.

After Jacques Nasser resigned from Ford in 2001, it renewed its focus on car making and it now has relationships with 1,600 production suppliers operating at more than 4,600 manufacturing sites that produce 130,000 parts for inclusion in the vehicles it sells. In addition, Ford purchases other non-production supplies, including services, marketing, construction, computers, industrial materials, health care and machinery from more than 9,000 suppliers. Overall, the company spends over $65 billion globally per year on production and non-production purchases.

One further example of this trend of moving from a vertical to a more horizontal business model is Boeing. In the 1950s, 98% of the early 707 aircraft was built inside the US. For the recently launched 787 Dreamliner aircraft, Boeing itself is only responsible for about 10% by value (the tail fin and final assembly), with the rest of the manufacturing being outsourced (e.g. the wings are built in Japan, parts of the fuselage in Italy and Japan, landing gear in France, engines in England). Boeing now calls itself a “systems integrator” rather than a manufacturer.

This trend to outsourcing became even more pronounced in the 1990s in the technology industry. Traditionally vertically integrated electronics manufacturers, which had been managing products all the way from design and development, through to manufacturing and distribution, found that they could reduce their capital requirements and improve return on equity by outsourcing low-margin manufacturing operations to Contract Equipment Manufacturers (CEMs).
The theory was that manufacturing was low value-added, with the greater value coming from understanding customer needs, product design, marketing and distribution. It was also felt that the CEMs could extract greater value from the capital-intensive production equipment (a semiconductor fabrication plant can cost over $1 billion to build, with values as high as $3 billion to $4 billion not being uncommon). This was because CEMs could achieve greater economies of scale (by consolidating and supplying components to several companies), improve ‘scalability’ (i.e. ability to increase / decrease production volumes as required) and run their operations more profitability as manufacturing was their core competency.

In addition to industrial companies moving from in-house manufacture to ‘buy and assemble’ business models, service companies are also increasingly outsourcing internal functions (from R&D through to customer service) – with business processing, IT operations, call centres, etc. often being located in different continents.

2. Offshoring: Combined with this outsourcing has been the globalisation of business, with many of these outsourced operations also being offshored, primarily to access lower property costs, labour costs and raw material costs. However, moving parts of the supply chain offshore to emergent economies can often increase the risk management challenges – with higher political and economic risks (such as political unrest, expropriation, foreign currency volatility) and lower standards of property risk control.

These emergent economies may also have lower risk management mind-sets – poorer labour employment practices and health & safety standards. This was illustrated by the tragic collapse in April 2013 of the Rana Plaza building in Bangladesh, which housed five factories making low-cost garments for brands in North America (e.g. Loblaw in Canada) and Europe (e.g. Primark in the UK), resulting in more than 1,000 deaths.

Reports stated that the building had been built without the correct permits (the proper building consent had not been obtained for the original five-storey building, it was not designed for industrial use and a further three storeys had been added illegally), and that factory work continued despite deep cracks being seen in the building the day before and the owners being asked to close the building.

This was the third major industrial incident in five months in Bangladesh (after the Tazreen Fashions factory fire, which killed 112 workers in November 2012, and another fire in January 2013 that killed seven). Bangladesh has 3.6 million garment workers and is the second-largest exporter of garments in the world (60% of its exports go to Europe, 23% to the US and 5% to Canada).

Offshoring can also increase exposure to natural catastrophe perils – for instance, the South East Asian region (where much production of electronic components, etc. has been offshored from the US and Europe to countries such as Japan, Taiwan, South Korea, China, Thailand) is susceptible to earthquakes, tsunamis, typhoons and floods, as recent years have shown. It also introduces increased transport costs and risk into the supply chain – 90% of the entire global trade flows through 39 bottleneck regions (these gateway regions include many ports, airports and train stations in metropolitan areas that may be vulnerable to terrorism), and piracy is a growing threat.

Manufacturing operations have been moved from one emergent country to another as costs in the first country rise relative to a second more newly emerging country.

When Bangkok airport was forced to close in 2008 due to protests, it cost the Thai economy $8.5 billion. The underlying nature of transport risks differ from many of the other risks posed to supply chains, which are mostly natural catastrophes. The primary cause of supply chain claims in the transport and logistics industry is human error.

In one instance, the pressure to reduce transport costs has actually also reduced risk, or rather increased resilience, i.e. the ability to respond to supply chain disruptions. Denmark’s Maersk Line, operator of the world’s largest container ship fleet, now sails more ships, but at a slower speed to conserve fuel (the round trip from Asia to Europe and back used to take 56 days, it now takes 70 days). However, this means that if there is a supply chain disruption, there is more stock already on the ships and the ships can increase speed to help make up any short-term inventory shortages.

However, moving production from country to country in response to low costs can also go in cycles. Manufacturing operations have been
moved from one emergent country to another as costs in the first country rise relative to a second more newly emerging country. It can even turn full circle – a British company, Symington, has transferred its production of noodles from two sites in China to Leeds in the UK because of rising Chinese wage and freight costs.

GlaxoSmithKline has repatriated some of its manufacturing from an outsourced position in India back to Scotland, for cost reasons. A survey by EEF (the UK Manufacturers’ Organisation) found that 40% of respondents had brought their production back in-house (reshoring), while 25% of companies had increased their use of local suppliers (nearshoring). Reshoring or nearshoring can also be driven by ‘green’ issues, such as concern over the carbon footprint of goods. (Supply chains may in future become more ‘regional’, rather than ‘global’.)

3. **Competition and cost pressures (or ‘lean sourcing’)**: Procurement focuses on cost and quality, not risk. Procurement functions tend to operate in ‘silos’, outside the normal purview of the Chief Risk Officer, and trying to drive cost out of the supply chain often drives risk into the business. This can lead to possible reliance on a few critical suppliers (supplier consolidation) or even single-sourcing.

As an illustration of balancing the potentially conflicting pressures of cost against risk in a supply chain, John Glenn, the first American to orbit the earth and third American in space, said in his retirement speech:

“I guess the question I’m asked most often is: ‘When you were sitting in that capsule listening to the count-down, how did you feel?’ Well, the answer to that is easy. I felt exactly how you would feel if you were getting ready to launch and knew you were sitting on top of two million parts – all built by the lowest bidder on a government contract.”

4. **Production methods**: The modern manufacturing mantra centres around the philosophy of lean manufacturing, including just-in-time delivery (or zero inventory). Lean manufacturing is defined as a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful and thus a target for elimination.

The highest profile example of lean manufacturing is the just-in-time (JIT) approach to manufacturing, where the inventory of components held for production operations is reduced to a minimum in the pursuit of cost efficiencies, with fresh supplies scheduled for delivery just when needed; however, this means that if the supply of any such component is disrupted, production has to be very quickly halted, because there is no or very limited buffer stock.

A pre-eminent exponent of the JIT approach is Dell Computers, a pioneer in computer supply chain management – but it had to issue profit warnings on several occasions in earlier times when there were interruptions in its supply chain, for instance a fire in Japan in 1993 and an earthquake in Taiwan in 1999.

Similarly, the pursuit of purchasing cost efficiencies will encourage the sourcing of components from fewer suppliers in order to obtain preferred supplier or volume discounts, but again, this increases the supply chain risk if one of these chosen suppliers experiences production problems of their own for any reason. According to Matthias Haller from St. Gallen University, Switzerland, “economies of scale always lead to diseconomies of risk.”

5. **Geographic clustering / local specialisation**: There are efficiencies for companies in the same or similar industries to locate in the same geographic region. This clustering of related companies can give rise to production synergies (e.g. leveraging sub-suppliers), jointly develops specialised manufacturing and labour expertise, and reduces transport costs – but increases interdependence risk. For instance, Puerto Rico produces a significant proportion of the world’s pharmaceuticals, but is served by just one airline, American Airlines.

Geographic clustering can also heighten the threats from natural catastrophes to that area of expertise and/or technology – for instance, the concentration of hard disk drive manufacturing in Thailand. Nearly one-third of the world’s hard disk drive manufacturing capacity was destroyed in the Thai Chao Phraya floods in July 2011 (see case study below), and production was not expected to be back to normal levels for around a year, by which time the main competitor, the solid-state drive, would have permanently increased its market share, and may even have taken the majority of the market share.
6. **Size and complexity, criticality and vulnerability:**

For many companies, supply chains have become large and complex – Ford's reliance on suppliers was detailed above. Boeing's commercial arm handles more than 750 million aircraft parts a year, from 1,200 companies operating 5,400 factories\(^\text{45}\). Two further examples\(^\text{46}\): (1) Swiss-Swedish industrial group has 5,500 suppliers linked via data networks and transport connections to assembly factories globally; (2) in 2010, SKF of Sweden, the biggest maker of industrial bearings, purchased parts and materials worth about $5 billion from more than 2,000 suppliers, co-ordinated by 1,000 supply planners in Belgium, Singapore and Tennessee, and supported by 200 people in Gothenburg, Shanghai, Mumbai and Chicago handling global logistics.

Companies will often have multiple tiers of suppliers – a tier-1 supplier being supplied by a tier-2 supplier, and so on. A 2011 study by the Business Continuity Institute\(^\text{47}\) found that 39% of disruptions originated below the tier-1 supplier (30% at a tier-2 supplier and 9% at a tier-3 or higher supplier).

But perhaps the key aspect with regard to risk is the criticality and vulnerability of a component or service in the supply chain. It is not always appreciated prior to a disruption that, in some extreme cases, a component does not have any ready substitute and is only produced at a single location – for example, the loss of all production of the pigment Xirallic used in metallic paint for cars, in the Japan earthquake / tsunami of 11 March 2011 (see case study below).

