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The Potential Effects of Improved Railroad Intermodal Technology Within a Competitive Environment

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ABSTRACT

Growth in railroad intermodal traffic, within an environment of motor carrier competition, is encouraging railroads to seek more efficient intermodal technologies to reduce costs and enhance profitability. Our study used a rail cost model to evaluate current railroad intermodal technology, several newly-introduced alternatives, and one possible future technology within the context of that competitive environment. The results of the analysis point to several important economic principles to govern the design of new railroad technologies.

I. INTRODUCTION

In recent years, railroad intermodal traffic has become increasingly important to the railroads. The trend of railroad intermodal traffic from 1965 through 1983 is shown in Table 1. The 1.1 million revenue cars loaded in piggyback service in 1965 represented 3.7 percent of the total 29.2 million revenue carloadings in that year; by 1983, the 2.3 million intermodal carloadings represented 12.4 percent of the 18.3 million total carloadings. Railroad intermodal traffic growth has been strong in the Southern and Western Districts, increasing 272 percent and 187 percent, respectively, between 1965 and 1983. However, as a result of intense motor carrier competition, as well as the relative decline in its industrial base since 1965, such growth has not been as evident in the Eastern District, whose 1983 volume was 10 percent above that of 1965 but 15 percent below the 1968 peak year volume.

Despite the growth in intermodal traffic, its general lack of profitability presents a problem for the railroads. With some exceptions, most of the major rail carriers view intermodal traffic as marginally profitable. As a result, the railroads are investigating several new equipment technologies as a means to reduce their cost of operations by improving efficiency.

Improved efficiency of railroad intermodal transportation would permit the railroads a range of pricing strategies for maximizing their profitability. One such strategy would be to reduce intermodal rate levels in an attempt to increase market share. Another strategy would be to maintain intermodal rate levels, thereby increasing profitability to the extent of the improvement in railroad efficiency. These and other potential pricing strategies influence the modal choice decisions of shippers.

II. SERVICE AND COST PERFORMANCE OF INTERMODAL RAIL AND TRUCK

In order to investigate how railroad intermodal train costs would change with new technology, railroad unit train costs of handling intermodal traffic were compared with costs of motor carriers over comparable long-distance routes between Chicago and Los Angeles. Among the cases investigated were the following:

- Conventional trailer-on-flat car (TOFC);
- Conventional container-on-flat car (COFC);
- Trailer-on-lightweight car;
- Container-on-lightweight car;
- Double-stacked containers; and
- Truck-equivalent net-to-tare weight ratio.

The first two cases represent conventional TOFC and COFC technology widely used in the railroad industry today. The next three cases represent recently introduced technology. The final case is hypothetical, intended to suggest the potential for improved efficiency in intermodal rail technology.

A computerized rail cost model was used to determine the variable operating costs for each of the rail intermodal alternatives. The rail cost model is route-specific, requiring detailed input data describing such physical characteristics as grades, curvature, and length of the route, as well as such operating characteristics as speed limits, crew change points, and helper locomotive locations (if applicable). Also required are detailed physical descriptions of the equipment operated over the route; for example, the specified cross-sectional area of the cars impacts the computation of fuel consumption.

The rail cost model uses the route and operating characteristics to compute running times, fuel consumption, and components of variable cost, including operating and equipment ownership costs. (The rail cost model is more fully described in a report entitled "Cost Models for Coal Transportation by Common Carrier", published in March 1979 by the Electric Power Research Institute (EPRI), Palo Alto, California.)

For both the rail and truck modes, the operating parameters we used were based on our knowledge of operating characteristics of intermodal service in the Los Angeles-Chicago corridor.

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Table 1
RAILROAD INTERMODAL TRAFFIC,
1965-1983

Year	Revenue Cars: United States	Eastern District	Southern District	Western District	Trailers and Containers
1965	1,076,820	508,189	173,762	394,869	1,664,929
1966	1,224,337	564,348	207,163	452,826	1,912,419
1967	1,277,410	568,089	225,053	484,268	1,983,793
1968	1,509,843	659,471	276,373	573,999	2,419,217
1969	1,539,797	632,433	303,236	604,128	2,497,586
1970	1,449,519	565,518	311,225	572,776	2,363,200
1971	1,356,394	511,877	319,422	525,095	2,203,530
1972	1,448,075	599,177	354,184	494,714	2,407,034
1973	1,630,795	610,874	403,929	615,992	2,758,044
1974	1,609,876	594,208	405,404	610,264	2,752,825
1975	1,307,520	463,779	337,005	506,736	2,238,117
1976	1,505,945	456,670	422,272	627,003	2,538,318
1977	1,688,806	471,965	483,050	733,791	2,850,231
1978	1,840,588	469,436	524,014	847,138	3,177,291
1979	1,857,705	479,662	508,903	869,140	3,278,163
1980	1,687,121	456,404	445,460	785,257	3,059,402
1981	1,752,479	449,634	471,020	831,825	3,150,522
1982	1,920,377	474,275	538,149	907,953	3,396,973
1983	2,338,527	558,301	645,702	1,134,524	4,078,454

