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INTRODUCTION

When economists discuss instruments to control pollution, their attention focuses on taxes, the creation of property rights, and various regulatory approaches; they rarely discuss liability, however.[1] The economic effects of liability law have been addressed in a variety of other contexts such as car accidents, products liability, and medical malpractice.[2] Because liability law in general has the function to compensate for damages caused to individuals, hence serving as a deterrent to the originator of the damage, and because pollution causes damages to individuals, the use of liability law for pollution control would be a logical extension of existing instruments.

The law of torts that governs non-contractual liability has been part of private law for centuries, but this segment of private law has done very little to control pollution in the past. This failure primarily stems from the historical fact that the law of torts was codified in the 19th century mainly to deal with "legal conflicts in which a single person affected confronted a single individual tortfeasor."[3] In these conflicts, plaintiffs easily established causal relationship between the defendant's action and damage. This conception of the law of torts seems ill-suited for modern pollution problems where a number of polluters emit a variety of pollutants, affecting major portions of the population in large regions. In order to establish a claim for compensation, the victim must show injury,

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1. The textbooks in environmental economics focus the instrumental discussion on standards, taxes, subsidies, and sometimes property rights. *Compare,* W. BAUMOL & W. OATES, THE THEORY OF ENVIRONMENTAL POLICY (1975); P. NIJKAMP, THEORY AND APPLICATIONS OF ENVIRONMENTAL ECONOMICS (1977); D. PEARCE, ENVIRONMENTAL ECONOMICS (1976). The survey of Fisher and Peterson, *The Environment in Economics: A Survey,* 14 J. ECON. LIT. 1 (1976) does not mention liability as an instrument at all.

2. There are a number of attempts to develop an economic theory of liability in general. *See,* R. POSNER, ECONOMIC ANALYSIS OF LAW (2d ed. 1977) (particularly Chapter 6), or Brown, *Toward an Economic Theory of Liability,* J. LEGAL STUD. 323–49 (1973). For the applications, *see,* G. CALABRESI, THE COSTS OF ACCIDENTS: A LEGAL AND ECONOMIC ANALYSIS (1973); Reder, *An Economic Analysis of Medical Malpractice,* 5 J. LEGAL STUD. 267–91 (1976); and McKean, *Products Liability: Implications of Some Changing Property Rights,* 84 Q.J. ECON. 611–26 (1970).

3. Lummert, *Changes in Civil Liability Concepts,* in TRENDS IN ENVIRONMENTAL POLICY AND LAW 238 (M. Bothe ed. 1980).

the identity of the injurer, a causal relationship between the tortious action and the injury, and negligence, because in most legal systems liability law is based on fault.[4] The victim more easily carries the burden of proof, and can successfully claim compensation, when wandering cattle damage neighboring crops than when a number of pollutants cause environmental disease. Multiple causes for the same disease, a long latency period, varying levels of exposure, lack of knowledge about effects, and a large number of tortfeasors, *inter alia,* confront the victims of air pollution claiming compensation from any polluter. If the polluter's chances of avoiding payment of compensation are high, the incentive of liability law to prevent pollution is low. Hence, the question arises whether all liability approaches can be ruled ineffective, or whether liability laws can be developed that make it easier for victims of pollution to claim compensation.

Liability law, court rulings, and compensation show a tendency to reduce the stringent proof requirements for the victim. Strict liability for operators of railroads, airplanes, and other public transportation exempts the victim from the burden of proof of fault. The burden of proof, however, falls on the victim when the defendant is a polluting industrial plant. In most cases, establishing a causal relationship between the polluter's behavior and the damage has been very difficult. The decision of Japanese courts to accept epidemiological evidence for air pollution was considered a break-through.[5]

Identification of the injurer remains a necessary fact to be established. In the past, the doctrine of contributory negligence usually served as a legal defense in cases where the pollution could be attributed to more than one defendant. Where the uncertainties of allocating liability are not a legal defense, the question becomes one of apportioning damages. If the compensation payments are continuous and the contributions of each polluter are based on his emissions, such a compensation scheme would amount to a court-administered fee system. In Japan, the general air pollution compensation scheme is financed on this basis as the result of specific law rather than court decision.[6] The deterrent effect of the compensation law depends on the criteria used to apportion monetary damages.

In cases where a sole polluter causes pollution-related damage, the polluter has to pay all the compensation. This will not always be the case, however, if insurance for compensation becomes relevant. Where

4. *Compare, id.* at 237–64.

5. R. LUMMERT & K. THIEM, RECHTE DES BURGERS ZUR VERHUTUNG UND ZUM ERSATZ VON UMWELTSCHADEN (1980), Berichte des Umweltbundesamtes 3/80 at 155.

6. *Id.* The contributions are based on emissions for large stationary sources and taxes on automobiles.

one pollutant emitted by only one polluter causes specific damages, the identification of the polluter is relatively simple. The *Minamata* and *Itai-Itai* cases are typical examples of easy identification. Oil tanker accidents are typical of the more difficult cases.