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7. **Modern communications:** The growth of the internet and social media has increased the pressures on supply chains. Any spreading of news of potential shortages can lead to panic buying, exacerbating any real or perceived shortages. Similarly, stories (sourced by consumers, pressure groups and others) about alleged product deficiencies, poor labour conditions or other unethical behaviour by any of the companies in the various tiers of the supply chain can spread very quickly and leave the ‘front’ company (high-street retailer or brand name) being quickly put on the back foot in dealing with criticism and damage to its reputation.
The seventeen case studies are each presented in the Appendix. The case studies were chosen to illustrate a variety of:

- Initial events that triggered the supply chain disruption – including natural perils (earthquake, tsunami, flood, wind) and man-made perils (fire & explosion, product design, insolvency, labour problems, product contamination, environmental issues).

- Contributory factors that exacerbated the scale of the disruption – including dependence on a single supplier, dependence on a clusters of suppliers in the same geographic region, dependence on transport infrastructure in the affected region, dependence on utilities (such as power) and telecommunications.

- Main impacts on the companies and regions affected by the disruption – including increase in costs, reduction in sales, longer-term loss of market share, fines or other actions by regulators or other authorities, damage to brand and/or company reputation.

The table below summarises the characteristics of each of the case studies and rates the contributory factors and main impacts under these classifications.
<table>
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<tr>
<th>Event</th>
<th>Trigger</th>
<th>Exposure to natural peril</th>
<th>Exposure to man-made peril</th>
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The management of supply chain risk follows the same principles as for any other class of risk facing a corporation – approaches include risk reduction and risk transfer. The main method of risk transfer is through insurance – such as standard Business Interruption (BI) or Contingent Business Interruption (CBI) policies, or even newly developing supply chain insurance products.

Airmic has recently published a separate review of the supply chain insurance market. However, insurance cover (however extensive) for any risk (supply chain or other) mainly treats ‘symptoms’ (not causes) – it does not prevent losses per se. Insurance may reimburse some loss of profits, but it does not cover potentially significant impacts such as long-term loss of market share or damage to reputation. Supply chain risk management (SCRM) should therefore also include prevention and mitigation measures – to enhance the resilience of the supply chain.

An event on one side of the world can stop production or delivery of a service on the other side of the world

Many, if not most, supply chain disruptions can be anticipated and hence mitigation plans prepared. Considering the main contributory factors from the grid above, few of those supply chain disruptions caused primarily by natural perils (earthquake, wind or flood) should have been much of a surprise – they all occurred in known earthquake, hurricane or flood-prone regions. However, the timing and exact course of events that unfold are unpredictable.

For instance, the nuclear power plant at Fukushima that was knocked out by the Japan earthquake and tsunami of 2011 was located in a known earthquake and tsunami region. However, the back-up generators to power the cooling systems for the nuclear towers were sited at ground level, rather than above ground level, and hence flooded when the tsunami breached the flood walls, leading to the reactors overheating, resulting in meltdown, explosions and the release of radiation over a wide area, and necessitating a 20km exclusion zone to be established.

Where the main contributory factor is man-made, the event is usually not sudden or accidental (such as economic difficulties or labour problems) and so there are usually some prior signals. One basic component of SCRM is to monitor the financial status of suppliers, although the insolvency of UPK-Thompson in 2001 appears to have caught Land Rover unprepared. With the cases of specific labour unrest (such as in the US West Coast port lockout of 2002) or more general poor labour relations (such as in the Nike and Apple case studies), there were early warning signs.

In the case of the US port strike, negotiations between the unions and employers had been deteriorating for some months; some companies including Wal-Mart and Costco took steps to build up inventory before the strike started, others including NUMMI and Mattel implemented mitigation measures once the strike had started. In the cases of Nike and Apple (and many other companies that have also become involved in allegations of poor labour employment practices), prior similar instances and publicity from human rights and other pressure groups meant that the risks should have been well known, but were not given the requisite management attention.

Whatever the main contributory factor, it cannot, and should not, be assumed that risk management practices, and compliance with those practices, will be consistent throughout the supply chain (as the comments under the Offshoring section above illustrate). Also, in the case of Mattel, and other recently reported stories involving outsourcing / offshoring to some Far East countries, some suppliers have subcontracted to other suppliers without the permission or knowledge of their prime buyer, and it has been the poor risk management practices in these sub-suppliers that have been the primary cause of the supply chain disruption.

SRCM is a specialist expertise and SCRM best practice (and in particular post-event Business Continuity Management) recommendations are beyond the scope of this report. However, there are some general SCRM lessons to be learnt from the case studies presented in the Appendix, including:

- The management of supply chain risk is an enterprise-wide issue. Strategic and operational decisions such as the location of manufacturing facilities and choice of suppliers may be made mainly with cost considerations in mind, but can have significant implications for supply chain risk – locating a new factory in an earthquake region because of the cheaper labour available locally or the consolidation of the number of suppliers to achieve bulk-buying discounts may prove to be a false economy.

- Be aware of high dependence on a single component, with no approved or available substitute. It may take time for an alternative component to be designed and receive the appropriate testing and safety certification. The existence of patents or other
commercial agreements can make it very difficult to modify or switch designs.

- Be aware of high dependence on single supplier. Dual or multi-sourcing may be more expensive than single-sourcing, but will usually significantly lower risk. However there are situations where dual-sourcing is not possible – there may not be a feasible second supplier because of issues of available production capacity, technology, expertise or patents – or even competition or political barriers.

- Be also aware of cluster of suppliers within the same region, and hence all exposed to common perils. Again dual or multi-sourcing may be more expensive than single-sourcing, but will usually significantly lower risk, particularly if different suppliers are in different geographic regions. The post-event response capabilities of tier-2, tier-3, etc. suppliers, the local power utilities, the local transport infrastructure, etc. are usually unknowable before a disrupting event – the best mitigation is geographic diversity and redundancy, wherever possible. Widespread power blackouts in India on 30/31 July 2012 left 600 million people without electricity, as well as impacting call centres and outsourced IT providers.

- Remember that the impact on financial performance and/or reputation does not necessarily bear a direct relationship to the cost of the disrupted component or service. A low-cost but unique and/or single-sourced component or service can significantly disrupt the whole supply chain. Conduct an impact analysis of the supply chain to identify critical components and/or critical suppliers, and consider building redundancy into the supply chain – by duplicating critical suppliers and/or holding emergency inventory of critical components. However, holding surplus inventory increases the costs of working capital and storage, and increases the risk of obsolescence (particularly in fast-moving and fashionable consumer products with short product life cycles).

- Supply chain resilience can also be improved by increasing flexibility, for example, by reviewing the whole business process from product design through production to distribution. Minor changes to product design or manufacturing methods at an early stage may enable more standardised or generic interchangeable components to be used, reducing dependence on particular components and/or suppliers, and hence mitigating the impact of any future supply chain disruption. Flexible production line set-ups may also allow production capacity lost at one factory to be made up by increased production at another unaffected location.

- Consider whether the level of vulnerability is absolute or relative – e.g. permanent loss or just deferral of sales. Manufacturing and retail businesses may be able to catch up after a disruption on some or all of any missed sales, but service businesses such as the transport, restaurant and entertainment industries have no mechanism for creating inventory of their ‘product’ – seats to travel or to eat or to watch a performance on any given day that are not sold cannot be resold at a later date. Similarly, many agricultural and most food products are perishable, and if not processed or transported because of a supply chain disruption, will usually be spoiled.

- Consider not just direct vulnerability to natural perils (such as earthquake, tsunami, hurricane, windstorm, typhoon, flood, etc.), but also indirect vulnerabilities (such as loss of utilities – power and communications – and damage to transport infrastructure as a result of the peril).

- Supply chains are not always simple and linear, but can be more complex networks, with interdependencies. This is particularly evident in business recovery plans, which tend to focus on property, equipment and computer systems, rather than people; for instance, the company may have back-up facilities prepared in the event that primary sites are destroyed or inaccessible, but will suitably trained staff be able to access them, will transport routes be open, will schools and nurseries be open for those staff who have children?

- Relocating supplies away from one or more perceived peril may introduce another. For example, ‘nearshoring’ to shorten supply chains back from Asia to Mexico (for the North American market) or Turkey (for the European market) – both are still earthquake zones.

- Monitor social media and blogs, etc. for trending stories about ethical or environmental issues that may concern companies in your extended supply chain. Outsourcing operations does not remove responsibility for quality and reputation.
The various survey results quoted in the section on the importance of supply chain risk above reported that supply chain risk rarely features in decisions about outsourcing production and that supply chain risk management was often felt not to be effective or receive the requisite attention. Risk management of supply chain risk faces the same challenge as managing any other class of corporate risk – it is often hard to justify the allocation of resources towards mitigating an event that has not happened yet – “it will not happen to us”.

The focus when designing a new product or service, setting up the production process, entering into any new outsourcing arrangements and buying in any necessary components or services is primarily on cost efficiency and quality, and less on any supply chain risks that are introduced or aggravated.

Supply chain risk is an enterprise-wide risk

This can give rise to tension between the risk management department and the company’s design, manufacturing and, in particular, procurement functions. However, without an enterprise-wide approach to supply chain risk management and communication across all the departments involved, there cannot be clear ownership of, or an integrated approach to, supply chain risk management.

A related problem can be the difficulty of escalating concerns of growing supply chain risks (such as potential unethical behaviour several tiers down the supply chain) up the company hierarchy to senior executive and/or Board level, the so-called risk glass ceiling – raising such issues may not be regarded as lying within the domain of the risk manager.
8. Appendix: Case Studies

Supply chain disruption

Event: Japan earthquake / tsunami, 11 March 2011

Main impacts on Japanese national economy and US / global manufacturing supply chains.

