

Utilizing Third-Party Inspections for Preventing Major Chemical Accidents

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This paper proposes using certified third parties, coupled with Model Risk Management Programs (Model RMPs), to implement EPA's Proposed Rule on the prevention of chemical accidental releases. We concentrate on the insurance aspects of this third-party approach and show that it could enable insurers to more cost-effectively provide coverage against the risks of chemical accidental releases. The third-party approach may also signal the facility's safety and reduce the enforcement costs of regulations.

KEY WORDS: Insurance; third-party inspections; Clean Air Act; EPA.

1. INTRODUCTION

Section 112(r) of the Clean Air Act Amendments (CAAA) of 1990 requires the U.S. Environmental Protection Agency (EPA) to develop regulations for the prevention and mitigation of major chemical accidental releases, including worst-case releases.⁽¹⁾ One of its major provisions, reflected in EPA's rule,⁽²⁾ requires chemical facilities to develop and implement risk management programs (RMPs)⁽³⁾ for preventing the occurrence and mitigating the consequences of such releases and share these prevention plans with the public.⁽⁴⁾

This paper examines the extent to which EPA can utilize market mechanisms, such as third-party inspections and insurance, as an alternative to traditional command-and-control procedures, to satisfy the CAAA requirements.⁽⁵⁾

The principal advantage of these inspections over command-and-control procedures is that there is a voluntary contractual relationship between the firm and the party auditing the facility. Rather than being viewed

strictly as an enforcer, the inspector can assist the firm in complying with a set of regulations.⁽⁶⁾ If any area is out of compliance, the regulated firms could choose to ignore the third-party reports and deal directly with the regulators; however, this would entail a lengthy and cumbersome negotiation and remediation process. A better alternative would be to have the third party work out a timely remediation program that would be agreeable to the regulators.

In the course of this activity, third parties will have an incentive to collect and analyze risk data which may prove useful to any firm under scrutiny, the regulators themselves as well as other interested parties such as insurance companies and the affected public. Third parties with considerable expertise in engineering risk and hazard assessment will be able to assist the regulated facility in using expert systems and probabilistic techniques such as event trees, fault trees, and influence diagrams, described in more detail by Yao.⁽⁷⁾ While many industrial firms constrained by resources do not have the capability to develop and use these techniques, third parties can apply the techniques over a large cross-section of different industrial segments, achieving both economies of scale and scope. In providing the information, the inspector may determine whether the firm is in compliance with specific codes and suggest the types of cost-

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effective loss prevention mechanisms which the facility might consider adopting.

The paper is organized as follows. The next section describes the CAAA of 1990 and characterizes the institutional arrangements associated with implementing risk-management programs as part of the major accident-prevention program. Section 2 also looks at some possible benefits of the third-party approach when compared to the traditional command-and-control approach.

Section 3 examines the positive role that third-party inspections and Model Risk Management Programs (Model RMPs)⁽⁸⁾ can play in characterizing the risks associated with major chemical accidental releases. We show that two side-benefits of this activity are to enable insurers to provide coverage against these risks and provide a routine signal to the public about the facility's safety. In addition, third-party inspectors, with their engineering expertise and experience gathered over a wide spectrum of clients are more likely to discover and to promote the development of new technologies, than would individual facilities. For example, the Hartford Steam Boiler Inspection and Insurance Company (HSB) initiated boiler inspections in 1866. HSB complemented these inspections with studies of boiler explosions involving testing the specifications for boiler construction and settings. Hartford's efforts eventually led to boiler-makers adopting safer designs which reduced the number of boiler accidents.⁽⁹⁾

The concluding section of the paper raises a set of questions and issues for future research based on a series of roundtables with relevant interested parties concerned with the implementation issues.

2. THE CLEAN AIR ACT AMENDMENTS (CAAA) OF 1990

2.1. Proposed Alternatives to Command-and-Control Process

EPA has been searching for other alternatives to its current command-and-control (cc) processes to implement its obligations under Section 112(r). This mission assumes has some urgency due to the agency's limited personnel and funds to enforce new regulations. Without employing third parties, EPA has to provide technical guidance and audit regulated facilities to ensure a high compliance level. The third-party approach transfers a portion of these regulatory costs back to the generators

of the externalities, as the inspectors would be hired and paid for by the regulated firms.

