The Cost of Empty Rail Car Supply: A Method of Allocating Empty Costs to Loaded Trips

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ABSTRACT

More than one-third of a railroad's car miles are due to empty car movements. The cost of empty rail car movements is thus a significant portion of a railroad's variable cost. The cost of these empty movements must be allocated to movements of loaded cars to determine the full cost of each loaded move. This cost information is required by railroad management for internal decision making on pricing and for performance evaluation. The reason is demonstrated why previous methods of allocating empty car costs to loaded trips do not provide accurate costs for economic decisions and a new method is proposed for allocating empty trip costs to loaded trips using a network model. The proposed method assigns to loaded trips a cost equal to the opportunity cost of an empty car at the loaded origin node less the opportunity cost of an empty car at the loaded termination node. The dual values from the linear programming optimization of empty car distribution are used to obtain the opportunity costs.

A railroad car is empty for more than one-third of the miles it travels (1); therefore, the cost of empty rail car movements is a significant portion of the variable cost of a railroad. The cost of empty car movements must be allocated to loaded cars to determine the full cost of each loaded move. Railroad management needs this cost information to make decisions about pricing and to evaluate performance. Deregulation has increased the need for an accurate and systematic method of allocating these costs.

Revenue from a loaded trip should be greater than the sum of the cost of moving the loaded car and the cost of moving an empty car to support the loaded move. Although railroad pricing decisions should be based on competitive factors, it is important for a railroad to know the floor price for a trip (i.e., the minimum price that will cover the cost of providing the trip). Different methods of allocating the cost of empty movements to loaded trips can lead to large variations in a railroad's floor price for a particular segment of traffic.

A method for allocating the cost of empty car movements to loaded, revenue-producing trips is presented in this paper. It is the intention of the author to stimulate discussion of the theory behind the method and to elicit suggestions for improvements to the basic method presented.

Unfortunately the empty movement cost allocation schemes used by railroads for internal decision purposes are not publicly available. It is the understanding of the author, however, that these allocation schemes are all sophisticated variants of either the supply or return methods discussed in the second section.

There are two areas of published research relevant to this topic: (a) physical distribution of empty cars, and (b) cost structure of railroad operations. The car distribution literature uses network algorithms to develop optimal car distribution strategies. The literature on cost allocation separates the railroad's costs into components that can be attributed to car trips. This second body of literature has provided increasingly sophisticated methods for separating fixed and variable costs and for assigning these costs to trips, both loaded and empty, but has not provided an adequate method for allocating the cost of empty trips to loaded trips.

This paper draws on both the car distribution literature and the cost allocation literature to develop a method for allocating the costs of empty trips to loaded trips. Although this paper is not concerned with the optimal distribution of empty cars, it applies the dual values from the linear programming solution to that optimization problem. The dual values provide the opportunity costs of delivering additional empty cars to each location on the network. The method proposed here uses these opportunity costs (the shadow prices) to develop the appropriate empty trip cost to be assigned to each loaded trip.

The following topics are discussed in this paper:

1. A review of the two areas of published research mentioned previously.
2. The uses of empty car cost allocation and why previous approaches do not provide accurate costs.
3. A new approach to allocating empty car costs and its application to a hypothetical three-node network.
4. The results of applying the method to the movement of intermodal trailers on an actual railroad network.
5. Conclusions and suggestions for further research.

LITERATURE REVIEW

The subject of the cost of empty car movements has primarily been addressed in the published research in terms of cost reduction rather than cost allocation. There is a substantial body of literature concerned with the actual movement of empty cars. This literature treats cost reduction as a primary goal for optimal distribution of cars.

The literature on car distribution has provided a series of increasingly sophisticated network models that can be used as tools in railroad operations (2-4). Instead of developing a complex network model for this analysis, a simple model is used in a new way. The contribution of this paper is to show how a network model can be used in cost allocation.

The idea of using a network model to determine the costs of moving empty rail cars was suggested by French (5). His work concerned the change in empty car cost that would occur with different foreign car reload strategies. He suggested using a network model to determine the effect of various policies on operations and thus costs. French was not concerned with allocation of empty car costs among loaded trips.

The work in the car distribution literature most closely related to this paper is the two-stage network model developed by Mendiratta (6). That application is similar because it specifically recognizes the usefulness of the dual solution to the linear programming minimization of car distribution costs. Mendiratta uses the dual values as opportunity costs that line managers must consider to ensure that the decentralized decision-making process of railroads is economically rational. Mendiratta, however, is clearly concerned with car distribution and cost reduction, not cost allocation.