Description of event: The earthquake was the most powerful earthquake ever recorded in Japan (MW 9.0) and the fourth-strongest worldwide; there were more than 300 aftershocks, with magnitudes of greater than MW 5.0 in the subsequent three weeks. Two particularly large aftershocks (MW 7.1 on the 7 April and MW 6.6 on the 11 April) caused many fires. The main earthquake caused a major tsunami, which came ashore within nine minutes in some locations, reached heights of over 10 metres and travelled nearly 10 kilometres inland in places; it was this tsunami that caused most of the fatalities and damage to commercial and personal property, with many towns almost completely washed away.

Another major aspect of the event was the subsequent meltdown of nuclear reactors and release of radioactive material from the TEPCO electricity generating plant at Fukushima, leading to the evacuation of all people living within 20 kilometres of the plant. Overall insured losses were estimated at $35 billion, but with economic losses at $210 billion (the most expensive natural catastrophe ever); Japan’s GDP fell by 3.5% in the Q1 of 2011. There were more than 19,000 deaths and many more injured or displaced; 129,000 buildings were destroyed and 945,000 damaged. The nuclear disaster killed three people and may cause a further 100 to 1,000 deaths from cancer.

Main consequences: The TEPCO-operated Fukushima nuclear power plant was closed down (prior to the tsunami, it produced an estimated 2.7% of the power in Japan). “About half of the country’s nuclear power plants have stopped operating”. An additional consequence was that doubt was thrown over the future of nuclear power programmes – not only in Japan, but also in other countries – as a result of the disaster at Fukushima; the German chancellor Angela Merkel announced a “measured exit” from reliance on nuclear energy and the decision to close all the country’s nuclear reactors by 2022.

Business context: Japan has dominant market shares in the manufacturing components used in other industries; for instance:

- 100% of protective polariser film for LCDs
- 89% of aluminium capacitors, used in electronic components
- 87% of games software
- 72% of silicon wafers used in manufacturing computer memory (other sources put this figure at 60%) – the shut-down of two factories (the Shirakawa plant owned by Shin-Etsu Chemical Company and another) by the earthquake took out a quarter of the world’s supply
- 46% of lithium-ion batteries for mobile phones
- 43% of electric components
• 36% of mobile phone camera modules.

Credit Suisse says that Japan makes 90% of a substance called BT resin, which is used to make printed circuit boards. Another source estimated that Japanese companies account for about 40% of the world’s technology component supplies, for instance:

• 30% of the world’s flash memories, which are used in smart-phones and digital cameras
• 10-15% of D-Ram memory, a key component in every personal computer
• Asahi, NH Techno and Nippon Electric Glass are three of the world’s top suppliers of glass for flat panels.

This same source also references an Asian Development Bank Institute paper, which estimated that Japanese components, such as flash memory and touch screens (both made by Toshiba), and an electronic compass (made by AKM Semiconductor Inc.) account for a third of the cost of making Apple’s iPhone. In fact, the iPhone is designed in the US but made and assembled by nine companies (including Toshiba, Samsung, Infineon, Broadcom, Numonyx, Murata and Cirrus Logic) in six countries (the Republic of Korea, Japan, Taipei, China, Germany and the US).

Business impacts

Car industry: Japan is a major car manufacturer, and several of its car makers had factories in the earthquake-affected Tohoku region in the north of Japan. Toyota said its domestic production fell by over 74% (due to power shortages, damage to factories and lack of parts supply) compared with the same month in the previous year, and Honda declared an 81% reduction in production (due to several factories being damaged). Toyota halted domestic car production at 18 plants entirely for at least 10 days and lost the production of 370,000 vehicles worldwide. Nissan had six plants damaged and production levels in March fell by over 50%. The share prices of Toyota fell by 16% and Honda by 13% within five days of the earthquake. Honda reported a nearly 90% drop in its Q1 revenues. Toyota and Honda originally expected to be back to their desired previous production capacity within about six months, by October 2011. Mazda, Mitsubishi, Subaru and Suzuki also reported temporary suspension of production at all of their Japanese plants.

Electronics industry: Texas Instruments reported that its factory in Miho that accounted for 10% of its 2010 revenue would not be back to operating at full volume for six months.

Electronic companies that had factories damaged included Canon, Fujitsu, Hewlett-Packard, Hitachi, Nikon, Panasonic and Sony. Most of Japan’s technology production plants are located around Tokyo and Osaka, and were not directly damaged by the earthquake and tsunami, but many (including Hitachi, Sharp and Toshiba) were forced to reduce production because of the shortage of power – a rolling programme of power blackouts was introduced across Japan to manage electricity supplies.

The Tokyo Disneyland theme park was closed for five weeks for the same reason.
lack of electricity. It was opened after three new gas-powered electricity generators were installed in the park.

**Steel industry:** Another Japanese industrial sector to suffer was the steel industry. Some blast furnaces were closed temporarily after the earthquake (including those of Nippon Steel Corporation), but were soon back in operation. However, because steel production is a big consumer of electricity, production levels were reduced. This had little impact outside Japan, because steel makers around the world at the time were operating at below full capacity due to the global recession, with spare capacity available nearby in the Asia region, including South Korea, China and Taiwan.

**Other industries:** Other companies to close production lines included Toyo Tire & Rubber Company and Sumitomo Rubber Industries; GS Yuasa’s car battery operations; Fuji Heavy Industries; Shin-Etsu Chemical; Kirin Holdings; GlaxoSmithKline; and Nestlé.

**Infrastructure and energy:** Throughout the region, roads, railways, bridges, dams, airports and ports were significantly impacted – the affected ports handled as much as 7% of Japan’s entire industrial output and port shut-downs cost $3.4 billion per day. The inability to distribute or ship goods affected many global companies and caused delays in importing / exporting coal and natural gas; some oil terminals were closed. At its peak, more than 30% of Japan’s refinery capacity was shut down. Telecommunication services were restricted, with landline and mobile phone networks down and undersea cables damaged by the earthquake and tsunami.

**Analysis and commentary:** The impact of disruption to the manufacture of components in Japan spread around the world as parts shortages started to bite – Apple did not have the components for its iPad 2. The initial impact was felt when the supply of small high-value electronic components that are air-freighted dried up; later components that are supplied by sea dried up, typically around four to six weeks after the earthquake – from mid-April onwards. For instance, in the car industry (because the lean inventory of car parts only allowed normal operations to last for up to three days), one source estimated that car assembly and export capacity was cut by:

- 39% in Guangdong, China in April
- 48.5% in Thailand in May.

Another source reported that:

- Ford Motor halted car assembly operations in the Philippines for 18 days, starting on 11 April 2011. Honda cut production in its Philippines factory by half.
- General Motors, Ford Motor, Honda and Subaru temporarily shut down plants in the US and Canada in mid-April.
- Toyota stopped production at five factories in Turkey, France, Poland and the UK for eight days in late April 2011 and early May, and ran a reduced output for the rest of May. It also halted production at its North American plants for five days in the second half of April. Honda cut production around the world, from the Philippines to the UK.
• Other European car manufacturers to cancel shifts included General Motors’ Opel plants in Spain and Germany, and Jaguar in the UK.

However, the impact of such an event can initially appear to be more serious than the final outcome: for instance, shortly after the earthquake / tsunami, General Motors gave its insurers notice of a potential claim of up to its full $1 billion limit, but later said that the catastrophe’s impact on its production was negligible.

Overall, 3.6 million units were lost from global vehicle production in 2011. Japanese car makers lost 4.5% of market share and the launch of new models was delayed.

A shortage of just one component can be enough to close a whole production line down. Such a shutdown was caused by the closure of the Hitachi factory that makes 60% of the world’s supply of airflow sensors used to measure the amount of air coming into car engines; for instance, General Motors was forced to shut a plant in Louisiana and PSA Peugeot-Citroen had to cut back production at most of its European plants.

Another specific impact was that of a pigment, Xirallic, used in metallic car paints. It was developed, patented and only produced in a single Merck-owned plant in Onahama, Japan, which was cut off from power, water and other utilities as a result of the earthquake. Many of the world’s car manufacturers were affected – for instance, Ford Motor and Chrysler had to restrict orders for cars in some shades of black and red. Dave Andrea, VP of the Original Equipment Suppliers Association in the US was quoted as saying “What vehicle manufacturers are finding are parts within parts within parts within parts that are sourced from a single-source Japanese manufacturer.”

There can also be an impact the other way round. GKN in the UK warned in March 2011 that it might cut the number of car components it makes because some of its Japanese customers might be unable to take deliveries. The Australian Treasury estimated that the Japan earthquake and tsunami would cost Australia around $2 billion in lost export earnings (on commodities such as coal and iron ore). Nissan planned to import six single engines from one of its US plants to replace lost capacity at its Iwaki plant (60km from the Fukushima nuclear reactor), which was expected to be out of production for at least a month.

A study commissioned by FM Global reported that a natural catastrophe in China on the scale of the 2011 Japan earthquake and tsunami would have an even more severe impact on supply chains, given China’s critical role in global manufacturing. The key finding was that 86% of the North America-based companies surveyed were more reliant on China for part of their supply chain for their key products than they were on Japan (at 43%).
Event: Thai Chao Phraya floods, July 2011

Main impacts on various industries (automotive, electrical, computer, medical equipment and food) – all vulnerable to water damage.

Description of event: In 2011, the Asian monsoon season started early, with record-high rainfall in March and April, and high rainfall levels throughout the rainy season. By the end of October, Central and Northern Thailand had received between 300 and 500 millimetres more rainfall than normal (and the highest on record for over 50 years). The Chao Phraya River basin experienced floods covering an area of about 30,000 square km, lasting from July to November 2011, with many locations continuously flooded for over two months.