Oil pollution of the oceans has a number of sources other than oil tankers, which are primarily land-based sources. Although oil pollution of the seas by tankers constitutes a secondary source, it has attracted a number of studies by economists.[7] The role of liability for tanker accidents has been analyzed previously from an economic approach by two of those authors.[8] Paul Bradley proposes a fine system to address the detection and enforcement problems for oil spillage control. This approach attempts to control spillage due to collisions and strandings as well as spills during transfer operations. The detection of spills is in fact a problem during transfers, but it is restricted to port areas where detection should not be too difficult. Detection becomes more of a problem for the discharges of ballast water and similar sources of oil pollution which take place far from coasts and harbours. This emission source, however, is operational and not accident-related. Accidents, such as grounding or collision, are easily detected, even if they do not result in the break-up of a tanker.

When discussing alternatives, Bradley skeptically reviews the liability approach. Because of the difficulties of assessing the damages, he doubts the ability of courts to establish correct damage estimates. Damage assessment, however, is a general problem and is equally relevant to a fine system, where the agency would have to produce these estimates. The administration and information costs create major problems for the proposed fine system, particularly if the calculation of fines is based on individual voyages.

Henry J. McGurren, on the other hand, seems more optimistic about the ability of the liability approach to control accidental oil pollution. He seems convinced that strict liability coupled with compulsory liability insurance "will compel individual shippers to take steps to reduce the probability of oil pollution damages in the most efficient manner."[9] The liability approach theoretically has the advantage over a fine system because it fits into the existing legal structure and the insurance industry

7. Burrows, Rowley & Owen, *Operational Dumping and the Pollution of the Sea by Oil: An Evaluation of Preventive Measures,* 1 J. ENVTL. ECON. & MGMT. 202–18 (1974); Bradley, *Marine Oil Spills: A Problem in Environmental Management,* 14 NAT. RES. J. 337–59 (1974); Burrows, Rowley & Owen, *The Economics of Accidental Pollution by Tankers in Costal Waters,* 3 J. PUB. ECON. 251–68 (1974); McGurren, *The Externalities of a Torrey Canyon Situation: An Impetus for Change in Legislation,* 11 NAT. RES. J. 349–72 (1971); and Conrad, *Oil Spills: Policies for Prevention, Recovery and Compensation,* 28 PUB. POL'Y. 143–70 (1980).

8. Bradley and McGurren, *supra* note 7.

9. McGurren, *supra* note 7, at 364.

could provide a market-oriented way to determine fines for non-continuous, single-event type pollution through insurance premiums.

THE ECONOMICS OF LIABILITY

Liability laws traditionally provide instruments for resolving conflicts between different property rights. They constitute the second possibility in the Coasian analysis of internalizing external effects besides the outright sale of property rights.[10] Under this solution, each property owner retains the rights conferred in him, but is restricted in the use of his rights to the extent of damages that are to be compensated. In the case of oil pollution by tanker accidents, the tanker owner has the right to use the ocean as a transport route without having to get permission from potential pollution victims, while the potential victims, fishermen or hotel owners, for instance, do not have to bribe the tanker owner to reduce the accident risk.

Tanker accidents cause damages to three groups: the shipowner, the freight owner, and third parties. Without liability laws, the shipowner would invest in ship safety solely in order to reduce his own damages. For a rational tanker owner, these investments would be undertaken until the marginal avoidance costs were equal to the expected marginal damages to the shipowner. In this situation, the level of safety investment would be too low from a societal point of view, because his behavior did not take into account the damages to the freight owner and to third parties.

Liability laws primarily function to compensate those parties who incur damage. As a consequence, most of the legal reasoning is based on considerations of fairness.[11] The economic function of liability law serves as an incentive to invest in accident avoidance measures to reduce the expected value of compensation payments. Whether a given liability law can be considered economically optimal depends on the allocation of compensation between the parties. Economists use the following criteria: whether the liability laws minimize and avoid costs. Posner argues that not only the avoidance costs of the "defendant" but the avoidance costs of the victim as well are relevant, because both have to be considered as social costs.[12] This effect is accomplished through the concept of contributory negligence. Legal scholars and judges justify this type of liability

10. In the Coasian analysis, the externalities that cause conflicts between property rights are the result of voluntary actions, either compensation payments or the outright transfer of property rights. With the presence of transaction costs, these voluntary transactions might not take place, thus leaving the externalities unaccounted for. With liability laws, a procedure for compulsory compensation exists. *See*, Calabresi & Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089–128 (1972).

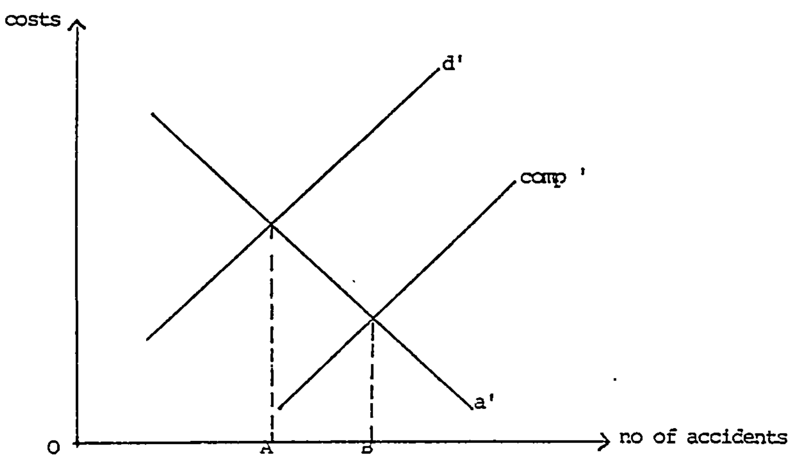
11. Fletscher, *Fairness and Utility in Tort Theory*, 85 HARV. L. REV. 537–73 (1972).

