How Indian supply chain disruptions and modern supply chain risk management practices produce troubling externalities and environmental consequences

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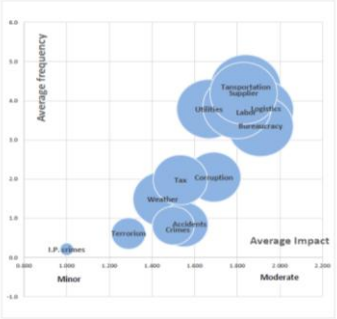


ABSTRACT
Activities under the banner "Supply Chain Management" now comprise a major share of the world economy. This encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities, such as transportation and inventory management. The various functions are visible, physical, highly exposed, and vulnerable to various risks and disruptions. Disruptive events have varying degrees of frequency and impact, and tend to not only negatively affect the operational and financial performance of the companies comprising the supply chains, but also hurt innocent outsiders through negative spill-over effects and externalities.
We performed empirical research in India that revealed the risk factors with the most prevalent and severe impact on supply chains. The research also showed which risk mitigation methods were the most useful and popular given the various categories of risks encountered. This paper argues that not only do the various disruptive events have a negative effect on the ecological and social environment, but the most popular mitigation methods applied to either prevent the events from happening or minimizing their damage are also hurting the environment in direct and more subtle ways. Nevertheless, the question remains whether society at large is better off with supply chains investing in risk mitigation methods rather than them operating "on the cheap" and having everybody suffer from more severe disruptions.
India presents a high risk operating environment for supply chains, with pervasive disruptions and much waste. The country would benefit in several environmental and sustainable ways from minimizing supply chain risks, leading to fewer harmful disruptions and less costly and elaborate systems of mitigation and damage control

1. INTRODUCTION

Activities under the general banner of supply chain management are necessary to ensure the physical delivery of goods to the ultimate consumers and end users. All kinds of goods travel along the supply chain, from the raw materials source and subsequently through a variety of links and intermediaries to consumers like you and me. The supply chains add value to products, mostly by disaggregating large quantities into small lots, and by providing space and time utility by delivering the right products in a timely fashion to where they are needed. A useful definition of *supply chain* provided by Sodhi et al reads *"a network of organizations possibly including suppliers, manufacturers, logistics providers, wholesalers/distributors, and retailers that aims to produce and deliver products or services for the end customer."*(Sodhi, Son, & Tang, 2012). A broad definition of the logistics sector attributes it to as much as 18.52% of India's gross domestic product (Shepherd, 2011).

Crucial elements within supply chains are the transportation, handling and storage activities that are involved with hauling products from one location to another. Depending on the nature of the product, these activities can be more resource intensive than the manufacturing itself. Transporting dense cargoes such as table salt or potting soil, for example, requires heavy trucks and fork lifts, and such products take up substantial storage space. In the specific case of potting soil, its production and distribution require multiple uses of heavy machinery, transportation and lifting equipment. Even under ideal conditions, without impediments and disruptions, getting such products to the end users is an energy intensive and polluting process.

Because supply chains exist in the physical and social world, they are constantly exposed to interruptions and mishaps that impede and complicate their effectiveness. Some of these disruptions can be expected as normal irritants or costs of doing business, while others are less predictable and more surprising and constitute elements of risk. Both the irritants and the unexpected disruptions will require some sort of risk management, either in the form of preventative efforts or as damage control after a negative event has happened.

The occurrence of disruptive events and the managerial efforts to prevent or mitigate such events will by themselves add to the already negative ecological consequences from producing and distributing any given product. Various risky events do not help the environment, but neither do the assortment of efforts to prevent risky events from happening. Both supply chain disruptions and the mitigation methods applied under what is labelled *supply chain risk management* will negatively affect the supply chains themselves as well as the ecological environment through unintended consequences and externalities.

Wagner and Bode defined supply chain risk as *"deviation from the expected value of a supply chain performance objective resulting in negative consequences for the affected firm"*, (Wagner & Bode, 2009), but a more hands-on definition may be *"unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain, and, as a consequence, expose firms within the supply chain to operational and financial risks"* (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007)Notice that both definitions concern themselves with the negative outcomes for the firm, or in other words, an insider within the supply chain. Supply Chain Risk Management concerns itself with methods and procedures for minimizing risks and the consequences of disruptive events, or in the words of the Supply Chain Risk Leadership Council, *"the practice of managing the risk of any factor or event that can materially disrupt a supply chain, whether within a single company or spread across multiple companies. The ultimate purpose of SCRM is to enable cost avoidance, customer service, and market position."*(SCRLC, 2012) Again, the emphasis here is on damage prevention and control for the company.

