

**GLOBAL SUPPLY CHAINS, DISASTERS AND EXTERNALITIES:
How complex supply networks create damaging externalities and its consequences.**

Andreas Udbye

Portland State University, Systems Science Program
P.O. Box 751, Portland, OR 97207, USA

ABSTRACT

Sprawling and global supply chains are doing a decent job of providing consumers with inexpensive and timely products. However, their size, complexity and lack of accountability make them originators of serious risks and disruptions. Such disruptions are not contained to the closed systems of the respective supply networks, but bleed over into society and the surrounding communities as negative externalities. Consequently, modern supply chains can expect to be subject to greater scrutiny and pressures to reduce risks and provide compensation for the costs imposed on others involuntarily.

Keywords: Supply chain management; Risk management; Globalization; Complexity; Externalities

SUPPLY CHAIN RISK MANAGEMENT

Supply chains operate in an environment of imperfection and unpredictability, as they are subject to a variety of risks and disruptions. Most of these disruptions are everyday annoyances that are mostly handled through sound management practices and corrective actions. We classify those as high probability, low impact disruptions. Other risks are more severe. They happen less frequently but tend to have larger operational and financial impact. Such disruptions can be classified as medium probability and medium risk. The focus of this paper is on the very serious disruptions that happen infrequently, including various disasters and catastrophic events. These shall be called low probability, high impact (“LPHI”) events. A classic risk assessment taxonomy (for example (SCRLC, 2011; Sheffi, 2005)) is to graph various risks on a two-dimensional chart with probability and impact as the two variables, as follows:

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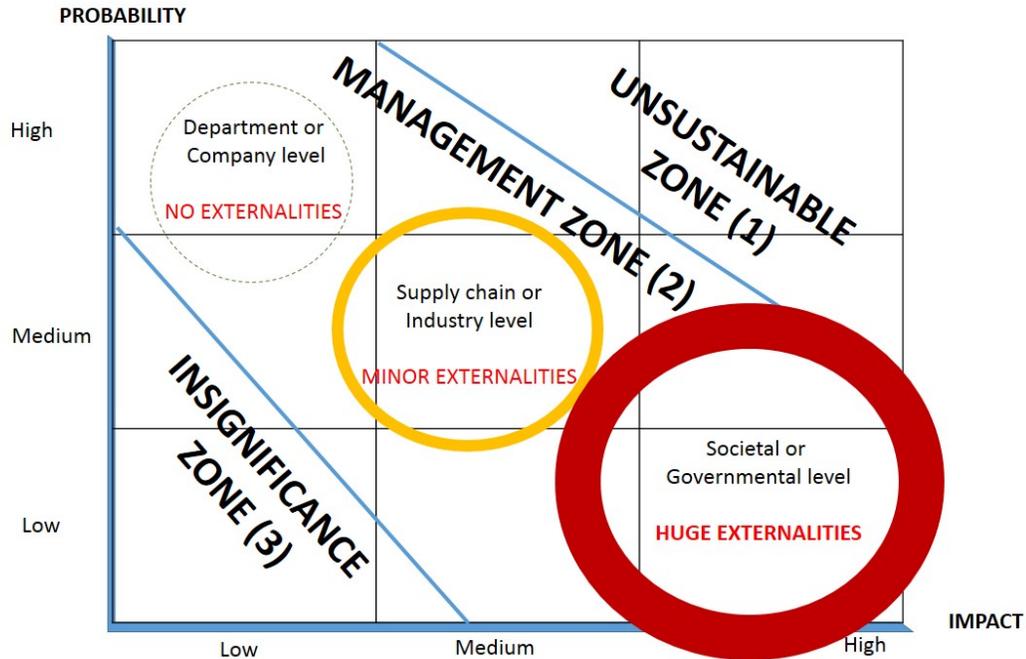


Figure 1: The Probability (likelihood) vs. the Impact (consequences) of Disruptions

Explanation to Figure 1: The three circles represent disruptions of high probability/low impact, medium probability/medium impact and low probability/high impact, respectively. In the smaller circle, the impact is mitigated on a department or company basis, and there are no outside victims (externalities). In the middle circle, the mitigation takes place at the supply chain or industry level, and there are only minor outside victims/externalities. The big circle represents disruptions which need to be mitigated with societal and governmental efforts, and where there are substantial externalities.

