

# Multimodal Transportation, Logistics, and the Environment: Managing Interactions in a Global Economy

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As transportation and logistics systems continue to integrate, their impacts on the physical environment (air, water, and land resources) will become more complex. Economic globalization, agile manufacturing, speed-to-market delivery, and supply chain management are creating greater demand for intermodal transportation services and multimodal transportation infrastructure. Coping with the environmental impacts will require the transportation industry and its customers and stakeholders to move from strategies based on regulatory compliance to those emphasizing proactive environmental management. Proactive management of environmental issues requires corporations to identify: (1) the interactions among transportation activities that have negative environmental impacts, (2) the types of environmental impacts emanating from transportation operations and facilities, and (3) alternative means of controlling and preventing environmental pollution and natural resource degradation. © 2000 Elsevier Science Ltd. All rights reserved

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Intermodal transportation services and multimodal transportation infrastructure will play central roles in the logistics systems of corporations competing in global markets in the 21st century. Four trends are fundamentally changing the business strategies of

multinational corporations: continued economic globalization as the driving force in trade and investment, the growing demand for speed-to-market product delivery, the adoption of agile manufacturing and business practices, and the need to manage supply chains more efficiently. Agile corporations with international supply chains depend on intermodal transportation services to meet customers' demands for rapid production and delivery.

Intermodality is a process of transporting freight 'by means of a system of interconnected networks, involving various combinations of modes of transportation, in which all the component parts are seamlessly linked and efficiently coordinated' (Boske, 1998, p. 1). It offers manufacturers a full range of transportation modes and routing options, allowing them to coordinate supply, production, storage, finance, and distribution functions to achieve efficient relationships.

As transportation systems expand and become more integrated, their impacts on the physical environment (air, water, and land resources) will become more complex. Regulatory compliance, while necessary, may not be sufficient to manage effectively the potentially negative environmental impacts of multimodal transportation. In the future, proactive environmental management will be essential for the transportation industry and for organizations managing multimodal transportation hubs that integrate several types of freight carriers, logistics services, and

manufacturing or processing activities at a single site. Governments in cities and metropolitan areas in which these facilities are located and corporations with international supply chains that depend on intermodal transportation to achieve and sustain competitive advantage will also have to pay closer attention to the environmental consequences of emerging logistics systems. Developing beyond-compliance, proactive environmental management systems requires a clear understanding of the potential environmental impacts of commercial transportation services.

This article provides a framework for understanding interactions among transportation activities and the environment. It explores the forces driving the growth of intermodal transportation services and multimodal transportation infrastructure, identifies the major environmental impacts of transportation operations and facilities, examines alternative means of controlling and preventing environmental hazards, and outlines the types of information needed for developing proactive environmental management systems.

## The Emergence of Multimodal Transportation Systems

Transportation services and facilities have grown rapidly in the United States and Europe in the wake of increasing demand by multinational corporations and their suppliers and distributors for seamless logistics services. Economic globalization requires firms to produce and deliver goods faster to customers around the world. In order to do so, corporations must manage their supply chains and integrate their logistics systems more effectively.

## Growth of Transportation System Components

The freight shipments of all four major transportation modes — air, water, rail, and road — have increased over the past decade, and forecasts indicate continued growth in the future. In Europe, freight traffic reached about 800 billion ton-km in 1996 and is expected to grow by 2–3 per cent a year (Burckhardt *et al.*, 1998). Land-based freight forwarding (which accounts for 80 per cent of all cargo transportation) generated \$150 billion in revenue in 1996. In the United States commercial freight distribution yielded \$342 billion in revenues during the same year. The US Department of Commerce (USDOC, 1998) predicts that rail cargo shipments will grow from 1.4 billion tons in 1992 to 1.9 billion tons in 2002. US air carriers transported nearly 18.5 billion revenue ton-miles (RTMs) of cargo in 1996, an increase of 4 per

cent over the previous year. Growth in air transport services (passengers and cargo) is expected to average at least 4 per cent annually over the next decade.

Globally, seaborne trade grew to its highest levels in 1998, reaching more than 5 billion tons, and the world merchant fleet grew to 788 million deadweight tons (UNCTAD, 1999). Airfreight has doubled in volume since the early 1980s. Airfreight shipments reached 119 billion FTK (freight ton kilometers) in 1998 worldwide, with the United States and Canada claiming 33 per cent of the world total, the Asia-Pacific Region 31.5 per cent, Europe 27.3 per cent, and the Middle East, Latin America and Africa a little more than 8 per cent (Schwartz, 1999a). The airline industry expects global airfreight to triple in volume between the years 2000 and 2015 as carriers achieve worldwide delivery targets of less than 48 hours from airport to airport (Wilson, 1998).

## Driving Forces

Four major trends are driving demand for intermodal logistics: (1) economic globalization, (2) speed-to-market product delivery, (3) agile manufacturing and business practices, and (4) integrated supply chain management. Since the early 1980s, international trade and investment have grown rapidly. The World Trade Organization (1998) reports that international merchandise export values reached \$5.2 trillion and import values exceeded \$5.4 trillion in 1998, having grown on average by nearly 7 per cent a year between 1990 and 1998. Exports of commercial services grew on average by nearly 8 per cent a year over the same period reaching about \$1.3 billion each in exports and imports. The value of transportation services in world exports rose to \$320 billion in 1997, accounting for nearly 24 per cent of all exports in commercial services. The world's foreign direct investment stock (the investment underlying international production) has grown on average by about 6 per cent a year since 1991 to reached \$4 trillion in 1998. The total assets of foreign affiliates of multinational corporations exceeded \$13 trillion and their sales reached more than \$4 trillion in 1998.