Even under the best of circumstances, supply chain activities result in pollution and harmful environmental consequences. Most of this comes from the transportation of goods. For example, transportation (road, water, rail and air) is the largest single source of air pollution in the United States, (UCSUSA, 2014) . In India, major sources

have been industrial chimneys and power stations, as well as the burning of wood and waste for cooking and heating, but it is likely that the ongoing growth in the number of cars and trucks now positions the transportation sector as one of the biggest contributors (Harvey, 2016).

Supply chains have insiders and outsiders. It is meaningful to include as insiders those parties that contractually or financially contribute to or benefit from the activities of the chains. This would include the chronological succession starting with primary industries (farming, fishing, mining, logging, etc.) through intermediaries such as manufacturers, wholesalers, distributors and retailers, and ending with the consumers or end users. Service providers, such as transportation firms and banks are part of the supply chain, as are companies engaged in reverse logistics, such as recyclers and garbage collectors. Necessary stakeholders that make supply chains function include the company owners, the managers, all the employees, the suppliers (several tiers of), the customers (also several tiers of), as well as government institutions that regulate and/or derive revenues through taxes and fees. These are obviously insiders, as they possess various sets of rights and obligations that tie them closely to the supply chains. One could also argue that competitors are insiders, as they are committed to playing in the same league with competing supply chains, subjecting them to the same operating environment, rules and regulations as any other participants. Any positive or negative externalities which might befall competitors are not externalities in a strict sense, because the competitors find themselves inside a delivery system consisting of all the actors with financial or legal interests in their respective markets. Actions by one competitor may result in negative "externalities" for another, but this is part of the competitive nature of free market economics that every player should be prepared for.

Mike Moffatt offers a suitable definition of externalities for our purposes: "spillover [SIC] effects that fall on parties not otherwise involved in a market as a producer or a consumer of a good or service" (Moffatt, 2016). The key phrase here is "not otherwise involved in a market", which limits the scope of which parties should be defined as external to supply chains. Thus, externalities – whether positive or negative – affect innocent parties that have no transactional, legal or market related involvement in the pursuits of any given supply chain.

2. SUPPLY CHAIN RISK MANAGEMENT IN INDIA

Our research in India dealt with supply chain risk factors and the mitigation methods company managers typically use to limit the effects of disruptions (Udbye, 2014). To get an overview of which risks were considered the most severe, we surveyed supply chain managers on which disruptions were most frequent and inflicted the most financial and operational damage. The product of occurrence multiplied by impact is an acceptable method to assess risk severity. It reveals that frequently occurring events that cause only minor damage can still add up to become as severe as rare events with major damage. For example, fifty annual traffic delays with an average impact of $100 will result in the same annual severity as one annual act of crime with an impact of $50,000. After identifying the risks that Indian supply chains were exposed to, we asked the managers to identify and rate the mitigation methods they used as part of their risk management.

The survey revealed that when managers had to rank thirteen different risk categories, the six with the highest severity were found to be supplier problems, inadequate logistics infrastructure, inadequate transportation infrastructure, labor problems, bureaucracy, and inadequate utilities infrastructure, in that order (Table 1).[1] The more dramatic disruptions, like crimes, accidents or flooding, were rated with a lower severity than a cluster consisting of the six first mentioned. In essence, the supply chain managers found the every-day, existential risks to be a greater impediment to their operations than risks

[1]The disruptions are ranked in order of average severity, defined as the product of frequency and impact. The middle column is included to illustrate the much higher overall incidents and severity of the first six disruptions, appearing as a cluster in Table 2.

garnering headlines and public curiosity (Table 2).[2]These risks represent "death by a thousand cuts", and constitute a constant challenge and drain for companies sourcing and operating in India.

Supply chain managers meet the ubiquitous challenges of operational risks by adopting various types of mitigation methods. These methods introduce procedures and practices that can help prevent the occurrence of risks, but more importantly, help the companies withstand and recover from disruptive events. The mitigation methods infuse a degree of resilience into the companies' operational effectiveness, enabling them to satisfy customer demands even after disruptive events. In supply chain risk management, there are mitigation methods that are tried and true, including buffering, redundancies, flexibilities, visibility, and the more basic doing it yourself ("in sourcing").