(1): Unsustainable zone: Nobody can sustain themselves here in the long run.

(2): Management zone: The management and mitigation of risks in this zone involve an increasing degree of societal involvement and systems complexity.

(3): Insignificance zone: The disruptions in this zone are handled through every day, routine operating procedures.

One could argue that it is impossible to survive in the long run in either zones 1 or 3. Zone 1 is obviously chaotic, while zone 3 is so tranquil and risk free that nobody can make money there. With good risk management, the money is to be made in zone 2, the “Management Zone”.

THESIS: Low probability, high impact (LPHI) disruptions cause widespread and often uncompensated damages (externalities) to a supply chain’s non-stakeholders and the broader society.

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High probability, low impact disruptions happen within fairly closed systems, where the damages are limited to individual companies and possibly their immediate customers or suppliers.

Medium probability, medium impact disruptions may cause some suffering and damages outside of the immediate supply chain system, but the effects are short term and financially modest.

Low probability, high impact events (disasters or Black Swans) that are caused by mishaps in the supply chain will have major negative consequences outside the immediate supply chain system.

The LPHI events or disruptions can be divided into several sub-categories, depending on what is causing them. Sometimes they don't fit neatly into just one category, or they start cascading. Extensive flooding, for example, can cause power outages, which again can trigger looting and riots. Major disasters are often characterized by such compounding. The three main subcategories of disasters (LPHI events) include natural disasters, man-made disasters, and disasters originating from within the supply chain. We will be concerned with the disasters stemming from or being caused by factors within the supply chain. These are the disruptions that spill over onto the general public and cause considerable externalities. For our purposes, an *externality* is a cost which results from an activity and which affects an otherwise uninvolved party who did not choose to incur that cost (Buchanan & Stubblebine, 1962). In other words, some supply chain disruptions hurt innocent people. The various transfer prices within the supply chain do not reflect the full social costs of the transaction. Externalities also occur wherever the actions of one supply chain impact another supply chain (Cachon, 1999)¹

The LPHI category of disruptions can also be described as events that transcend the otherwise fairly closed system of a supply chain or supply network. Because of the complexity and extensive interconnections of modern supply chains, the current trend is to call them supply networks (Pathak, Day, Nair, Sawaya, & Kristal, 2007). Figure 2 shows what can be labeled a closed-loop system consisting of a simple network of a focal firm, two tiers of suppliers and two tiers of customers. The typical flows within the supply network are shown, including the one-way product flow, the two-way information flow, the opposite direction money flow, and the two-way what we shall call human relations flow. Outside this closed system is the operating environment of this supply network. This environment includes the many outsiders who can be hurt when something goes terribly wrong within the closed system and it overflows. Such impact spillovers from LPHI events tend to affect a wide circle of constituents, causing wide ranging personal, corporate and societal suffering.

Although supply chains can be modeled as closed systems, research has shown that they are indeed interactive adaptive systems. The constant interaction with the environment forces them to change (Peck, 2005). Even though they must adapt to sustain themselves in the long run, they can still cause considerable trouble for the outside environment.

¹ Although in a competitive market some of this is to be expected.

