

Despite these drawbacks, it is believed that it resolves important theoretical issues. It is hoped that this paper will stimulate additional research in empty movement cost allocation.

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REFERENCES

1. P. French. Managing Freight Cars in a Period of Surplus: Does Utilization Matter? *Railway Age*, Feb. 1981.
2. S.C. Misra. Linear Programming of Empty Wagon Disposition. *Rail International*, Vol. 3, March 1972, pp. 151-158.
3. B.P. Markowicz and A.L. Kornhauser. Car Management Opportunities: Actual Return Mileage vs. Optimal Return Mileage. Princeton University, Princeton, N.J., 1983.
4. W.C. Jordon and M.A. Turnquist. A Stochastic, Dynamic Network Model for Railroad Car Distribution. *Transportation Science*, Vol. 17, No. 2, May 1983.
5. P.W. French. Car Surplus Decision Making: System Car/Foreign Car Trade-Offs. *Proc., Freight Car Management Seminar*, Memphis, Tenn., Jan. 1982.
6. V.B. Mediratta. A Dynamic Optimization Model of the Empty Car Distribution Process. Ph.D. dissertation. Northwestern University, Evanston, Ill., June 1981.
7. H. McFarland. Major Studies of Railroad Costs: A Review. Working Paper. Transportation Center, Northwestern University, Evanston, Ill., 1976.
8. M.R. McBride. An Evaluation of Various Methods of Estimating Railway Costs. *The Logistics and Transportation Review*, Vol. 19, No. 1, 1983.
9. Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs. Statement 7-63. Bureau of Accounts, Interstate Commerce Commission, Washington, D.C., 1963.
10. Rail Carload Cost Scales: 1977. Statement 1C1-77. Bureau of Accounts, Interstate Commerce Commission, Washington, D.C., 1977.
11. W.C. Jordon. The Impact of Uncertain Demand and Supply on Empty Railroad Car Distribution. Ph.D. dissertation. Cornell University, Ithaca, N.Y., 1982.

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General Model of Multirailroad Freight Car Management

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ABSTRACT

The freight railroad system of North America is comprised of many independent railroads. Most freight cars are loaded on one railroad and unloaded on another. The question of how to use the originating railroad's car once it has become empty has a long and complex history involving the railroads, shippers, and government regulatory bodies. This issue is so complex that traditional solutions to it have used one variable only--the amount of money received from other railroads for the time one's own cars are in use by those railroads. This has been supported frequently by a marketing strategy that stresses the value of placing for loading only those cars with the originating carrier's marks. The result of this and similar strategies has been a gross underutilization of and excessive investment in freight cars. The model described is a close approximation of present-day freight car management. It

shows clearly the costs associated with lack of cooperation among railroads. It also can be used to try out solutions to those problems. Better use of existing freight cars will reduce future ownership and present operating costs of all railroads.

The model described in this paper focuses on a few of the variables of a complex system--multirailroad freight car management. By taking a simplified view of what is a complex subject, the model can show the underlying reasons for certain inefficiencies in traditional practices by individual railroads. It shows that cooperative efforts among railroads are necessary if an individual railroad is to improve the level of service to shippers and reduce costs.

The model uses only two railroads: A and B. Each railroad has 1,000 miles of line. Activities related to railroad A are shown on the left half of each diagram, and activities related to railroad B are shown on the right half of each diagram. There is

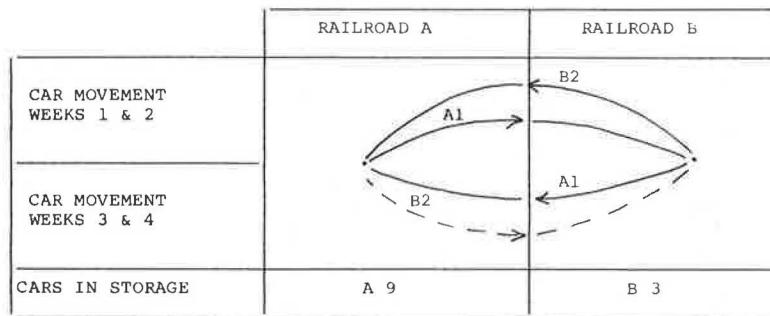


FIGURE 1 Sample car movement diagram.

only one loading and unloading point on each railroad. Railroad A owns 10 cars and railroad B owns 5 cars. There is only one car type. Loadings from A to B are always higher than loadings from B to A. It takes a car 7 days from origin to interchange, and 7 more days from interchange to destination. Loading and unloading are instantaneous. Empty travel from origin to destination takes the same length of time as loaded travel (14 days). The model in this paper is limited to a 4-week period for each situation. Thus, each car is always back at its starting point at the end of the time covered by the model. Car movements in weeks 1 and 2 are shown on the top half of each diagram, and car movements in weeks 3 and 4 are shown on the bottom half of each diagram.