Economic globalization is internationalizing markets for nearly all goods and services, requiring firms to adapt agile business practices (Gilmour, 1998). Multinational corporations have pioneered new manufacturing practices, including demand-driven sales planning, supplier partnering, lean manufacturing, just-in-time inventory and delivery management, and speed-to-market distribution to manage their supply chains more efficiently. Speed-to-market delivery requires manufacturers to adopt concurrent engineering in which all aspects of a product's design and development are coordinated and integrated. Large multinational corporations such as Whirlpool, Caterpillar, Boeing, General Motors, IBM, Motorola, Toy-

ota, Procter & Gamble, Harley-Davidson, Nestle, and British Petroleum are revolutionizing their logistics systems. Logistics planners in competitive corporations seek to reduce replenishment cycle times and inventory carrying costs, provide immediate logistics support in new international markets, and outsource non-core or low value-added functions. Logistics managers try to lower transportation costs by utilizing several modes for seamless distribution, consolidating service providers, and leveraging shipment volumes (McClenehen, 1997). The formation of corporate strategic alliances and global manufacturing networks are among the most important responses to global competition and among the strongest forces driving the expansion of intermodal transportation services. International corporations must increasingly connect components of their production and distribution systems in many locations around the world.

New technologies are also driving the expansion of intermodal logistics services. Intermodal market-linking systems optimize transport chains, electronic and digital information systems monitor the flow of goods among transportation channels, and large enterprise-resource-planning (ERP) systems such as SAP, and advanced-planning-and-scheduling systems (APS) allow logistics planners to integrate transportation requirements in supply chain management. Transportation hubs are using integrated intermodal packaging infrastructure to speed the transfer and delivery of goods among different forms of transport, automatic vehicle guidance systems to convey and load cargoes more efficiently, and multimodal transshipment terminals to link one form of transportation with others. These technological changes accompany innovations in containerization, integration of inland and ocean shipping, high-speed water transport, the development of larger long-haul air cargo planes, use of double-track rail freight cars and higher speed locomotive engines, and improved designs and engines for trucks.

## Multimodal Transportation Infrastructure

Globalization, agile manufacturing, and speed-to-market delivery requirements are also driving the demand for new types of multimodal transportation infrastructure (Muller, 1998). Intermodal transportation services are an integral part of supply chain management in companies requiring coordinated, continuous, flexible, and reliable transportation, and are generating demand for new ports, airports, and rail and trucking terminals that integrate transportation and logistics services in order to facilitate agile business practices. Intermodal transportation began in the United States and Europe with the use of containers that could be transferred between ships and railcars, thereby minimizing cargo loading and

unloading time, linking water and land routes, and speeding the delivery of raw materials and intermediate and finished goods. Containerization was ultimately extended to freight transfers among ships, railcars, trucks, and airlines, thereby linking all four major modes of cargo transport. Some industry analysts predict that intermodal traffic will grow in the United States from 8 million loads a year in the mid-1990s to as much as 15 million loads annually by 2010 (Melbin and Bowman, 1996).

Multimodal facilities help firms achieve what Greis and Kasarda (1997) call 'economies of conjunction' derived from the capacity to conduct multiple events or transactions at the same time or place. Airports with large volumes of freight — in Atlanta, Dallas-Fort Worth, New York, Los Angeles, and Chicago — are developing multimodal transportation facilities that attract private investment in warehouses, distribution services, and complementary transportation infrastructure such as trucking terminals and rail links, while seeking improved surface access to nearby maritime ports.

Maritime ports are taking the strongest initiative in developing multimodal transportation infrastructure. In Canada, Vancouver's Deltaport combines ocean-going shipping facilities with a 64-acre container yard, intermodal rail and trucking yards, and access lines to two off-site transcontinental rail yards (Middleton, 1998). Large high-speed gantry cranes lift loads weighing up to 55 tons and deposit them directly onto railcars and trucks without cargo touching the ground. Freight can be delivered by rail or truck to other air or water ports in Canada and to airports and rail terminals in Chicago. Similarly, the Port of New York and New Jersey is expanding its infrastructure to link maritime shipping facilities with ExpressRail and trucking terminals, connecting them to regional airports by highway (Harrington and Knee, 1998). By the year 2001, the Alameda Corridor Project in California will link the Port of Long Beach to Los Angeles' maritime ports, airports, and rail yards by a modern highway system and rail route, creating an integrated regional multimodal transportation system. San Francisco is constructing a Joint Intermodal Terminal that houses a new rail yard and trucking facilities to speed intermodal transfers from its seaport facilities. The Port of Oakland, one of the five leading seaport container facilities in the United States, also owns and operates the Oakland International Airport, and leases facilities for railroad and trucking operations.

Intermodal services and multimodal transportation hubs are also emerging rapidly in Europe. The European Union is seeking to integrate the transportation systems of member countries by identifying more than 400 billion ECU of investments in transportation improvements. These include the construction of high-speed rail infrastructure as well as road improvements to connect rail lines with other land,

air, and water transportation systems (Roll and Verbeke, 1998). The ports of Rotterdam, Antwerp, Hamburg, Bremerhaven, and Le Havre are quickly becoming multimodal hubs that combine deep-sea line haul facilities with rail, inland waterway, and road transport systems linkages. The Port of Rotterdam in The Netherlands is expanding its 'distriparks' — combined intermodal transportation and logistics services centers — to connect maritime shipping facilities with truck, barge, and rail systems. These transshipment centers cluster firms providing information and communications technology, storage, repacking, labeling, assembling, and container loading services, and are linked by highways to nearby rail, air, and inland water transportation infrastructure.

France's Port of Le Havre is expanding its shipping and cargo shuttle services and connecting them with rail terminals. Europort Vatry in France's Champagne Region has an all-cargo airport equipped for wide body jets that will interface with a road transport center connecting Europe's major east-west and north-south highways, a rail freight terminal, and a logistics complex and service center concentrated on the same site (Schwartz, 1999b). The Port of Hamburg, which has the largest rail container-handling center in Europe, is linking its shipping ports to Germany's growing system of inland water and surface transportation terminals. The Port of Antwerp is developing facilities to link its deep-sea shipping facilities with barge canal services to Liege, Brussels, the Ruhr area of Germany, and through the Rhine – Maine – Danube canal systems to the Black Sea. The port connects to 12 international railway terminals in Antwerp, trucking facilities, and the European motorway system that extends trucking services into Germany, Northern France, Brussels, Paris, and Amsterdam. Airfreight forwarding services transfer cargo from Antwerp's shipping ports to its own and to Brussels' airport by road and rail.