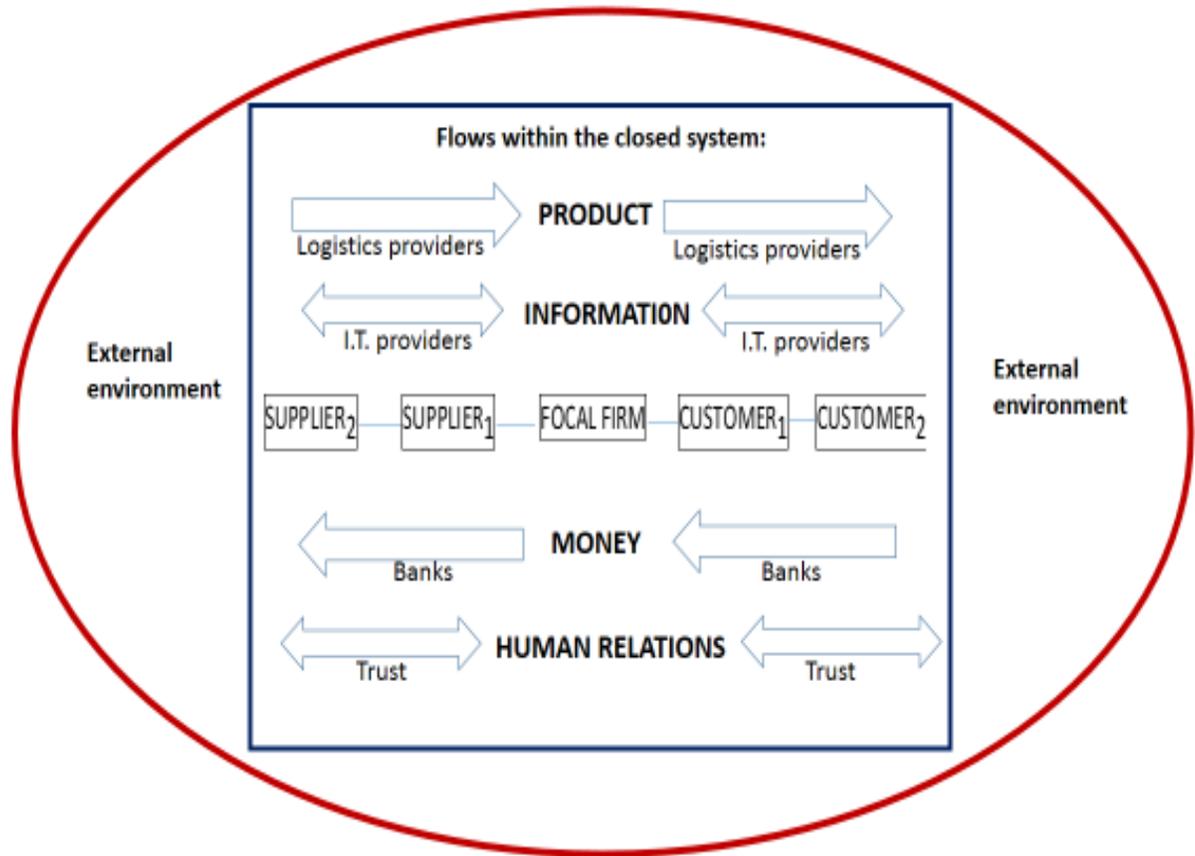


Figure 2: The flows within a supply network depicted as a closed system within system boundaries separating it from the external environment.

WHEN SUPPLY CHAINS GO BAD

When is a supply chain suddenly a problem for all of us? When are a supply chain's externalities over the top?

Any modern supply chain or network is prone to a variety of disruptive events. Some of these are everyday irritants that slow down operations or customer service. Such disruptions are solved internally and are hardly noticed by anybody outside the organization or immediate supply chain. Other risks or disruptions are more serious but happen less frequently. An example of such a "mid-range" event could be a highway accident involving one of the company's trucks and causing damage to the cargo, several vehicles and even personal injuries. The overall effect, however, is limited and usually remedied by using insurance and classic supply chain mitigation methods such as buffer inventories and redundancies. The scary events, with wide ranging societal effects, are the low probability but high impact (LPHI) disasters that increasingly seem to afflict our global supply chains. All of us suffer from natural and human caused disasters. One cannot blame earthquakes, flooding, terrorism or civil war on supply chain operations. However, there are preventable and controllable risks within supply chains that should be dealt with through appropriate and deliberate management systems and practices. It is unfortunate and inexcusable

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that supply chains themselves create risks that they can or will not control, especially when the consequences of disasters spill over into the general community.

