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Integrating Supply Chain and Facility Risk Analyses For Improved Business Decisions

S. Dharmavaram, C. Leyson, R.F. Pinchot, and C.A. Soczek
E.I. du Pont de Nemours & Co.
Brandywine 7202
1007 Market Street
Wilmington, DE 19898USA
Phone: (302) 774-8093
Email: Charles.A.Soczek@usa.dupont.com

ABSTRACT

Typically, business supply chain risks are managed separately from fixed facility risks. However, where significant fixed site risk reduction can negatively impact a supply chain, a study that addresses both the supply chain and fixed facility risk can be done to help the business integrate all available information into the decision process. To assure a comprehensive risk analysis, a supply chain risk study should include rare/high consequence events, as does the fixed site study. A case study is presented for a facility that imports, stores, and consumes large volumes of a highly toxic material, and is located in a densely populated area. The methods used to analyze risks and identify risk reduction opportunities for the facility and the supply chain are described. The business team integrates the results of this study with other information to make better decisions.

Introduction

Many businesses manage risks separately using a wide variety of techniques that range from qualitative to quantitative. There is a heavy reliance on the judgement of key personnel to make good decisions based on these risk analyses, coupled with their experience, corporate culture, and other factors. While this process has resulted in acceptable risk management, there is a sense of growing vulnerability to large losses. This has led businesses to seek more information to help allocate scarce resources, particularly those resources aimed at decreasing risk from large losses.

In recent years, increased attention is being placed on determining a broad range of business related risks. The objective has been to use such risk determinations to improve the quality of many of the strategic and tactical business decisions.

The acceptance of these developments by business decision-makers has been mixed. This is a result of a variety of reasons including cost of the studies, difficulty in understanding results, a changing regulatory environment, pressures from the community and activists, and lack of processes for making better decisions. In addition, because these studies can provide estimates of risks that range up to an order of magnitude in accuracy there is some concern about their application.

This paper focuses on risk related to manufacturing operations and presents current thinking around the application and use of quantitative risk determination to improve business decisions. A detailed case study is presented.

Types of Business Risks

A business is an economic enterprise that generates a cash flow. This cash flow can be associated with a brand name or trademark. Anything that can have a negative impact on this cash flow is a business risk. Examples include product liability, natural disasters, equipment failure, loss of containment incidents during transportation or from fixed facilities resulting in human or environmental impact, technology failure, currency fluctuations, geopolitical changes, and changing regulations. Operational risk is a limited array of these risks that result from incidents related to the manufacturing supply chain.

Risk has been defined in a wide variety of ways, but for a business it can be simplified as the product of consequence and frequency. Consequences can be determined in a number of ways, but for a business it is defined as the negative dollar impact resulting from an operational incident or event. Frequency is defined as events per year. This results in:

$$\text{Risk} = f(\text{Consequence (\$/event) X Frequency (events/year)}) = f(\text{\$/year})$$

In the insurance terms, this is called annual expected loss in $/year.

Many of the events related to operational risks are rare, that have a frequency of occurrence of once in thousands of years. Because of this, the risk calculations can be done in current dollars, without discounting the value.

Value of Quantitative Analyses

Currently, businesses manage all risk categories separately. Information is provided in widely varying forms, and can range from qualitative to quantitative. In most cases, businesses consider this input, and couple it with experience and other factors to reach decisions concerning resource expenditures. Generally, no attempt is made to compare risks from different risk categories. In this environment, there is no certainty that decisions to expend finite resources will result in the greatest benefit.

The objective of quantitative analyses done in a uniform manner on a broad range of risks is to provide a rational basis for decision making. While other factors influence risk decisions, a common basis of measurement of risk is a key initial step to provide such an understanding.

Decision-makers have yet to readily embrace the process. There are significant barriers when introducing a process that is difficult to understand, and produces results that have a broad range of accuracy. Part of the problem stems from collapsing both frequent/low consequence events and rare/high consequence events into a single measurement. Rare/high consequence events pose special problems, and can often dominate the overall risk. These events can be of such magnitude as to jeopardize the existence of the company, but the extreme rarity leads to a sense that it will not happen.