The need for RMPs in this type of environment becomes clear. A model RMP translates required general performance standards to specific technological standards and codes. With specific requirements, third-party inspectors have greater ease in helping clients meet compliance and in proving nonnegligence should a court case arise. The greater ease in compliance under the third-party approach translates to higher compliance rates and thus more cost-effective accident prevention. EPA is then able to reduce its frequency of audits, resulting in lower enforcement costs.

Researchers have argued for alternative approaches to cc because of concerns that administrative agencies responsible for issuing regulations are vulnerable to "capture" by the very industries they are supposed to regulate.⁽¹⁰⁾ More specifically, there is concern that organized groups can utilize the regulation to gain monopoly power. Empirical evidence supporting this claim comes from a study by Magat *et al.*⁽¹¹⁾ on water pollution regulation where it was shown that weaker standards were applied to industries that have higher profits and better financed trade associations.

2.2. Institutional Arrangements

Figure 1 depicts the responsibilities of the different groups in the context of environment regulation such as the CAA. The perceived concerns by the public about the consequences catastrophic risks imposed on them by industry, lead Congress to pass environmental laws to modify the firms' behavior. EPA and other regulatory agencies (e.g., OSHA and state agencies under the CAAA) are responsible for designing policies and regulations to satisfy the requirements of these environmental statutes.

Coordination between EPA and other regulatory agencies, particularly OSHA, in setting and enforcing these requirements may be necessary to avoid conflicting standards and duplication of efforts. The other stakeholders, such as third-party inspectors and insurance companies, operate within this regulatory environment. Third-party inspectors have to be recognized by EPA through a qualification and licensing process.

The firm may purchase insurance (e.g., fire, boiler, and machinery, etc.) as part of its risk management strategy. It may also be required in the future to show financial responsibility in the form of insurance coverage or offer proof that it has adequate funds to compensate victims of a catastrophic accident. The insurance company

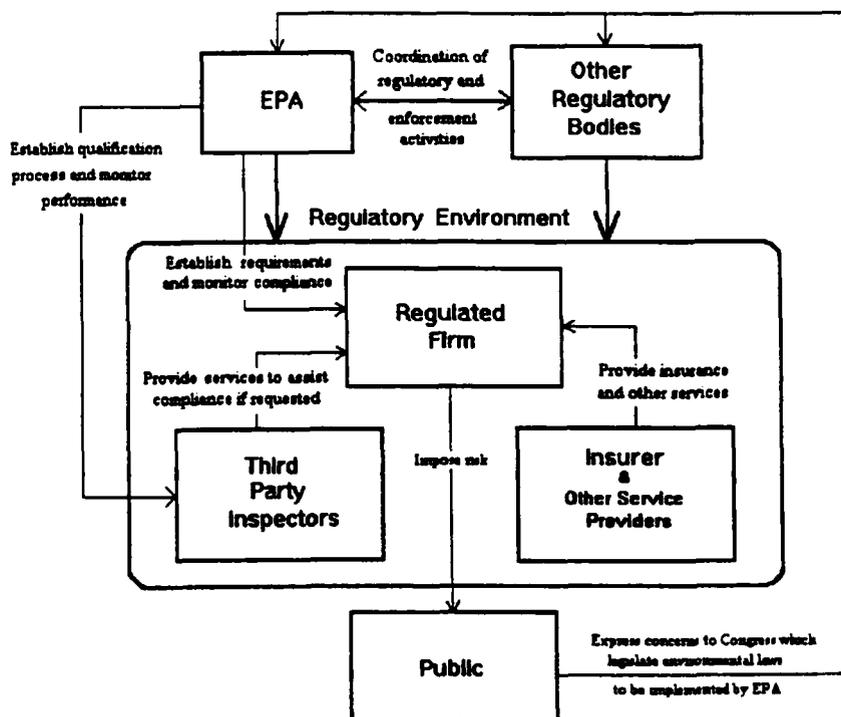


Fig. 1. Responsibilities of different groups in the context of environment regulation such as the CAA.

could also have a reinsurance arrangement to protect itself against catastrophic losses.⁽¹²⁾ There may be other service providers, such as engineering consultants, providing loss control services, verification services, and other technical services and advice to the regulated firms. It is important to note that the employees of insurers or other service providers may be recognized by EPA as qualified third-party inspectors enabling them to provide these services in addition to offering coverage.