Main consequences: More than 800 people were killed, hundreds of thousands of people were left homeless and insured losses were estimated by several sources at between $15 and $20 billion; even at the Swiss Re estimate of $12 billion insured losses, it was by a factor of about four the highest insured loss in monetary terms in the history of fresh water floods and, at 3.4% of GDP, it was by a factor of over five the largest insured loss as a percentage of its country’s GDP. Overall, damage has been estimated variously at $30 billion by Swiss Re, $41.4 billion by the Thai government or $45.7 billion by the World Bank – private sector (as opposed to public sector) losses made up most of these losses, as follows:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Economic losses</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>$32.9 billion</td>
<td>Most losses sustained at industrial factories</td>
</tr>
<tr>
<td>Tourism</td>
<td>$3.1 billion</td>
<td>Loss of tourism revenues over a six-month span</td>
</tr>
<tr>
<td>Households / Personal Property</td>
<td>$2.7 billion</td>
<td>Includes structural and indoor content losses</td>
</tr>
<tr>
<td>Agriculture</td>
<td>$1.3 billion</td>
<td>Loss of agricultural production</td>
</tr>
</tbody>
</table>

Source: Aon Benfield.

Floods lasted several months, disrupting and damaging manufacturing operations across the region – even if property, machinery and stock was not directly affected by the contaminated ‘black flood water’, the duration of the floods and local humidity meant that there was significant mould damage. More than 14,000 businesses were forced to close nationwide, with more than 1,300 factories affected and more than 750,000 people temporarily out of work. These closures disrupted supply chains inside and outside Thailand, in particular from the seven large industrial estates that had to be closed because their flood defences were breached. None of the industrial parks in Thailand had been flooded in the previous 40 years; during the last major flood in 1995, the dykes in the industrial parks had kept the floodwater out. The seven main affected industrial estates were:
<table>
<thead>
<tr>
<th>Industrial Park</th>
<th>Number of companies</th>
<th>Companies impacted (example)</th>
<th>Reported flood height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bang Pa-in</td>
<td>90</td>
<td>Western Digital</td>
<td>&gt;1.0m</td>
</tr>
<tr>
<td>Bangakdi</td>
<td>50</td>
<td>Nidec, Nissan, Sony, Toshiba Semiconductor</td>
<td>3.0m</td>
</tr>
<tr>
<td>Factory Land</td>
<td>99</td>
<td>Canon Engineering, HDK, Sony</td>
<td>1.5m</td>
</tr>
<tr>
<td>Hi-Tech</td>
<td>143</td>
<td>Canon Engineering, HDK, Sony</td>
<td>3.4m</td>
</tr>
<tr>
<td>Nava Nakorn</td>
<td>227</td>
<td>Western Digital, Toshiba, Casio, Fujitsu, JVC, Seiko</td>
<td>2.0 – 3.0m</td>
</tr>
<tr>
<td>Rojana</td>
<td>198</td>
<td>Honda, Furukawa, TDK, Nidec, Canon, Nikon, Panasonic, Sanyo Semiconductor</td>
<td>3.0m</td>
</tr>
<tr>
<td>Saha Rattana Nakorn</td>
<td>43</td>
<td>Yamamoto</td>
<td>&gt;1.0m</td>
</tr>
</tbody>
</table>

Source: Guy Carpenter.

**Business context:** Over 60% of the companies operating in these industrial parks were Japanese. Many international companies had invested heavily in Thailand to establish manufacturing and assembly plants; the situation was made worse since after the Japan earthquake / tsunami of March 2011 (case study above), some Japanese companies had shifted their production to Thailand to negate the strong yen and power shortages that continued to affect Japan. One company to suffer particularly from this ‘double whammy’ was Sony, which sustained a record £3.67 billion loss in 2011 that it blamed on disruption to production from the Japan earthquake and Thailand floods.

**Business impacts**

**Car industry:** All nine of the Japanese car manufacturers with operations in Thailand were forced to suspend production at the height of the flooding, with the loss of approximately 6,000 vehicles per day. The impact on selected manufacturers was as follows:

- Toyota – supply shortages caused lost production of 260,000 vehicles (3.4% of annual target). The impact was also felt outside Thailand, overtime was cancelled at Toyota’s Japanese vehicle plants, and production was cut back elsewhere in region (Indonesia, Vietnam and Philippines) and across the world (US, Canada and South Africa). Toyota suffered an annual earnings hit of $1.55 billion and a 56% decrease in net revenue.

- Nissan – lost production of 19,931 vehicles (13.5% reduction on prior year). The main plant was unaffected by floods, but production was shut down due to lack of parts from other factories in Thailand.

- Honda – extensive flooding at main manufacturing plant in Thailand led to...
global disruption in car production due to lack of parts, with production being halved at plants in US and Canada – and full production only being resumed in April 2012. Honda also incurred losses of $88 million due to lost inventories and $93 million due to damaged property and equipment.

- Mazda – again the company’s primary factory was not directly affected by flooding, but production was suspended for more than one month due to lack of supplies. Mazda reported operating losses of $266 million because of the 2011 Japan earthquake and $51 million because of the Thai floods.

- Mitsubishi – main Thai plant was not damaged by flooding, but production was suspended due to local parts suppliers having sustained damage.

**Technology industry:** The impact on selected technology and other manufacturers was as follows:

- Sony – two of Sony’s three manufacturing facilities were damaged by the floods, causing the loss of all production of digital SLR cameras and reducing the production of televisions and other products. The launches of the new NEX-7 and Reflex Alpha 65 cameras were postponed – causing tremendous losses in its high-end market share. Sony reported $107 million of losses due to the repair, removal and cleaning of facilities, plus losses of $56 million due to idle facility costs at manufacturing sites and other expenses.

- Canon – the company’s printer production was disrupted and it reported a negative impact of $607 million on net sales and a reduction in operating profit of $225 million.

- Toshiba – significant disruption of production at 10 separate manufacturing facilities, where home appliances, semiconductors and lighting products were made.

- Western Digital – major disruption at its factories due to high floodwaters. It reported $199 million in losses relating to the Thai floods (made up of $109 million fixed assets impairment, $39 million recovery charges, $28 million write-down on damaged inventory and $23 million in wage continuation costs). Western Digital’s main competitor, Seagate, was largely unaffected, because its facilities were located on higher ground.

- Nikon – significant damage closed its primary factory, responsible for producing 90% of its digital SLR cameras. Nikon estimated that the impact on business performance was a $786 million reduction in net sales and a loss of $302 million in operational income due to lost sales, plus damage of $132 million to fixed assets and inventories.

- Hitachi – hard disk drive production dropped to 17.2 million units in Q4 2011 (from 31.9 million in Q3). Brake pad production also shut down. Hitachi announced a $176 million loss due to the Thai floods and falling sales of its flat screen televisions.

- Microsemi – two subcontracted facilities were shut down, causing the loss of 5% of total quarterly revenues.
• Nidec – suspended production of hard disk motors for a while.

• ON Semiconductor – extensive damage to its facilities, one of which it decided to partially close permanently (the recovery and reconstruction costs would be too high) and to shift production to other company-owned facilities with excess equipment capacity and floor space. The company announced a 15% decrease in quarterly revenue for Q4 2011.

Other industries: Industries other than cars and technology also suffered. Denmark-based Ecco, the world’s leading footwear company, expected its revenue generated from its Thai subsidiary’s factory to be halved.

Goodyear suffered flooding at its main aviation tyre manufacturing facility, causing a severe disruption in production, which (despite ramping up production in facilities outside of Thailand) led to a decrease in the supply of tyres for the commercial airline industry in February and March 2012. Goodyear reported losses resulting from the Thai flooding of $16 million (including business interruption and clean-up costs).

The impact of the flooding was not limited to the flooding of production facilities; the transportation infrastructure also sustained major damage, with road and bridges and train tracks submerged or destroyed. Bangkok’s secondary airport (Don Mueang) was forced to close from October 2011 until March 2012 because of floodwater damage to the terminal and runways.

Analysis and commentary: One of the products that Thailand specialised in producing was hard disk drives – in the first half of 2011, Thailand accounted for between 40% and 45% of worldwide production. As noted above, two Western Digital Corp plants, responsible for approximately 60% of the company’s hard drive production, were closed by the floods. One of the US computer companies to suffer from the disruption to the supply of disk drives from Thailand was Hewlett-Packard (HP). One of HP’s key suppliers was Seagate, whose operations are based in the north of Thailand and were not affected by the floods, but the components used by Seagate came from the south of Thailand, in flood-affected areas.

So although only about 30% of disk drives were manufactured in the flooded zones, 70% of their components were. Other companies impacted by the shortage of hard disk drives included Dell, which cited the flooding in Thailand as one reason for missing Wall Street sales expectations in Q3 of 2011, and Intel, which warned that Q4 earnings in 2011 would miss forecasts. Globally, PC shipments were expected to be down by as much as 20% in the first three months of 2012, due to the shortage of hard disk drives.

One sometimes under-appreciated aspect of such natural catastrophes on industrial operations is employee costs. Most Japanese companies operating in Thailand continued to pay wages to (rather than lay off) local employees at their affected plants whilst operations were suspended, because it is difficult to find skilled workers due to the country’s tight labour market (with the unemployment rate before the flooding at 0.7%). And relocating skilled local workers to another country is unlikely to be a viable option.

The Thai economy suffered overall, with the Thai central bank reducing its GDP growth forecast for 2011 from 4.1% to 1.5% and the Thai baht depreciating by about 3.9% in three months.
Product recall

Event: Grounding of the Boeing 787 Dreamliner aircraft, 17 January 2013

Description of event: On 7 January 2013, a lithium-ion battery on board a Japanese Airlines (JAL) Boeing 787 Dreamliner at Boston's Logan Airport caught fire after landing from Tokyo; this was followed on 16 January 2013 by smoke coming from a lithium-ion battery causing a 787 Dreamliner flight, operated by All Nippon Airlines (ANA), to make an emergency landing in Takamatsu, western Japan.