## The Environmental Impacts of Multimodal Transportation

The increasing importance of multimodal infrastructure and intermodal services will intensify the environmental impacts of transportation activities in the future. Identifying major transportation activities with impacts on natural resources is an essential first step in effective environmental management. Three sets of activities associated with transportation — vehicle operations, equipment maintenance, and facilities operations — can have negative impacts on the environment. In addition, transportation infrastructure construction and expansion often generate pollutants or endanger natural resources. Major transport activities with environmental impacts are depicted in Figure 1.

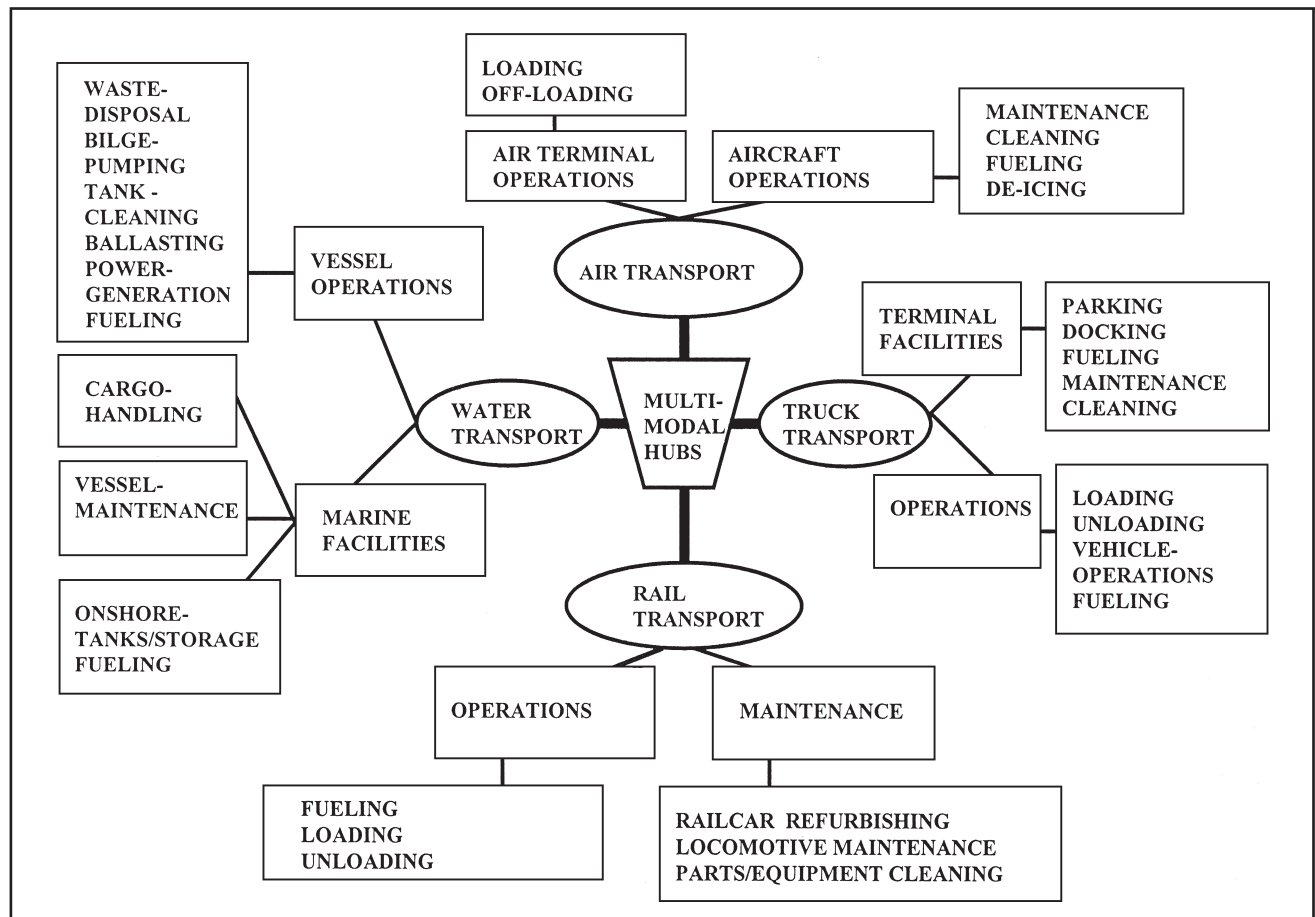
As multimodal transportation and intermodal logistics services expand, potential environmental threats increase. The US Environmental Protection Agency (USEPA, 1998) reports that the transportation industry in the United States releases more than 800,000 tons of air pollutants annually from stationary sources alone. These sources are responsible for nearly 129 tons of carbon monoxide (CO), 551,000 tons of nitrogen oxide (NO<sub>2</sub>), 2500 tons of particulate matter of 10 microns or less (PM<sub>10</sub>), 5500 tons of total particulate matter (PT), 8400 tons of sulfur dioxide (SO<sub>2</sub>), and 105,000 tons of volatile organic compound (VOC). In addition, transportation activities generate soil, ground water, and surface water contaminants. The major sources are petroleum product disposal, sulfuric acid from battery leaks and disposal, organic hazardous air pollution (HAP) emissions, water and soil pollution from waste solvents, cleaning and de-icing fluids, fuel spillage, degreasers, coolant releases, and solid and liquid wastes from terminal operations. Figure 2 summarizes the major environmental impacts from transportation activities.