One way to achieve a high compliance level is to provide guidance, technical assistance, and expertise to those small- and medium-sized firms that may have difficulty in complying with regulations.⁽¹³⁾ The use of a Model RMP coupled with third-party inspections and audits may enable insurers to provide coverage to these smaller operations where they may have been unwilling to do so in the past.

Members of the public have an implicit stake in the implementation of 112(r). Elected local officials are responsible for the general safety and well-being of the whole community that they serve. It is likely that they want regulations to ensure a clean environment but at the same time, recognize that the regulations should not be so stringent as to discourage business activity in the area. Local officials and citizen groups such as Local Emergency Planning Committees (LEPCs)⁽¹⁴⁾ serve as

watchdogs and help residents in the affected community plan for emergency in the event of a chemical catastrophe.

3. THE ROLE OF THIRD-PARTY INSPECTIONS IN IMPROVING RISK ESTIMATES

By providing more accurate information on the risks facing a firm and data on potential areas for loss control, third-party inspectors coupled with model RMPs can encourage insurers to enter the market while at the same time helping to convince the public that a facility is safe.

3.1. Facilitating Insurance Markets

Suppose there are two types of firms that are operating industrial facilities where there is a chance of a catastrophic accident causing a loss of L dollars. Firm 1 (low risk) has probability p_G and firm 2 (high risk) has probability p_B that a catastrophic accident will occur. Third-party inspections can aid the insurance process by reducing adverse selection, moral hazard, and ambiguity of risk as shown below:

3.1.1. Eliminate Adverse Selection

The classic adverse selection problem facing insurers is that they are unable to distinguish the low risks from the high ones. If it is unaware that these differences exist, the insurer will set a premium based on the average risk but only the poor risks will want to purchase a policy. This will be an unprofitable operation in the long run, so the insurer will *not* want to market coverage. Both good and poor risk types will now be uninsured.

One way to reduce or even eliminate adverse selection problem is for the insurer to require some type of audit or examination procedure to estimate the risk faced by each facility. The inspector could use a general hazard classification scheme to identify hazards encountered by the organization (e.g., chemical, physical, biological, and mental hazards) and construct fault trees to determine initiating events, known as perils and the extent of the hazard exposure. The potential insured may have implemented loss control measures to reduce the probabilities of the initiating events and the extent of the losses should an event occur.⁽¹⁵⁾ If loss control measures are in place, the inspector would then determine whether they are effective.

The use of model RMPs with third-party inspections by insurers eliminates those firms from consideration that are unable to fulfill the requirements. If the level of risk of the regulated facility when in compliance with the model RMP defines what is meant by a low risk,⁽¹⁶⁾ then the insurer should now be able to offer insurance coverage to all these companies which satisfy these requirements. Those firms with even lower risks than those specified by the model RMP, would be offered a lower premium than the standardized rate to reflect their risk status.

3.1.2. Avoid Moral Hazard Problems

Through periodic inspections, the activities of the insured firm can be monitored over time. Therefore, third-party inspections can reduce the chances that the firm will become more careless once it has passed an initial audit. Without this feature, a firm may be less vigilant in its activity so that the accident probability increases. The moral hazard problem is directly related to the difficulty in monitoring and controlling behavior once a person is insured.⁽¹⁷⁾

If the insurer can learn in advance that a chemical facility will be less interested in loss reduction activity after purchasing a policy, then it can charge a higher

insurance premium to reflect this increased risk or it can require specific protective measure(s) as a condition of insurance. Alternatively, the regulator can set certain standards which would necessitate that the firm invest in these measures as a way of satisfying them. Third-party inspectors could indicate that such actions would need to be undertaken to satisfy these regulations. Moreover, periodic inspections by third parties would monitor the insured's behavior and discourage or prevent adverse actions that increase the risk.

3.1.3. Reduce Ambiguity of Risks

In a series of empirical studies, Kunreuther *et al.*⁽¹⁸⁾ showed that actuaries and underwriters are so ambiguity-averse and risk-averse that they tend to focus on worst-case scenarios in determining what premiums to set. To illustrate, a questionnaire was mailed to 896 underwriters in 190 randomly chosen insurance companies to determine what pure premiums⁽¹⁹⁾ they would set for a leaking underground storage tank (UST) risk. The UST scenario involved liability coverage for owners of a tank containing toxic chemicals against damages if the tank leaks. A neutral risk scenario acted as a reference point for this context-based scenario by providing probability and loss estimates for an unnamed peril.

