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An Evaluation of Options for Freight Carriers During a Fuel Crisis

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Demand-reduction alternatives that carriers (truck, rail, air, and inland waterway) could logically adopt during a fuel emergency are examined and the fuel savings attributable to their use are quantified. Opportunities for improvement in fuel efficiency may be classified as systemwide (increasing load factors, reducing congestion) or vehicle and operation specific (adapting available technologies, improving maintenance, changing operating practices). Nevertheless, fixed and variable nonfuel costs could increase such that, for a given alternative (e.g., phased advance-technology retrofit), the payback period could exceed the duration of any shortfall, and the investment thus would not be justified on the basis of the shortfall alone. Specific alternatives under each of the five general categories of fuel-efficiency improvement are considered for each mode and a percentage of reduction in fuel consumption is estimated based on reported effectiveness and the expected degree to which such measures would be adopted systemwide. An aggregate estimate of petroleum savings (roughly 4 to 8 percent) was found to be attributable to demand-reduction alternatives that could be adopted by freight carriers without drastically curtailing service. Because carriers are moving toward improved fuel efficiency as an integral aspect of normal operations, the potential for reducing fuel demand will decline in the future.

The two predominant features of the federal emergency planning for oil supply interruptions are (a) the intent to rely on the basic economic forces of supply and demand to allocate the scarce resource and (b) the use of the Strategic Petroleum Reserve (SPR) as the principal method to mitigate the effects of an oil shortfall. Allowing the fuel price to rise during a shortfall more accurately reflects the value of the commodity, which permits consumers to make better-informed decisions concerning their use of a product in short supply. No false price signals regarding the severity of the shortage are given to the public, as would be the case with arbitrarily controlled prices. The development and use of the SPR is regarded a national insurance policy in which stored oil can be substituted for imported (or domestic) oil the flow of which has been disrupted.

In the freight transportation industry as a whole, energy contingency planning currently receives little attention. Other more pressing problems, such as the decline in traffic because of a poor economy, have been the focus of management's attention. Contingency planning, especially with the current availability of fuel, is likely to be reactivated in the event of a crisis. Wide variation, however, does exist. Some companies have extensive energy management programs and not only have plans ready in the event of a fuel supply interruption but have taken steps in their own self-interest, such as increasing their fuel storage capacity. In a more general way, most carriers have reacted to the higher fuel costs by purchasing more fuel-efficient equipment, which in turn puts them in a more favorable position (compared with that a few years ago) in the event of a fuel shortfall.

Conceptually, contingency planning for freight carriers, whether explicitly stated or implicit in their operations, covers two time periods: before the shortfall and during the shortfall.

Elements in planning before the shortfall include

1. Purchasing fuel-saving equipment,
2. Increasing fuel storage capacity and fuel stocks,
3. Providing firm contractual arrangements for fuel supplies as well as alternative fuel suppliers, and
4. Planning both the management functions and the technical requirements for an energy shortfall.

Elements of a contingency plan that a company can invoke during a shortfall will depend on the magnitude and duration of the fuel interruption but will likely be taken in the order of increasing severity. Those elements include

1. Actions that necessitate little or no increase in capital or operating expense,
2. Actions that incur higher capital costs or increases in nonfuel operating expenses or both, and
3. Actions that require significant capital expenditures and drastic operating changes that markedly affect the perceived quality of service.

CONSERVATION OR CONTINGENCY PLANNING

In identifying contingency actions, an important distinction should be maintained between contingency and conservation. Contingency actions, because of the immediate nature of the emergency situation, must be quickly instituted to be effective in reducing the impact of an oil shortfall. Energy conservation, which also has as an objective the reduction in the demand for fuel, is oriented toward efficiency improvements that can be accomplished over the long term. Many of the contingency actions identified in this analysis could rightfully be called conservation and have, in varying degrees, been instituted in the transportation industry. Under conditions of stable fuel prices and relatively abundant fuel supplies, economic and service considerations may override energy concerns. During an energy shortfall, rapidly rising fuel prices and the lack of fuel availability become the driving forces that change a carrier's perception of the practicality of actions that could reduce fuel demand. For any actions that require an increase in capital or operating expense, the payback period becomes shorter. Thus some contingency actions can be considered a subset of conservation actions.