## Air Transportation

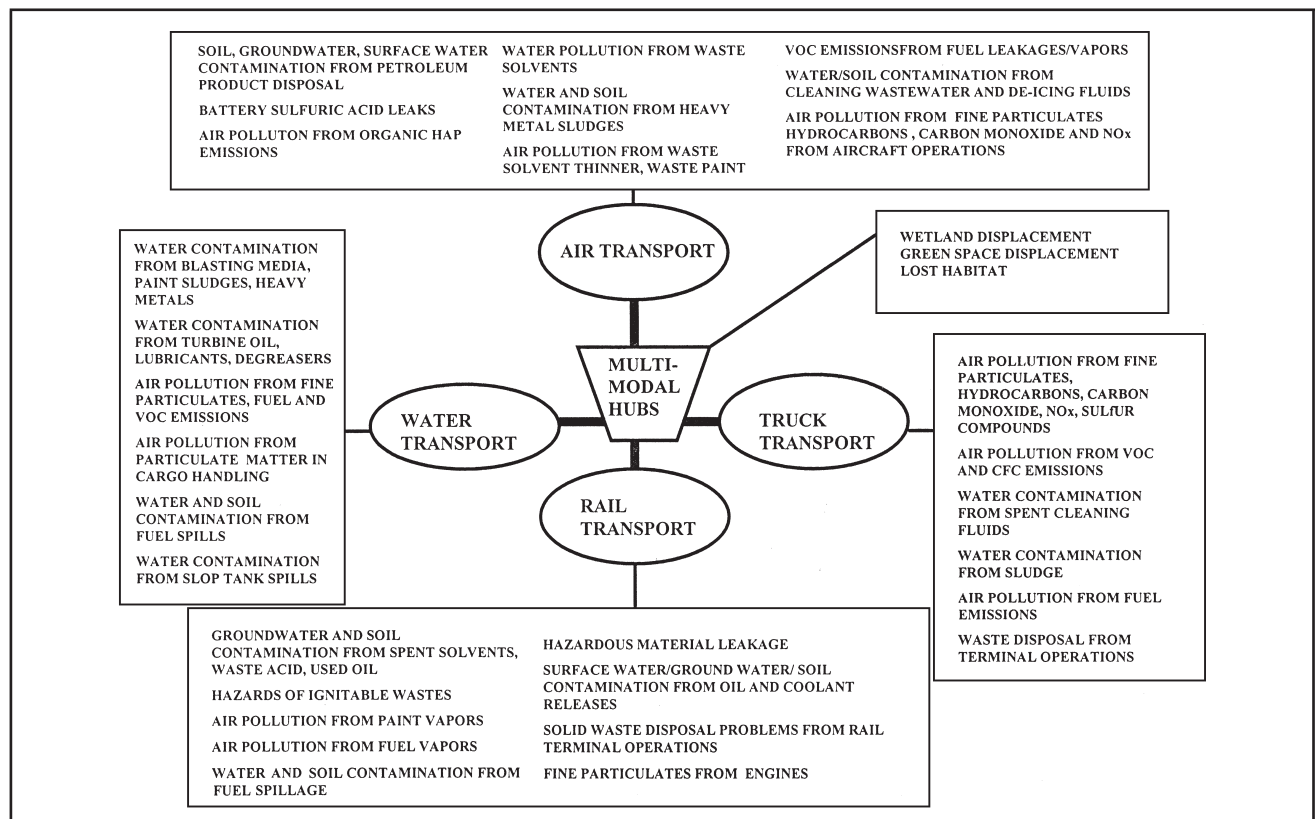
Cargo and passenger air transport generates a variety of potentially harmful environmental impacts. Aircraft operations create noise pollution, engine emissions, and waste disposal problems. Air terminal operations, especially cargo loading and offloading, aircraft operations, equipment maintenance, fueling, de-icing, and cleaning can all contribute to environmental pollution. Kerosene combustion in aircraft engines emits carbon dioxide (CO<sub>2</sub>) and water vapor, accounting for more than 3 per cent of global carbon dioxide emissions (Noble, 1999a). Scientists at the international ozone conference in Buenos Aires estimated in 1998 that air pollution from aircraft is increasing at three times the previously predicted rates. This will add greenhouse gases over the next 20 years that could entirely negate the 5.2 per cent reductions that developed countries agreed to at the Kyoto Conference in 1997.

Moreover, operating aircraft emit hydrocarbons, CO, and nitrogen oxide (NO<sub>x</sub>) from incomplete combustion during takeoff, descent, idling, and taxiing. Vehicle maintenance and refurbishing operations can contaminate soil, groundwater, and surface water from the storage, transfer and disposal of petroleum products during lubrication and fluid changes, from sulfuric acid in battery repair and replacement, and from paint storage and disposal. Maintenance and refurbishing of aircraft and other equipment can have serious environmental impacts, primarily organic HAP emissions from chemical milling maskant application, parts cleaning, and metal finishing using chemical solutions, cyanide, and heavy metal baths. The application of coating generates organic HAP





**Figure 1 Components of Transportation Logistics System with Environmental Impacts**



**Figure 2 Major Potential Environmental Impacts of Transportation Activities**

emissions, and painting emits VOCs. Fuel leaks also result in potential air, water, and soil pollution. Glycol-based materials used in aircraft de-icing can run off into surface waters or infiltrate groundwater, depleting oxygen and introducing toxins that adversely affect life forms in water. Airport cargo and passenger operations generate large quantities of solid waste in the forms of paper, wooden pallets, aluminum, plastic, and glass containers, and consume large amounts of energy from lighting, heating, cooling, and computer use.

## Rail Transportation

Environmental damage can result from improper fueling and cargo handling at rail terminals and from equipment maintenance activities such as railcar refurbishing, locomotive maintenance, and parts and equipment cleaning (USEPA, 1997). Railroad operations — fueling (air pollution from vapors and water and soil contamination from spillage), hazardous material transport (leakage or spillage) and oil and coolant releases (surface and ground water and soil contamination) — contribute to smog and natural resource degradation in cities. Wastes from railcar refurbishing and maintenance operations using degreasers, solvents, acids, paint thinners, paints, and epoxies can pollute water and soils and emit VOCs. Locomotive maintenance produces sludge, waste solvents, and cleaners that can cause air pollution and, if ignited, serious threats to human health. Ineffective disposal of all of these materials can cause groundwater and soil contamination. Rail terminals must also carefully dispose of solid wastes to prevent soil and water contamination.