On the other hand, the published research on railroad cost allocation has not fully addressed the costs incurred by empty car movements. The primary focus of the published literature on railroad cost allocation has been the distinction between accounting and economic costs and, concurrently, between fixed and variable costs (7,8). The allocation of the cost of empty car movements has not received debate in the literature. Allocation has been based on simple techniques, such as multiplying the loaded cost by the overall ratio of empty-to-loaded miles. Although these techniques serve to allocate empty cost among loaded trips, the allocations to specific loaded trips often do not reflect the costs incurred accurately. Railroad cost professionals, however, have debated the appropriate method for allocating empty movement costs for at least 20 years.

The Interstate Commerce Commission (ICC) policy has been to treat the empty car movement cost as a joint cost that cannot be differentiated by the direction of movement of the loaded trip (9,10). Recently the ICC has introduced a new costing system, Uniform Railroad Costing System (URCS), which provides regression equations to develop fixed and variable cost components. This system, however, continues to allocate empty car cost in a broad, imprecise fashion.

Empty Car Cost Allocation

Empty car costs must be assigned to loaded trips so that management can compare the revenue generated from the trip with the variable cost incurred to make the trip. When total empty car movement costs are greater than a railroad's total contribution (revenue minus variable cost), the improper allocation of the railroad's empty car movement costs among the loaded trips may make unprofitable traffic segments look profitable and vice versa.

Deregulation has given railroad management tremendous flexibility in setting prices. Now accurate allocation of empty car movement costs are necessary for contract negotiations. A railroad's contract negotiators must have an accurate estimate of costs to avoid a contract that requires the railroad to move the traffic at a loss. Empty car cost must be accurately allocated and paired with the cost of loaded trips to develop a price floor below which the railroad cannot afford to accept the traffic.

An empty cost allocation method must address two issues: (a) supply versus return, and (b) backhaul. The first issue is essentially a chicken or egg question--whether a load should be assigned the cost of the previous empty (supply of an empty car to the loaded origin) or the subsequent empty (return of an empty car after a loaded trip delivery). Previous methods of allocating empty car movement costs to loaded trips have used either the supply or the return perspective. The second issue is whether some loaded moves actually reduce the necessity for empty movements and should therefore be allocated a credit rather than the cost of an empty trip.

Supply Versus Return

The question of supply versus return is illustrated in Figure 1, which shows a simple railroad network with four nodes (A, B, C, and D) serving Grain Inc. and Lumber Company. Grain Inc. loads cars at B and ships them 500 miles for unloading at C. The cars are then moved empty for 200 miles from C to D. At D, Lumber Company loads the cars for a 500-mile trip from D to A. At A the cars are unloaded then moved empty for 400 miles to B. The cycle repeats starting with Grain Inc. at B.

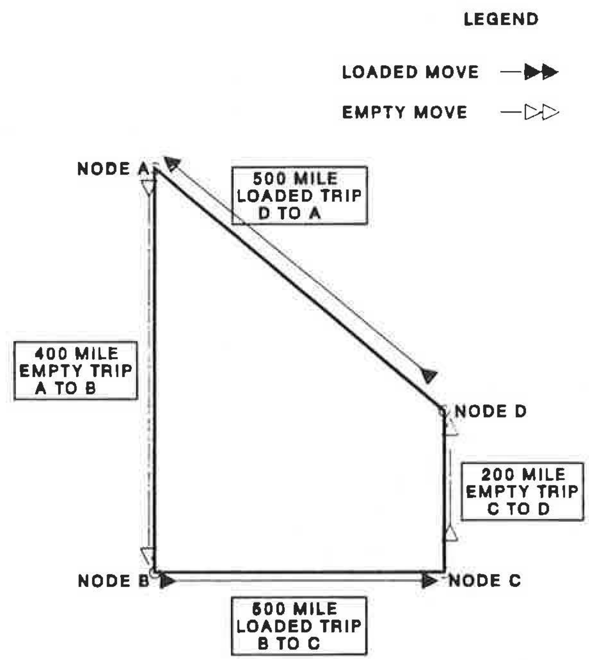

FIGURE 1 Supply versus return.