The goal of supply chain risk management is to mitigate disruptions that negatively affect the focal company and its closest supply chain (Finch, 2004). There is a huge emphasis on meeting demand and maintaining customer satisfaction in case of disruptions (Singh, Smith, & Sohal, 2005; Sodhi & Tang, 2012). Various protection, prevention, reduction, restoration and recovery methods are implemented for the benefit of a narrow group of stakeholders and to reduce the financial impact of the disruptions. Managers are evaluated and rewarded on the basis of how well they limit the operational and financial damages. This is hardly surprising given the law of agency which compels managers to act to the benefit of their principals (Zsidisin & Ellram, 2003). Managers are paid to focus on the immediate interests of their employer, which means avoiding damage to external stakeholders or outsiders is not a high priority.

The concern here is that complex and sprawling supply chains create their own risks and hazards in their quest for efficiency, low prices and speed. The World Economic Forum points out that “systemic risks are created or magnified by the way supply chain systems are configured” (Bhatia, Lane, & Wain, 2013). These risks are not just internal to the networks of suppliers, manufacturers, logistics providers and customers. They put the general public and marginal stakeholders at risk, usually without due compensation. The supply chains are not just receivers of risk as various disruptions happen; they are also generators of risks that innocent bystanders may have to suffer and absorb. The web of interaction and connections with the overall environment means that the complex activities of modern, global supply chains are no longer a private matter of concern only to the nearest supply chain participants. The chains or networks have the unfortunate ability to leave a trail of carnage – externalities – in their wake.

This paper argues that the more severe the impact of a risk or disruption, the more serious the negative ripple effects become throughout society. It is the risks created internally within supply chains that are of concern. Internal risks arise as a result of the structural drivers described below and faulty procedures or processes among the supply chain participants. This includes poor communication and performance incentives of anti-social nature (e.g. resulting in greed and corner cutting). Unfortunately, these internally hatched disruptions are also the ones that outsiders often suffer from. Risks external to the supply chain, on the other hand, cannot be blamed on something that went wrong internally. External risks, like natural disasters, are more “equal opportunity” hazards that can randomly affect anybody, whether inside or outside of supply chains. Supply chains cannot be blamed for natural disasters or many other externally generated risks. They can, of course, be blamed for not being properly prepared. Lack of preparedness may unnecessarily add to the suffering of bystanders.

There are many drivers of supply chain risk, both internal and external to the supply networks. Because of higher global population density and property development, natural disasters tend to have more serious human and financial impacts than just a few decades ago. When wind storms, flooding and earthquakes happen, more infrastructure, more buildings and more people are being affected. The 2011 earthquake and tsunami on the east coast of Japan is so far the world’s most expensive natural disaster, at an estimated 300 billion dollars. It also claimed almost 20,000 human lives (Swiss-Re, 2012).

Internal supply chain disasters, on the other hand, are a result of human endeavors and organizational structures. They can be even more damaging to the supply chain participants and

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outsiders than natural disasters, and the long term effects can be just as lasting. Many of the drivers of internal supply chain risk are factors that are typically found in modern supply chains (Christopher, 2002; Pettit, Fiksel, & Croxton, 2010). From an efficiency standpoint, many of these factors are desirable, even though they may make the supply chain more vulnerable:

- Long and globalized supply chains, with dispersed tiers of suppliers
- Specialized factories, often clustered and producing niche products for a whole industry
- Centralized distribution, making each warehouse a critical node
- Increased outsourcing, implying less direct production and logistics control
- Reduced supplier base, in an attempt to reduce handling and inventory costs
- Increased volatility of demand, with rapidly changing consumer tastes and preferences
- Lean manufacturing practices, which eliminated buffer inventories and safety margins
- Faster product life cycles, which put pressure on suppliers for quick turnarounds
- Globalized customer base, adding complexity to the manufacturing and shipping schedules

The race to save money and cut inventory have caused supply chains to become more fragile and risk prone. They are like race cars that are ill fitted to operate in rough terrain.