For each scenario, four cases were presented, reflecting the degree of ambiguity and uncertainty surrounding the probability and loss. A well-specified probability (p) refers to a situation in which there are considerable past data on a particular event that enable "all experts to agree that the probability of a loss is p ." An ambiguous probability (Ap) refers to the case where "there is wide disagreement about the estimate of p and a high degree of uncertainty among the experts." A known loss (L) indicates that all experts agree that, if a specific event occurs, the loss will equal L . An uncertain loss (UL) refers to a situation where the experts' best estimate of a loss is L , but estimates range from L_{\min} to L_{\max} .

Four different cases were considered in the questionnaire to the underwriters. Case 1 was represented by providing a well-specified probability ($p = .01$) and a well-specified loss ($L = \$1$ million). The other three cases introduced ambiguity and uncertainty into the picture. For the case where $L = \$1$ million, the uncertain estimates ranged from $L = \$0$ to $L = \$2$ million. One hundred seventy-one completed questionnaires (19.1% of the total mailed) were received from 43 insurance companies (22.6% of those solicited). Table I shows the average ratio of the premiums for the three cases where

Table I. Ratio of Average Pure Premiums Specified by Underwriters Relative to Well-Specified Case (Case 1)^a

Scenario	p, L (Case 1)	Ap, L (Case 2)	p, UL (Case 3)	Ap, UL (Case 4)
Neutral ($N = 24$)	1	1.5	1.1	1.7
UST ($N = 32$)	1	1.5	1.4	1.8

$p = .01, L = \$1$ million
 $N =$ Number of respondents

^a Source: Kunreuther, Hogarth, and Meszaros (1995).

Table II. Each Firm's Share of Development Cost of a Fail-Safe Device

Number of firms	Development costs
1	\$5000
10	\$500
20	\$250
N	$\$(5000 \div n)$

there is uncertainty and ambiguity in either p and/or L compared to Case 1 where both p and L are known. The data reveal that underwriters will charge a much higher premium when there is ambiguity and uncertainty regarding probabilities and/or losses. For example, as shown in Table I, the premium for the UST (Case 4) was 1.8 times higher than for the well-specified Case 1 scenario.

Third-party inspections coupled with RMPs will increase the accuracy of the risk estimates and thus reduce the premiums insurers will want to charge for providing coverage. If the insurer receives information that the potential insured has a model RMP in place and that it is being monitored by third parties, the insurer may be able to establish more favorable estimates. This could increase the availability and affordability of insurance coverage to regulated facilities.

3.2. Encourage Cost-Effective Loss Control Measures

There may also be opportunities to reduce the probability of a loss associated with a catastrophic accident. Third-party inspection coupled with the development of an RMP will enable the firm to determine possible opportunities for such investments.

Suppose that the firm were able to reduce the probability of an accident from $p = .003$ to $p' = .001$. If the loss from the accident were $L = \$10,000$ then the expected savings by the firm would be \$20 annually. If

one anticipated that the firm will operate over the next 20 years, then the aggregate discounted savings over this period using an annual discount rate of 10% would be \$187.⁽²⁰⁾ If the cost of the loss reduction measure were less than this amount then the firm should want to invest in it.

Insurance can play a key role in encouraging firms to invest in loss reduction measures through premium reductions. In this example, the insurer could reduce the annual premium by \$20 to reflect the lower probability of a catastrophic accident. The third-party inspection coupled with RMPs would enable the information on the discounted expected benefits of certain loss reduction measures (e.g., \$187) to be communicated both to the industrial firm and the insurance companies.⁽²¹⁾

Third parties with considerable expertise can offer regulated firms loss control services since it is often more efficient for them to invest in this research rather than individual firms.⁽²²⁾ This efficiency depends on the number of firms that would benefit from such research and technology. To illustrate, assume that a new fail-safe device, costing \$5000 to develop, would reduce the annual probability of a catastrophic loss of \$1,000,000 from .002 to .001 over a period of 5 years. This means that there is a reduction of annual expected loss of \$1000 $[(.002 - .001)1,000,000]$. With a discount rate of 10%, the firm would only anticipate an expected discounted savings of \$4169 over the next 5 years.⁽²³⁾ Since this is less than the initial investment of \$5000, the firm would not invest.