12. R. POSNER, ECONOMIC ANALYSIS OF LAW 137–38 (2d ed. 1977).

on fairness arguments. Contributory negligence also serves as an economic incentive for the potential victim to avoid behavior that might increase the likelihood of damage.

Compensation for negligence is based on the legal standard in unintentional tort cases where "the defendant is guilty of negligence if the loss caused by the accident, multiplied by the probability of the accident occuring, exceeds the burden of the precautions that the defendant might have undertaken to avert it."[13] The avoidance costs are defined as average costs: the preventive care of a reasonable person. German liability law defines negligence as not applying the necessary preventive care—not the usual preventive care.

In tanker accidents, contributory negligence of the victim never arises as an issue for third party damages, because the victims usually do not have the means to avoid the accidents and damage. The question then becomes whether the liability for tanker accidents should be based on negligence or strict liability. Strict liability means a stronger incentive to invest in ship safety because lack of negligence would not be a defense. Certain situations arise, however, when the tanker owner would not be liable even under strict liability: e.g., in case of war, faulty navigational aids, and so forth. The question of the efficiency of a given liability law can be answered only if one compares its outcome with the minimum of damage and avoidance costs. One major reason for the deviation from this minimum could be that compensation payments are systematically lower than damages. This hypothesis is illustrated by the following diagram:



13. *Id.* at 122 (United States v. Carroll Towing Co., 159 F.2d 169 (2d Cir. 1947)).

The social optimum would occur when marginal damages d′ and marginal avoidance costs a′ are equal in point a. If compensation payments are systematically lower than damages, the tanker owner would invest less in safety, and more accidents would occur (B). Under this scheme, the compensation payments, and not the damages, are relevant to his investment decision resulting in a higher number of accidents. Traditionally, national liability laws have resulted in lower compensation payments, compared to the damages incurred by tanker accidents, for the following reasons:

- under negligence liability the victims had difficulty proving negligence;
- not all types of damages were compensated for;
- the transaction costs of getting compensation were too high for a number of victims; and
- the assets of the defendants were too low to cover all claims. If negligence liability puts the burden of proof on the victims, they might be hard pressed to establish their case. Decisions in criminal or admiralty cases, however, may aid sick victims.

A second hindrance to full compensation might be the fact that all types of damages do not warrant compensation. Usually, personal injury, property damages, and loss of income, as well as cleaning efforts and expenditures, are compensable. Damages to ecosystems are not classified personal, because they are public goods, e.g., nature preserves. The German civil code provides compensation for private property damages, including loss of profits, but does not give compensation for injury to preserves. The relevant specific laws do provide for minimal fines.[14] Estimating the damages for those public goods poses great difficulty, but it is possible to establish a potential range in which damage amounts could be determined if compensation were permitted.[15]

Damage and compensation divergence due to transaction costs varies with the location of the court. For *Torrey Canyon,* where damages had occured in another country, claim settlement for third party damages began with the question of the location of the responsible court: in the flag state, the state of the shipping company, or the state of its holding company. For victims with small damages, the incentive to claim compensation is rather small where the cost of placing a claim is high because the court

14. For example, Bundesnaturschutzgesetz (Federal Nature Protection Law) Art. 30, allows for a fine of DM 30.000.

15. The advantages and disadvantages of the various methods of evaluating eco-systems and thus damages to them are well established. *See,* Knetsch & Davis, *Comparisons for Methods of Recreation Evaluation,* in ECONOMICS OF THE ENVIRONMENT 450–68 (R. Dorfman & N. Dorfman, eds. 1977). These methods will provide a range of damages which could overcome the systematic lack of consideration of these damages in court cases thus far.

is located in a different country. If there are a number of these victims, a high proportion of damages go unclaimed. Moving the responsible court to the country of damage reduces the transaction costs for a number of victims. It might increase the defendant's costs, but most likely would result in a lower total transaction cost and would not alter the behavior of the defendant.

Another factor which reduces compensation occurs when individual damage is very small, but the aggregate amount resulting from the injury is large. The transaction costs of the individual victim might be higher than the award, even when the court is in his own country, if the claim for compensation has to be settled on an individual, case by case, basis. If the transaction costs could be lowered due to economies of scale, the incentive for the victim to claim compensation might be increased. One way to gain from economies of scale is to allow class action suits.[16] Not all countries allow class action suits, and even where they are permitted, restrictions might prevent maximum economies of scale and reductions in transaction costs from being fully achieved.

A major obstacle to using traditional liability law as an incentive for reducing oil pollution damage is the defendant's lack of financial resources to cover valid compensation claims. Often, the capital of a shipping company consists only of one ship, owned by a separate corporate entity. As a consequence of a tanker accident, this capital is lost or its scrap value too low to cover all compensation. To protect against this loss of wealth, the owner has an incentive to insure the vessel, but only for the value of the vessel itself. The cargo owner has a similar incentive, but again only to the extent of the value of the cargo. While the damaged third party might try to recover his claim against the vessel owner, recovery from the cargo owner is not possible. Damage that exceeds the value of the vessel will not be recoverable. Therefore, the vessel owner has to invest in ship safety beyond the value of the vessel. If one compares the sales value of a modern tanker, e.g. $40 million, with the damages in some cases amounting to $200–300 millions, the discrepancies become obvious. One way to solve this problem is to introduce compulsory liability insurance.