Fewer empty miles are incurred by moving the cars in a cycle instead of returning the empty car to its previous loading point. A total of 600 empty miles are incurred for the cycle. If the empties were reverse routed at their unloading point, 1,000 empty miles would be incurred. Given that the railroad moves cars in the more efficient traffic pattern, 600 empty miles must be allocated to the two shippers. If empty cars are viewed as goods supplied to a shipper, the loaded trip would be charged for the empty movement to the loading point. Thus Grain Inc. would be charged for the 400-mile empty movement from A to B and Lumber Company would be charged for the 200-mile empty movement from C to D.

An alternative view is that empty cars are the result of loaded moves, the unfortunate end result of a loaded termination. In this view loaded trips create empties that must be moved (returned) to the next loading point. From this perspective Grain Inc. should be charged for the 200-mile empty movement from C to D and Lumber Company should be charged for the 400-mile empty movement from A to B.

The merits of the supply viewpoint are illustrated in Figure 2. The railroad depicted here has a three-node network with all but one of its shippers moving loads between A and B. Lumber Company is located outside the bidirectional loaded flow; it loads cars at C that are destined for B. Clearly Lumber Company should bear the cost of moving the empties from B out to C. The return view is inappro-

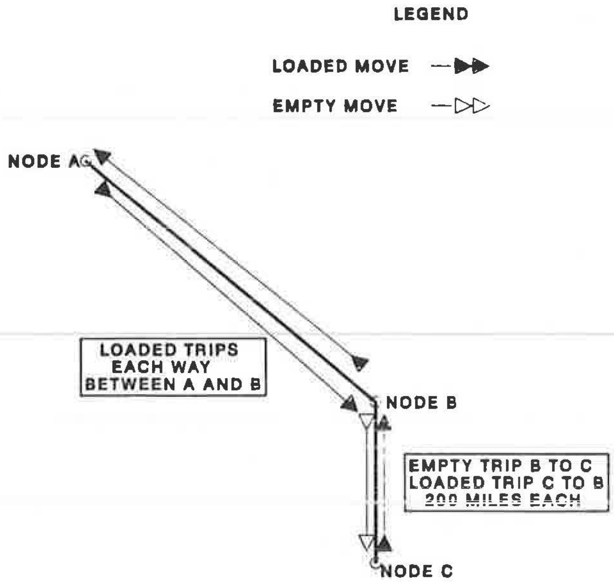

FIGURE 2 The supply view.

priate in this case because it would assign only some of the cost of moving empties from B to C to Lumber Company, leaving the other shippers to bear the remainder of the cost.

The merits of the return viewpoint are illustrated in Figure 3. As in Figure 2, the railroad has a three-node network with all but one of its shippers moving loads between A and B. Here the unusual movement pattern is caused by Grain Inc., which ships loaded cars out of B to C. In this case Grain Inc. should bear the cost of moving the empties from C back to B. The supply view is inappropriate because it would spread the burden of the C to B empty movements over all shippers when the cost is only incurred by Grain Inc.

Neither the supply view nor the return view is correct in all situations. However, each provides the correct solution in some situations. An allocation method based on either view would be in error because its perspective would be limited to the individual shipper's movements. An appropriate allocation method must reflect the implications for both supply and return of each shipper's movement. To do this the analysis must be expanded to recognize shippers' movements in a network context. The method must transcend the question of supply versus return to provide a way of analyzing network flows.

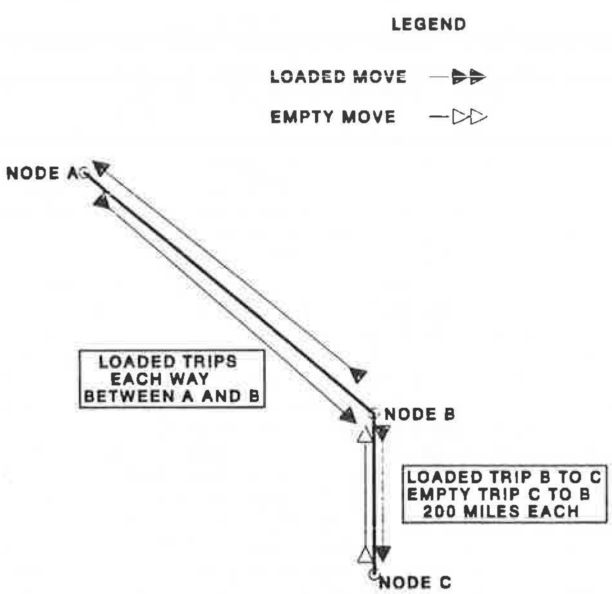

FIGURE 3 The return view.