However, if a third party were to develop the fail-safe device for ten similar firms, the development would cost each firm only \$500 $(\$5000 \div 10)$. With 20 firms, this cost per firm decreases to \$250. As the number of firms benefitting from this new technology increases, the share of each firm in development costs decreases as shown in Table II.

Besides research and development, the third-party inspectors can acquire considerable expertise in performing inspections over a large clientele base. It is reasonable to assume that there is a learning curve in that the more inspections a third party undertakes, the less effort and costs will be incurred by each further inspection.⁽²⁴⁾ For example, experienced inspectors would be familiar with the statutory language and requirements, they know what the common out-of-compliance items are and what loss-prevention measures may be employed. Thus, in the steam boiler industry, even large, technically sophisticated companies employ the loss-prevention services of insurance companies rather than use their own staff because it is cost effective for them to do so.

3.3. Alleviating Public Concerns

The public is concerned with the risks associated with catastrophic accidents even though experts in the firm and scientists may view them as highly improbable. Because much of the public focuses on the enormous impact of the event should it ever occur, laypersons' fears often exceed those of the experts.⁽²⁵⁾

To illustrate this point, note that for the 5-year period 1988–1992, there were two industrial accidents in the United States that highlighted the potential of man-made catastrophes: the Exxon Valdez oil spill (1989) and the Phillips refinery explosion (1990). Loss estimates for the Exxon Valdez clean-up⁽²⁶⁾ have exceeded \$2 billion and for the Phillips explosion are more than \$700 million.⁽²⁷⁾ Although accidents of this magnitude are infrequent, they have triggered public concern as to how safe companies' operations really are. The prevailing view of many experts and risk managers is that the local communities and the general public react to limited, false, or inadequate information.⁽²⁸⁾ One reason the public is concerned about these risks even if the experts are not is that many individuals no longer trust firms or government institutions concerning pronouncements on what is safe.⁽²⁹⁾

To determine whether a risk is acceptable, the basic question for the community is: Is this activity, technology or facility acceptably safe? Implicit in this question is a risk-benefit analysis.⁽³⁰⁾ Recent data suggests that some of the costs associated with new or proposed legislation for a cleaner environment far outweigh their benefits. For example, in testimony before Congress on Reforming Title III of the 1990 Clean Air Act, Robert Hahn⁽³¹⁾ estimated that air toxics legislation is likely to create a \$9 billion drain on the economy, even after accounting for health benefits.

The presence of an objective and reputable third-party inspector may credibly signal to the community that the facility is "safe," or that, at a minimum, the risk is credibly mirrored in the facility's risk management plan which is publicly available. If the third-party inspectors coordinate with other groups, such as Local Emergency Planning Committees who deal with the emergency response, this might increase public trust. If the model RMP adopted by the firm is widely accepted by the general public, this would further strengthen the signals that the facility is safe. Furthermore, the information that the industrial firm is able to obtain insurance at a reasonably low premium for protection against catastrophic losses might serve as a signal to the public that the facility is safe.

4. SUMMARY AND CONCLUSIONS

In addition to the benefits to the regulated firm and EPA, the presence of a model RMP may encourage and enable insurers to monitor their clients continually to ensure that the programs are in place. When insurance problems such as adverse selection, moral hazard, and risk ambiguity are at least partially addressed, insurers should be more willing to provide more accurately lower-priced property and liability insurance to small- and medium-sized firms. Various concerns of parties involved in the CAAA should be addressed by combining third-party inspections with model RMPs as summarized in Table III.

In a series of roundtables held from May 3, 1994 to March 24, 1995, the Wharton Risk Management and Decision Processes Center assembled a diverse group to explore this use of third parties in connection with a model RMP for the ammonia refrigeration industry. The participants included academics, Federal and State regulators, and representatives from the refrigeration industry and insurance industry.