FUEL DEMAND-REDUCTION ALTERNATIVES

Fuel conservation activities in the freight transportation industry are well recognized. Before the 1973 Arab oil embargo, fuel costs were a relatively minor expense for most carriers. Since then the steady increase in fuel prices has been an impetus for carriers to control expenses by reducing fuel use. More fuel-efficient motive power is being used to replace retired vehicles. Retrofit devices are being used to increase the efficiency of existing vehicles. Operating practices have been changed to reduce fuel consumption in both the line-haul and the local-access portions of the trip.

Nevertheless, in the event of a fuel-supply interruption, the sudden and rapid rise in fuel price will dramatically affect the economics of freight transport. As fuel costs become an even larger portion of operating expense, capital and operating changes that in normal times would not be appealing will suddenly be considered workable options. In addition to high fuel prices, spot shortages throughout the country may exist for short periods of time in which fuel may not be available at any price.

In general, the approach in this analysis was to estimate (a) the fuel-saving potential of a contingency response, (b) the percentage of participation that could be expected within the industry (considering the extent to which the actions are already being used in conservation), and (c) the net reduction in fuel demand that could be anticipated. The estimates are made at the aggregate level (e.g., for the entire trucking or rail industry). Wide variations, however, may exist for individual carriers. The consequent effects that these contingency responses have on a carrier's service (e.g., travel time) or nonfuel operating costs are qualitatively addressed. Statistical data do not exist for the number of carriers (or vehicles) within a particular industry that have adopted each of the conservation practices. As a result, estimating those parameters and the potential participation rates was done through numerous industry contacts.

INCREASING THE LOAD FACTORS

Freight transport is a service in which efficiency is often measured by the time taken to complete deliveries. As a result, carriers often are not able to fully use the available capacity of their equipment. Several factors contribute to this, including commodities that require specialized equipment, unbalanced commodity flows, and size and weight restrictions of the loads. Obviously, some empty mileage is unavoidable. However, if operating practices are changed during a fuel shortfall to increase the percentage of capacity used (by reducing the number of trips needed), carriers will be able to transport, on an aggregate basis, the same shipments with less fuel.

Truck Mode

Truck loaded miles have been estimated by the Interstate Commerce Commission (ICC) to be 80 percent when measured as vehicle miles and 73 percent when calculated as capacity miles (1). Although empty vehicles and less-than-capacity travel cannot be completely eliminated, steps can be taken to improve vehicle utilization. Recent legislation, including the Motor Carrier Act of 1980 and the Surface Transportation Act of 1982, addressed some of the more acute problems of hauling inefficiencies such as size and weight limitations, gateway restrictions, and circuitous route provisions, and excessively restrictive limitations on commodities transported and territories served were greatly eased. Also, the restrictions on intercorporate backhauling were significantly reduced. These actions should improve vehicle efficiency or utilization or both, in turn reducing the demand for fuel.

In addition to these opportunities, motor carriers could improve their load factors by utilizing tractor-trailer matching programs for the return trips and reducing their service frequency.

Computerized trailer-matching programs offer the potential for improving equipment utilization. In the trucking industry, a private company has provided this service for 4 years. The current program, known as Extra Equipment Shipment Service (XESS), handles all phases of shipping, matching the freight on dock to available trailers and motive power. XESS combines two earlier programs—Computer Interchange Substitute Service (CISS) and Computer-Assisted Load Matching (CALM). Although the service is available to carriers, brokers, and truck manufacturers, industry utilization is relatively low, perhaps because of a combination of factors, including fear of increased competition, initial reluctance to use the computer system, or lack of familiarity with the program. However, with the system in place, it could easily be expanded during a crisis.