One common denominator among the drivers listed above may be the key word “complexity”. The sprawling, global networks of suppliers, manufacturing plants, distribution centers and customers are very challenging for companies and constellations of companies (e.g. supply chains) to organize and manage. So many things can go wrong, and disruptions and mishaps tend to reverberate quickly throughout the network and, unfortunately, the outside environments. Complexity is characterized by interconnections and dependencies between the various elements or agents in the supply chain (Speier, Whipple, Closs, & Voss, 2011). Activities and connections between components at various levels of the supply chain will often affect the effectiveness of the whole supply chain. A delayed freight shipment between second tier suppliers can easily ripple through the network and cause production delays and late deliveries to the ultimate customers. The inherent complexity causes many disruptions to reveal the fragility of the overall supply network.

It is easy to see how sprawling and decentralized supply networks can cause or magnify risks. Because it consist of many participants, nobody is really in control of the whole supply chain, and there is lack of accountability. Supply chains typically attempt to optimize locally, so that each component gets out of its investment as much financial gain as it can. This creates suboptimal supply chains as a whole. Even though supply chains may be closed systems, they are not achieving optimal, system-wide profitability. And they are definitely not coherent and motivated enough to reduce the overall risk to their surrounding environment. Such supply chain systems are ticking time bombs. When disaster strikes, the surrounding communities tend to pick up the pieces. As Heal et al. point out, connections between networks also mean that failures in one may compromise operations of other networks (Heal, Kearns, Kleindorfer, & Kunreuther, 2006).

THE NATURE OF DISASTERS

Because operating in a high probability, high impact risk environment is unsustainable, high impact disruptions and disasters fall into the low probability category. It could be decades or more between each event. This precludes learning, and it is often easy for supply chain participants to fall into complacency or be ignorant of the risks. In any case, some natural disasters may be so random and severe that no preparation would help in mitigating them, and

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their frequency is so seldom that people resign to live with and accept the somewhat theoretical risk. How do you realistically prepare for a magnitude 9 earthquake? The only way to be safe would be to move the operations somewhere else, perhaps thousands of miles away.

Natural disasters are random events that cannot be blamed on or are not caused by human activities. When they happen, everybody suffers and everybody is an innocent victim.

There are many recent examples of supply chain originated disasters with externalities that hurt uninvolved and innocent parties. It might still be early to place blame for the recent factory collapse in Bangladesh, but it seems that several things went wrong within the apparel supply chains. The western clothing brands lost sight of who was sewing their clothes, their buyers put heavy deadline and production pressures on their suppliers, the building owner was irresponsible, and the public inspection authorities were ineffective. In short, the race to the bottom became extremely costly for a lot of people, not the least the 1,100 who lost their lives and their relatives. In the aftermath of this disaster, the negative ripple effects throughout the Bangladeshi garment industry are having a negative impact on business and employment (Greenhouse & Yardley, 2013).

It is ultimately the consumers of apparel products – people like you and me – who are not paying the full price for the total cost imposed on society from the production of these garments. As end-users of these products we are enjoying a lower price than morally required to compensate the innocent victims of the fallout from activities throughout the upstream supply chain. From this perspective, occasional disasters are just spikes in a continuous hum of externalities produced during the long, complex and often globalized process of converting raw materials into clothing and getting it to us so we can wear it. Supply chain activities involve sourcing, production and transportation processes that throw off by-products that are hurtful to others. Most of these by-products are marginal and incremental, and involve various types of pollution and congestion. One more semi-trailer loaded with clothing will add a bit more pollution, a bit more noise, a bit more congestion and a bit more accident risk.

Society is of course aware of these externalities and use policy measures to try to compensate for them. Taxation and regulation are the most common. It is becoming more expensive to own and operate trucks, and these costs are ultimately passed on to the consumers in the form of higher freight charges.