Much of the Center's thinking was influenced by the successful use of third parties in regulations involving boilers and pressured vessels at the State and local level (referred to as the "boiler model"). Past experience reveals that insurance companies and third-party inspectors have worked together in developing loss-control measures and risk-assessment methodologies aimed at helping to set appropriate policy premiums for boilers. These insurers and inspectors assist boiler owners and operators by developing programs for remediating deficiencies and furnishing regulatory agencies with the information they need to carry out their legislative mandates.⁽³²⁾

At the roundtables, there were discussions of the impact of the Section 112R Rule on the ammonia refrigeration industry and the question of whether and how the "boiler inspection model" could be of use in implementing the rule. The roundtable group endorsed the idea that the EPA should develop a third-party approach but felt that it was most applicable to small facilities that pose low probability–high consequence risks from common, homogeneous, and well-developed technologies. Ammonia refrigeration, drinking water chlorination, and propane retailing industries fall within the scope of this model. Rosenthal *et al.*⁽³⁴⁾ provide detailed accounts of the proceedings and major issues identified at these roundtables.

It was generally agreed that there needs to be in place a qualification process to certify and recognize third-party inspectors, reference standards (e.g., model

Table III. Possible Beneficial Effects of Third Party Inspections and Model RMPs

Party	Area of concern	Effects of third party inspections and model RMP
Community	Social costs (externalities) not fully accounted for by responsible firms	A portion of the costs of environmental regulation is shifted to the responsible firms as they are responsible for hiring the third parties
EPA	General public concern over risks imposed by the regulated facility	Facilitate the communication of risk to the public by providing access to an independent and objective third-party perspective
	Lack of resources for monitoring and control	Compensate for reduced EPA's audit frequencies by ensuring risk management plans are in place
	Low compliance level	The model RMP enables easier and lower-cost compliance, resulting in higher compliance level
Small- and medium-sized regulated facilities	Lack of resources and expertise/high costs	Enable regulated facilities comply with CAA regulations at affordable costs
Insurance company	Unavailability of insurance	(See concerns of insurance company)
	Loss control	Enable insured to invest in cost-effective risk reduction measures
	Moral hazard ⁽³³⁾	Periodic inspections would monitor the behavior of the operators of the regulated facility and discourage adverse actions that increase the risk
	Adverse selection	A model RMP has the potential to "homogenize" a population of risks, especially if the model RMP is designed to attain the optimal level of risk
	Risk ambiguity	The presence of a model RMP with periodic third-party inspections would provide more underwriting information

RMPs, accepted industrial standards), inspection programs, and a system for the EPA to audit the performance of recognized third parties and compliance of regulated facilities. In developing these processes, programs, and systems, some of the issues that arise are:

- How do we translate "societal views" on acceptable risk into model RMPs and third-party procedures?
- Are there other needs besides compliance review which would benefit by use of a qualified third party? Remediation planning? Loss-prevention services? Operator training?
- How can we best use third parties to improve the credibility of communications between the firm and the public?
- How do we address the concerns of third-party inspectors in regard to negligence suits which may be initiated in the event of an accidental chemical release affecting the public?

Because of "public moral hazard,"⁽³⁵⁾ insurance representatives at the roundtables feared that the perceived "deep pockets" of the insurers would make them attractive targets for negligence suits in their capacity as third-party inspectors. The two factors that contribute to public moral hazard are the existence of unexplained health conditions and the perception that insurers have "deep pockets" of funds. Some juries would not hesitate to award judgments in favor of the plaintiffs so that

those who have "suffered" may be sufficiently compensated from the "deep pockets." This problem is covered in greater detail by Er.⁽³⁶⁾

The third-party approach may still be applicable even if the above issues are not fully resolved. The technical standards required for the model RMP could be developed using available industrial practices and be updated appropriately as more information on available technology and the effectiveness of the standards and codes are available, hopefully after appropriate cost-benefit analysis.

At the moment, there is much uncertainty regarding the precise character of third-party inspections, the precise elements that should be covered in the audit, the exact nature of relationship of the inspectors to the regulated facility and regulator, and the qualification process. As a first step toward the third-party approach, the EPA is working closely with the various trade associations in jointly developing model RMPs for those industrial segments that use relatively simple and similar processes and technologies where industrial practices exist which can be easily adopted as codes and standards. The jury is still out on how well third-party inspections are likely to work in practice. To the extent that the boiler inspection model can serve as a useful prototype in these other situations, there is an opportunity to substitute market-based mechanisms for the traditional command and control methods currently used to deal with the management of chemical facilities and the prevention of catastrophic accidents.