During a fuel crisis, motor carriers are likely to find shippers more willing to consolidate their shipments in order to control their shipping costs. This in turn allows the carrier to reduce the frequency of service, beginning with the marginal shipper, while increasing the load factor. Any reduction in empty mileage will still require improved information exchange and sufficient guarantees for both the consignor and the carrier concerning rates, delays, and insurance. Even so, reductions in empty mileage of 10 percent may be all that can be expected without a drastic reduction in service frequency. [In the previously mentioned ICC study of empty truck miles it was indicated that 16.7 percent of the empty trucks in the sample could have been paired with similar empties traveling at the same time in the opposite direction but it was cautioned that the figure was not an accurate estimate of the potential savings.] With over-the-road fuel efficiency of an empty truck roughly twice that of a loaded truck, a 10 percent reduction in empty backhauls could reduce energy demand by 1.6 percent.

Air Mode

In air transport, freight is shipped either in all-cargo aircraft or in the lower deck of passenger aircraft (belly freight). During a fuel crisis, belly freight service will be affected by carrier decisions relating to passenger flights, which is beyond the scope of this study. On a revenue basis, all-cargo aircraft carry 43 percent of the air freight (2). The load factor for all-cargo flights has remained fairly constant in recent years at 61 percent. The principal means that carriers have to increase load factors is to reduce flight frequency, a response that air carriers used during the previous fuel crises. A reduction in average service frequency of 10 percent for all-cargo aircraft should yield a 2 percent increase in overall average load factors (3). The variation in energy intensity by incremental load factor would indicate a 1.6 percent reduction in average energy consumption. Reduced service frequencies would also be expected to decrease operating costs.

Rail Mode

Reduction in service frequency will be an expected result of the economic slowdown during a petroleum shortfall; further reductions would affect the railways' competitive position and are likely to be resisted unless all competing modes are subject to the same pressures. This is improbable, given the generally greater flexibility of the trucking industry, for example, to respond quickly to short-term changes in demand for service or fuel supply.

Car and shipment matching programs, through which the pairing of shipments with available empty cars is facilitated by computer data banks, may become more workable as railroads' car-tracking procedures improve, but effective car management programs are barely beyond the embryonic stage even on the largest railroads. Perhaps the most promising way to increase average rail freight load factors in a short-term fuel crisis is to reduce empty backhauls.

A 10 percent reduction in empty backhauls (28 percent of backhauls moving loaded rather than the current estimated 20 percent) would result in a net reduction of about 3 percent of average energy intensity for boxcar or gondola movements and a 2 percent reduction for piggyback movements. Net costs are reduced because revenues associated with the shipment of the additional loaded tonnage help offset the costs of moving the cars. Wait times increase slightly because of the additional time required to locate the 10 percent loaded cars to complete train consist blocks formerly filled out with empties.

Water Mode

Little opportunity to achieve significant additional fuel savings is available to barge and push-tow operations by increasing load factors. One-way bulk commodity hauls are the mainstay of river transport, and self-propelled barges are rarely dispatched outbound loaded at less than capacity. Ballast (empty) trips by these barges cannot be eliminated without substantial relocation of primary and secondary sectoral activity nationwide.

Fleet pooling of dumb (unpowered) barges is now practiced to some extent with the objective of sharing in the revenues of an outbound tow with available capacity. This strategy incidentally reduces the number of tows operating at less-than-full complement and increases average load factors generally. The average load factor for all inland waterway movements has not been directly computed because the waterway industry is unregulated and thus not subject to ICC reporting requirements. One estimate places the figure at 60 percent (4). Without additional and possibly (to the carrier) costly port calls to locate loaded barges, it is unlikely that this figure can be increased and have carrier operations remain profitable. Even so, gross tonnage per tow would only increase 10 to 20 percent for the 5 percent of the tows likely to be involved. Thus, a maximum of 1 percent reduction in energy intensity is estimated for new activity in increasing load factors of waterway movements during a petroleum shortfall.

REDUCING CONGESTION

In a shortfall congestion may be reduced because there will be less travel. However, peak-period congestion may increase if work schedules are consolidated to meet transit and carpool schedules. Where severe capacity deficiencies exist, it is likely that only capital improvements can resolve the problem (e.g., reconstruction of highways and locks and dams). In such cases, the solution is beyond the carrier's responsibility and beyond the time frame for contingency planning. Actions that the carrier could initiate, although difficult to quantify, should lead to changes in shipment time and operating costs.