## Truck Transportation

Trucking operations (hauling, freight loading and unloading, and fueling) can pollute air and water, as can parking, docking, fueling, equipment maintenance, and vehicle cleaning activities at truck terminals. Motor oil, brake and transmission fluids, coolants, solvents, and lubricants emit CFCs and VOCs at truck terminals and maintenance facilities, and their improper disposal contaminates soil and water. VOC emissions also come from the detergents, caustic solutions, and solvents used in washing vehicles, and from residuals from shipments and tank cleaning. Waste and used equipment (batteries, tires, and other parts) disposal problems at terminals also create environmental degradation and pollution. Trucking operations generate hydrocarbons, CO, NO<sub>x</sub>, sulfur compounds, and particulate matter that pollute air. In addition, the trucking industry has come under increasing criticism in Europe for heavy use of non-renewable fossil fuels, creating smog, transporting hazardous cargoes, by using ozone-

depleting refrigerants, and ineffectively disposing of solid and liquid wastes and used vehicles.

## Maritime Transportation

The activities of maritime vessels that can be environmentally harmful include ship waste disposal, bilge pumping, tank cleaning, ballasting, power generation, and fueling. Ship operations emit nitrogen oxides, sulfur dioxide, particulate matter, and hazardous pollutants into the air. Marine port facilities generate air, water, and soil pollutants from cargo handling, and from vessel maintenance, fueling, and onshore tanks and storage facilities. Oil and grease spills, and the use of paints, solvents, fuels and sediments in vessel maintenance and repair can pollute surface water and air. Ineffective processing and disposal of oils, grease, petroleum hydrocarbons, surfactants or solvents used in vehicle washing and degreasing degrade surface water (AAPA, 1998).

Port facilities construction and renovation contribute to surface and ground water contamination and air pollution from asbestos, lead-based paint, dust, sediments, PCBs and petroleum hydrocarbons. Construction or expansion of port facilities can threaten marshlands, wetlands, and water channels. Improper disposal of demolition and construction debris also creates serious environmental problems around construction sites. Intrusion into natural areas by port expansion and maintenance can pose serious threats to wildlife and sensitive species and habitats. Shipping channel maintenance and deepening can cause both environmental pollution and natural resource degradation, raising important issues about the disposal of dredging materials.

## Multimodal Transportation Complexes

As new multimodal transportation hubs are constructed and as existing ports, airports, rail terminals, and trucking and distribution complexes expand to provide intermodal transportation services, the potential environmental impacts associated with each type of transportation can be multiplied and compounded. The expansion of multimodal freight transportation facilities in Chicago, for example, is attracting new businesses and construction of new industrial plants, warehouses, and light manufacturing in surrounding areas. Development in and around these transportation hubs changes land uses, increases density, and generates more intensive local and cross-town traffic, all of which can create new environmental problems (Rast, 1998). Expansion of multimodal facilities in Atlanta, Fort Worth, Los Angeles, and Miami provided opportunities for nearby clustering of spin-off activities in the computer, food packaging, container, apparel, and boat-

ing industries, from which the total environmental impacts were never systematically assessed. Expansion of the Oakland International Airport to enhance its cargo facilities and link its operations to port and surface transportation hubs has multiple environmental impacts, including noise pollution, wetlands destruction, air pollution from increased traffic congestion, emissions of suspended particulate matter, nitrogen oxides, and reactive organic gases.

The Global TransPark (GTP), now under construction on a 15,300 acre site in eastern North Carolina, will be an international air cargo-industrial complex centered by two long-range runways, just-in-time manufacturing and distribution facilities, and taxiways enabling air cargo planes to nose-dock or side-dock with the manufacturing and distribution facilities (Kasarda and Rondinelli, 1998). The complex will link several transportation systems, including interstate highways, regional airports, rail lines, and North Carolina coastal ports. The GTP will have significant environmental impacts not only on the TransPark site but also on surrounding cities, towns, and rural communities. The growth spurred by GTP will require vast amounts of groundwater and new sources of drinking water for the surrounding areas that now depend on wells. More than 4800 acres of wetlands must be created to replace those lost at the site. More than 39,000 ft of canals must be plugged and 664,000 trees will have to be planted to mitigate the loss of 871 acres of wetlands that will be filled in during construction.

The GTP's environmental impacts on surrounding areas will include permanent conversion of lands in agricultural use to industrial purposes; increased consumption of potable water from groundwater and surface supplies resulting in increased pressures; and large volumes of wastewater discharge. The GTP will bring changes in storm-water discharge characteristics from both industrial and residential areas. The facilities will reduce marginally wet woodland areas and other wetlands within the GTP complex, increase requirements for physical infrastructure and public services associated with growing populations, and accelerate urbanization to bring broad-scale, gradual changes to existing communities.

## Business Risks of Environmental Hazards

Failure to manage the environmental impacts of their operations raises serious potential risks for firms involved in intermodal logistics and multimodal transportation (Berry and Rondinelli, 1998). Threats of increased regulatory control by national governments and international organizations pose the most immediate risks. In the United States, land areas contaminated by toxic spills or leaks fall under Super-

fund legislation requiring expensive cleanups. In both the United States and Europe industries that do not manage their own environmental impacts will see stronger demands by localities and environmental groups for more stringent government regulation. The European Union's Transport Commission, for example, is considering higher taxes on kerosene in order to encourage fuel conservation and emissions reduction in the airlines industry, and plans to adjust the already heavy road tax system to penalize 'dirty' trucks and give incentives to those that are environmentally cleaner (Noble, 1999a). As regulations tighten both firms that ship goods and those that carry them may face new legal liabilities for environmental damage and health and safety violations in criminal and civil suits.

A second set of risks is financial. Pollution prevention and elimination of waste from operations can save logistics services firms and multimodal transportation facilities significant amounts of money. Firms that ignore negative environmental impacts not only incur opportunity costs, but also potentially higher absolute costs for pollution control technologies in the future and the loss of competitive pricing advantages.

Damages to corporate image from environmental pollution or natural resource degradation can cause serious competitive problems and strong backlashes from stakeholders. Environmental interest groups that uncover serious hazards or the potential for pollution and degradation can permanently harm a company's reputation. Public demands for corporate responsibility are growing in the wake of expanding international trade agreements. Shareholders and corporate directors are becoming increasingly intolerant of environmentally dangerous conditions. Customers who may share the liability and higher costs from environmental damages are likely to seek logistic services and transportation providers that have strong environmental reputations.