ACKNOWLEDGMENTS

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REFERENCES

1. A "worst-case release" would mean the loss of all of the regulated substance from the process in an accidental release that leads to the worst offsite consequences. See 58 FR 54190.
2. The proposed rule for accident prevention, "Risk Management Programs for Chemical Accidental Release," was published by the EPA on October 20, 1993 (58 FR 54190), the final rule in 1996. The EPA has also enacted on January 31, 1994, 59 FR 4478, the final rule listing designated substances and their thresholds subject to chemical accident prevention regulation, as required by the Clean Air Act.
3. A risk-management program consists of three major elements: hazard assessment, accident prevention, and emergency response. As defined in the CAAA, the risk-management plan summarizes the risk-management program and the management system used to implement and coordinate the elements of the risk-management program. The hazard assessment would include offsite consequence analyses. The prevention program would consist of a process hazard analysis, process safety information, standard operating procedures, training, maintenance, pre-startup reviews, management of change, safety audits, accident investigations, and a management system. The emergency response program would require emergency response plans, drills or exercises, and coordination with public emergency response plans, required to define the offsite impacts of a range of potential accidental releases, including worst case.
4. The regulated facility has to submit risk management programs (RMPs) to the Chemical Safety and Hazard Investigation Board, the implementing agency, State Emergency Response Commissions (SERCs), and Local Emergency Response Committees (LEPCs). These bodies and the EPA must make the RMPs available to the public.
5. E. W. Orts, "Reflexive Environmental Law," *Northwestern University Law Review* 89 (1995). Command and control procedures refer to the enforcement of regulations by the relevant Federal agency, determining whether there are violations of specific rules or standards and punishing violators with civil penalties or criminal sanctions. It relies heavily on active governmental oversight and its effectiveness is thus dependent on the enthusiasm, competence, and available resources of the regulators.
6. However, if the third party were to become aware of an imminent and substantial problem, it would most likely be under common law obligation to take action and report to the appropriate authorities.
7. C. Yao, "Fire and Explosion Research at FMRC." An invited lecture that was presented at the First International Seminar on Fire and Explosion Hazards of Substances and Venting of Deflagrations, Moscow, Russia, July 17-21, 1995.
8. RMP was the acronym used for risk management plan in the CAAA and the EPA's proposed rule. See 58 FR 54190. The acronym model RMP, used in this paper for Model Risk Management Program, was adopted by the roundtable group that held a number of meetings at the Wharton School. A risk-management program consists of three major elements: hazard assessment, accident prevention, and emergency response. The risk-management plan summarizes the risk-management program and the management system used to implement and coordinate the elements of the roundtable are presented in the latter part of this paper.
9. G. Weaver and J. B. McNulty, *An Evolving Concern: Technology, Safety and The Harford Steam Boiler Inspection and Insurance Company 1866-1991* (The Hartford Steam Boiler Inspection and Insurance Company, 1991).
10. R. G. Noll, "Economic Perspectives on the Politics of Regulation," in R. Schmalensee and R. D. Willig (eds.), *Handbook of Industrial Organization*, Vol. II (Elsevier Science Publishers B. V., 1989). Noll provides a comprehensive overview of alternative theories of regulation and relevant empirical studies.
11. M. A. Magat, A. J. Krupnick, and S. Harrington, *Rules in the Making* (Resources for the Future, Washington, D.C., 1986).
12. In many cases where property and liability risks are too large for a single firm to handle, the insurance company may transfer part of the risk it has insured to another company, known as the reinsurer. The reinsurer receives a portion of the premium, and if the insured event occurs, the reinsurer is liable to the ceding company for its portion of the risk. A reinsurer can further reinsure (or retrocede) all or part of the risk with another reinsurer, known as a retrocessionaire. By assuming some of an insurer's risks, reinsurance reduces the impact of catastrophic losses and provides additional capacity for the insurance company to write more business.
13. L. Schaller, P. McNulty, and K. Chinander, "Impact of Hazardous Substances Regulations on Small Firms in Delaware and New Jersey," *Risk Analysis* 18, 181-190 (1998). In their study on how hazardous substances regulations impact on small firms in Delaware and New Jersey, provided further insights on why small firms, compared to large firms, find it more difficult to comply with regulations. For example, large firms in both states provided technical assistance to the state officials in formulating new process safety regulation. The result is that these regulations often incorporate many of the practices common among major chemical companies that have in-house experts in all aspects of process safety. Besides being able to allocate overhead expenses of maintaining in-house expertise over a larger operating base, large firms are also more concerned over loss exposures, liability, and public image. Small firms have none of the necessary expertise, infrastructure, and programs in place and are more inclined to circumvent the regulations or meet the minimum requirements.
14. LEPCs were established by the Emergency Planning and Community Right-to-Know Act (EPCRA) (1986). Under the EPCRA, facilities are obligated to work closely with their LEPCs and to use these entities as a means of informing the public about their operations.
15. Loss control incorporates loss prevention and loss reduction. Effective loss prevention reduces the probability of the loss event, while loss reduction reduces the severity of the loss if the event occurs.
16. This might happen when the low risks have all along been operating at the optimal level of risk.
17. R. A. Winter, "Moral Hazard in Insurance Contracts," in G. Dionne (ed.), *Contributions to Insurance Economics* (Kluwer Academic Publishers, 1991).
18. H. Kunreuther, R. Hogarth, and J. Meszaros, "Insurer Ambiguity and Market Failure," *Journal of Risk and Uncertainty* 7, 71-87 (1995).
19. The questionnaire instructions stated that pure premiums should exclude "loss adjustment expenses, claims expenses, commissions, premium taxes, defense costs, profits, investment return, and the time valuation of money."
20. These savings are determined by calculating $20[1 + 1/(1 + .10)^1 + 1/(1 + .10)^2 + \dots + 1/(1 + .10)^9]$.