Truck Mode

The long-haul portion of intercity truck travel would rarely be congested except for the portion that occurs during the morning and afternoon peak rush-hour periods in cities. Most of the congestion-induced delays are therefore likely to occur during the pickup-and-delivery (PUD) portion of the trip, which accounts for about 17 percent of the total mileage of intercity truck trips (4). However, not all of the PUD travel is congested. Furthermore, most of the PUD travel involves only movement of local goods and services. PUD of intercity freight represents less than 1 percent of the stops and only 7 percent of the intracity mileage, although it accounts for 45 percent of the tonnage (5). In effect any actions taken to relieve congestion will have the most significant impacts on the industry for urban goods movement and concomitantly on urban passenger travel; less change will be experienced by the intercity freight industry.

Shifting the hours of truck operation could significantly improve fuel efficiency during the PUD portion of the trip. However, the overall savings for intercity truck fuel consumption is expected to be less than 0.5 percent. The shift to avoid rush-hour traffic may in the process lengthen the total travel time for the mode. Little change would be expected in nonfuel operating costs due to offsetting cost trends. Nighttime labor and terminal operating costs would increase, although the shift should result in more efficient utilization of equipment and personnel by spreading out the peak operations and thus perhaps even reducing daytime operating costs. However, the ability of a carrier to alter operating hours is constrained by labor contracts, the receiver's hours, and security considerations.

Air Mode

The frequently noted congestion at airports primarily concerns passenger aircraft, scheduled for the convenience of the business traveler. Belly cargo is essentially captive to the passenger aircraft schedule; thus changes to relieve passenger congestion should work to the benefit of that portion of air freight. All-cargo aircraft generally operate when there is less congestion. To a large extent air freight operation avoids much of the congestion because it is a 24-hr/day service in which much of the handling occurs at night. Consequently, no fuel savings or fuel demand reduction is attributed to the emergency relief of congestion for air freight.

Rail Mode

Activities to reduce congestion in the rail system are applicable primarily to switchyard operations. Centralized traffic control helps to maximize the efficiency of trunk-line movements. In the yards the most important effect of congestion delays is the increase in nonfuel operating costs, chiefly labor (6).

Energy efficiency of yard operations will increase rather than decrease as car management programs improve, and modern yard operating procedures stress minimization of engine idling time by switchers. Petroleum shortfalls are likely to bring about no net increase in the volume of cars handled by yards, and the expected economic downturn likely will mean a decrease in car throughput requirement. Centralization and modernization of railway yard operations are likely to continue irrespective of the threat of a reduction in petroleum supply. For these reasons, no extra reduction in fuel demand attributable to reduced congestion is assumed for rail freight operations.

Water Mode

Congestion of traffic at locks has been cited as a problem by waterway carriers, but lock capacity and cycle time constraints that give rise to such congestion are not susceptible to remedies short of major reconstruction. In reaches that occasionally become congested, improved radio communications could enhance the efficiency of push-tow movements, but regular coordination of movements among operators would be necessary. Barge owners have indicated that fuel savings from such procedures would be negligible compared with the effect of reducing congestion at locks. Therefore, no reduction in fuel consumption is credited to this action.

ADAPTING AVAILABLE TECHNOLOGIES

The purchase of fuel-saving equipment by the various modal carriers has been accelerating since the 1973-1974 oil embargo. In general, this is a conservation not a contingency measure because it often involves a long-term, capital-intensive commitment to reducing fuel consumption. However, just as the conversion to fuel-saving technologies was spurred by rising fuel prices during the last decade, rapidly increasing fuel prices during an energy shortfall can prompt the replacement of old equipment with fuel-efficient equipment at a faster rate than would have otherwise taken place. This accelerated replacement is again limited by the extensive conservation actions that have already occurred.

Truck Mode

One of the most prominent conservation programs has been the Joint Industry-Government Voluntary Truck and Bus Fuel Economy Improvement Program. Much of the program is devoted to new equipment purchases, some of which (e.g., high torque-rise diesel engines and power train modification) are clearly beyond the scope of short-range contingency measures because of the high costs involved. A few devices have a low enough cost (including quick installation) that a payback could be achieved during a fuel shortfall as energy prices rise. These devices include temperature-controlled fans, aerodynamic devices, radial tires, and fuel heaters.