Main consequence: On 17 January 2013, the entire fleet of fifty 787 Dreamliners was grounded by the US Federal Aviation Administration (FAA) – this was the first time in 34 years that regulators had insisted on such a grounding.

Business context: Boeing had announced its new 787 Dreamliner aircraft in 2003, but then had to announce a series of delays beginning in late 2007. The maiden flight finally took place in December 2009 and Boeing began pilot training for its first customer, ANA, in April 2011. When the 787 Dreamliner entered service in 2011, it was more than three years behind schedule and with a cost over $200 million per jet. As of January 2013, Boeing had total orders for 848 aircraft. This is the first grounding of an entire model or airline type by the FAA for 34 years.

To reduce development time for the 787 from six years down to four years, and development costs from $10 billion to $6 billion, Boeing had adopted a development and supply chain strategy new to the aircraft manufacturing industry. For the previous 737 aircraft, Boeing played the traditional role of a key manufacturer that assembles different parts and subsystems produced by thousands of suppliers. For the 787, Boeing formed strategic partnerships with about 50 tier-1 suppliers or ‘integrators’, which assemble different parts and subsystems produced by tier-2 suppliers. The tier-1 suppliers are responsible for delivering complete sections of the aircraft to Boeing to allow Boeing to complete final assembly of an aircraft in three days (rather than the 30 days taken for the 737 aircraft) at its plant in Everett, Washington. (This resembles the approach adopted by Toyota to car development and production.)

However, a series of problems delayed the development of the 787 – including technological challenges such as developing new carbon fibre reinforced plastic for the fuselage, the failure of tier-2 and tier-3 suppliers to notify their tier-1 ‘integrator’ of parts shortages and other problems, the lack of the appropriate supply chain management expertise in the Boeing leadership team and a strike in December 2008 by more than 25,000 Boeing employees over concerns about their job security.

Business impact: ANA estimated that the grounding cost it operating profits of $66.3 million and JAL estimated that it cost JAL $40.8 million, and both will seek compensation. Other airlines operating 787 Dreamliners (including Air India, LATAM Airlines Group, LOT Polish Airlines, Qatar Airways and United Airlines) will also expect to be compensated – but Boeing’s potential liability is limited by purchase sales agreements that exclude or limit the aircraft maker’s liability. Boeing’s chief executive has stated that there was “no contractual obligation to pay airlines that had to ground their Dreamliners and suffered disruption to their flight schedules … Having said that … we will work with our customers to ensure
… that disruption does not hurt their operations more than it needs to\textsuperscript{113}. Air India flew several of its 787 Dreamliners in spite of the grounding order, to avoid high parking charges at Delhi airport; with the permission of India’s civil aviation regulator, the aircraft were flown to Air India’s maintenance depot in Mumbai, with crew but no passengers on board\textsuperscript{114}.

Boeing obtained approval from the FAA on 12 March 2013\textsuperscript{115} for its proposals to upgrade the 787 Dreamliner’s lithium-ion batteries, by improving insulation between the battery cells, putting the battery in a fire-resistant box and allowing smoke from any overheating to vent outside the aircraft. A ‘functional test flight’ was successfully completed on 25 March 2013\textsuperscript{116}; it was expected that the 787 Dreamliner would return to passenger service within weeks, after further laboratory tests and another test flight.

US regulators approved Boeing’s planned fix for the battery safety problem on 19 April 2013, the first passenger-carrying flight was made on 26 April 2013 and it was expected at time of writing that most of the 50 Dreamliners already delivered to eight airlines around the world would resume commercial service in late May or early June 2013\textsuperscript{117}. This grounding is estimated to have cost Boeing $600 million\textsuperscript{118}.

**Analysis and commentary:** Lithium-ion batteries were used by Boeing to improve fuel efficiency, because they are smaller and lighter, but they have previously been involved with overheating and explosion in consumer devices\textsuperscript{119}. In December 2006, Dell recalled approximately 22,000 laptop batteries; in December 2006 and March 2007, Lenovo (the ThinkPad manufacturer) recalled approximately 526,000 and 205,000 batteries at risk of explosion respectively; in August 2007, Nokia recalled more than 46 million batteries at risk of overheating and explosion.

In the Dell and Lenovo cases, the batteries were made by Sony; in the Nokia case, they were made by Matsushita. The lithium-ion batteries were the first of their type to be used by Boeing; the French company Thales S.A. makes the battery system and GS Yuasa of Japan (one of the world’s leading battery groups) makes the actual batteries.

Airbus reconsidered the use of lithium-ion batteries in the development of its new A350 jet, and has now announced that it is reverting to traditional nickel-cadmium batteries.

This is not the first time that Boeing has suffered from supply chain problems. In 1997, it announced that it would take a $1.6 billion pre-tax charge against Q3 earnings and would incur a further estimated $1 billion in charges and unanticipated costs in 1998.

These charges included penalty payments to airlines for late deliveries (of 737 and 747 jumbo planes), and overtime and other unexpected production-related expenses, mainly because internal and external parts shortages had thrown production lines significantly out of sequence; and Boeing’s suppliers faced their own bottleneck, because many of their own suppliers went out of business during the aerospace industry’s downturn in the early 1990s. Boeing had limited flexibility in increasing supplies of parts, because it had previously cut back on the number of its suppliers as part of its push towards ‘lean manufacturing processes’\textsuperscript{120}. 

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Supply chain disruption – Natural causes

Event: Hengchun earthquake (Taiwan), 26 December 2006

Main impact on subsea cables and communication networks.

Description of event\(^{12}\): On 26 December 2006, at least two huge earthquakes occurred off the southwest coast of Taiwan island; the first, larger earthquake was estimated at magnitude \(M_w\) 7.1. Property damage was reported in southern Taiwan, and two people were killed and 42 injured. There were limited power cuts. The earthquake was felt all over Taiwan, including the capital city of Taipei, 450 km north of Hengchun, and in Hong Kong and some areas of China, although no major damage was reported. A tsunami was detected in Taiwan, but the change in water level was only 25 cm and so no damage was caused.

Main consequences: The main impact was on telephone and internet services in Asia. The earthquakes triggered a landslide on the sea bed, which damaged several submarine cable systems so severely that they could no longer carry traffic, disrupting IDD, telephone and internet communication systems of Taiwan with China, Hong Kong, Malaysia, Singapore, Thailand and the US. Financial transactions, particularly in the foreign exchange market were seriously disrupted.

Communications between China and the US were also seriously affected, and connections between Hong Kong and foreign websites kept failing. Fears that call centres and other outsourced business processes that have become a major industry in the Philippines might have their operations seriously hampered by the cable damage proved largely unfounded; only two call centres were totally shut down by the problems. One benefit was reported in the US, where there were reports that the volume of spam was dramatically reduced; one network saw its mail from Korea drop by 90% and from China by 99%.

Although fibre optic systems tend to have a degree of redundancy built into their networks, the topology of the landmasses running down from Japan, South Korea, east cost of China, Taiwan, Hong Kong, Philippines, Malaysia and Singapore meant that there was a concentration of network cables running through the Luzon Strait, just south of Taiwan, the area hit by the earthquake. The Luzon Strait (which connects the South China Sea with the Philippines Sea) is the favoured North to South Asia Passage, because of its position, depth and width. Eighteen cable faults had to be repaired, each taking seven to 10 days to complete. Repair work was completed by 30 January 2007, using five cable ships.
Main impact on agricultural, fishing, mining and forestry industries and local infrastructure within Chile.

Description of event: Magnitude $M_w$ 8.8 earthquake with epicentre just off the coast of central Chile at 3:34am local time on 27 February 2010, followed by over 200 aftershocks, of which 150 were greater than magnitude $M_w$ 5.0 and 12 were greater than magnitude $M_w$ 6.0. It was the seventh-strongest earthquake ever recorded, lasted about two minutes and 45 seconds, and was felt as far north as Ica in Peru to Buenos Aires and São Paulo to the east, and triggered a pan-Pacific tsunami. At least 550 people were killed; of the 4.5 million households in Chile, at least 1.5 million were damaged, more than 500,000 of which were destroyed. Insured losses were estimated at $8 billion.

Main consequences: Within hours of the main earthquake, widespread looting of the shops and port started in the city of Concepción, as well as parts of Santiago, Chillan and Talcahuano, until the Chilean government declared a ’state of catastrophe’ and military soldiers were deployed on the streets with assault rifles and tear gas to restore order.

The more serious economic impact was on utilities, industry and infrastructure. Widespread power outages occurred throughout Chile, following the main earthquake, with more than two million homes losing electricity – although electricity was restored within five days to the majority of the region, with the main power grids not suffering extensive damage. There was also disruption to landline and mobile phone networks, and the enormous demand for the limited available signals caused a network overload.

On the industrial front, Chile produces about 34% of the world’s supply of copper (and it is Chile’s main export commodity). Several mines sustained damage and others were forced to shut down production because of loss of power – about one-fifth of Chile’s total copper production capacity was impacted. Further disruption to deliveries was experienced because of damage to roads and ports. Chile is also a significant exporter of coal; the price of coal rose because of restrictions on exports. Chile’s two oil refineries were also affected, but Chile was not expected to sustain any fuel shortages.

Chile’s transport infrastructure was severely impacted, with hundreds of roads damaged, key bridges and overpasses collapsing. Many failures were also reported along Chile’s only major road route, the north-south Pan American Highway. Santiago’s international airport was shut for 24 hours, whilst significant damage to the main passenger terminal was inspected, but the runways were largely unaffected. Ports closest to the epicentre were destroyed or damaged, but imports and exports were re-routed to other ports north of the epicentre.