The diagram accompanying each situation, or case, uses curved lines with arrows to show car movement over the single route between A and B. Car ownership and the number of cars involved are shown on top of each line. Loaded movements are shown as solid lines, and empty movements are shown as dotted lines. In the interest of brevity a diagram is not shown for each situation. A sample diagram is shown in Figure 1.

Costs are set as follows:

1. Ten dollars per day or \$70 per week are owed by railroads to financial institutions for the long-term lease of one car.

2. The same rate (\$10 per day or \$70 per week) is owed by the railroads to each other for each day

a car from another line (foreign car) is used (loaded or empty).

3. Ten cents per mile for each loaded mile is for transportation (e.g., fuel, labor, clerical).

4. Five cents per mile for each empty mile is for transportation (e.g., fuel, labor, clerical).

No cost is allocated for placing or keeping a car in storage. The model does not recognize the difference in maintenance cost between empty cars in motion and empty cars in storage. There are no mileage payments by one railroad to the other--only time payments. All these costs could, however, be added in a more elaborate version of the model.

Table 1 gives the situation sample that is used to tabulate all independent and dependent variables and gives the operating and financial impacts of various strategies used by the railroads in dealing with shipper demand and car management. In every situation described in this paper, the number of cars owned (column 1) by A is 10 and by B is 5. This is represented as 40 car weeks or 280 car days for A, and 20 car weeks or 140 car days for B. At \$10 per car day or \$70 per car week, ownership cost, therefore, is always \$2,800 for A and \$1,400 for B.

The per diem paid (column 2) is always \$70 per car week or \$10 per car day for every day a foreign car is on line. This can be adjusted by per-diem-free agreements or cash payments between the railroads. Per diem received (column 3) by one railroad must always equal per diem paid by the other. It is calculated on the same basis as column 2. Net per diem paid (column 4) is the algebraic sum of column

TABLE 1 Situation Sample

	(1) Car Ownshp. Cost		(2) Per Diem Paid		(3) Per Diem Rec'd		(4) Net Per Diem Pd		(5) Net Car Time Cost		(6) Loaded Mile Cost		(7) Empty Mile Cost		(8) Revenue	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
UNITS	40 CW ^a	20 CW														
RATE	\$70/CW		\$70/CW		\$70/CW		\$70/CW		\$70/CW		10¢/mi		5¢/mi		\$1.00/mi	
DOLLARS (000)	2.8	1.4														
(2)+(3) (1)+(4)																

	(9) Cars Stored	(10) Shipper Demand	(11) Loads Origina- ted	(12) Loads Hauled	(13) Total Cost (\$000)	(14) Contri- bution (\$000)	(15) L/E ^b Miles	(16) E Miles Per Load	(17) E Car Days OnLine	(18) E Car Days/ Load
A										
B										
TOTAL										
(5)+(6) (8)-(11) (6)÷(7) (7)÷(12) (17)÷(12)										

^a Car week.

^b Loaded/empty ratio.

2 and column 3. It can be negative if a railroad receives more than it pays. Net car time cost (column 5) is the algebraic sum of car ownership cost (column 1) and net per diem paid (column 4).

Loaded mile cost (column 6) is calculated at 10 cents per mile and is absorbed completely by the railroad handling the car. There is no mileage payment to the car owner, although this could be included in a more sophisticated version of the model. Empty mile cost (column 7) is figured at 5 cents per mile in the same way. Revenue (column 8) is determined by multiplying the number of loaded car miles (column 6) by \$1 per car mile.

Cars stored (column 9) counts the number of its cars each railroad does not use for transportation, either involuntarily (no demand) or voluntarily (as part of a strategy to reload foreign cars).

Shipper demand (column 10) is the number of cars needed by each shipper (one on A and one on B) during the 4-week period depicted. As long as the car is supplied within the first 2 weeks and gets to its destination by the end of the 4-week period, this demand is considered satisfied. This is reflected in loads originated (column 11). Loads hauled (column 12) is simply the total loads a railroad handles, both outbound and inbound. Total cost (column 13) is the sum of net car time cost (column 5), loaded mile cost (column 6), and empty mile cost (column 7). Contribution (column 14) is the difference between revenue (column 8) and total cost (column 13).

Four measures of a car fleet's efficiency that are frequently used in the railroad industry are also calculated for each situation. Loaded/empty miles (column 15) is loaded miles (column 6) divided by empty miles (column 7). Empty miles per load (column 16) is empty miles (column 7) divided by loads hauled (column 12). Empty car days on line (column 17) is taken from the movement/storage diagram (Figure 1). It includes all empty cars, whether stored or moving, system or foreign. Empty car days per load (column 18) is derived by dividing empty car days on line (column 17) by loads hauled (column

12). As for all other variables, these measures are calculated for each railroad.