Transportation and logistics firms that do not manage their environmental impacts proactively also face competitive risks. Increasingly, international trade agreements and treaties include requirements for complying with international environmental standards such as ISO 14000, the British Standard 7750 or the European Committee's Standard Eco-Management and Audit Scheme (EMAS). In both the United States and Europe, new transportation facilities face increasingly stringent and complex Environmental Impact Assessments and the expectation that logistics firms have environmental management systems that meet international standards. Firms that fail to comply with regulatory controls and international standards risk losing competitive advantage in international markets.

## Managing Environmental Impacts of Multimodal Transportation

Managers can mitigate the negative environmental impacts of their operations by diligently identifying current environmental problems and monitoring potential new ones. Stringent regulatory compliance is a good start, but it is unlikely to be sufficient unless transportation and logistics services companies adopt proactive environmental management systems that go beyond legal compliance. Proactive companies try to prevent pollution and eliminate sources of environmental degradation. To do so, managers have to identify and assess environmental impacts carefully and develop innovative and creative means of preventing pollution before it occurs through effective environmental management systems (EMSs).

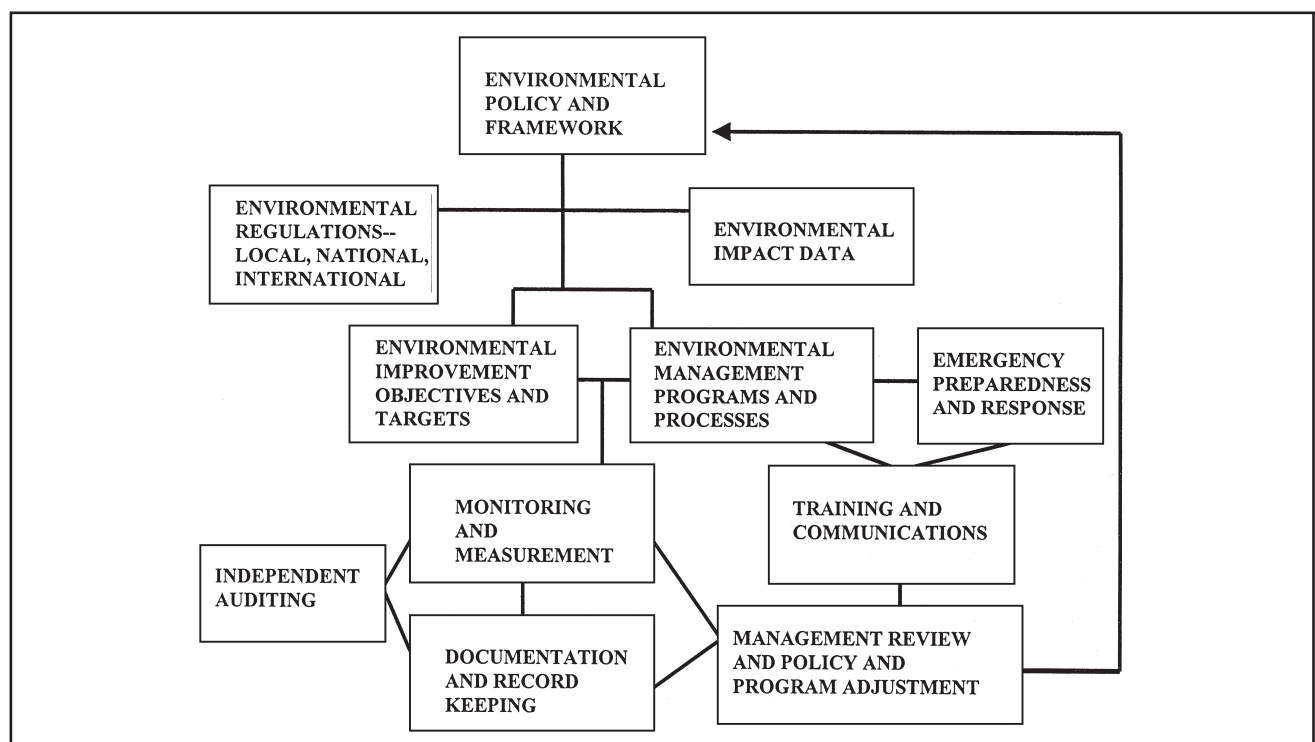
Airport authorities in Turin, Milan, Munich, and Dublin have undertaken trial projects funded by the European Union to determine the benefits and cost-effectiveness of developing environmental management systems that conform with EMAS standards or than can be certified under ISO 14001 standards. Lufthansa Technik AG, a subsidiary of Lufthansa Airlines registered two aircraft service centers under EMAS and became the first company in the airline industry to receive EMAS certificates (Victory, 1998). Schenker-BTL (1999), one of Europe's largest air, land, and sea transportation and logistics companies, certified EMSs for three of its facilities — in Sweden, Denmark and Finland — under ISO 14001 and aims to certify all of its operations in Europe by 2002.

With a proactive EMS intermodal logistics firms and multimodal transportation facilities can achieve significant environmental performance improvements through a combination of stringent regulatory compliance, technological innovation in transportation equipment and processes, and the application of cleaner operations and maintenance procedures. Companies that recycle and reuse wastes, substitute cleaner materials in transportation and distribution activities, and adopt new pollution prevention technologies and processes can improve environmental performance and reduce business risks. Figure 3 depicts the essential elements of an environmental management system for transportation logistics.

## Environmental Policy and Framework

The well-defined structures and functions of the transportation industry provide a template for environmental analysis and policy formation and for collecting information on the environmental attributes of each transportation activity, as illustrated in Figures 1 and 2. Managers should prioritize these attributes by their significance and extent of environmental impacts. Perhaps the greatest challenges for managers in creating a proactive EMS for transportation, however, are updating information on rapidly changing legal requirements and collecting accurate, reliable and consistent data on the environmental impacts of operations and facilities.