The earthquake halted 8% of world market pulp capacity; prices increased drastically in China and South Korea, the top two Asian pulp importers. In the US, where 50% of pine lumber and mouldings are imported from Chile, prices increased by 25% to 35% – the counterbalance is that this has provided a boost to producers in other countries, such as Canada. Chile’s agricultural and fishing industries also suffered significant losses from the earthquake and tsunami – millions of fish were killed when they were washed ashore – and the farm-raised salmon industry was impacted when delivery trucks were unable to transport fish to the seaports due to the main Pan American Highway being

Other case studies
impassable.

Chile’s tourism industry was largely unaffected, with the most popular tourist destinations being in the far north and far south of the country.

**Event: Eyjafjallajökull (Iceland) volcanic ash cloud, April 2010**

Main impact on air transport across Europe.

**Description of event**: The Eyjafjallajökull volcano in Iceland erupted on 20 March 2010 and an ash cloud spread across the skies of northern Europe.

**Main consequences**: Flights across Europe were grounded over a six-and-a-half-day period – 95,000 flights were cancelled. The International Air Transport Association (IATA) stated that the total loss for the airline industry was around $1.7 billion; the Airport Operators Association (AOA) estimated that airports lost $128 million over the six-and-a-half days. Significant economic damage was incurred in Europe (mainly business interruption, which was mostly uninsured), with the movement of goods, and business and personal travel plans disrupted.

These flight disruptions impacted industrial sectors in Europe that depend on air-freighted imports and exports.

This included the importing into Europe of fresh flowers, fruit and other foodstuffs, and imports and exports of electronic hardware. The pharmaceutical industry was impacted – by delays and potential spoilage of exports of time-sensitive products from the UK, and local stocks elsewhere running short as imports were halted. The car maker BMW suspended production at three of its plants in Germany because of interruptions in the delivery of supplies (including transmissions and other parts from elsewhere in Europe and leather seat covers from South Africa).

Some sectors benefited from the ash cloud disruption – such as railway companies, road haulage, car hire and ferry operators – as companies and individuals looked for alternative modes of transport. However, in the UK alone, 13 travel firms collapsed during the summer of 2010, and the ash cloud was cited as one of the contributing factors. Freight companies in Dubai also benefited, where the big freight airport is next to one of the world’s largest container airports; European-bound goods were being stockpiled in Dubai until European airspaces were open again, or transferred to alternative sea and/or land transport.

The flight disruptions also impacted economies outside Europe, primarily in countries that export fresh produce into Europe. This included flowers from Kenya (at a loss of $3.8 million per day), flower and vegetables from Zambia, and fish and flowers from Uganda. Nissan suspended production of three models in Japan because supplies of parts had been disrupted; Honda announced a partial halt to production. However, the sales of New Zealand salmon were boosted, with New Zealand suppliers benefiting from the difficulties in exporting fresh salmon from Norway and other northern European countries.

There were also impacts in the political, cultural and sporting arenas – with attendance at meetings and events by participants and/or audiences reduced or cancelled.
The overall economic impact of this event totalled around $5 billion in GDP, including productivity losses, air travel disruption, international trade and visitor spending\textsuperscript{276}.

**Event: Superstorm Sandy (US), October 2012**

Main impact on New York City.

**Description of event**\textsuperscript{127}: Hurricane Sandy developed in the Caribbean Sea and first made landfall in Jamaica on 24 October 2012 and hit Cuba the next day as a Saffir-Simpson category 2 storm. It continued to track north and, by 28 October, tropical storm force winds extended more than 800 km from Sandy’s centre, affecting large parts of the US coast from North Carolina up to Massachusetts.

Hurricane Sandy then curved north-westwards and made landfall close to Atlantic City, New Jersey in the evening of 29 October, impacting more or less the whole of the north-eastern seaboard of the US with the combined effects of wind, storm surge and rainfall / snow precipitation. Hurricane Sandy had the largest reach of tropical storm-force winds ever recorded (spanning almost 1,000 miles of coastline), although peak wind speeds were somewhat below major hurricanes to have previously hit the US Northeast. The associated storm surge however exceeded previous record levels in some areas, such as Manhattan and the greater New York area.

**Main consequences**: Total economic damage due to Hurricane Sandy is estimated at approximately $70 billion, of which $35 billion was insured. On the residential side, insured losses were roughly split equally between wind and flood damage; on the commercial side, it is estimated that 65% to 70% of insured losses were caused by flood. There were 216 deaths and 21 missing people.

The effects of Hurricane Sandy were particularly severe in New York City, its suburbs and Long Island\textsuperscript{128}. The New York City subway system was flooded; all but one of the road tunnels linking the island of Manhattan to the mainland were flooded, and several of the road bridges were closed; all three of New York’s major airports (JFK, LaGuardia and Newark) were closed for several days; large parts of the city lost power for several days; the New York Stock Exchange was closed for two days. Economic losses across New York City were estimated at $19 billion and $32 billion across New York State.

One supermarket chain, Ahold, suffered $31 million in product losses across 202 stores as a result of storm damage. Thirty-two stores had to be closed for safety reasons, and additional costs included $3.8 million in labour costs to clean-up affected stores. One unexpected loss was $100,000 in cash that the US Federal Reserve would not accept because of contamination\textsuperscript{129}. 
Supply chain disruption – Man-made causes

Event: US West Coast Port Lockout, September / October 2002

Main impact on US car manufacturers and retailers.

Description of event: Following months of deteriorating relations between the International Longshore and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA – representing the port users), strikes by about 10,500 union dockworkers on the US West Coast started on 29 September 2002. This meant that 29 ports were closed down for 10 days until a federal judge ordered an injunction to end the lockout. At the time, 60% of the US's imports and exports, with a value of around $320 billion, passed through West Coast ports annually.

Main consequences: Because most of the West Coast was affected, container ships could do little else but wait in open water for the strike to end – most were too big to be handled by Canadian or Mexican ports, or to pass through the Panama Canal to the East Coast. Losses to the US economy were estimated at up to $1 billion a day in the first week, rising to $2 billion a day in the second week of the strike. Had the strike lasted into a third week, the estimated cost would have risen to $3 billion a day. The jobs of 4 million US workers were impacted.

The car industry was particularly hard hit, because imported parts and vehicles could not be delivered. However, because of the advance warning of the potential strike action, some manufacturers such as New United Motor Manufacturing Inc. (NUMMI – a joint venture between Toyota and General Motors) were able to mitigate the impact by building up inventory at their US plants in the weeks prior to the strike, contracting with air cargo companies to lease several cargo planes to transport parts during the strike and investigating alternative ports of entry in Mexico and Canada that stayed open during the strike.

NUMMI typically worked with only four to six hours’ worth of parts on hand at any time, but increased its store of parts to several days. But four days after the strike started, NUMMI closed its plant in Fremont, California, which employed 5,500 workers. Seven days after the strike started, it then decided to charter several Boeing 747s to fly in parts from Japan to restart production. After the strike finished, NUMMI made up the lost production, but only at the cost of expensive airfreight, added storage and handling costs, and substantial worker overtime.

Similarly, some large retailers, such as Wal-Mart and Costco, recognised this impending threat and took steps to ramp up imports prior to shutdown in order to minimise the risk that they would be left without inventory, particularly of vital pre-Christmas stock. Even after the strike was over, there was still considerable disruption for several months in clearing the logjam of deliveries; Mattel began to bring in toys by air, at significant increased costs.

Transport problems spread inland, with freight cars loaded with goods locked in West Coast ports, trains bound for West Coast ports began to back up eastwards as rail yards became progressively filled to capacity.

On the export side, the strike coincided with the peak grape harvest, meaning...
that nearly $400 million of grapes ready to ship out through West Coast ports were spoiled, as were other fruits and vegetables.

There was also an eight-day strike on the West Coast in the ports of Los Angeles and Long Beach over late November / early December 2012. This was estimated to cost the Southern California region $8 billion, including lost wages and value of cargo re-routed to other ports.

A similar situation pertained when major strikes were threatened by longshoremen along the US East and Gulf Coasts in September 2012, but were suspended whilst negotiations took place and were finally called off in April 2013.

**Event: Buncefield explosion (UK), 11 December 2005**

Main impacts on local businesses and fuel rationing at London Heathrow Airport.

**Description of event:** Explosion and fire at the Hertfordshire Oil Storage Ltd (HOSL) depot at Buncefield, UK. Total direct damage of £130 million was incurred, but indirect costs exceeded £1 billion; there were no fatalities but 43 casualties, only two of which were serious (since the event took place at around 5:30am on a Sunday morning, there were few people in the surrounding industrial premises).

**Main consequences:** Severe damage and disruption to commercial properties on the Maylands Industrial trading estate and nearby residential properties; 2,000 people had to be evacuated from their homes. The fires continued for five days and thick clouds of smoke spread over southern England.

Although Maylands was an ‘industrial’ estate, it also contained various service companies, including several providing outsourced IT services to London City companies – for instance, Steria UK, which provided managed IT services for Lloyd’s, Xchanging and several major insurance companies. Steria lost its head office building in the blast, but was able to replicate all its systems and move operations to a pre-arranged back-up facility by mid-afternoon the same day.

The Final Report by the Major Incident Investigation Board (December 2008) estimated the overall cost of the event at £1 billion. These costs included:

- Claims of £103 million from other businesses inside the HOSL site.

- Claims of £490 million from 90 severely affected businesses outside the HOSL site, but within the Maylands industrial trading estate in which HOSL was located – including damage to buildings and other assets, loss of stock, disruption to business and loss of sales. There was a high level of interdependence between the 630 companies (which between them employed 16,500 people) on the estate, so that even those whose premises that were not damaged suffered through loss of suppliers or customers who were affected.