The situations are shown in Table 2 where each is identified by a Roman numeral and a letter. The Roman numeral indicates the shipper demand for cars. The letter C or R after the Roman numeral indicates a current or recommended car management strategy in response to the shipper demand. In some situations there is more than one recommended practice. These are indicated by Arabic numbers after R. The remainder of this paper illustrates the application of the model to the situations and strategies shown in Table 2.

SITUATION I-C: HEAVY DEMAND, 20 PERCENT RELOAD

There is a heavy demand for cars (20 on A and 10 on B). Each railroad, therefore, allows only 20 percent of its cars to be reloaded by the other. This situation is illustrated in Figure 2.

A loads all 10 of its cars to B, and B loads all 5 of its cars to A. B reloads 2 A cars and sends 8 A cars back empty. A reloads one B car and sends 4 back empty.

The results of the current practices are given in Table 3. Out of a total of 30 possible loads, only 18 were realized. Because each railroad wanted to get its own cars back, 12,000 empty miles and 84 empty car days were generated on each railroad. This yields a load/empty ratio of only 1.5, and empty-car-day-per-load ratio of 4.7.

SITUATION I-R: HEAVY DEMAND, 100 PERCENT RELOAD

The same demand exists (20 cars on A and 10 on B) as for situation I-C. In this case, however, neither railroad puts restrictions on the loading of its cars by the other. Situation I-R is illustrated in Figure 3.

A loads all of its 10 cars to B, and B loads all

TABLE 2 Situation and Strategies

SITUATION	CAR MANAGEMENT STRATEGY
I. Heavy Demand	C - Traditional 20% Reload
	R - 100% Reload
II. Mild Recession	C - Car Warfare - No Storage
	R1 - Unilateral Storage by B
	R2 - Unilateral Storage by A
	R3 - Shared Storage
	R4 - Per Diem Relief
III. Severe Recession	C - Car Warfare No Planned Storage
	R1 - Maximum Storage by B
	R2 - Maximum Storage by A
	R3 - Shared Storage Plus Per Diem Relief
IV. Severe Recession	C - Car Warfare No Planned Storage
	R1 - Maximum Storage Shared by A & B Only
	R2 - Maximum Storage by A
	R3 - Shared Storage Shared by All Three Railroads

5 of its cars to A, as in situation I-C. In weeks 3 and 4, however, A reloads all 5 B cars on line. B loads 5 A cars, thus filling all demand and returns the 5 surplus A cars empty.

The recommended practice results in several improvements, which are given in Table 4. A originates 4 more loads and B originates 3 more loads, resulting in each railroad handling 25 loads, or 7 more than before. Moreover, although the total miles remain the same for each railroad, loaded miles go up and empty miles go down by 7,000 on each railroad.

Total cost increases by \$350, but revenue goes up by \$7,000 on each railroad, causing contributions to rise by the same amount. Improvements in loaded/empty mile ratio, empty miles per load hauled, and empty car days per load are also achieved (Cols. 13-16).

Situation I-R is a simplified version of what happens on railroads that participate in the freight car clearinghouse. When the supply of cars is small, each railroad uses more foreign cars for outbound loads and empty handling is reduced.

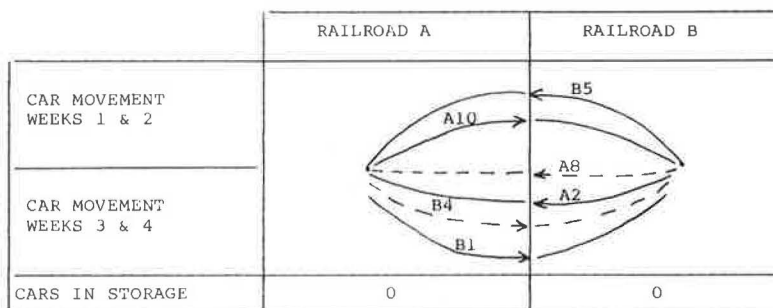


FIGURE 2 Situation I-C: Heavy demand, 20 percent reload.

TABLE 3 Situation I-C: Heavy Demand, 20 Percent Reload

	(1) Car Ownshp. Cost		(2) Per Diem Paid		(3) Per Diem Rec'd		(4) Net Per Diem Pd		(5) Net Car Time Cost		(6) Loaded Mile Cost		(7) Empty Mile Cost		(8) Revenue	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
UNITS	40 CW ^a	20 CW	10 CW	20 CW	20 CW	10 CW	-10 CW	10 CW	30 CW	30 CW	18K mi	18K mi	12K mi	12K mi	18K mi	18K mi
RATE	\$70/CW		\$70/CW		\$70/CW		\$70/CW		\$70/CW		10¢/mi		5¢/mi		\$1.00/mi	
DOLLARS (000)	2.8	1.4	.7	1.4	1.4	.7	-.7	.7	2.1	2.1	1.8	1.8	.6	.6	18	18

	(9) Cars Stored	(10) Shipper Demand	(11) Loads Origina- ted	(12) Loads Hauled	(13) Total Cost (\$000)	(14) Contri- bution (\$000)	(15) L/E ^b Miles	(16) E Miles Per Load	(17) E Car Days OnLine	(18) E Car Days/ Load
A	0	20	11	18	4.5	13.5	1.5	667	84	4.7
B	0	10	7	18	4.5	13.5	1.5	667	84	4.7
TOTAL	0	30	18	18	9.0	27.0	1.5	1334	168	9.4

^a Car week.