A sound environmental management system must,



**Figure 3 Elements of an Environmental Management and Information System for Transportation**



of course, provide current information on local, State, provincial, and national laws on air, water, and soil pollution, hazardous materials disposal, and natural resources protection. As multimodal transportation systems expand to facilitate international logistics, transportation managers must also have current information on changes in international standards such as ISO 14000, bilateral and multilateral trade agreements containing environmental restrictions or guidelines, and international environmental agreements regarding, for example, the reduction of CFC's or greenhouse gases.

Managing regulatory compliance is an increasingly complex but essential function for firms involved in transportation logistics. Transportation services and facilities in the United States are closely regulated by the US Environmental Protection Agency and by state and local governments from which they must obtain permits for many of their operations. Transportation facilities and operations are subject, for example, to provisions of the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response Act, the Hazardous Materials Transportation Act, the Compensation and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), the Clean Water Act, the Safe Drinking Water Act, the Toxic Substances Control Act, and the Clean Air Act. Environmental requirements are also embedded in the regulations of the Federal Aviation Administration (FAA), the Department of Transportation (DOT), the Occupational Safety and Health Administration (OSHA), and other agencies. National Ambient Air Quality Standards for ozone and particulate matter issued by the USEPA in 1997 is creating stronger pressures to reduce emissions from transportation sources. The regulation lowers allowable fine particulates to less than 2.5 microns and places increasing pressures on State and local governments to restrict particulate emissions from surface vehicles.

Proactive environmental management systems require accurate and reliable data that allow corporations to control existing environmental pollution while, at the same time, find ways of preventing or eliminating potentially negative environmental impacts of transportation activities. British Airways (1999), for example, has developed a data collection system that allows it to track environmental performance. It collects data on (1) noise pollution from aircraft landings and takeoffs, engine ground running, and auxiliary and ground power units; (2) emissions to the atmosphere; (3) fuel efficiency; (4) energy use; (5) waste generation and disposal from inflight and ground operations; (6) runoff and possible contamination from de-icing, vehicle washing, and sewage; (7) water consumption; and (8) environmental impacts of fuel burning and congestion from flight arrival and departure holding delays. The data collection system helps British Airways to set environmen-

tal objectives and targets for performance improvement.

## Environmental Objectives and Targets

Transportation and logistics firms need to develop information systems that help managers select objectives and targets for improving environmental performance and eliminating sources of environmental hazard. Increasingly, not only by government regulatory agencies but also shareholders, public interest groups, customers, employees, and other stakeholders measure environmental performance. In a proactive EMS, clearly defined objectives and targets guide operational controls so that all aspects of transportation operations and facilities contribute to achieving environmental policies. For example, the Port of Long Beach Authority (1999) goes beyond compliance to develop objectives for aggressive pollution prevention, storm-water and water quality monitoring and improvement, soil and groundwater investigation to reduce or eliminate threats of contamination, 'brownfields' restoration, sediment evaluation and soil remediation. It sets targets for controlling air particulate emissions associated with bulk cargo operations and reduction of vessel emissions. In addition, the Port Authority conducts alternative fuels demonstration projects, participates in restoration of coastal wetlands, and monitors biological resources within its harbor area.

After careful analysis of its operations, UPS developed ambitious objectives for waste disposal improvements by recycling materials, substituting more durable packaging for less durable types, and adopting reusable packaging. UPS has reduced plastic bag waste by 1000 tons a year by using reusable nylon-mesh bags in its package sorting operations. It uses recycled computer paper, paperboard for express mail, and recycled paper for delivery notices, saving more than 30,000 trees a year. Since 1995 UPS has diverted more than 34 per cent of its total wastes — whiteboard, cardboard, mixed paper, glass, pallets, plastic, metal and aluminum — from local landfills.

## Environmental Management Programs and Processes

Firms that adopt programs for cleaner operations and maintenance can reduce significantly the environmental hazards from transportation activities. Trucking firms are learning, for example, that they can reduce much of the pollution from truck operations through careful attention to good operating processes, proper engine maintenance and driving techniques, and the purchase of new trucks with cleaner

engines. CSX Corporation (1998), the owner of Conrail, developed policies, procedures, directives, and training programs that reduced fuel spillage at its rail terminals from 646,000 lb in 1992 to less than 40,000 lb in 1997. An Environmental Operations Group with more than 20 environmental specialists who also oversee environmental audits of more than 70 items at the company's rail terminals, manages the system.

Comprehensive management programs and processes allow organizations to experiment with creative means of solving environmental problems. SAS Airlines, operating from an ecologically sensitive region in Scandinavia, was one of the first European air carriers to recognize the necessity of reducing pollution and developed innovative ways of improving fuel efficiency by 50 per cent between 1968 and 1998. Trucking terminals and fleet companies can mitigate environmental damage by using 'single multi-purpose solvents' or water-based or water soluble cleaners instead of chemical solvents, and by extending the life of solvent baths. Installation of environmentally-friendly truck washing facilities at Allied Systems' Norfolk Terminal, for example, removed and captured in a fully contained unit oil and grease and used water and biodegradable soaps in place of chemicals. Some firms choose on-site solvent recovery techniques using decanting, filtration or distillation. Oil recycling, mechanical parts cleaning, and use of water-based paints with no solvents can reduce pollution in vehicle maintenance and cleaning operations. By adopting new paint processes in its paint and body shops, United Parcel Service (1998) was able to decrease paint usage by 40–50 per cent and solvent and paint cleanup waste by 95 per cent. Applying new technology in its parts washers to extend solvent life allowed it to decrease solvent disposal by 78 per cent.

Careful analyses of operations processes are leading several large transportation service firms to improve environmental performance by recycling and reusing waste materials — for example, recycling freon, scrap metal, waste antifreeze, and scrap tires and batteries. Separation of waste streams into hazardous and non-hazardous materials and into different types of wastes can increase the efficiency of treatment, recycling and reuse. Ryder Systems (1997), a leading truck leasing and integrated logistics services firm, adopted on-site management techniques for reusing coolants and anti-freeze and for converting waste to energy. The company uses off-site vendors to recycle refrigerants, scrap metal, old tires, batteries and drums, and to remanufacture salvageable vehicle parts. Federal Express' recycling and materials reclamation program diverted 6.3 million lb of materials from landfills and saved the company over \$9 million in 1998 alone. The company reclaimed or reused materials such as cargo nets, trailer load bars, container doors, pallets, tarps, and document boxes.