Ideally, compulsory insurance would provide an incentive for the vessel owner to invest in ship safety. If the insurance premium were proportional to the marginal risk of damage (likelihood and size of damage), investment in ship safety would reduce the risk of damage, thereby reducing the premium until the marginal safety investment cost were equal to the marginal premiums. This effect, however, is not likely, because of market

16. Backhaus, *Forensische Korrektur von Marktversagen*, INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND SOCIETY (Berlin 1977).

imperfections in the insurance industry due to information costs.[17] For these imperfections, the term "moral hazard" has been coined, although it does not adequately describe the cause of these imperfections.[18] To set the premium proportionate to the individual risk of the insured, an insurance company would have to know before concluding the contract all factors of the insured that contribute to accidental risk. These include the quality of the vessel, its navigational equipment, the skill and experience of its captain and his crew, the mileage of the vessel, its potential routes, and the "driving" behaviour of the captain.

The same problem occurs with liability insurance for automobiles. Some of this information is neither too difficult nor too costly to obtain, but to obtain complete information about the driving behavior of an automobile owner would imply continuous monitoring of an insured. This is obviously too costly, so the insurance companies set average rates. In the automobile insurance industry, the age and experience of the driver, previous accident record, and size of car are the most important factors in determining risk. The resulting rates allow the insured to change his behavior or conceal factors contributing to risk. With average premiums, a higher likelihood exists that bad risks will be subsidized by good risks, thereby decreasing the incentive of investing in safety equipment and driving "defensively" as a means of avoiding accidents. Some insurance schemes offer lower premiums after years of accident-free driving, to provide some incentive for reducing risk. Nevertheless, the fact remains that the insured usually has better information about his status as a risk than does the insurer. This informational asymmetry between the buyers and the sellers of insurance causes, to a large extent, premiums to have more of an average than a proportional character, thus creating a market imperfection.

NEW DEVELOPMENTS IN LIABILITY LAW

The grounding of the *Torrey Canyon* off the British Coast in 1967 and the resulting spillage of 10,000 tons of crude oil illustrates the difficulties in claiming compensation from tanker accidents.[19] The vessel was sailing under a Liberian flag, with Greek captain and crew, and was chartered by a British oil company. The ship, however, was registered in the Ber-

17. Sinn, *The Efficiency of Insurance Markets,* 11 EUR. ECON. REV. 321–41 (1978).

18. The information asymmetry which causes the "moral hazard" is not restricted to insurance industries. For the general relevance of this asymmetry, *see,* Akerlof, *The Market for "Lemons," Quality, Uncertainty, and the Market Mechanisms,* 84 Q. J. ECON. 488–500 (1970). For the insurance industry, *see,* Pauly, *Overinsurance and the Public Provision of Insurances: The Role of Moral Hazard and Adverse Selection,* 88 Q. J. ECON. 44–54 (1974), and Marshall, *Moral Hazard,* 66 AM. ECON. REV. 880–90 (1976).

19. *See* Burrows, Rowley & Owen, *The Economics of Accidental Pollution by Tankers in Coastal Waters,* 3 J. PUB. ECON. 259 (1974).

mudas. The problem of settling the claims was so immense, starting with finding the appropriate court, that the claims were settled out of court, with only the British and French governments being compensated for a part of their clean-up costs. Other claims were left uncompensated.

This unsatisfactory result of national liability law led to new international conventions and agreements, and national laws specifying a new liability regime for tankers.[20] The Civil Liability Convention and the Fund Convention changed this legal situation considerably by:

- introducing strict liability
- limiting liability to $17 million per accident
- making liability insurance compulsory
- enumerating specific damages to be compensated
- specifying pollutants
- providing the establishment of a compensation fund up to $36 million per accident.

Before the international conventions became effective law, the tanker owners established a private liability agreement to compensate for damages up to $17 million per accident (TOVALOP) and a separate private compensation fund (Christal) covering $30 million per accident. The international conventions have been ratified subsequently and are now law, being supplemented in some countries by specific national liability schemes, the most prominent being the Superfund in the United States. These agreements and conventions considerably improve the chances of liability law serving as an instrument to reduce oil pollution by tanker accidents.

In the light of the previous discussion, a number of questions arise about whether these changes were adequate. The changes that lowered the transaction costs for the victims (such as strict liability and location of the responsible court in damaged country) are part of the improvement. The limitation of individual tanker owner liability in combination with the communal compensation funds remains a critical point. The limits of the liability barely would cover the quantifiable costs of third party damages for the Torrey Canyon ($7.7 million) in 1967. Unlimited liability with a high minimum compulsory insurance was not introduced because the insurance industry in 1969 considered the risk uninsurable. This assessment, based on currently marketable premiums, indicated the proposition would be unprofitable. This argument would only have been valid if the insurance market were so small that coverage of more than $17

20. The Civil Liability Convention was the first convention to be affected in this area by the Torrey Canyon, together with the Intervention Convention. A presentation of the legal development in this field can be found in Wood, *Toward Compatible International and Domestic Regimes of Civil Liability for Oil Pollution in Navigable Waters,* 5 ENVTL. REP. 50.116–.145 (1975). Here only those changes in civil liability are presented that bear a direct relationship to the economic reasoning.