^b Loaded/empty ratio.

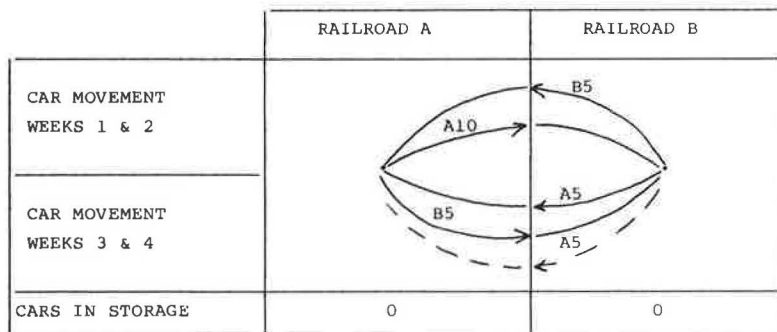


FIGURE 3 Situation I-R: Heavy demand, 100 percent reload.

TABLE 4 Situation I-R: Heavy Demand, 100 Percent Reload

	(1) Car Ownshp. Cost		(2) Per Diem Paid		(3) Per Diem Rec'd		(4) Net Per Diem Pd		(5) Net Car Time Cost		(6) Loaded Mile Cost		(7) Empty Mile Cost		(8) Revenue	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	40 CW ^a	20 CW	10 CW	20 CW	20 CW	10 CW	-10 CW	10 CW	30 CW	30 CW	25K mi	25K mi	5K mi	5K mi	25K mi	25K mi
UNITS																
RATE	\$70/CW		\$70/CW		\$70/CW		\$70/CW		\$70/CW		10¢/mi		5¢/mi		\$1.00/mi	
DOLLARS (000)	2.8	1.4	.7	1.4	1.4	.7	-.7	.7	2.1	2.1	2.5	2.5	.25	.25	25	25

	(9) Cars Stored	(10) Shipper Demand	(11) Loads Origina- ted	(12) Loads Hauled	(13) Total Cost (\$000)	(14) Contri- bution (\$000)	(15) L/E ^b Miles	(16) E Miles Per Load	(17) E Car Days OnLine	(18) E Car Days/ Load
A	0	20	15	25	4.25	20.15	5.0	200	35	1.4
B	0	10	10	25	4.85	20.15	5.0	200	35	1.4
TOTAL	0	30	25	25	9.7	40.3	5.0	400	70	2.8

^a Car week.^b Loaded/empty ratio.

SITUATION II-C: MILD RECESSION, CAR WARFARE

In this situation there is a mild recession. Demand on A is for 10 cars and on B is for 5 cars. Each railroad allows reloading of all its cars by the other.

A loads all of its 10 cars to B, and B loads all 5 of its cars to A. To keep its own cars off line earning per diem, each railroad has allowed the other to reload any of its cars. For the same reason, however, each railroad sends the other's cars home empty. This mutual returning of foreign empties and favoring of system cars for loads could be called car warfare. Results of the model are shown in the summary table (Table 8) under situation II-C.

Each railroad has met 100 percent of its shippers' demand by using only its own fleet. By using only its own cars for outbound loads, each railroad has prevented a deterioration in its net per diem compared with situation I (heavy demand).

The corollary of this policy, however, is that empty miles increase at the same time as loaded miles and therefore revenue is dropping. This is precisely what happened in 1980 compared with 1979,

as shown by the figures given in Table 5. The first half of 1979 was a period of heavy car demand. The first half of 1980 was a period of mild recession. The first five railroads are clearinghouse railroads, and the last three railroads are not. The car types included are the seven included in the clearinghouse (e.g., general-purpose boxcars, gondolas, and flats).

Another way of illustrating excessive car movement and lack of storage is to count the number of general-purpose cars delivered and received at an interchange in a loaded or empty condition. Five railroads were studied, and the results are given in Table 6. The car types are general-purpose, 50-ft box and general-purpose gondolas; and all ownerships are included (system plus foreign). The five railroads shown are not the same as those used in Table 5.