Source: Association of American Railroads, Railroad Facts, 1984 Edition.

In Table 2, the model run specifications are shown for the various intermodal rail cases analyzed. Although the weight-to-cube relationship of various commodities affects the cost characteristics of rail and truck—and, therefore, the extent of their competition—our focus was on an approximate current average load of 20 tons for railroad intermodal traffic.

In Table 3, the net-to-tare characteristics of the various intermodal rail cases are compared on a per trailer or per container basis against truck. The net-to-tare ratio, the ratio of the weight of the net load, or contents, to the combined tare weight of the trailer or container plus the other components of a truck (the tractor) or train (cars, locomotives, and caboose), affects power requirements, fuel consumption, and other operating characteristics. As shown in Table 3, the net-to-tare ratio of a truck is approximately double that of the conventional trailer-on-flat car technology predominantly used in the railroad industry. However, available existing technology such as the double-stacked container car has an improved net-to-tare ration of 1.33, in contrast to the 1.54 net-to-tare ratio of the truck mode.

Intermodal rail performance for each of these cases is shown in Table 4 as a percent of truck performance. While the net load is identical in each case, the tare weight indices vary widely. Thus, for example, conventional TOFC has tare weight over twice that of truck, while tare weight for the double-stacked container car is only 16 percent greater than that of truck. Consequently, while the net-to-tare ratio of conventional TOFC is 45 percent that of truck and conventional COFC is 48 percent that of truck, the net-to-tare ratio of the double-stacked container car is about 86 percent that of truck. The implications of differing net-to-tare ratios are reflected in the horsepower per net ton and the fuel consumption indices. While intermodal rail is seen to be superior to truck in both these indices, the double-stacked container and the hypothetical truck-equivalent container technology display considerable superiority in terms of efficiency.

A "Comparison of Truck and Intermodal Rail Service Performance" is given in Table 5. Truck transit times over the route have been calculated both for an average speed of 50 miles per hour and at the speed limit of 55 miles per hour, and allow twenty percent additional time for hours stopped en route. In our opinion, because the 55 MPH speed limit is often violated, the truck speed at 55 MPH should be considered the appropriate competitive standard for transit time.

At present, the fastest, published railroad schedule between Chicago and Los Angeles is 50 hours. A 50-hour schedule is considered fully competitive with truck, even though loading and unloading delays constitute a service disadvantage for the rail-

Table 2
MODEL RUN SPECIFICATIONS FOR INTERMODAL RAIL

	Conventional		Lightweight		COFC	Truck
	TOFC	COFC	TOFC	COFC	Double	Equiv.
Load Type	TLR	CONT	TLR	CONT	CONT	CONT
Number of Loads	100	100	100	100	200	200
Load Tare (Tons)	6.1	4.5	6.1	4.5	4.5	4.5
Number of Cars	50	50	10	10	10	10
Car Tare (Tons)	34	34	105	110	143	128.7
Caboose Tare (Tons)	30	30	30	30	30	0
Number of Units	4	4	4	4	5	5
Locomotive Wgt. (Tons)	130	130	130	130	130	82.6
Total Horsepower	14,400	14,400	14,400	14,400	18,000	18,000
Train Net Wgt. (Tons)	2,000	2,000	2,000	2,000	4,000	4,000
Train Tare (Tons)	2,860	2,700	2,210	2,100	3,010	2,600
Net/Tare Ratio	0.70	0.74	0.91	0.95	1.33	1.54

Table 3
NET-TO-TARE COMPARISON OF TRUCK AND INTERMODAL RAIL
(PER TRAILER OR CONTAINER BASIS)