- The other major cost was to the aviation industry. London Heathrow Airport received 40% of its fuel supply from HOSL, and the event resulted in fuel rationing, which cost the industry approximately £245 million.
There were many unquantified costs of the event, such as the closure of the M1, M10 and M25 motorways for most of the day (HOSL was purposely located close to the junction of the key M1 and M25 motorways).

**Event: Evonik Industries explosion (Germany), 31 March 2012**

Main impact on car industry.

**Description of event:** Explosion and fire at Evonik’s CDT (cyclododectatriene) Degussa plant in Marl, Germany. Two Evonik employees were killed.

**Consequences:** CDT-based products, in particular the resin PA12 (polyamide 12), are used widely to make engineering plastic parts that are key components in car production (used to make fuel tanks, brake and fuel-line coatings), in the photovoltaic industry (for solar panels) and in cable coverings for offshore oil and gas production. The Evonik plant produced about 70% of the global feedstock for PA12, so the fire created a short-term crisis for automotive engineers and a search for substitutes. The Automotive Industry Action Group held a meeting in April 2012 in Detroit, Michigan, attended by more than 200 executives from companies including General Motors, Volkswagen, Toyota and Ford to assess the impact of the shortage and to seek alternatives. However, it can take up to six months to get safety approval from the authorities on replacement materials.

**Event: G4S (UK) failure to recruit and train staff, 2012**

Main impact on security staffing at London 2012 Olympics.

**Description of event:** Not all supply chain disruptions concern problems with supplies of components, they can also be the result of failure of support services, such as IT systems, logistics and staff resources. G4S had secured the contract to supply the paid security staff for the 125 venues of the London 2012 Olympics. It emerged only two weeks before the opening of the Olympics that G4S had only recruited and trained less than half of the 10,400 staff it was contracted to supply (despite having repeatedly provided assurance that it would overshoot this target).

G4S is the world’s largest security company (with 657,000 employees) and was one of the UK Government’s largest contractors, with deals worth £759 million in 2010-11 – providing services including the running of prisons and hospitals, back-office operations for the police, moving cash and reading meters.

**Main consequences:** G4S shares fell 17% when the news of the shortfall in staffing became clear, wiping £700 million from its market value. Three-and-a-half thousand military personnel were called up as emergency cover to make up the shortfall and hundreds of extra police had to be drafted in at the last minute when promised G4S staff failed to turn up at various venues.

Nick Buckles, the CEO of G4S, had to appear before the House of Commons Home Affairs Committee in mid-July 2012 to explain the position and faced calls for G4S to waive its £57 million management fee (part of the overall £238 million contract) to provide Olympic security.
The report of the House of Commons Home Affairs Committee, published on 21 September 2012, said that the final number of staff provided by G4S was only 4,389. It criticised Nick Buckles for failing to inform the Government minister when he first knew that G4S would not be able to fulfil the security contract and renewed calls for G4S to return its £57 million management fee.

Despite pressure to resign and his admission that G4S’s performance had been a “humiliating shambles” and that the “company’s reputation was in tatters”, Nick Buckles retained his job (although he did not get a bonus in 2012) – but G4S’s regional head for the UK and the head of global events division both lost their jobs. G4S agreed to reimburse the military for their efforts and finally to reduce the management fee from £57 million to £31 million, and an expected £10 million profit on the contract turned into a £88 million loss. G4S also suffered from being excluded from some tenders for future Government contracts.

Despite the problems of the Olympics, G4S did manage to adequately staff the Paralympics, but by then the reputational damage had been done.
Supply chain disruption - Economic causes

Event: UPF-Thompson insolvency (UK), 2001

Main impact on Land Rover.

Description of event: UPF-Thompson, the sole supplier of chassis frames to Land Rover (then a subsidiary of Ford) for its Discovery models, unexpectedly went bankrupt on 4 December 2001 with debts of around £75 million. This threatened the jobs of 1,400 Discovery production line workers and 10,000 employees at companies that made parts for the Discovery.

Main consequences: KPMG, the receivers for UPF-Thompson, threatened to stop the supply of chassis frames to Land Rover, unless Land Rover made a goodwill payment of £35 million to UPF-Thompson. KPMG justified its actions by pointing out that it was legally obliged to recover money on behalf of UPF-Thompson’s creditors and the sole supplier agreement represented a valuable asset. After Land Rover won a temporary injunction against this threat on 11 January to maintain the flow of chassis frames into its Solihull plant, it put £1 million into UPF-Thompson, which looked likely to find a buyer if the company was guaranteed a new contract to supply chassis frames to Land Rover.

After further legal action, an agreement was finally reached between Land Rover and KPMG in February 2002, under which Land Rover was believed to have paid between £10 million and £20 million of UPF-Thompson’s debt in exchange for the replacement of KPMG by its preferred receivers, Grant Thornton.

This case echoes supplier insolvency events that have impacted other motor companies; for instance, in 2000, Ford Motor Company spun-off Visteon, which made many parts for Ford cars. Over the period 2000 to 2004, Visteon made losses of more than $3 billion. At the end of 2004, it had 70,000 employees worldwide in more than 200 facilities and sales of $18.7 billion. Ford was then forced to bail out Visteon in 2005 to secure its longer-term viability, at a cost of $1.15 billion over the following four years (including $250 million to repay debt, $300 million for inventory and $500 million for restructuring costs), and absorb operating losses of up to $425 million, plus relieve Visteon of a $2 billion liability in relation to employee health care and life insurance benefits.

Another instance is BMW and Edscha, the German manufacturer of sun roofs, door hinges and other car parts. BMW was about to launch its new Z4 convertible sports car, with an Edscha-supplied roof, when Edscha filed for insolvency in February 2009. It would have taken BMW six months to find an alternative supplier, so it was forced to provide financial assistance to Edscha to enable it to keep trading.
Supply chain disruption - Reputation causes

Supply chains can also be disrupted not only by physical damage (either natural or man-made) to a supplier’s premises, or economic impairment to supplier, but by damage to a supplier’s reputation – which feeds back up the supply chain and threatens the primary company’s reputation. The following mini-studies illustrate cases where this has happened in recent times because of allegations of poor employment practices or environmental behaviour by companies down the supply chain.

Event: Nike – ‘cheap / child’ labour in Far East

Description of event:\textsuperscript{142}: Nike has a history of being accused of using ‘sweatshops’ in the Far East to manufacture its products. Workers in these so-called sweatshops can often work long hours for pay far below a ‘living wage’ and can be exposed to hazardous materials, extreme temperatures and abuse behaviour by supervisors. In these factories, 75% or more of the workers are female, mostly in their teens or early twenties – and they have to work nine to 13 hours a day, six days a week, and may be forced to work overtime several days a week.

Similar accusations are also regularly made against other major manufacturers of clothing, shoes and sporting goods whose products are made in the developing world; for instance, Adidas was accused in a 2008 lawsuit of coercing prisoners in China into waxing, stitching, sewing and making Adidas soccer balls for the 1998 World Cup 14 to 18 hours a day under inhumane conditions\textsuperscript{143}. Allegations also regularly surface about the use of child labour, ever since a Life Magazine article by Sydney H. Schanberg in 1996 about child labour, which carried as its lead a photo a 12-year-old boy in Pakistan, Tariq, sewing together a Nike soccer ball, for which he was only being paid 60 cents a day – or as the article’s headline put it ‘Six Cents an Hour’.

Main consequences: These accusations of using sweatshops go back to the 1970s, when Nike produced goods in South Korea and Taiwan. As these economies developed (wages rose and workers moved on to higher-paying jobs, and labour unions gained more influence), Nike moved manufacturing to cheaper labour economies in Indonesia, China and Vietnam, which prohibited labour unions.

The accusations that Nike was unethically taking advantage of these cheap labour markets continued through the 1990s and became a PR nightmare when consumers and activists constantly associated the Nike brand with sweatshops. In the US, anti-sweatshop protest groups grew, often based around university sports activities – hunger strikes and boycotts by Feminist groups were organised. Nike constantly denied the accusations and claimed that it did not have any control over the factories.

This approach changed in 2001 when Todd McKeen, Nike’s director of compliance, stated in an interview that the “As a company, we certainly had our shortcomings along the way. Our initial attitude was, ‘Hey, we don’t even own the factories. We don’t control what goes on there.’ Quite frankly that was a sort of irresponsible way to approach this. We had people there every day looking at quality. Clearly, we had leverage and responsibility with certain parts of the business, so why not others?”\textsuperscript{144}
Nike introduced a contract factory audit tool called SHAPE: Safety, Health, Attitude, People, and Environment, to cover such issues as work hours, wages and benefits, freedom of association and grievance systems, as well as environmental, health and safety standards, and has a Code of Conduct (latest edition is dated 2010) posted on its Compliance website.

**Event: Apple – suicides, riots and other issues at Foxconn, China, 2009/2010**

**Description of event:** Over the period January to November 2010, 18 employees at the Foxconn’s Shenzhen factory in China attempted suicide, with 14 deaths. There were also several outbreaks of labour unrest at its Chinese factories over the period September to October 2012. Foxconn is a large Taiwanese multinational electronics contract manufacturer (the largest in the world in revenue terms, assembling around 40% of all consumer electronic products sold), with 1.23 million employees (2012 figures) in operations in Asia, Europe (Hungary, Slovakia and the Czech Republic) and South America (Mexico and Brazil).

Its major clients (and products) include Apple (iPad, iPhone, iPod), Amazon (Kindle), Sony (PlayStation) and Nintendo (Wii U) – and also include or have included Acer, Cisco, Dell, Google, Hewlett-Packard, Microsoft, Motorola, Nokia, Toshiba, and Vizio. However, press reports of these and other incidents related to employment practices at Foxconn tend to highlight the Apple connection.