million would place the whole industry in jeopardy. But given the size of the market, the potential of reinsurance, and the coverage of risks in existing contracts, these arguments are not convincing. Marketing considerations establish the limits of liability for the insurance industry where increases in premiums are not desirable. These arguments were in fact integrated into the Civil Liability Convention, as indicated by the official records of the proceedings.[21] Nevertheless, through reinsurance, the coverage of the insurer has been raised to $100 million since February 1979, with no changes in the Civil Liability Convention.[22]

The arguments against higher or unlimited liability, e.g., the undesirability of increases in premiums, conflict with the goal of liability insurance which is the control of oil pollution by avoidance of tanker accidents. The increases in premiums for bad risks, *i.e.*, badly maintained and equipped vessels, over those premiums under traditional national liability law, are necessary to increase the incentive to invest in ship safety. Given these increases, the tanker owner has a choice of improving the vessel and crew standards or scrapping the vessel if improvements or higher premiums make the continuation of business unprofitable. Both the selectivity of premium changes and the resulting reaction of tanker owners are critical to the success of the liability insurance approach. They are especially desirable from an environmental point of view, because they eliminate oil pollution risk by scrapping or upgrading tankers.

The existing limits of liability restrict this effect considerably. The premiums for third party damages will be lower than under unlimited liability or higher limits. Import fees finance the International Compensation Fund, and sales charges finance the Superfund in the United States, thereby not discriminating between varying risks of individual tankers. While they improve the level of compensation, they are not an incentive to reduce tanker risks.

The question remains, however, whether the situation would improve if these restrictions were removed and only individual insurance were available. In this case, the ability of the insurance industry to discriminate between the individual risks is most important. To move towards a system of a proportional rate setting, the collection and assessment of more information relevant to tanker risks would be necessary, as well as a continuous updating of this information. This system would help to take into account a number of factors contributing to risks such as ship standards, navigational equipment, and local qualifications. The monitoring of driving behavior would be prohibitively costly, however, so that this factor would not be taken into account *a priori*. Hence, whether pro-

21. Intergovernmental Maritime Consultative Organization (IMCO), The Records of International Legal Conference on Marine Pollution Damage 596–97 (1969).
22. United Kingdom P + I Club Rule 79, Rule 34 (14).

portional rate setting is too costly will depend on the number of average tariff rates and the difference between the actual rate setting system and the optimal proportional rate structure based on complete information.

An analysis of the present rate-setting practice in the insurance industry for extreme risks (low probability, high damage) will give some qualitative results in general, but will never be able to quantify the deviation from the economic optimum based on perfect information. One observation can be made from current practices: the assessment improves as the ex post distribution becomes denser, i.e., as more accidents occur, the rate-setting structure becomes more accurate.

The branch of the insurance industry covering tanker risks raises further doubts.[23] Protection and indemnity (P and I) clubs, mutual associations with a non-profit character, usually undertake to insure these risks. The clubs consist of ship owners and charterers, and arose during the 19th century to cover third party losses such as personal injuries, or pier damages, that commercial marine insurance was not willing to cover at that time. Fifteen clubs today cover about 380 million tons. An individual club covers a certain amount of damage, varying from year to year, with a maximum of $600,000 in the year 1980. The pool of all clubs covered up to $3.4 million in 1980, with the excess going to the reinsurance markets. The premiums, or calls as named by this branch of the insurance industry, are calculated on an ex-post basis for the entire fleet of an individual shipowner for all third party risks. For an individual vessel, ex-ante assessment for oil pollution damages does not take place. This procedure would be against explicit club policy. Therefore, the clubs do not collect information about safety equipment of individual vessels, their overall standards, or hiring practices. The premiums vary between different fleets, because a proper classification by the marine insurance is a condition for membership; hence, ship standards are taken into account by the clubs. This procedure does not guarantee safe vessels for two reasons: (1) the results of classification societies are seldom updated and (2) P + I clubs do not update this information themselves. As one club representative explained during a parliamentary inquiry in Britain: "It is not their job to check on every owner's crewing standards. It would be impertinent for them to tell, for example, British Petroleum how they should man and train men for their ships."[24]

Given these circumstances, a liability insurance scheme theoretically and factually cannot provide an optimal level of pollution control. Never-

23. *See* Measures to Prevent Collisions and Strandings of Noxious Cargo Carries in Waters Around the United Kingdom, Second Report from the Expenditure Committee together with the Minutes of the Evidence taken before the Trade and Industry Sub-Committee in Session 1977–78 and Appendices (Session 1978–79)(TISC-Report), HMSO 1978, 105-I-III-Vol. II at 59–103.

24. TISC-Report, *supra* note 23, at 88.

theless, the question arises whether the resulting level of pollution control remains superior to a regulatory approach where governments require certain safety measures to be undertaken by the ship owner. The argument in favor of a market-oriented type of pollution control relies on the assumption that this approach improves the efficiency of control because the polluter can choose the least-costly control technology.

The Cost Effectiveness of Tanker Safety Regulation

Any governmental policy which attempts to decrease the number of accidents without relying on liability must incorporate a level of pollution which is considered acceptable as well as instruments to achieve this policy goal. Economists prefer minimization of damage and avoidance costs, because they set forth an easily-defined theoretical optimum. (This optimum is usually presented by a graph similar to that presented at the beginning of this paper.)