In June of 2013 a semi-trailer hit the guard rail and tipped over during rush-hour on an important freeway near Seattle². Such an event normally falls into our medium probability, medium impact category, implying that both the supply chain participants (inside the box) and the affected community (outside the box) overcome the disruption relatively easily. The incident near Seattle, however, became particularly serious because the highway was completely blocked for three hours. As this was close to the airport, many people missed their flights. In cases like these it turns out that we are all “self-insured”, meaning that people are willing to absorb costs imposed upon them by the actions and possible carelessness of others. Suffering the economic and possible health consequences of someone else’s actions is part of how humans spread the risk.

In the Seattle accident a few people sustained minor injuries and their cars were damaged. It is likely that auto and medical insurance plans took care of this, and that the trucker did not have to

² <http://www.king5.com/news/cities/renton/Overtuned-semi-blocks-I-405-in-Renton-210077021.html>

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compensate them. However, the people who were stuck for several hours and possibly lost their flights will have little or no recourse to claim compensation from the trucker or his supply chain. The individual damage for some of these people could amount to thousands of dollars (if they had nonrefundable flights to Asia to attend an expensive professional conference there). Collectively the aggregate, but unaccounted for economic impact from this accident could add up to an amount close to \$100,000. In this case the externality of a \$500 freight movement was quite severe.

Human-induced disasters such as building collapses, factory fires, food contamination and I.T. breaches can have externalities that amount to millions, if not billions of dollars. The reality is that the innocent victims are not able or equipped to seek compensatory damages for the negative impact imposed on them. Modern supply chains, in effect, get away with practices and behavior that they don't have to pay for. As consumers and the last link in any supply chain we are all benefiting from a situation where the real cost of the product is higher than what we actually paid. The dark side of free trade and globalization is perhaps that consumers in the rich world are benefiting from uncompensated externalities suffered by the population in the poor, developing world. Many of these countries have gained bustling extraction and manufacturing sectors, but at a cost of exposing their populations to severe pollution, erosion of the ecological environment, congestion, and questionable labor and safety practices. People there are willing to sacrifice current living and working conditions for possible future prosperity.

It is worth mentioning that externalities hurt players within supply chain networks, too. The actions of one supply chain can hurt the performance of another supply chain (Heal et al., 2006). When one instance of Mad Cow Disease was found in an animal in Washington State ten years ago³, it did not just hurt the owners and processors of this animal. The dire finding caused many Asian countries to ban the importation of American beef products for years thereafter, thus causing billions of dollars in lost sales to those markets. The discovery of horse meat in European food products⁴ has caused consumers to shy away from processed meat products such as hamburgers, sausages and pizza toppings. Firms that had absolutely no contamination suffered tremendous losses in sales.

IS CREATING EXTERNALITIES A PROBLEM FOR MODERN SUPPLY CHAINS IF THEY CAN GET AWAY WITH IT?

Supply chain participants have been slow to react to spillover effects from disruptions unless they directly hurt their operations or financial results. The aftermath of high impact disasters often include new laws, prohibitions and regulations, and firms can often be embroiled in costly litigation for years. This will hurt financially and add new constraints to the operations. After the recent building collapse and factory fires in Bangladesh, companies found themselves under pressure from consumer and advocacy groups to clean up their practices by taking a more active role in certifying and approving production facilities and working conditions. As explained by Heal et al., the garment industry is now exhibiting a degree of tipping behavior, which means that a critical mass of companies have now been persuaded to change their practices (Heal et al., 2006). The companies consist of leading clothing brands, and they see a benefit from working

³ <http://www.foxnews.com/story/0,2933,106547,00.html>

⁴ <http://www.euronews.com/2013/02/16/still-more-horse-meat-found-in-european-beef-products/>

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together to reduce the externalities that previously fell on each one of them and the outside community.