The appearance of recent articles in trade publications (7,8) concerning ways to improve truck fuel economy indicates that there is still room for further conservation and to a lesser extent contingency savings through the same actions. A rough estimate (provided by industry contacts) of the current extent of conservation is that 40 percent of the trucking companies, representing about 70 percent of the total ton miles, are extensively utilizing the widely referenced conservation techniques. For contingency planning purposes, it is estimated that of the remaining 30 percent of ton miles, approximately 20 to 40 percent may be affected by the accelerated purchase of fuel-saving equipment during an energy emergency, for a participation rate of 6 to 12 percent. The fuel-saving potential of the devices is not additive, but if the maximum savings is estimated at 10 percent, the range of fuel demand reduction is between 0.6 and 1.2 percent. Nonfuel operating cost will increase with the purchase of the devices, but the relatively short payback period should limit the operating cost increases to 0.3 to 0.6 percent, or half the rate of the fuel savings.

Air Mode

Discussions with knowledgeable people within the air freight industry have not identified any retrofit technologies that could be adapted during a short-term fuel crisis. Purchase of new fuel-efficient aircraft as replacement for older units, however, has been going on for some time and is one of the principal means that the airline industry is using to reduce their vulnerability to fuel shortages.

Rail Mode

Three types of devices or support systems, developed at least in part to limit the wasting of locomotive power and thus improve the utility of fuel consumed, are considered feasible here for addition to a railroad's repertoire of fuel-stretching measures during a shortfall. Use of this equipment is already widespread among the carriers, but the planned rate of retirement of less-efficient devices still in use could be accelerated without intolerable costs being incurred. The most promising equipment includes fiberglass air filters, improved roller bearings and seals, and slippage control systems.

Wasted heat is recovered aboard locomotives for crew service (compartment heating), but devices to convert wasted heat to useful propulsion remain at the test-bench stage of rail application. Little experimentation with such equipment in revenue operations could be expected during a fuel shortfall. Based on the evaluations of the equipment described, railroad adaptation of available energy-efficient technology during a shortfall could result in fuel savings of up to 1.5 percent.

Water Mode

Propeller pitch and blade design (together with hull hydrodynamics) determine the amount of useful thrust that can be obtained by a tug or self-propelled barge and thus the quantity of fuel expended under way. Many of the newest self-propelled barges have been fitted with controllable-pitch propellers in order to achieve the optimum angle of attack under various channel depth and flow conditions (9), but additional penetration of the fleet by such craft probably could not exceed 0.5 percent during a period of shortfall. Retrofitting of these advanced propellers has not been explored by waterway carriers but would probably not be cost effective unless a vessel were already in drydock for a major overhaul.

CHANGING MAINTENANCE PROCEDURES

During a time of scarce fuel supplies, all facets of a carrier's operation should be reexamined for new fuel-saving potential. This includes a company's maintenance program. With the rising fuel prices during the 1970s, most companies oriented their maintenance programs toward improving their fleet's fuel efficiency; the larger companies used computerized systems for scheduling preventive maintenance.

Truck Mode

Although preventive maintenance (PM) varies by company, several large carriers perform their PM inspection on their tractors after 25,000 miles (about 30 to 60 days) at which time the air filters and oil filters are changed. At 100,000 miles engine oil and transmission fluid are changed and the differential is greased. Obviously, a good PM program is required in order to maintain these service intervals. Consequently, little improvement could be anticipated during an emergency. Three types of maintenance in which there may be some room left for improvement are

1. Reducing exhaust back pressure,
2. Maintaining proper tire pressure, and
3. Using synthetic lubricants.

Current estimates of improved vehicle maintenance indicate a fuel-saving potential of 1 to 3 percent per vehicle. Given that much of the trucking industry already has good maintenance programs in place, the potential applicability of a change in maintenance procedures may be limited to 10 to 20 percent of the industry; the fuel-saving potential for the industry as a whole may be less than 1 percent.