The figures in Table 6 show that although handling of loads dropped by 129,100, handling of empty cars increased by 74,300. This is shown also by the drop in the loaded/empty ratio from a healthy 1.61 to a very inefficient 1.09. It is the thesis of this paper that the railroad industry cannot afford the

TABLE 5 Situation II-C: Effects of Car Warfare on Utilization of Foreign General-Purpose Cars

RR	LOADED MILES (MILLIONS)				EMPTY MILES (MILLIONS)				L/E RATIO	
	First Half 1979	First Half 1980	CHANGE	CHANGE%	First Half 1979	First Half 1980	CHANGE	CHANGE%	First Half 1979	First Half 1980
A	161.	116.	-45.7	-28	87.1	84.0	- 3.0	- 4	1.86	1.38
B	38.8	33.6	- 5.2	-13	17.7	32.2	+14.5	+82	2.19	1.04
C	73.2	63.7	- 9.5	-13	39.2	52.4	+13.2	+34	1.87	1.22
D	75.1	64.3	-10.8	-14	35.5	50.0	+14.5	+41	2.11	1.29
E	39.8	32.1	- 7.7	-19	18.4	20.7	+ 2.3	+13	2.16	1.55
F	12.9	12.6	- .3	- 3	4.7	7.5	+ 2.8	+59	2.73	1.67
G	275.	242.	-32.6	-12	170.	213.	+43.5	+26	1.62	1.14
H	28.9	24.3	- 4.6	-16	14.9	18.2	+ 3.4	+23	1.94	1.33
TOTAL	705	589	-116.6	-17	387	478	+91.1	+24	1.82	1.23

TABLE 6 Cars Handled in Interchange: General-Purpose, 50-Foot Box and General-Purpose Gondola—All Ownerships (second quarter 1979 versus second quarter 1980)

	Railroad A		Railroad B		Railroad C		Railroad D		Railroad E		SUBTOTAL		GRAND TOTAL
	DEL ^a	REC ^b	DEL	REC	DEL	REC	DEL	REC	DEL	REC	DEL	REC	DEL + REC
Loaded Cars 1979 ^c	29.1	43.7	62.2	45.5	110.4	141.6	68.5	52.1	43.0	44.7	313.4	327.6	641.0
1980 ^c	<u>26.7</u>	<u>41.9</u>	<u>55.4</u>	<u>38.7</u>	<u>76.9</u>	<u>107.6</u>	<u>50.1</u>	<u>39.5</u>	<u>36.8</u>	<u>38.3</u>	<u>245.9</u>	<u>266.0</u>	<u>511.9</u>
Change	-2.4	-1.8	-6.9	-6.8	33.5	-40.0	-18.4	-12.6	-6.2	-6.5	-67.5	-61.6	-129.1
Change (%)	-8.3	-4.1	-11.1	-14.9	-30.4	-23.9	-26.8	-24.2	-14.4	-14.5	-21.5	-18.8	-20.1
Empty Cars 1979 ^c	30.2	15.2	27.7	46.1	90.9	55.2	27.9	44.8	30.1	29.2	206.8	190.5	397.3
1980 ^c	<u>38.9</u>	<u>22.1</u>	<u>33.3</u>	<u>49.8</u>	<u>93.0</u>	<u>68.1</u>	<u>41.0</u>	<u>52.9</u>	<u>36.5</u>	<u>35.0</u>	<u>243.6</u>	<u>228.0</u>	<u>471.6</u>
Change	8.7	6.9	5.6	3.7	2.1	12.9	14.0	8.1	6.3	5.9	36.8	35.5	+74.3
Change (%)	28.8	45.6	20.2	8.0	2.4	23.4	50.3	18.1	21.1	20.2	17.8	19.7	+18.7
Loaded/Empty Ratio 1979	0.96	2.88	2.25	0.99	1.21	2.57	2.46	1.16	1.43	1.53	1.52	1.72	1.61
1980	0.69	1.90	1.66	0.78	0.83	1.58	1.20	0.75	1.01	1.09	1.01	1.17	1.09

^a Delivered

^b Received

^c In thousands

kind of inefficient practices represented by these numbers.

Particular attention is directed to the "delivery empty" numbers. These are foreign cars being sent home. A good portion of these probably could have been used for outbound loads if system cars had been stored. Comparing empty deliveries to empty receipts, one can see that for a given railroad the numbers do not balance. For the system as a whole, of course, they must balance. This is shown in the subtotal column--36,800 deliveries is approximately equal to 35,500 receipts. There is a difference of 1,300 because these five railroads do not represent all the railroads in the country.

In Table 6 the increase in empty cars delivered for railroads A, B, D, and E is greater than the increase in empty cars received. That these railroads are pushing more empties than they are being pushed by empties obscures the fact that empty deliveries and receipts should be declining for all railroads because of the recession. The numbers show clearly that for every railroad, handling of both delivered and received empty cars increased even though the number of loaded cars delivered and received (revenue business) had declined. The average increase in handling of empties was 18.7 percent, and the average decrease in handling of loads was 20.1 percent. This inefficiency is reflected in the model when II-C (recession) is compared with I-C or I-R (strong demand).

SITUATION II-R-1: MILD RECESSION, UNILATERAL STORAGE BY A

A loads all of its cars to B. On the assumption that it will be better off by reducing empty car miles to a minimum, B stores all 5 of its cars. B then uses 5 of the A cars to fill all of its demand, and returns 5 A cars empty. Results of the model are shown in the summary table (Table 8) under situation II-R-1.