Often a collaborative approach is required, not just between supply chains, but with non-profit and governmental entities. As the World Economic Forum puts it, “Risk management must be a shared responsibility between the public and private sectors, between industries, and between functional decision-makers in companies” (Bhatia et al., 2013). This is what most likely will happen as a result of the disasters in Bangladesh. The new safety rules and measures will help to reduce the negative side effects and externalities of unbridled production activities. The goal is that the manufacturing processes become less risky and with lower potential to hurt people. This will, of course, have an economic impact on the international clothing brands. It will ultimately be more expensive to produce in Bangladesh and other developing countries, and the cost will be passed on to us consumers in the form of higher prices. It is likely, though, that most consumers are happy to pay a bit more to ensure a safer supply and production process. In a moral sense, nothing should be produced at the expense of innocent people.

There will always be market participants and supply chains that choose to take the lower road. It is always difficult for regulators to ensure safety, especially on a global basis. There will be countries and states that choose to compete for business by lowering or not enforcing standards, and corruption is a perennial problem. Over the next few years we will see the proliferation of a variety of sourcing and production certifications, akin to the existing “Certified Organic” or “Fair Trade” initiatives. Because it is good marketing, it will behoove companies to attach themselves to such initiatives. Eventually the number of customers wanting to deal with deficient supply chains will shrink to an unsustainable level, ensuring the cleaning up of the practices of entire industries. Nevertheless, supply chains can probably never quite rid themselves of free-riders and moral hazard type reasoning, where the real risks are carried by others.

FOUR WAYS TO REDUCE EXTERNALITIES WHEN DISASTER STRIKES

Of course, prevention is the best cure for supply chain disasters. Better risk management within the supply networks is necessary. This implies conscious policies and efforts of all the supply chain components and internal collaboration and coordination. When externalities start costing supply chains money – i.e. they are increasingly internalized – this motivates them to synchronize their efforts to reduce the likelihood of internally generated risks. They will work to limit the risks to themselves and the outside communities.

- 1) **Tipping behavior:** This means that key players in an industry take deliberate initiative to clean up and improve their practices. Hennes & Mauritz (H&M) was a recent example of that in the aftermath of the Bangladesh factory collapse⁵. When leaders start, others are convinced to follow suit, and the industry starts to govern itself. Sometimes trade associations will act on behalf of their members and proactively institute and suggest policies.
- 2) **Consumer-driven initiatives:** Consumers can walk with their feet by refusing to buy a company's products or organize non-profit organizations that will introduce certifications or standards. The pressure of public opinion can be quite convincing, and many supply chains have changed their ways based on it.

⁵ <http://money.cnn.com/2013/05/13/news/companies/hm-bangladesh-safety/index.html>

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- 3) **Government-driven initiatives:** Usually government agencies don't just suggest; they regulate and mandate policies and procedures. This may not always be an ideal solution, as it is often reactive and overshoots. When you are dealing with decentralized and uncoordinated supply chains it may be the only effective way to institute change. Government has a duty to protect its citizenry and its infrastructure, so it is eminently entitled to legislate and regulate if supply chains fail to self-regulate.
- 4) **Lawyer-driven enforcement:** In an increasingly litigious world, it is becoming harder to walk away from externalities or shirk ultimate responsibility. It is almost certain that many brand-names would go bankrupt and disappear if Bangladesh-like disasters were to happen within the United States. It is almost inconceivable that J.C. Penney and others would not completely lose their shirts if such catastrophes happened here⁶. Even in the developing world it is increasingly possible that disasters caused by supply chain negligence or oversights would be subject to lengthy and costly litigation.

WHAT'S NEXT?

Supply chains cannot continue to expose innocent populations to costly externalities. Certain natural disasters, human strife and accidents can be explained and forgiven, but collateral damage caused by sloppy supply chain practices will come back to haunt the supply chain participants. In a connected and media driven world, there is nowhere to hide for irresponsible supply chains. Supply chains do not operate in a vacuum as closed systems. They will increasingly be held responsible for the wide ranging, societal consequences of their sins and transgressions. The growing globalization and complexity of supply chains mean that more people are being affected by high impact supply chain disruptions. Externalities might become the next challenge for supply chain managers.

It is suggested that empirical research focus on mapping the societal effects – financially and human – of disruptions emanating from supply chain operations. This will help to shed some light on this serious problem and will become a basis for policy discussions.

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