Air Mode

Extensive maintenance programs have been common in the airline industry for many years because of the obvious safety concerns. Rising fuel prices in recent years have been another reason for increased attention to airline maintenance procedures. The focus of the maintenance improvements has been on three parts of the aircraft: airframe, engine, and instruments. Significant deterioration of both engine and airframe normally occurs during the first two or three years of an aircraft's operation, resulting typically in a 3 percent decrease in fuel efficiency (10). With routine maintenance the fuel efficiency can be held relatively constant after that initial decline. It is doubtful, however, that a fuel shortfall would produce energy savings in airframe and instrument maintenance.

Estimates of potential fuel savings from improved engine maintenance are about 3 to 5 percent; 10 to 20 percent of full implementation has currently been achieved within the industry (11). However, technological and cost constraints currently limit the detailing of cost-effective engine maintenance actions. Current research on this problem, combined with rising fuel prices during a shortfall, could stimulate an overall improvement in fuel efficiency but probably one of less than 1 percent.

Rail Mode

Locomotives are almost never put in the shop for engine retuning unless a severe operational problem has been diagnosed. Layup and labor costs preclude putting locomotives in the shop at regular intervals simply to ensure that they are running at optimum fuel efficiency; such costs will almost always be greater than any savings in over-the-road operations. However, some roads have adopted a 92-day inspection schedule for each locomotive, at which time engine performance is routinely checked. Again, the reduced demand for motive power during the economic downturn that is attendant to a petroleum shortfall will permit railroads to mothball their less efficient engines for extended periods no matter what the regular maintenance schedule. During a shortfall, all locomotives would be maintained at least once under a 92-day schedule; the resulting average fuel savings would be 3 percent (12). For the perhaps 40 percent of total locomotives in service that are affected, a net reduction in energy intensity of 1.2 percent or less could be expected.

Water Mode

Reduction in ton-mile demand attributable to the economic impact of a petroleum shortfall could free excess motive power for drydock maintenance or outright retirement in favor of more efficient craft. To some degree this has already occurred as a result of the current recession and excess power is now available. On the assumption that even closer attention to engine tuning and performance monitoring would be feasible during a shortfall, a potential fuel saving of 0.5 percent by waterway carriers is estimated for this activity.

CHANGING OPERATING PRACTICES

In a manner similar to the other fuel-saving categories that have been described, increased attention to a carrier's operating practices is likely to occur during a fuel shortfall. Again, rising fuel prices have prompted conservation along these lines, and it is likely that another crisis-induced fuel price increase would spur operational contingency efforts to reduce fuel consumption.

One particular operating strategy that applies to all carriers, and thus need not be discussed for each mode, is the use of the most efficient vehicles in the fleet. To a large extent carriers have already adopted this strategy. In the event of a fuel shortfall, the general economic decline would reduce the demand for freight transport so that excess motive power would exist for each mode. Consequently, it is likely that carriers would continue to use their most efficient equipment; thus no additional reduction in fuel demand is attributed to this action.

Truck Mode

The key to fuel efficiency improvements in the actual operation of a truck is the driver during normal or fuel-crisis periods. Consequently a number of trucking companies have initiated fuel-conservation programs that focus on the driver: teaching fuel-saving techniques, keeping accurate records, and rewarding the most fuel-efficient drivers. Although these programs are increasing in frequency, they are not universal in the industry. Even the existence of a program does not ensure compliance. Drivers can make a significant difference in fuel consumption over two critical operating modes--speed and idle--which become an important focus of attention during a fuel shortfall.

Only a few states differentiate car and truck speeds when filing their quarterly speed-monitoring reports with FHWA. Data from four states (Illinois, Minnesota, North Carolina, and Michigan) indicate that for the past few years car and truck speeds have been fairly close for almost all highway functional groupings but that truck speeds in most cases are lower than car speeds. If these states can be taken as representative (and FHWA statistics have shown increasing national conformity and speeds recently declining in western states), the data show that 47 percent of the trucks exceeded 55 mph, 13 percent exceeded 60 mph, and 2 percent exceeded 65 mph. By using midpoint speeds and the fuel-saving potential of 2.2 percent for each mile per hour above 55 (13), the maximum energy savings would be 5.3 percent, although a 50 percent compliance would be more likely. Because these speeds would apply only to the line-haul portion of the trip, 83 percent of total intercity mileage (4), an estimated potential fuel savings of 2.2 percent could be achieved with either increased voluntary adherence by drivers or increased enforcement of the posted speed limit.