**Main consequences:** Employment practices and working conditions at Foxconn’s Chinese factories have been criticised at various times, alleging such issues as long working hours, low pay, discrimination against mainland Chinese workers by their Taiwanese co-workers and insufficient pay for overtime. The Chinese factories are huge – Shenzhen has more than 200,000 employees, mostly migrant workers living in worker dormitories. Employees have to work long hours under high pressure – one report described Foxconn Chinese factories as ‘labour camps’ and detailed widespread worker abuse and illegal overtime.

Suicides – The death of a Foxconn worker who fell from an apartment building in July 2009 after losing a prototype iPhone 4 in his possession attracted particular worldwide media attention. There were then a series of deaths and injuries of Foxconn workers as a result of falling from buildings during 2010, with seven alone in May. It was suggested that these were connected with wage disputes. Foxconn installed suicide-prevention netting at some sites and promised to offer substantially higher wages at its Shenzhen plants.

Workers were also forced to sign a legally binding document that they and their descendants would not sue the company as a result of unexpected death, self-injury or suicide. Suicides significantly reduced over the period 2011 and 2012, but did not completely cease. It has since been pointed out that, even at its peak, the suicide rate at Foxconn, expressed as a per head of population figure, was lower than the national figure for China, or even each of the 50 states of the US.

Labour unrest – “About 2,000 Chinese employees of an iPhone assembly company fought a pitched battle into the early hours … forcing the huge electronics plant where they work to be shut down. Authorities in the northern city of Taiyuan, China, sent 5,000 (paramilitary) police to restore order … The unrest is the latest in a string of incidents at plants run by Foxconn …” (Business
Insurance, 24 September 2012). “Foxconn hit by fresh outbreak of unrest at iPhone 5 factory” (Financial Times, 8 October 2012). As mentioned above, such stories tend to highlight the Apple connection.

Foxconn has now said that it will allow its 1.2 million workers to vote for what it says will be a genuinely representative union – Foxconn’s employees will elect 18,000 representatives by 2014 146.

Apple has a code of conduct for its suppliers that specifies certain safety standards and restricts workers to 60 hours per week; Chinese law further restricts overtime to 36 hours per month. Apple carries out audits of its suppliers and it is reported that, in 2009, of the 100 audits of production facilities, more than one half violated the policy of only working 60 hours per week. However, worldwide protests continue, with demonstrations at Apple stores, such as in February 2012 in the lead-up to the iPhone 5 launch.

Event: Ikea – production in former East Germany, 2012

Description of event 147: In 2012, media reports in Sweden and Germany suggested that the Swedish furniture group Ikea had used political and other prisoners to produce furniture in the former East Germany between 1960 and 1990. This was a blow to Ikea, which likes to tout its ethical culture. It had previously suffered claims about the use of child labour in the 1990s, and since 2000 has introduced a supplier code of conduct and carries out about 1,000 audits each year.

Main consequences: Ikea commissioned an investigation by Ernst & Young (E&Y), the auditors. E&Y examined 20,000 Ikea documents, 80,000 objects from German archives, 90 interviews and 75 calls to a telephone hotline in preparing its report. The E&Y report found that at least 66 East German companies with 117 factories had connections with Ikea over the period 1960 to 1990; political and other prisoners made furniture for Ikea at these companies and in prisons. The E&Y report also suggested that some managers from Ikea were aware of this use of prisoners from about 1978-81.

Ikea said it deeply regretted the use of political and other prisoners to produce furniture and made a donation to a scientific research project on forced labour in East Germany.

Event: Social media attack on Kit Kat, 2010

Description of event 148: On 17 March 2010, the environmental group Greenpeace launched a social media attack on Nestlé’s Kit Kat brand. Greenpeace had found that Nestlé was sourcing palm oil from Sinar Mas, an Indonesian supplier that Greenpeace claimed was engaged in unsustainable forest clearing. Greenpeace posted a video on YouTube parodying the “Have a break: have a Kit Kat” slogan; in the video, a bored office worker bites off a finger of a Kit Kat that turns out to be the bloody finger of an orang-utan, one of the many species threatened by unsustainable forest clearing for palm oil production.

Main consequences: Nestlé’s initial response was to make a statement that it only used 0.7% of global palm oil production and to force YouTube to take down the video, citing copyright. However, this led to an outbreak of criticism on social media (such as Facebook) and prompted Greenpeace to just post
the video on Vimeo, another social media site, and then on 21 March 2010, it reappeared on YouTube.

So Nestlé suspended palm oil purchases from Sinar Mas and entered dialogue with Greenpeace. Nestlé also chose Forest Trust, a non-profit organisation, to help it liaise with Greenpeace and audit its suppliers. Then in May 2010, Nestlé joined the Roundtable for Sustainable Palm Oil, a partnership of companies and other parties aimed at eliminating unsustainable production. Nestle now has a goal of using only palm oil certified as sustainable by 2015.
Product recall

Increasing consumer concern about product and food safety is leading to a rising number of product recalls. For instance, the US Consumer Product Safety Commission (CPSC) lists product recalls on its website www.cpsc.gov/en/recalls; on 8 April 2013, this listing contained 6,249 recall notices. The top 5 product categories are babies and kids, containers and packaging, plastic panels for doors or windows, toys and metal polishes; the top 5 hazards are injury, fire, falling, burns and choking.

So product recalls are relatively frequent events, but a few gain high publicity and notoriety (such as Perrier water in February 1990). Some of the factors that can contribute to attracting press and media attention are when a common source appears to be the problem (such as Chinese suppliers), or one manufacturer has several recalls in succession (such as Toyota in recent years), or vulnerable consumers (such as children) are put at risk. All three of these factors were present in the Mattel case study below.

Event: Mattel toys, 2007

Description of event: Like many toy manufacturers, Mattel had occasional product recalls, but was then forced to make a series of toy recalls in 2007. There were two main causes. Firstly, small magnets inside various toy figures or accessories (such as Batman, Barbie, Doggie Day, Polly Pocket) could fall out and be swallowed or aspirated by young children; if more than one magnet was swallowed, the magnets could then attract each other and cause intestinal perforation or blockage, which could have been fatal.

Secondly, surface paints on various toys and accessories contained excessive levels of lead, which was prohibited under federal law; lead is toxic if ingested by young children and can cause adverse health effects. In the worst cases, some of Mattel’s toys had levels of lead in paint that was 180 times the US Federal limit. All the affected toys, magnets and lead paint were manufactured in China.

In the case of the magnets, this problem had been recognised in 2006. Mattel worked with others in the industry and regulators to develop a new design standard for fitting small magnets in toys, and began implementing the new ASTM International standard in January 2007, before it was officially published. The August 2007 recalls were to allow Mattel to retrospectively apply the new design standard to the 18.2 million toys produced before 2007. In the case of the lead paint recalls, the toys with non-compliant levels of lead in paint were produced by various Chinese contract manufacturers – which were found when investigated by Mattel to have either carelessly or deliberately avoided following Mattel’s well-established rules to either use certified paint suppliers or test any paint used for compliance.

Main consequences: Zhang Shuhong, co-owner of the Lee Der Toy Company, one of Mattel’s contract manufacturers, committed suicide in August 2007 – the non-compliant paint was produced by a company owned by a close friend – and Lee Der ceased business (before hanging himself, Zhang Shuhong paid off all his 5,000 staff). Over the year following the scandal, Mattel had recalled a total of 21 million toys from China as a result of the magnets and lead paint issues.
In December 2008, Mattel reached a settlement with 39 states to pay $12 million to educate the public about the dangers of lead paint and lead poisoning. On 5 June 2009, the US Consumer Product Safety Commission fined Mattel $2.3 million for violating the Federal lead paint ban; while Mattel agreed to the fine, no wrongdoing was admitted on the company’s part.

The Mattel product recalls were not the only cases to involve Chinese manufacturers at this time. In 2007, there were a series of product recalls and import bans imposed by public safety institutions of the US, Canada, the European Union, Australia and New Zealand on products manufactured in and exported from the mainland of the People’s Republic of China because of numerous alleged consumer safety issues – involving such goods as pet food (containing melamine, killing pets), toys (lead paint), sunglasses (lead paint), toothpaste (containing diethylene glycol, a poisonous constituent of antifreeze) and lipstick.

Although the products concerned represented a small fraction of China’s exports, worth more than $1 trillion per year, Chinese officials worried that the US government could use these quality problems to restrict trade. Zheng Xiayou, the head of China’s state food and drug administration over the period 1998 to 2005, was convicted of dereliction of duty and taking bribes from manufacturers of the substandard medicines that had been blamed for several deaths – and was executed on 10 July 2007.
9. Endnotes

Essentially, a fire that lasted less than 10 minutes at the Phillips’ plant had a relatively small Property Damage loss of around $10 million, but a BI loss of nearer $500 million, caused by the interruption in the supply of radio frequency chips for use in mobile phones to principally Nokia and Ericsson. Nokia managed the crisis well, but Ericsson did not, and this disruption was the main factor in more or less putting an end to Ericsson being a major player in the mobile phone business and having to merge with Sony to maintain a manufacturing presence. For further details see, for instance, The Resilient Enterprise, by Yossi Sheffi, MIT Press, 2005, chapter 1, Big Lessons from Small Disruptions.

High levels of the toxic substance benzene were discovered in bottles of Perrier in 1990, due to the failure to routinely replace a filter costing a few cents. Perrier did not handle the resultant PR well. Although it finally recalled 160 million bottles worldwide, this was only after considerable damage to Perrier’s reputation had been sustained. Perrier never recovered its previous dominant market share for bottled ‘pure’ water.

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