21. The insured would have to permit third-party inspectors to provide reports to the insurer. The insured would do so if it results in lower premiums. Alternatively, the insurer could obtain this information if the third-party reports are included in the risk-management program that is accessible to the public, as required under Section 112(r) of the CAA 1990.
22. Although the EPA theoretically could also perform this role, it is limited in resources. Thus, it is more concerned with achieving a high compliance level from those regulated facilities.
23. The savings over 5 years is obtained by calculating $1000[1 + 1/(1 + 10)^1 + \dots + 1/(1 + .10)^5]$.
24. A. Belkaoui, *The Learning Curve: A Management Accounting Tool* (Westport, CT, Quorum Books, 1986). The learning curve was first recognized in the aircraft industry and later translated into an empirical theory in 1925 when it was observed in a military manufacturing facility.
25. P. Slovic, "Perception of Risk," *Science* **236**, 280–285 (1986).
26. Prudential Securities, "A Company Report on Exxon" (October 16, 1991).
27. Marsh and McLennan, "Large Property Damage Losses in the Hydrocarbon/Chemical Industries: A 30-Year Review" (1992).
28. A. Plough and S. Krimsky, "The Emergence of Risk Communication Studies: Social and Political Context," *Science, Technology, & Human Values* **12**, 4–10 (1987).
29. I. Rosenthal, "The Corporation and the Community: Credibility, Legitimacy, and Imposed Risk," *Process Safety Progress* **12**, 209–215 (1993).
30. I. Rosenthal, P. J. McNulty, and L. D. Helsing, "The Role of the Community and Risk Communication in the Implementation of EPA's Rule on Risk Management Programs for Chemical Accidental Release Prevention," *Risk Analysis* **18**, 171–180 (1998).
31. R. W. Hahn, "Reforming the Clean Air Act: The Case of Reducing Hazardous Air Pollutants," Testimony Before the Subcommittee on Oversight and Investigations, U.S. House of Representatives on June 29 (1995).
32. For example, the Department of Labor and Industry is responsible for administering Boiler Law in the Commonwealth of Pennsylvania.
33. The community would also be concerned with moral hazard, if they know that the availability of insurance actually increases the risk of an accidental release of chemicals.
34. Rosenthal, Er, and Kunreuther, "The Use of Third Parties in Implementing EPA's Proposed Rule on RMPs for Chemical Accident Risk Prevention," Working paper, Wharton Risk Management and Decision Processes Center, University of Pennsylvania (1995).
35. Public moral hazard is used to describe the tendency of the public to blame "unexplained" adverse health effects on accidentally-released chemicals, and especially so, when insurers have conducted inspections on the premises prior to the release. This term was suggested by Paul Kleindorfer, University of Pennsylvania.
36. J. P. Er, "A Third Party Approach to Environmental Regulation," A Dissertation in Insurance and Risk Management, University of Pennsylvania (1996).