Engine idling at truck stops and terminals is a frequent occurrence, especially during the winter, to keep cabs warm or because of the difficulty in restarting a cold engine. Fuel heaters can solve the latter problem and cabs can be warmed within a few minutes after a restart. An indication of the magnitude of the problem is shown in a truck-stop survey in which 55 percent of the trucks were left with their engines idling on a 34°F day in February (14). No reliable estimates of the magnitude of wasted fuel due to idling have been found, but the amounts are likely to be significant for some operators.

Air Mode

Although the airlines have achieved substantial improvements in their fuel efficiencies, marginal fuel-saving actions may not have been carried out because of consideration of other costs (especially labor) in providing their services. Rapidly rising costs of fuel during a shortfall or extremely diminished supplies in some locations (short-term spot shortages) may result in more extensive use of some generally accepted conservation actions. Two concepts offer potential fuel savings in the event of a fuel shortfall.

It is likely that all airlines have reduced the cruise speed for their jets, generally from a range of 0.82 to 0.85 Mach to a range of 0.80 to 0.82 Mach, depending on aircraft type. Nevertheless, because of other operating costs, some airlines still use a cruise speed that is about 0.2 or 0.3 Mach above the long-range cruise point, because this minimizes total operating costs. During a fuel shortfall, the demand for fuel may be reduced an additional 1.0 percent by use of the optimum cruise speed.

Air traffic control procedures require 1,000 ft of vertical separation below a flight level of 29,000 ft (FL 290) but 2,000 ft of separation above FL 290. Changing to a uniform 1,000-ft separation would double the capacity for flying at these efficient altitudes and increase the probability that individual aircraft would be able to fly at their most efficient altitude during congested periods (15). No quantifiable fuel savings have been found, but they are likely to be less than 0.5 percent.

Rail Mode

There appears to be strong concurrence throughout the rail industry that improvements in fuel inventory control will be the key to truly significant energy savings in the future. The final disposition of up to 10 percent of rail fuel is unknown; practices such as better fuel tracking after purchase, fuel storage security, automatic shutoff and spillage control during refueling, spilled-fuel recycling, and fill metering could together save a railroad at least part of this 10 percent. Modern refueling equipment has penetrated the Class I carriers extensively in recent years, but smaller roads are only now becoming active in fuel control and security. It is expected that during a shortfall the carriers responsible for 20 percent of the fuel purchased for rail operations could account for the disposition of an additional 5 percent of their initial fuel inventory, whereas the carriers that buy the remaining 80 percent could introduce measures sufficient to account for an additional 2 percent. If it is assumed that 50 percent of unaccounted fuel is profitably used, this estimate results in a net saving of 1.3 percent industrywide.

In the range of possible railway operational modifications to save fuel, the six listed below would probably be initiated or expanded during a shortfall by roads not already using them. Most of these are already in place on Class I lines, but a margin does exist for further implementation.

1. Reducing power in locomotive consists,
2. Matching consist load to locomotive power requirements,
3. Using helper engines at the more difficult grades,
4. Disengaging parasitic loads (cooling systems and so on) when not in use,
5. Eliminating unnecessary idling,
6. Eliminating cabooses where feasible, and
7. Traveling at more efficient speeds.

The combined effect of all measures to improve rail operating practices for fuel efficiency during a shortfall could provide a reduction in energy intensity of 5 percent.