There are other barriers to implementing multi-faceted risk analyses. Quantitative risk assessments are costly. Also certain risk categories have potential legal, regulatory and community issues when consequences are expressed in dollars.

Case Study

A non-US manufacturing operation produces non-hazardous products, but many of the raw materials and intermediates are highly hazardous. Significant quantities of materials are highly toxic, while others are highly explosive. The site land area is small, measuring roughly 275 X 275 meters, and is located in a densely populated area. As a result, major releases and accidents could impact the local population. Also, the location is on a peninsula, making evacuation difficult under certain meteorological conditions. The residences in this locality are in good condition and the weather in the area is moderate. Figure 1 shows a satellite picture of the complex terrain and the star marking the location of the facility.

The business proposed a significant risk reduction by ceasing the manufacture of a non-hazardous intermediate that is consumed at the facility and is produced from a raw material that is highly toxic. However, this meant that the intermediate would need to be purchased from another country, and shipped to the site. This has the potential for increased risks as a result of the longer supply chain.

The objective of this study was to develop quantitative information to help the business team make better decisions. The specific information included the determination of:

- Current risk of the existing manufacturing facility
- Risk reduction achieved by ceasing manufacture of the intermediate
- Risk increase from the longer supply chain
- Impact of risk mitigation for the existing facility

Quantitative Risk Analysis for Fixed Site

A quantitative risk analysis of the existing manufacturing facility was done using the SAFETI® software. This analysis required the following information:

- Local meteorology, based on the nearest meteorological station, located about 7 km from the site
- Accurate day/night local populations
- Toxicology based on best available data
- Development of all scenarios with potential off-site impact

- Development of frequency of events based on the Dutch Purple Book (1999), fault tree analysis, and site specific data

Hazard identification is the starting point for a quantitative risk analysis. This involves identification of potential failures that can result in an off-site impact. The major hazards for this study were the toxic effects from exposure to all chemicals with a potential for serious offsite impact. Chemical Process Quantitative Risk Assessment guidelines established by the American Institute of Chemical Engineers (2000), along with PHAST® consequence modeling, were used to identify the scenarios of concern.

Meteorological data (wind speed and direction, and atmospheric stability) are needed to model the dispersion of releases. This data was separated into normal working and shift working hour distributions. The nearest meteorological station was located about 7 km from the site, with a large hill between the site and the station. Because of this, extensive analysis of the local topography was done, and some limited weather data from the site was compared to the meteorological station. The raw data was processed using a variety of tools to generate the frequency distributions.

The population data for the offsite residential area was determined based on information collected by the plant from the local government agencies. The populations of nearby industrial operations were also obtained. Day and night populations were developed, and there were some seasonal adjustments associated with an increase in tourism on the peninsula during summer.

A quantitative risk analysis for a fixed site produces risk that can be expressed as both societal risks and individual risks. Both measures are useful in identifying risk and quantifying the impact of risk reduction measures.

Societal risk can be expressed as the mean interval of time between fatalities, the Process Hazards Index (PHI). While it is possible to convert this index to an annual expected loss, it is not always necessary. By inspection, judgements can be made relative to the other risks that are quantified as annual expected loss. Individual risks are expressed as risk contours. Industry and regulatory agencies in the United States have not established criteria for off-site individual risks. Nevertheless, companies can establish a continuous improvement process to reduce off-site risk to very low values. While there is often a relationship between societal risk and individual risk indices, it is generally found that both must be addressed.

Once the risk of current operations is determined, a list of release scenarios that are the key contributors is developed. Technical & operations personnel review these key scenarios and develop mitigation measures. The analysis is then repeated to quantify the impacts of mitigation measures.