The arguments concerning liability have focused on the fact that compensation payments were systematically lower than damages, which led to more than the economically optimum number of accidents. A lower number of accidents, or a zero solution, possibly might be politically desirable. Economists indicate, however, the combined avoidance and damage costs will be higher at the politically desirable level of pollution control in terms of additional resources needed. A textbook presentation of this concept, which usually depicts the optimum in the middle of the graph, does not imply the existence of factual information about the two cost functions. Possibly, damage costs are so high that a zero solution would be economically optimal.

The translation of this reasoning into a guide to policy making has been a major asset in environmental economics. Methodological difficulties encountered in studies of damages have caused the economic definition of environmental quality to be abandoned and replaced with a political definition. Any attempt at this approach is more difficult for tanker accidents than for routine air pollution because of the stochastic nature of this source of discharge. The definition of an environmental quality goal, e.g., water suitable for swimming, or 'x' tons of BOD discharge into a river per year, seem to be communicable to politicians and the general public. The likelihood of accidents, on the other hand, makes it nearly impossible to arrive at a level of total oil discharge which is suitable as a goal. Instead, goal definitions, such as "reduce the number of accidents by 'x'%" or "reduce the maximum outflow per accident to 'x'tons," seem more viable. These goal definitions are closer to instruments of pollution control than the goal of avoiding damage. Damage avoidance, however, does not exist for this source in practice and can only be imputed from the instruments used. Instruments availability, costs, and effectiveness, are usually analyzed first, and the resulting improvements are then developed as goals.[25]

The following examines the existing information concerning the costs and effectiveness of various instruments for tanker safety to evaluate the "grand" alternative liability versus governmental regulation. The possible instruments in this context have already been listed and grouped:[26]

A. Prevention of accidents
   1) crew training
   2) navigational equipment of the vessel
   3) traffic safety measures (rules of the road, sea lanes, navigational aids, piloting)
   4) ship safety (such as measures to maintain maneuverability, back-up power, back-up radar, structural stability)
B. Limiting discharges after an accident
   1) tank size limitations
   2) tanker size limitations
   3) increased strength of hull
   4) emergency pumping arrangements.

With the exception of tanker size limitations, all of the above instruments have been incorporated into national or international regulations.

The quality of personnel has been the subject of the Training, Certification, and Watch Keeping Convention of 1978. Traffic safety has been the topic of the International Conference on Revision of the International Regulations for Preventing Collisions at Sea of 1972, the MARPOL Agreement of 1973 and various national legislation. Navigational equipment of the vessel and other measures relating to ship safety have been regulated by the Safety of Life at Sea Convention of 1974 and its 1978 Protocol. Tank size limitations and requirements concerning hull strength have been a part of the Pollution Prevention Convention of 1973.

Once ratified and rigorously enforced, these control measures surely will have a positive effect on the tanker accident record. Comparing the cost effectiveness of these various instruments requires knowledge of the factors that cause accidents and information about the impact of the various instruments on these factors. One approach studies the history of past accidents to determine their causes and to assess the effect of the various instruments by imputing an average effectiveness of an individual instrument, e.g., the reliability of a particular piece of navigational equipment. If a certain percentage of accidents occured because one type of navigational equipment did not exist on board ship, then the requirement

25. *See* the press declaration of the White House for the Ocean Pollution Policy of President Carter: "It is the goal of the President to reduce oil pollution by tankers by the following means . . .," White House (March 18, 1977).

26. *See* Bradley, *supra* note 7, at 340.

of that piece of equipment can be assumed to prevent this percentage in the future, if properly used. To the extent that a cause and remedy relationship can be determined for a missing piece of equipment, an assessment of effectiveness is straightforward since costs are easily identifiable. The estimate of overall cost effectiveness requires only the knowledge of the number of vessels to be outfitted.

With regard to behavioral causes of accidents such as navigational errors, the assessment of effectiveness of particular instruments, e.g., education and training, is elusive. First, to develop a baseline of the existing training quality is difficult. Second, establishing a causal relationship between training and navigational error is not convincing due to the possible intervention of such factors as fatigue. Because of these difficulties, cost effectiveness studies exist for only four groups of instruments where the behavioral element of individual vessels plays a minor role:

- navigational equipment of the vessel
- traffic safety measures
- tank size limitations
- increased strength of the hull.

All instruments were analyzed in Coast Guard studies: the first two in a traffic management study in 1977,[27] and the outflow control measures in preparation for the 1973 MARPOL Conference.[28]

The Traffic Management Study based its analysis on 78 casualties off the United States coast between 1972 and 1977, of which 63 involved tankers. The study estimated the total number of incidents in this period to be 121, but it limited the analysis to the 78 casualties where information was available. On the basis of this analysis, 339 accidents were projected for 1980-1990. As a base of comparison, a complete introduction of the LORAN-C navigational system was assumed, resulting in a baseline projection of 271 accidents. The distribution according to the causes of accidents is shown in the table below:

TABLE 1[29]

Projection of Tanker Accidents off the United States' Coast, 1980–1990

Cause	Status quo	LORAN-C
Grounding	253	196
Collision	70	65
Ramming	16	10
Sum	339	271

The study surveyed 31 navigational technologies available at the time for their potential effectiveness and analyzed 18 in detail. The study grouped the 18 technologies into seven categories, labeled as strategies. These strategies consisted of:

1) the LORAN-C system as a baseline
2) high level improvement of vessel navigational equipment
3) moderate level of improvement of navigational equipment
4) vessel passport system
5) radar surveillance
6) automatic monitoring
7) satellite system.[30]

The LORAN-C system provides a method of improving the accuracy of location-finding for individual vessels based on coastal stations. The high level improvement of navigational equipment includes six pieces of equipment, in addition to those that are required already by international regulations. They encompass a navigational alert, a collision avoidance aid, a VHF transponder, a radar perimeter device, a scanning sounder and a depth alert.