Dredging — a crucial function at seaports to maintain

existing channel depths and to expand them for construction of new shipping berths — creates serious problems in disposing of dredged materials. Through a program focused on meeting both disposal and natural resource protection objectives, the Port of Houston is using 52 million yd<sup>3</sup> of dredged material to create 4250 acres of new marshland and bird habitats.

Emergency preparedness is the key to environmental crisis management, which begins with the development of emergency scenarios and procedures for preventing or responding to incidents causing serious environmental hazards. An effective environmental management program must be well-structured and clearly understood by employees and managers throughout a transportation system. Companies must articulate roles and responsibilities and provide resources provided at all levels of operation in order to implement programs effectively. Training is often the primary mechanism for expanding awareness and problem-solving competence. For example, the European transportation and logistics giant Schenker-BTL provides basic training in environmental issues for all of its new employees and is extending more advanced training in topics such as environment and the market, environmental legislation, and environmental management systems to all of its management groups.

## Environmental Monitoring, Auditing, and Reporting

A functional EMS relies on the development and maintenance of environmental reports and documents. EMS documentation helps managers demonstrate performance improvement, which relies on accurate accounting information, operations records, and continuous monitoring and measurement of the environmental impacts of all transportation activities. Records should identify incidences and patterns of non-conformance and indicate how management can take corrective and preventive action. Managers should supplement internal information systems with independent EMS audits to verify performance data and do periodic reviews to identify potential improvement measures and adjustments needed in the EMS.

Information drives effective internal and external communications on environmental issues with employees, regulators, and stakeholders. Increasingly, corporations involved in providing logistics services and in operating transportation facilities are improving their environmental monitoring, reporting, and management systems. The operators of Swissair (1997), for example, monitor, manage and report on progress in improving air quality, reducing noise pollution, saving energy, and treating water.

Similarly, the Schiphol Airport Authority (1998) in Amsterdam issues an annual environmental report that provides performance data on noise pollution, air quality, energy use, soil contamination, and waste materials disposal. The report also describes progress on reducing de-icing agents in rainwater runoff, improving the purification of wastewater, and mitigating the environmental impacts of office operations.

ASG (1999), a major European road, multimodal transportation and logistics firm uses a creative set of metrics for monitoring and auditing its environmental performance. It measures overall economic efficiency (net turnover/ton of fossil carbon dioxide), carbon dioxide intensity, overall risk exposure (number of environmental-related incidents), overall environmental efficiency of transport (fossil CO<sub>2</sub>/ton-km), regional environmental impact (NO<sub>x</sub> + SO<sub>x</sub>/ton-km), and the number of incoming environment-related complaints. In addition, it uses its metrics for measuring staff and customer satisfaction through a questionnaire seeking their perceptions of ASG as an industry leader in environmental issues.

## Management Review and Program Adjustment

Companies involved in providing transportation and logistics services can reduce or eliminate the negative environmental impacts of their activities by reviewing and adjusting their environmental management programs regularly. Corporations that are seeking to manage the environmental aspects of their transportation activities should take into account the environmental impacts of other participants, including transportation equipment makers. Innovations in engine technology for aircraft, locomotives, and trucks can reduce air pollutants and other forms of emissions. The German government is supporting experiments between MTU Munchen and BMW Rolls-Royce on new aircraft engine technology that can lower combustion emissions (Noble, 1999b). Low combustion chambers can substantially lower the emissions of NO<sub>x</sub>, CO, and unburned hydrocarbons. The development of new aircraft types, alternative fuels, and engines with increased fuel efficiency can all mitigate the environmental impacts of aircraft operations.

Companies seeking technological improvements in all aspects of the transportation value chain can substantially reduce negative environmental impacts throughout transportation systems. All firms have some influence over the environmental impacts of their suppliers through inbound logistics processes and supplier evaluations (Walton *et al.*, 1998). And some companies can help their customers to understand the environmental implications of their logis-

tics activities. The European multimodal transport company, Schenker-BTL, has created an Emission Report that can calculate for each customer the output of transport-related emissions based on vehicles used, loads, and loading degrees. It calculates and can provide online reports from its Internet website of the emission in kilograms of carbon dioxide, nitric acid, hydrocarbons, sulfur dioxide, and particulate matter for each consignment. The Emission Report covers 44 countries and 4215 locations and can calculate at the speed of 3000 consignments per minute.

Managers can also mitigate the negative environmental impacts of intermodal transportation logistics by using EDI and Internet tracking of freight, global positioning satellite systems, and other means of coordinating and tracking cargo movements that increase efficiency. Electronic and digital logistics management can reduce delivery time, optimize transportation and distribution routes, and provide greater flexibility in the use of transportation modes, thereby reducing environmental hazards (Krapf, 1997). Management reviews and program adjustments should lead to changes in policies and frameworks guiding environmental practices by closing the loop of continuous improvement depicted in Figure 3.

## Conclusions

As the demand for intermodal logistics services and multimodal transportation facilities grows and as seamless transportation becomes more central to integrated logistics and efficient supply chain management in the 21st century, pressures will increase to manage the environmental impacts of transportation systems proactively. Proactive environmental management seeks to prevent pollution and eliminate sources of environmental degradation. A proactive EMS offers comprehensive policies and frameworks for continuous planning, action, and improvement.

Multimodal transportation infrastructure adds value in logistics as an integrated system managed holistically. The impacts of transportation on air, water, land, and natural resources can thus be more readily identified, assessed, and mitigated by proactive environmental management systems than by attempts to regulate single environmental media. Regulatory compliance and beyond-compliance management, however, both require strong commitments from the transportation industry, local and national government agencies, transport service users, and other major stakeholders. In order to achieve significant improvements in environmental conditions, all participants in multimodal transportation networks must identify the potential environmental impacts of their activities, monitor their environmental performance, and control or prevent environmental damage through proactive environmental practices.



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