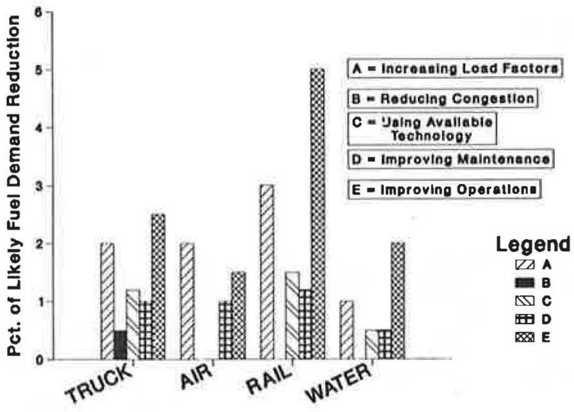
Water Mode

Forward speed adjustment as a means to reduce fuel consumption is not tractable to ready analysis in the context of waterway transport. A study of least-energy use operation of river shipping that included a means to estimate the most energy-efficient speed through water under differing channel depths and current conditions for upstream and downstream movement showed that the speed of minimum propulsion fuel consumption tends to be 3 to 5 mph less than the speed at which minimum total costs are achieved. That is, assigning the highest priority to the control of time-accrued costs such as crew wages, auxiliary fuel expense, food, depreciation, maintenance, and management may still be the key to profitability of an operation despite the high cost of fuel. As the author of the study remarks (16), "The easiest way to incur excessive cost is by going too slowly."

Although according to available information, tows and barges are currently operating on average slightly above the most fuel-efficient speeds for river operation (in discussions with the industry, midstream tow speed was reported to average 5 to 6 mph downstream and slightly less upstream), the congestion problem at locks will continue to frustrate carriers' efforts to achieve a trade-off between time costs and fuel expenditure by smoothing out trip speed profiles. Nevertheless, the lock situation provides an opportunity to cut wasteful fuel consumption at no additional cost. Some operations routinely throttle down when approaching a lock and run only enough engines to maintain steerage during intermediate delays. All engines may be shut down if extended waits are anticipated. These practices are already widespread; nevertheless, their adoption by all inland waterway operations could save an additional 1 to 2 percent of fuel.

Pilot training for efficient operation has been explored since the mid-1970s, but no formal programs appear to be in place. As noted earlier, some pilot practices can be identical but produce quite different results under apparently identical stream conditions, although the degree to which good pilots know the river does not always extend to uniform recognition of all the factors of wind and water that affect the translation of engine power to for-

Figure 1. Comparison of effectiveness of contingency responses for freight transportation.



ward thrust. Therefore, a more formalized approach to pilot education with an emphasis on energy consciousness must be considered as an option by any waterway carrier seeking to assure the best use of available fuel supplies in a shortfall. Such training is unlikely to have much payoff if it is not initiated until a shortfall occurs, but the additional benefits of prior training might save the industry up to 5 percent of normal fuel consumption if fuel cost as a percentage of total operating costs reaches the likely shortfall level of 80 percent or more and if comparison with expected results from similar training programs in the rail industry is legitimate. (Up to 5 percent reduction in propulsion-fuel consumption is attributed by many railway operations personnel to fuel-conscious education and training programs for enginemen and other train operations staff.)

CONCLUSIONS

The freight transportation industry has a maximum fuel demand reduction potential of about 4 to 8 percent, depending on the mode, without drastic curtailing of service. In Figure 1 the expected changes that each category of contingency responses could have for the various modes are summarized. Changing operating practices and increasing the load factors are the most significant options available for carriers to reduce their fuel demand during a fuel crisis. However, only an extremely severe shortfall would precipitate a fuel use restriction of this magnitude. In addition, carriers will become more fuel efficient as the rising price of fuel causes companies to replace older vehicles with energy-efficient equipment and to continue to improve their operating practices. Consequently the potential for curtailing fuel demand in the future will be less than it is now, simply because the entire freight transportation system will have become more efficient. The benchmark of fuel consumption, against which savings can be measured, will have been lowered.

On the other hand, the potential for enhancing the fuel supply during a shortfall is growing. The SPR has stored in excess of 250 million bbl of crude oil--enough to displace a 10 percent shortfall for 6 months if it were to be entirely drawn down. By the end of the decade an authorized level of 750 million bbl of storage should be reached. Private storage (company-owned stocks) of fuel may again increase after the current recession has ended, providing a further hedge against a fuel-supply interruption. Fuel extenders, many of which are experimental, may be available for use should a shortfall occur several years in the future. Alcohol fuels can be used now, but the production capacity is low.

In short the demand-reduction options are generally less significant than the alternatives to enhance the fuel supply, although both are important in developing a coordinated response to a sudden loss of fuel availability.

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