The moderate level consists only of the navigation alert and the VHF transponder. The Vessel Passport System is a traffic control system for harbor entrances where vessels are required to report for harbor entrance 24 hours before entering national waters. Access to the harbor is then allowed on the basis of computerized checks of past vessel history. The radar surveillance is a traffic control system based on radar stations on the coast while the automatic monitoring is an enlarged vessel passport system which provides additional information for incoming vessels with respect to other traffic. The satellite system is a traffic control system utilizing transmissions.

Because the various technologies control different causes of accidents, the study calculated their effectiveness on an individual technology basis, then combined them for the strategies and assessed them against the baseline system. The full effectiveness, according to the assumption, will be fully reached after a five-year introductory period, i.e. in 1985. On the basis of these assumptions, the costs are calculated and discounted at 10 percent for the period between 1981 and 1990.

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27. United States Coast Guard, Dept. of Transportation, Offshore Vessel Traffic Management Study, Vol. I-III (1978).

28. Intergovernmental Maritime Consultative Organization (IMCO), International Conference on Maritime Pollution Prevention, Report on Study I, Segregated Ballast Tanks, A Note by the United States of America, MP/CONF/INF. 2, at 55–86 (May 7, 1973).

29. United States Coast Guard, *supra* note 27, Vol. II, Ch. 6.

30. *Id.*, Vol II, Ch. 5.

The comparison of all six additional strategies shows that the vessel passport system seems to be the most cost-effective.[31] The highest effectiveness is achieved by the automatic monitoring system that reduced the number of casualties from 271 to 76 at a total cost of $54 million. The radar surveillance system ranks second with a reduction to 143 accidents at a cost of $36.2 million, and the passport system with a reduction to 155 accidents ranks third with the extreme low cost of $9.5 million. All these alternatives compare favorably with the high vessel improvement strategy with a reduction to 188 accidents at a cost of $319.2 million. A choice could be made among these alternative strategies either on a cost effectiveness basis, favoring the passport system, or on a cost-benefit basis. A cost-benefit calculation in this context is, as already mentioned, particularly difficult, because oil pollution damages are hard to quantify.

The question remains whether the surveillance and the automatic monitoring are better choices than the passport system. Their effectiveness is considered higher, but at higher costs. The choice of automatic monitoring, without concomitant higher cost, can be supported if the benefits of the prevention of one accident would exceed on average the $277 prevention costs per accident. This question can be answered only if the distribution of damages in all the cases were known, such as damage to vessel, loss of cargo, and the damage to the environment. If one assumes that the average accident would cause the loss of 1,000 tons of cargo, then the benefits would already exceed the costs.

The second study which the Coast Guard prepared for the MARPOL Conference compares tank size limitations (IMCO Design) with double bottoms and double sides. Based on the analysis of tanker accidents in 1969–1971, the average outflow per tanker accident was estimated for a 250,000 dwt standard tanker (Tables 2 and 3).

Based on an estimated 365 million dwt tanker fleet for 1980, the average outflow of product per standard tanker was estimated at 157 m^3. This total outflow would be reduced if the various alternative vessel designs were adopted, depending on the particular design and on whether the design would be required for new construction only, or for the entire fleet. The Coast Guard then calculated the costs for these designs for a standard tanker on an annualized basis and developed cost-effectiveness figures. For the IMCO-Design, the reduction of 1 m^3 of outflow would cost an additional $1,150; for double bottom, additional costs were estimated at $5,940; and for the double bottom and double sides, $14,330.[32] The double sides did not result in a reduction in outflow and hence were excluded from further discussion.

31. *See infra* Table 2.
32. IMCO, *supra* note 28, at 36.

TABLE 2

Cost and Effectiveness of Seven Possible Strategies

Strategy	Number of Vessels	Vessel Cost ($ mil)	Government Cost[1] ($ mil)	Total Cost ($ mil)	Net Effectiveness (%)	Casualties Prevented Through 1990	Costs per Casualties Prevented
A. Baseline System LORAN-C	6,100	0	0	0	0 (23)[2]	0 (68)[2]	1,000
B. High Vessel							
Navigation Alert	6,100	15.7	0	15.7	8		
Collision Avoidance	2,500	215.1	0	215.1	5		
VHR Transponder	6,100	28.9	0.9	29.8	13		
Radar Perimeter Device	3,600	7.7	0	7.7	6		
Scanning Sounder	2,500	43.0	1.3	44.3	5		
Depth Alert	3,600	6.2	0.4	6.6	11		
Total		**316.6** **(622.0)**	**2.6** **(3.0)**	**319.2** **(625.0)**	**37**[3]	**83**	**3,850**
C. Moderate Vessel							
Navigation Alert	6,100	15.7	0	15.7	8		
VHF Transponder	6,100	28.9	0.9	29.8	13		
Total		**44.6** **(87.6)**	**0.9** **(1.0)**	**45.5** **(88.6)**	**21**	**47**	**960**
D. Vessel Passport System	2,670	0	9.5	9.5	40	116	82
E. Radar Surveillance	6,100	0	36.2	36.2	57	128	283
F. Automatic Montoring	6,100	18.8 (39.8)	35.2 (69.9)	54.0 (109.7)	67	195	277
G. Satellite System	6,100	223.5	84.5	308.0	65	131	2,350

[1]Net present value through 1990. Cumulative cash outlays shown in parenthesis.
[2]Effectiveness of Baseline over system in use during FY 1972–1977.
[3]See text for explanation.