		Conventional		Lightweight		COFC	Truck
	Truck	TOFC	COFC	TOFC	COFC	Double	Equiv.
Net Load (Tons)	20	20	20	20	20	20	20
Tare (Tons)							
Trailer/Container	5	6.1	4.5	6.1	4.5	4.5	4.5
Car	--	17.0	17.0	10.5	11.0	7.2	6.4
Tractor/Loco. & Cab.	8	5.5	5.5	5.5	5.5	3.4	2.1
Total	13	28.6	27.0	22.1	21.0	15.1	13.0
Net/Tare Ratio	1.54	0.70	0.74	0.91	0.95	1.33	1.54

Table 4
INTERMODAL RAIL PERFORMANCE AS PERCENT OF TRUCK

	Truck	Conventional TOFC	Conventional COFC	Lightweight TOFC	Lightweight COFC	COFC Double	Truck Equiv.
Net Load	100	100	100	100	100	100	100
Tare	100	220	208	170	162	116	100
Net/Tare Ratio	100	45	48	59	62	86	100
HP/Net Ton[1]	100	58	58	58	58	36	36
Fuel Consumption[2]	100	54	48	51	44	32	31

[1] Assumes horsepower per net ton ratio of 12.5 for truck.

[2] Fuel consumption measured in terms of gallons per net ton-mile. Assumes truck fuel consumption of 5.2 miles per gallon.

roads. No comparison of pickup and delivery times were made because we view these as equivalent for over-the-road truckers and rail intermodal service.

In our analyses, we maintained intermodal rail service performance standards approximately competitive with truck, but then minimized horsepower and related costs. Thus, we assumed that competitive transit time standards will be maintained by each of the intermodal rail technologies; however, the cost performances of the technologies differ, reflecting the inherent advantages and disadvantages of each.

In Table 6, The primary cost components of intermodal rail service are shown as a percent of total cost for conventional TOFC, with all costs computed on a per trailer or container basis. The total costs are separated into four basic components:

- crew wages;
- locomotives costs;
- car costs; and
- roadway maintenance.

As shown, each of the alternative technologies improves railroad cost efficiency beyond that of conventional TOFC. Thus, replacing conventional TOFC with lightweight TOFC cars reduces costs by 12 percent; if containers were operated on lightweight cars, costs would be reduced an additional 5 percent, for a total reduction of 17 percent. For the newer technology of double-stacked containers, as well as for the postulated case of a "truck equivalent" net-to-tare weight ratio, even greater efficiency improvements would occur. As shown in Table 6, those two technologies would cut railroad costs down to 56 to 59 percent of conventional TOFC; stated differently, rail cost efficiency would be nearly doubled.

For purposes of comparison, the relative costs of the alternative technologies are also shown in Table 7 as a percent of the individual cost components of conventional TOFC. Table 7 indicates that the double-stacked containers and "truck-equivalent" technologies are significantly lower in cost (on a per trailer or container basis) than each of the corresponding cost components for conventional TOFC, with cost reductions of one-half for crew wages and nearly two-thirds for car costs.

Finally, Table 8 shows the relative importance of the separate cost components for each of the six technologies. Thus, car costs and crew wages for the "COFC double" and"truck-equivalent" technologies comprise smaller shares of total cost than for conventional TOFC and COFC, while locomotive costs and roadway maintenance comprise relatively higher shares of the totals for the newer technologies.

III. CONCLUSIONS

Based on the results of our investigation, it is apparent that several important economic principles should govern the design of new railroad technology.

First, cost efficiency will be at its greatest when net load per train is maximized within the constraint of a specific train's rectangular solid. Both the double-stacked container car and the "truck equivalent" scenarios demonstrate this principle. Doubling the net load per train is a primary reason why total cost is reduced by about one-third below that of the next available technology, as shown by Table 6.

Second, new railroad intermodal technology designs should maximize net-to-tare ratios. Otherwise, railroads' overall technological advantages will be dissipated by the high quantities of tare weight per unit of payload. From our analysis, we observe that, except for the added effects of increased payloads cited above, the fuel consumption and cost improve-

Table 5
COMPARISON OF TRUCK AND INTERMODAL RAIL SERVICE PERFORMANCE[1]