TABLE 1: Supply Chain Disruptions Ranked in Order of Severity

Disruption	Sum of individual severity scores	Average severity (frequency x impact) score:[117]
Supplier problems (quality, reliability, timeliness, or financial strength)	325	14.13
Inadequate logistics infrastructure (distribution, warehousing, or cold storage)	296	14.10
Inadequate or slow transportation infrastructure (road, rail, ports or air)	344	13.76
Labor problems (strikes, skills shortages, incompetence, turnover, absenteeism)	324	13.50
Bureaucracy (red tape, unclear, inconsistent restrictions or regulations)	254	11.55
Inadequate utilities infrastructure (electricity, water, sewer, telephone or internet)	235	11.19
Corruption or bribery	133	8.31
Tax system (burdensome, arbitrary, or inconsistent)	90	6.00
Property or violent crimes (theft, robbery, hijackings, vandalism, computer viruses or fraud)	47	5.88
Intellectual property crimes (counterfeiting, copyright violations, or hacking)	5	5.00
Major accidents, incl. fires, explosions, structural collapses, or spills	57	4.75
Flooding and weather related events	76	4.00
Terrorism, riots or civil unrest	21	3.00

The five genetic supply chain risk mitigation methods are explained more fully here:

Buffering : Have safety inventories, extended lead times or excess capacity

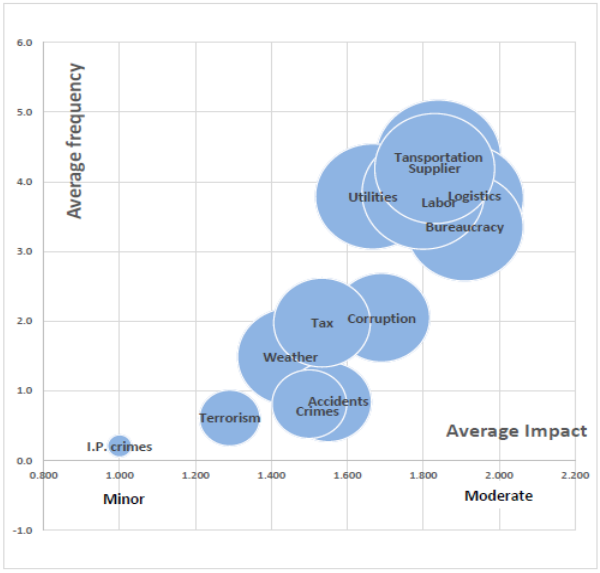
Redundancy: Have multiple suppliers, sites or equipment

Flexibility : Have suppliers or facilities that can quickly respond, adjust, or change over

Visibility : Collaborate with and get timely information from trusted suppliers, customers and service providers

In source : Produce and source internally instead of relying on outside suppliers or sources, or integrate vertically.

TABLE 2: The Disruption Frequency vs. Impact Map



[2]Table 2 shows the frequency of disruptions on the vertical axis, where the numbers refer to the number of average occurrences over a three year period. The horizontal axis refers to average scores on a Likert scale, where 2.0 equals "moderate" impact.

When we asked which mitigation methods were the most useful in alleviating the six most severe risk factors they had previously identified, they gave the average ratings listed in Table 3.

TABLE 3: Most popular mitigation methods for the six top ranked risks

Disruption	Mitigation	Score	Usefulness
Supplier problems	Redundancy	2.10	Useful
Inadequate logistics infrastructure	Buffering	1.77	Useful
Inadequate transportation infrastructure	Buffering	1.67	Useful
Labor problems	Redundancy	1.29	Somewhat useful
Bureaucracy	Flexibility Visibility	0.76 0.76	Somewhat useful Somewhat useful
Inadequate utilities infrastructure	Buffering	1.38	Somewhat useful

It turns out that across all the six risk factors, redundancy scored the highest (ranked useful or very useful by 48% of the sample), closely followed by buffering (45%), visibility/collaboration (45%), and flexibility (44%). Insourcing was found to be useful or very useful by only 27%.

3. NEGATIVE EXTERNALITIES FROM DISRUPTIONS AND MITIGATION METHODS

It is not surprising that redundancies and buffering are popular (and effective) risk mitigation methods. Having back-up capabilities and extra inventories make intuitive sense and are indeed ingrained in human nature. The concept if visibility is crucial in modern supply chain management, as it entails possessing enough information about what is going on throughout the whole supply chain. Information cuts down on uncertainty, and less uncertainty makes it easier to practice crisis management, thereby reducing the need for buffers and redundancies. Flexibility is having the ability to change course by having operating procedures, assets and resources that can switch to other products or processes on short notice.

In Table 4 we have made an attempt to assign examples of negative externalities not only to the primary types of supply chain disruptions, but also as direct or indirect results of the typical mitigation methods used. This is not a comprehensive or all-inclusive list, and readers may think of other effects on innocent parties as a result of either the disruptions themselves or their associated risk management remedies. It is also possible that some of the mitigation methods come with identifiable positive externalities. For example, visibility and collaboration among supply chain partners might enable managers to avoid or steer clear of risky situations that could harm innocents or the environment.