TABLE 3[33]

Outflow Estimates for Different Standard Tanker Designs

	Outflow per accident (m^3)		Average Outflow per tanker per year (m^3)
	Stranding	Collision	
Base design	6,400	21,900	157
IMCO-Design	4,950	17,400	123
Double bottom	2,300	17,600	80
Double side	12,200	9,700	220
Double bottom and side	4,200	12,100	97

These indicators, however, do not allow a comparison between outflow reduction and accident prevention measures. The costs are calculated in a different way, and the references for the effectiveness diverge between outflow and accident control. To make them comparable, the cost calculations must be made compatible, and the number of accidents translated to outflow figures. The cost calculation for accident prevention consists of the net present value of the various strategies for 1981–1990. If one does the same calculation for the various vessel designs, the numbers in Table 4 emerge.

The second step in making the numbers comparable is to convert numbers of accidents into outflow. The Coast Guard study assumed an average product outflow of 10,400 m^3 or at 30^0 API 11,900 Ton. A German study evaluating tanker risks in the North Sea considers a range between 2,100 and 5,600 tons as the most likely outflow.[34] A comparison of traffic safety measures based on the extreme values of outflows (2,100 and 11,900) is seen in Table 5.

TABLE 4

Cost and Effectiveness of Various Tanker-Designs

Design	Outflow per fleet m^3	Savings in Outflow m^3	Cost for new tankers worldwide in $ mio.	Cost per m^3 outflow saved in $
Base	2,137,000	0	0	0
IMCO-Design	2,032,000	105,200	118,9	1,130
Double bottom	1,899,000	238,000	1,408,9	5,920
Double side	2,331,900	−194,800	1,752,1	—
Double bottom and side	1,951,000	185,500	2,422,5	13,000

TABLE 5

Cost per t of Oil Outflow Prevented in $

Measure	Average hypothetical outflow per accident 11,900 t	Average hypothetical outflow per accident 2,100 t
A. Traffic Safety		
high vessel improvement	320	1,830
moderate vessel improvement	80	460
vessel passport	7	40
radar surveillance	24	135
automatic monitoring	23	132
satellite system	200	1,120
B. Vessel Design		
IMCO	990	
Double bottom	5,160	
Double bottom and double sides	11,410	

The three systems considered most favorable as a result of the traffic management study[35] are superior in terms of cost effectiveness to outflow reducing design measures, including the adopted IMCO Design. They are superior to moderate and high improvement strategies, as well as vessel design measures under the control of the vessel owner. A similar set of safety investment strategies would result in the least-cost solution. Public measures also could be more cost-effective. The reduction of accidents requires the complimentary provision of a public good—the management of traffic. The regulation of automobile traffic to reduce accidents has been taken for granted when the costs of accidents were analyzed. This might be the right approach when the productivity contribution of traffic regulation at a given level of traffic is exhausted. In the case of navigational safety, the contribution of a higher level of public regulation in terms of providing traffic management is more cost effective than further investment in safety measures on board ship. The level of safety in air traffic depends to a large extent on the safety of the planes, but also on the quality of air traffic management which is far above what the maritime industry has reached so far.

33. *Id.* at 80.

34. Dornier System, Ermittlung von Schwachstellen—Massnahmen zur Vermeidung von Umweltschaden bei industriellen Aktivitaten im Meer, 30–31 (Appendix II)(1979).

35. The concrete result of the vessel traffic management study could be in the self-interest of the Coast Guard, and they might have influenced the study. Whether such a self-interest bias actually influenced the outcome of this study cannot be determined by the author of this article, since the nautical engineering knowledge is lacking. Until there is another study which allows the evaluation of the basic accident data, one has to take the result of this study as a first approximation of the possible effectiveness of vessel traffic management schemes.

CONCLUSION

This article assesses the contribution of liability law to the prevention of pollution by examining an area where the conditions for successfully claiming compensation are comparatively favorable for the victim. Difficulties that stand in the way, under traditional tort law, of narrowing the gap between pollution damages and compensation payments (such as identity of the polluter, proof of damages and causal relationship) do not arise in tanker accident cases.

Changes in liability law have improved the legal position of the victims, but remain insufficient as an incentive for accident prevention. Additionally, optimal pollution control on the basis of liability alone is not possible because of data asymmetries in the insurance industry. And the assumption implicit in taxes and licenses, as well as in the liability law approach, that the polluter is best-qualified to make the best choices to minimize accident pollution control costs, is disproven by the Coast Guard studies which indicate that least-cost control technologies for tanker accidents are outside the purview of individual polluters.

These conclusions indicate that liability can play only a supplementary role in pollution control. This supplementary role can be enhanced when compensation laws for pollution problems are discussed again in the future, if the incentive effects of the financing of compensation receive more attention than they have in the past.