Storage of the maximum number of its cars by B has caused several important changes. First, net car

time cost for A has dropped by 10 car weeks because it is not paying B anything for foreign cars on line. Net car line cost for B has risen by the same amount. Second, empty miles have indeed been reduced--by 10,000 on each railroad. The contribution for A has risen by \$1,200. Because of the high value of car time and the relatively low value of car miles, however, the impact on the bottom line for B is less contribution than under situation II-C. B therefore rationally returns to car warfare as its best option.

SITUATION II-R-2: MILD RECESSION, UNILATERAL STORAGE BY A

Given the same shipper demand, what would happen if railroad A stored 5 cars? Results are shown under situation II-R-2 in the summary table (Table 8).

As can be seen from the previous discussion, A finds itself in the same quandary as B if it absorbs the total responsibility for storage of cars. This solution produces the highest contribution yet attained for B (\$11,850), but the worst bottom line for A. During car warfare (situation II-C) A produced a contribution of \$10,650; now it has only \$10,450.

In each of the solutions attempted, the best situation for one railroad is the worst for the other. The total contribution is higher than car warfare in either case by \$1,000, but the relatively greater importance of car time compared with car miles prevents either railroad from taking a unilateral action to solve the problem so that both railroads would be better off than in the car warfare situation.

SITUATION II-R-3: MILD RECESSION, SHARED STORAGE

What if A and B share the storage responsibilities? Because it has already been established that 5 cars

must be stored to eliminate all excess empty miles, one solution might be for A to store 2 cars and B to store 3 cars.

A loads 8 of its cars to B, and B loads 2 of its cars to A. A reloads the 2 B cars, thus meeting all demand. B reloads 3 of the A cars and sends the remaining 5 home empty. The results are shown under situation II-R-3 in Table 8.

By sharing the storage of surplus cars the railroads have eliminated all unnecessary empty car movements, and each has achieved a higher contribution than under current practices. These contribution figures are not as high as when the other railroad absorbed all storage costs, but they are a large improvement over car warfare (\$640 for A and \$360 for B). The important conclusion is that if car time cost is high enough and car mileage costs are low enough, the cost of per diem revenue foregone must be shared.

Another solution to this problem would be for one railroad to pay the other railroad to store the necessary number of cars. This payment would equal the difference between the amount received by that railroad under an optimal solution (e.g., the one above), and the amount received under unilateral storage (situation II-R-1). In this case A would pay B \$560 if B would store 5 cars rather than 3.

A comparison of situations I and II reveals a major weakness of the present clearinghouse arrangement. The clearinghouse improves utilization of cars when demand increases, but it neither encourages nor requires mutual storing of cars when demand drops.

SITUATION II-R-4: MILD RECESSION, PER DIEM RELIEF

Another variant on the sharing of cost for storage has been used, or at least proposed, in the past. It provides, for example, that if railroad A loads a railroad B car rather than sending it home empty, B will forgive A all the per diem on that car while it is held by A. Although the arrangement focuses on whether or not to load a foreign car, it is really a way to encourage and pay for the storage of a system car (in this case an A car). This is similar to the proposal the Consolidated Rail Corporation (Conrail)

made to the other railroads in September 1980. Situation II-R-4 in Table 8 gives the result.

The model shows that this strategy results in the perfect division of cost for storage of cars. A pays no per diem but receives per diem as usual. B receives no per diem for its cars off line, but it pays per diem as in the past. By using all of B's cars possible (in this case 5), A ends up storing half of its own fleet; and all excess empty miles have been eliminated. Contribution is exactly equal for both railroads, and contribution is better than situation II-C (car warfare) by \$500 on each railroad.

The advantage of this solution is that it does not set up a new method of payments between the railroads. A knows exactly what to pay or not to pay B based strictly on activity and decisions on its own lines.

SITUATION III-C: SEVERE RECESSION, CAR WARFARE

Shipper demand for transportation has dropped off sharply. Railroad A has orders for only 6 cars, and shippers on B want only 3 cars. The current industry practice would be a continuation of car warfare. A fills all its demand with its own cars, as does B. Each returns the foreign cars empty. Four A cars and 2 B cars are stored unintentionally. They are surplus in spite of the generally inefficient use of rolling stock. Situation III-C in Table 8 shows the condensed effect.

The results are similar to, but more extreme than, traditional practices in a mild recession (situation II-C). Compared with situation I-R each railroad hauls 25 loads with only 5,000 empty miles, the railroads now haul 9 loads with 9,000 empty miles each.

SITUATION III-R-1: SEVERE RECESSION, MAXIMUM STORAGE BY B

The recommended practice during a severe recession is maximum storage of cars. One way to achieve this would be for B to store all 5 of its cars and A to store the remaining excess--5 cars.