	Truck @ 50 MPH	Truck @ 55 MPH	Conventional TOFC	Conventional COFC	Lightweight TOFC	Lightweight COFC	COFC Double	Truck Equiv.
Distance (Miles)[2]	2,095	2,095	2,167	2,167	2,167	2,167	2,167	2,167
Time:								
Hours Moving	41.9	38.1	43.7	40.9	41.5	38.8	42.5	41.8
Hours Stopped								
Crew Change			3.0	3.0	3.0	3.0	3.0	3.0
Inspections			1.5	1.5	1.5	1.5	1.5	1.5
Helpers			0.5	0.5	0.0	0.0	2.0	1.0
Subtotal	8.4	7.6	5.0	5.0	4.5	4.5	6.5	5.5
Total Vehicle-Hours	50.3	45.7	48.7	45.9	46.0	43.3	49.0	47.4
Loading Time (Hrs.)	--	--	2.0	2.0	2.0	2.0	2.0	2.0
Unloading Time (Hrs.)	--	--	2.0	2.0	2.0	2.0	2.0	2.0
Total Time (Hrs.)	50.3	45.7	52.7	49.9	50.0	47.3	53.0	51.4
Total Time as Percent of Truck @ 55 MPH	110	100	115	109	109	104	116	112

[1] Represents one-way trip as average of round trip.
[2] One-way distance between Chicago and Los Angeles.

Table 6
PRIMARY COST COMPONENTS OF
INTERMODAL RAIL SERVICE
AS PERCENT OF CONVENTIONAL TOFC
TOTAL COST*

	Conventional		Lightweight		COFC	Truck
Cost Component	TOFC	COFC	TOFC	COFC	Double	Equiv.
Crew Wages	17	17	17	17	9	9
Locomotive:						
Maintenance	10	10	10	10	7	7
Own. (incl. cab)	5	5	5	5	3	3
Fuel	31	28	29	25	18	17
Subtotal	46	43	44	40	28	27
Car:						
Maintenance	8	8	2	2	1	1
Ownership	5	4	5	4	4	3
Subtotal	13	12	7	6	5	4
Roadway Maintenance	24	23	20	20	17	16
Total Cost	100	95	88	83	59	56

*Cost comparison on a per trailer or container basis.

Table 7
PRIMARY COST COMPONENTS OF
INTERMODAL RAIL SERVICE
AS PERCENT* OF CONVENTIONAL TOFC
COST COMPONENTS

	Conventional		Lightweight		COFC	Truck
Cost Component	TOFC	COFC	TOFC	COFC	Double	Equiv.
Crew Wages	100	100	100	100	50	50
Locomotive:						
Maintenance	100	100	99	99	63	63
Own. (incl. cab)	100	95	93	88	65	60
Fuel	100	89	93	82	59	57
Subtotal	100	92	95	86	61	59
Car:						
Maintenance	100	100	22	21	11	10
Ownership	100	88	95	89	77	74
Subtotal	100	95	52	49	38	36
Roadway Maintenance	100	97	87	84	72	68
Total Cost	100	95	88	83	59	56

*Cost comparison on a per trailer or container basis.

Table 8
PRIMARY COST COMPONENTS OF
INTERMODAL RAIL SERVICE
AS PERCENT OF TOTAL COST

Cost Component	Conventional TOFC	Conventional COFC	Lightweight TOFC	Lightweight COFC	COFC Double	Truck Equiv.
Crew Wages	17	18	19	21	15	15
Locomotive:						
Maintenance	10	11	12	12	11	11
Own. (incl. cab)	5	5	6	6	6	6
Fuel	31	29	32	30	31	31
Subtotal	46	45	50	48	48	48
Car:						
Maintenance	8	8	2	2	1	1
Ownership	5	5	6	5	7	7
Subtotal	13	13	8	7	8	8
Roadway Maintenance	24	24	23	24	29	29
Total Cost	100	100	100	100	100	100

ments shown in Table 6 flow from the improvements in the net-to-tare ratios shown for each of the technologies.

Third, competitive transit times and reliability must be assured. Numerous discussions with shippers have indicated to us that the shipping public demands reliable transit time for railroad intermodal rail service, in addition to dock-to-dock transit times which are competitive with motor carriers. Thus, we conclude that advanced railroad intermodal technology will not be competitive with motor carriers in the future transportation marketplace unless that advanced technology is fully reliable, and we recommend that component redundancy be incorporated within the newer technologies to ensure such reliability.

Shippers' modal choice decisions are strongly influenced by considerations of the price and service alternatives offered by competing transportation modes. Although a wide variety of pricing strategies are utilized in pricing transportation services, those pricing strategies in turn must ultimately reflect the costs of the alternative modes.

Both price/cost and service considerations are dependent in large measure on the technology available to the competing modes. The results of our study suggest that two intermodal train designs—the double-stacked container and a "truck equivalent" container—show potentially substantial improvements in operational efficiency. Widespread introduction of such significantly more efficient railroad intermodal technology would be expected to alter shippers' modal choice decisions toward greater use of railroad intermodal service.