Supply Chain Risks

A study to determine the risks of the longer supply chain was also initiated. This study determined the impact of a wide range of natural, fixed site, and transportation events using various fixed storage and fleet sizing options. The required intermediate was to be manufactured by suppliers in another country and shipped in iso-containers (ISO) by transport ships across the ocean.

This study was done using Igrafx® Process 2000 (Ver. 8.0) from Micrografx software to create a simulation model of the proposed supply chain. The ISO tank unit was used in the model as the entity that traveled through the supply chain, as in real life. The model is a complete supply chain map that includes all the major legs, such as production, transportation (both land and sea), customs in each country, and other possible delays to and from the facility, that the ISO tank encounters. Random variation of shipping and process cycle times was modeled using normal distributions. The ISO represents a fixed quantity of product that traveled to the facility and an empty container journeying back to the suppliers.

The following were some of the assumptions used:

- Maximum unloading for ISO tanks was six per day
- If the plant goes down for lack of raw material, it stays down until three days of raw material are accumulated
- There is no limit to the number of ISOs that can be loaded on each transport ship
- A ship sails every seven days.
- Two suppliers are used. One produces 1 ISO per day; the other produces 2 ISOs per day
- Uptime is based on a similar plant's performance
- Every 18 months, each supplier is assumed to take a major outage
- Natural disasters occur once every 500 years, and cause a two month outage
- Weather delays can increase ocean travel time

Base cases were run using a staggered major shutdown for the two suppliers and coincident major shutdowns to start the simulation. The capacity of each ISO was assumed to be 17 tons, and there were 100 ISO tanks available. No finished inventory is maintained at the suppliers. The site operates 365 days per year. Site storage capacity is 1035 tons. Normal distributions for the process and shipping times were used. Transaction/shipping cycles times are as follows.

• ISO order placement, loading, transit to pier at supplier's port	5 days
• Await next vessel	7 days
• Ocean transit	4 days
• Clear customs and transit from consuming port, unloading	5 days
• Await next vessel	7 days
• Ocean transit	4 days
• Clearance, transit to producing site	4 days

Based on the above parameters, the model was used to determine the increase in downtime as a result of the longer supply chain. This loss of production can be expressed in dollars lost per year.

Results

Supply Chain

Two base cases were run. These were with major shutdown initiated 6 months out of phase and with the shutdowns initially in phase. With an ISO tank fleet set at 100, only 5 total shutdown days per year were predicted, and the risks associated with a major shutdown in excess of thirty days was very small (2 events every 1000 years). For the case where the major shutdown was in phase, 56 shutdown days occurred per year and the risk of a 30-day or greater shutdown was higher (4 events very 1000 years). When the inventory was increased with either fixed storage or additional ISO tanks, significant risk reductions were obtained.

It was concluded that the increase in risk from purchasing the intermediate was very low provided the shutdowns at the two suppliers were not allowed to occur simultaneously. 140 ISO tanks would be required to eliminate the risks from site controllable events. There are still risks from the non-site controllable catastrophic events, but these events are rare, 0.002 events per year. The annual expected loss is, therefore, low ($10 to $100K).

Fixed Site

The base case QRA analysis indicated that significant improvements needed to be made at the facility, as determined by both societal and individual risk indices. The individual risks are expressed as contours as shown in Figure 2. The 1E-05 contour is indicated and all other contours increase or decrease in orders of magnitude.

Based on experience and studies at other sites, it was recommended that priority be given to improving or eliminating this risk. In this study, the options were to either cease manufacture of intermediates that consume and produce highly hazardous materials, or make substantial risk improvements in the existing plant.

Several mitigation measures were developed and risk reduction benefits quantified. The mitigation measures included:

- elimination of large storage tanks for highly toxic materials
- Modifications to a highly toxic material transfer piping
- Installation of a toxic material tank in a closed, scrubbed room
- Reduction of flanges to a minimum
- Inventory reduction in a columns bottom
- Inventory reductions in storage tanks

These improvements reduced the societal risk, i.e. rate of fatality, by nearly three orders of magnitude.