TABLE 7 Situation IV-C: Severe Recession, Car Warfare—Three Railroads

	(1) Car Ownshp. Cost			(2) Per Diem Paid			(3) Per Diem Rec'd			(4) Net Per Diem Pd			(5) Net Car Time Cost			(6) Loaded Mile Cost			(7) Empty Mile Cost			(8) Revenue		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
UNITS	280	140	0	36	72	36	96	48	0	-60	24	36	220	164	36	7200	7200	3600	7200	7200	3600	7200	7200	3600
	CD ^a	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	mi	mi	mi	mi	mi	mi	mi	mi	mi
RATE	\$10/CD			\$10/CD			\$10/CD			\$10/CD			\$10/CD			10¢/mi			5¢/mi			\$1.00/mi		
DOLLARS (000)	2.8	1.4	0	.36	.72	.36	.96	.48	0	-.6	.24	.36	2.2	1.64	.36	.72	.72	.36	.36	.36	.18	7.2	7.2	3.6

	(9) Cars Stored	(10) Shipper Demand	(11) Loads Origin- ated	(12) Loads Hauled	(13) Total Cost (\$000)	(14) Contri- bution (\$000)	(15) L/E ^b Miles	(16) E Miles Per Load	(17) E Car Days OnLine	(18) E Car Days/ Load
A	4	6	6	9	3.28	3.92	1.0	800	166	18.4
B	2	3	3	9	2.72	4.48	1.0	800	110	12.2
C	N/A	0	0	9	.90	2.70	1.0	400	18	2.0
TOTAL	6	9	9	9	6.90	11.10	1.0	2000	294	32.7

^a Car days.

^b Loaded/empty ratio.

TABLE 8 Summary of Situations

SITUATION	CAR MANAGEMENT STRATEGY	CARS STORED			EMPTY MILES (000)			CONTRIBUTION (\$000)		
		A	B	TOTAL	A	B	TOTAL	A	B	TOTAL
I. Heavy Demand	C -Traditional 20% Reload	0	0	0	12	12	24	13.5	13.5	27.0
	R -100% Reload	0	0	0	5	5	10	20.15	20.15	40.3
II. Mild Recession	C -Car Warfare No Storage	0	0	0	15	15	30	10.65	10.65	21.3
	R1-Unilateral Storage by B	0	5	5	5	5	10	11.85	10.45	22.3
	R2-Unilateral Storage by A	5	0	5	5	5	10	10.45	11.85	22.3
	R3-Shared Storage	2	3	5	5	5	10	11.29	11.01	22.3
	R4-Per Diem Relief	5	0	5	5	5	10	11.15	11.15	22.3
III. Severe Recession	C- Car Warfare No Planned Storage	4	2	6	9	9	18	4.82	5.38	10.2
	R1-Maximum Storage by B	4	5	9	3	3	6	5.99	5.71	11.7
	R2-Maximum Storage by A	7	2	9	3	3	6	5.15	6.55	11.7
	R3-Shared Storage + Per Diem Relief	5	4	9	3	3	6	5.57	6.13	11.7
IV. Severe Recession Three RR's	C -Car Warfare No Planned Storage	4	2	6	A 7.2 B 7.2 C 3.6 TOT 18.0	A 3.92 B 4.48 C 2.70 TOT 11.1				
	R1-Maximum Storage Shared by A & B	5	4	9	2.4 2.4 1.2 6.0	4.2 4.56 2.94 11.7				
	R2-Maximum Storage Shared by All 3 RR's	5	4	9	2.4 2.4 1.2 6.0	4.16 4.72 2.82 11.7				

A uses 6 of its cars to move its 6 loads to B. B uses 3 of the A cars to move its entire demand to A and returns 3 A cars empty. The car utilization and financial impacts are shown in Table 8.

As in situation II-R, maximum storing of cars by the railroads involved in the loaded movements results in a better solution for both railroads than car warfare (situation III-C). Although B receives no per diem, it saves 6,000 empty car miles. A receives a higher net per diem and also saves 6,000 empty car miles. Contribution increases by \$1,170 for A and \$180 for B.

As in situation II-R-1, the savings from reduced empty car miles are unbalanced in favor of the railroad with the highest number of cars in service. The decision as to which railroad's cars should be used and which stored can be worked out in any of the numerous ways illustrated in situation II-R. The essential change is that between them the railroads must store the 9 excess cars so the full 12,000 empty car miles are eliminated.

SITUATION III-R-2: SEVERE RECESSION, MAXIMUM STORAGE BY A

If railroad A were to store the maximum number of cars instead of railroad B, the situation would be as shown under situation III-R-2 in Table 8.

Railroad A is worse off under situation III-R-2 than III-R-1 because it loses 12 car weeks of per diem receivable. This causes its contribution to drop to \$5,150; however, it is still better than during car warfare (situation III-C) where it was making only \$4,820. The lesson is the same for a severe recession as for a mild one--all surplus cars must be stored.