TABLE 4: Examples of negative externalities from disruptions and typical mitigation methods

Supply chain disruption	Potential negative externalities due to this disruption	Mitigation method for this disruption	Potential negative externalities due to mitigation
Supplier problems	Product quality and safety	Redundancy	Sprawl, pollution, congestion
Logistics infrastructure	Product quality and safety, traffic congestion	Buffering	Waste, sprawl, pollution
Transportation infrastructure	Pollution, road safety, congestion, delays, quality of life	Buffering	Same as above
Labor problems	Product quality and safety, interruptions	Redundancy	Same as above
Bureaucracy red tape	Underinvestment, stunted development	Flexibility & visibility	Waste, sprawl
Utilities infrastructure	Product safety, power outages	Buffering	Same as above
Corruption or bribery	Lack of trust, safety, costs	Redundancy	Same as above
Tax system	Underinvestment, stunted development	Buffering	Same as above

Flooding or weather related	Shortages	Buffering	Same as above
Major accidents	Collateral damage[3]	Redundancy	Same as above
Property or violent crimes	Collateral damage	Visibility	No negative externalities
Terrorism, riots, unrest	Collateral damage	Buffering	Same as above
Intellectual property crimes	Costs, product safety	N/A	

There are numerous examples of negative externalities experienced from disruptive events in supply chains. While the world's worst industrial disaster is the Union Carbide chemical cloud that eventually killed more than 10,000 innocent villagers in Bhopal more than thirty years ago, the more prevalent and pedestrian externalities appear as a result of the various disruptions outlined above. Supplier problems result in subpar products that can harm not only the buyer of the product (a supply chain "insider" as previously argued), but also innocent outsiders. Shoddy products represent dangerous safety hazards, in addition to the various inconveniences and delays incurred from poorly made products. A classic example of an Indian logistics infrastructure problem is the common lack of proper warehouses, especially cold storage facilities. This can result in product contamination and unsafe products, as well as stock-outs that necessitate additional transportation with its resulting pollution and congestion. Transportation problems lead to air pollution, traffic congestion and degraded quality of life for a lot of people. India already has one of the least efficient traffic situations in the world (NationMaster). Labor problems have many of the same effects as supplier problems, in addition to the negative effects of work stoppages and strikes. Many innocents are affected by such conflicts. Bureaucracy and red tape put a damper on efficient business operations, which subsequently leads to uncertainty, waste of resources, and underinvestment. The last of the top six, bad utilities infrastructure, will cause business interruptions from various utilities outages, including power, internet and water. The lack of capacity will hurt innocent parties when the networks are incapable of serving all users at all times.

The mitigation methods themselves will lead to negative externalities. Chopra and Meindl observe that "every mitigation strategy comes at a price, …, and may increase other risks." (Chopra & Meindl, 2016) This "price" involves costs for both supply chain insiders and outsiders. So while it is easier to identify and quantify the costs of mitigation borne by the supply chains themselves, it is always more difficult to assess and put a value on the costs borne through externalities. It is quite obvious that to mitigate effectively, supply chains have to invest in more equipment, incur longer lead times, carry higher inventories, and spend more time and money on information technology. It gets more difficult to quantify the effects of externalities on the world outside the supply chains. In table … we are listing some examples of negative effects as a result of not only the risk itself, but also from the mitigation methods typically applied. For example, more equipment and higher levels of inventories will, in the aggregate, lead to more space taken up by factories and warehouses, as well as more waste through obsolescence and depletion. All the extra equipment and inventory have to be transported, increasing pollution and congestion. All-in-all, mitigation methods by themselves consume resources and create more waste.

4. CONCLUDING COMMENTS

At this point we know that both supply chain disruptions and their attendant mitigation methods contribute to negative externalities on innocent outsiders to the offending supply chains. However, the more interesting question is whether the mitigation methods are effective enough to actually reduce the disruption externalities more than the externalities incurred through the

[3]We have taken the liberty of using the militaristic term "collateral damage"as a label for bodily, physical or property damage (unintentionally) inflicted on innocent parties (e.g., outside "stakeholders" such as the public and natural environment)

mitigation methods themselves. By preventing and containing disruptive events, mitigation methods may indeed be more than worth their expenses, also from a systems or societal standpoint. As pointed out by Udbye, other benefits of reducing negative externalities include better customer retention, fewer lawsuits, lowered risk of punitive regulations, as well as less resources spent on damage control through industry initiatives (Udbye, 2013).

It is quite clear the insiders to the supply chains find it worthwhile to invest in mitigation methods, as managers expect that the extra costs will be compensated for by a reduction in the financial and operational costs of disruptive events. So will this also then translate to the outsiders? Are societies (e.g., innocent people and the natural environment) better off, as well, by having supply chains invest in costly ways to alleviate more serious risks and disruptions? Should society at large actually be thanking companies for investing in risk mitigation methods, and encourage such practices in the interest of preventing potentially even worse outcomes? For supply chain risk management, this would be the best of both worlds.

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