Integrating Risks

In this study, the purpose was to provide a business team with quantitative risk information concerning supply chain and fixed site risks. This risk information is integrated along with other considerations, by the business team, leading to an improved decision.

The fixed facility risk, after implementing improvements, was then judged to be of the same order of magnitude or less than the supply chain risk associated with the purchase of the intermediate. This means that from a risk point of view, the option to cease manufacture and purchase of the intermediate was equivalent to mitigating the fixed site risk.

In addition to quantifying the fixed site and supply chain risks, it is also necessary to consider other costs in the decision making process. The purchase of the intermediate has three principle components. These are cost of exiting current manufacture (dismantling, restoration, and personnel), cost of ISO fleet and facility modification, and an increase in material costs. These costs can be substantial.

The business integrates the risk information provided, with the cost data and other considerations, to make a better decision.

CONCLUSIONS

Businesses, typically, manage supply chain risks separately from fixed facility risks. However, where significant fixed site risk reduction (i.e. exiting a business) can negatively impact a supply chain, a study that addresses both supply chain and fixed facility risks must be conducted.

A study was initiated to develop quantitative risk information to help a business team make better decisions. The facility under consideration imports, stores, and consumes large volumes of a highly toxic material. The business team requested risk information on the impact of ceasing operations and purchasing intermediates from an overseas supplier.

The methods for quantifying risks and the use of results as input for improved business decisions have been presented. The quantitative risk analyses showed that the fixed site risk could be significantly reduced using a series of mitigation measures. This risk is then equivalent to the supply chain risk from ceasing operations and purchasing the intermediate. With this understanding, the business then integrates this risk information with other factors to make better decisions.

REFERENCES

Center for Chemical Process Safety (CCPS), 2000, **Guidelines for Chemical Process Quantitative Risk Analysis**, Second Edition, American Institute for Chemical Engineers, New York, NY.

Purple Book, 1999, " Guidelines for Quantitative Risk Assessment CPR18E, " 1st edition, Committee for the Prevention of Disasters, The Netherlands.

Figure 1: Satellite view of the location

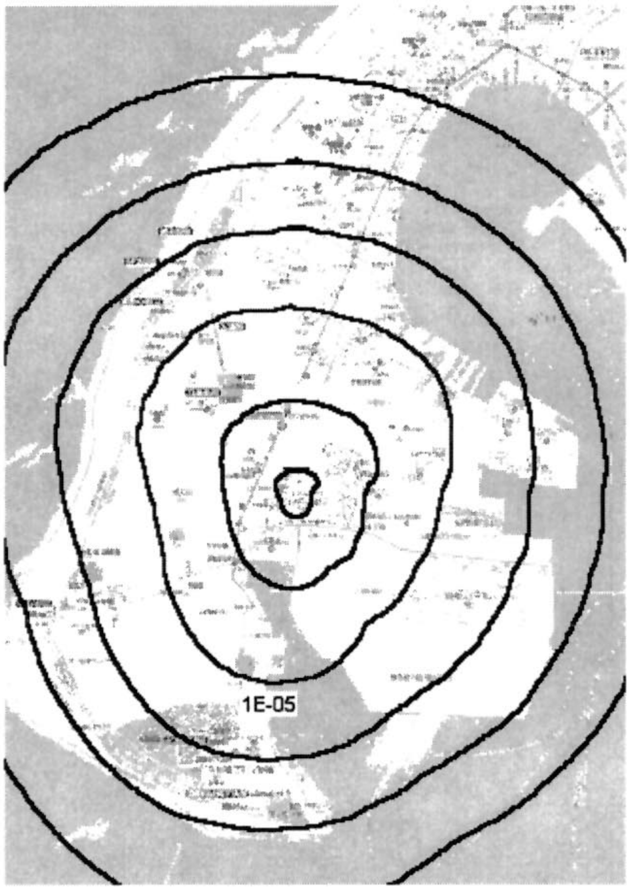

Figure 2: Individual Risk Contours