SITUATION III-R-3: SEVERE RECESSION, SHARED STORAGE, AND PER DIEM RELIEF

To match the benefits exactly between the two railroads the difference in benefits must be determined

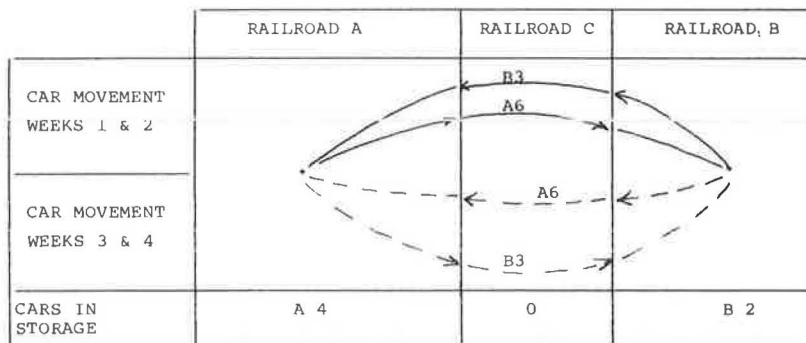


FIGURE 4 Situation IV-C: Severe recession, car warfare—three railroads.

between storing 9 cars instead of only 6 under car warfare. Under car warfare the total contribution is \$10,200. Under maximum storage the total contribution is \$11,700. The increased contribution of \$1,500 should be split evenly, so each railroad would receive an increase of \$750. This would leave A with \$5,570 and B with \$6,130. To do this would require that A store 5 cars and B store 4 cars and that A give B per diem relief for the use of one of its cars.

Why would A agree to do this? Because B is capable unilaterally of pushing A back into car warfare (situation III-C), causing A to end up with the least contribution of the four alternatives. "Half a loaf is better than none" could be said to be the moral of the story. That is, sharing the cost of storing surplus cars is preferable to the certainty that all cars will come home empty and all inbound loads will be in foreign cars.

SITUATION IV-C: SEVERE RECESSION, CAR WARFARE--THREE RAILROADS

The model can be adapted to accommodate more than two railroads. This is an example of the same system except that it now has a third (bridge) railroad (C) that neither originates nor terminates cars. It also owns no cars. The model shows that such a railroad might benefit more than originating or terminating railroads by maximum storage of excess cars in a recession and also how this problem could be ameliorated (see Tables 7 and 8).

In this situation the length of haul for A and B is 800 miles each, and for C it is 400 miles. The total length of haul is thus kept at 2,000 miles. For simplicity, it is assumed that both A and B take 6 days to move a car over their lines, and C takes 2 days to move a car over its line. Thus, the origin-destination time of 14 days is kept constant. For clarity of display, all car time rates have been changed from \$70 per car week to \$10 per car day. Traditional railroad practice would be as shown in Figure 4.

The model shows overall utilization totals equal to the two railroad situation. By not owning any cars, railroad C pulls a high portion of its total revenue to the contribution category, in spite of hauling one empty car mile for every loaded (revenue) car mile.

SITUATION IV-R-1: SEVERE RECESSION, SHARED STORAGE BY A AND B--THREE RAILROADS

One recommended practice, as in situation III-R-3, is to have A store 5 cars, B store 4 cars, and have A give B one of its cars per diem free (see situation VI-R-1 in Table 8).

This solution makes all three railroads better off than they were during car warfare (situation IV-C). The contribution for A is up by \$280, for B up by \$180, and for C up by \$240. From the viewpoint of equity, however, A and B might object to this. Without any help from C, A and B have lowered costs for all three railroads. If A or B wanted to, it could force C back to a contribution of only \$2,799, and C could do nothing to prevent it. One might say that C should benefit to the extent of having few empty car miles, but C should assist A and B on the time cost of cars that are stored. This solution can be worked out with the help of the model.

SITUATION IV-R-2: SEVERE RECESSION, STORAGE SHARED BY ALL THREE RAILROADS

What if railroad C received only the mileage savings resulting from maximum storage of cars and the remaining savings were divided between A and B? The car movement and storage diagram would be the same as situation IV-R-1, but the financial result would be as follows.

C would save 2,400 empty car miles, at 5 cents per mile (or \$120), compared with situation IV-C. The contribution for C would thus go from \$2,700 to \$2,820. Therefore \$480 of the total increase in contribution of \$600 (\$11,700 minus \$11,100) would be left to railroads A and B. If \$240 were added to A's original contribution of \$3,920, A would get \$4,160. If \$240 were added to B's original contribution of \$4,480, B would get \$4,720.

The model shows that by having C pay B \$120 and A pay B \$40, all the savings can be apportioned in a fair manner. Why will A and C agree to do this? They will agree because they know that if they do not, B's car ownership and outbound loads can force both of them back to situation IV-C and its lower contribution amounts.

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