Backhaul Trips

The second issue an empty car cost allocation method must address is the treatment of backhaul trips, which are loaded movements in the direction empties are usually sent. Backhaul trips are desirable because they reduce the number of empties that must be moved. The backhaul load replaces one empty car movement.

Backhaul loads provide an economic benefit to the railroad. The cost of a loaded trip is incurred, but the cost of an empty car movement is avoided. The railroad's net cost for the backhaul movement is the loaded cost less the avoided empty car cost. For backhauls, instead of adding some empty movement cost to the loaded cost, the avoided empty movement cost should be subtracted from the loaded trip cost. Backhauls should get empty movement credits for the empty trips they replace.

An appropriate allocation method must assign empty car credits to backhaul loads while still allocating the full costs incurred in moving empty cars on the network. If the full empty cost incurred were assigned to loaded trips, then reduced by backhaul credits, the net result would be an allocation of empty costs that would sum to less than the total empty cost actually incurred. Backhaul credits cannot be included as an afterthought or the total cost will not be allocated. The allocation method must account for backhauls as an integral part of its allocation scheme.

The solution to the backhaul issue is basically the same as the solution to the supply versus return issue--treat each load as it relates to the system network. Both issues occur because trips are treated out of the network context, which gives rise to the necessity of empty movements. If empty car costs are allocated to loaded trips without considering the place of each loaded trip in the network, railroad management will not have the necessary economic information to make rational decisions.

METHODOLOGY FOR A NEW APPROACH

It was asserted in the previous section that an appropriate allocation of empty car costs will occur only if the allocation method recognizes the place of each loaded trip in the network. In this section a method is developed that uses such a network perspective to allocate empty car costs to loaded trips.

Two concepts underlie the proposed method of allocating costs of empty car movements to loaded car trips:

- A loaded rail car trip not only transports goods from one location to another, but it also transports an empty rail car from one location to another.
- An empty rail car has a value to the railroad that is dependent on the rail car's location on the system.

Taken together, these concepts imply that a loaded car trip is taking, at the loaded trip's origin, an empty car worth one value and leaving, at the loaded termination, an empty car with a different value.

The loaded trip changes the value of the empty rail car by moving it from one location to another.

The proposed method is based on these two concepts.

- Determine the value of an empty at each node that reflects supply and demand for empties at that node; and
- Assign the empty car values to loaded trips (a) as a cost when the loaded move takes an empty from a node and (b) as a credit when the loaded move delivers an empty to a node.

The value at the node should be the opportunity cost to the railroad of providing an additional empty at that node. The empty car cost assigned to the loaded trip would then be the opportunity cost of having available the empty car used to supply the load, less the opportunity cost of the empty car the load leaves at the loaded trip termination.

Opportunity cost is an economic concept that means the value of the best available opportunity is foregone because of the action. A loaded trip is initiated by removing one empty car from the pool of available empty cars and targeting it for the loaded trip. The opportunity cost of the targeted empty is the amount of money that had to be spent to make the empty available at the location.

Information on the supply and demand for empties is necessary to determine the opportunity cost of empties at each node. At nodes with surplus empty cars, this value would be low because empties are readily available. At nodes with a deficit of empty cars (i.e., with more originations than terminations) the value would be higher because empties must be brought from distant points to meet the loading demand.

The following example demonstrates the concept of opportunity costs for the three-node railroad network shown in Figure 4. Table 1 gives the relevant loaded flow statistics. There are no interchanges in this example so all loaded and empty movements are between the three nodes: A, B, and C. Node A has more originations than terminations, so empty cars must be brought to A to meet loaded demand there. Conversely B and C have more terminations than originations, thus excess empties are available at these two nodes. Because there is no slack in the system, there is no question about car distribution. To meet the demand, all the excess empty cars at both B and C must be moved up to A.

This example is provided to show how the opportunity cost of an empty at each node is derived. Table 2 provides the relevant cost information. For simplicity it is assumed that the cost of moving between nodes does not vary with direction. Note that the total cost of moving the empty cars to loading points is $14,400 (i.e., 13 x $300 for moving empties from B to A plus 15 x $700 for moving empties from C to A). The value of having an additional empty car at A would be $700. A $700 cost could be avoided if one less empty car were moved from C to A.

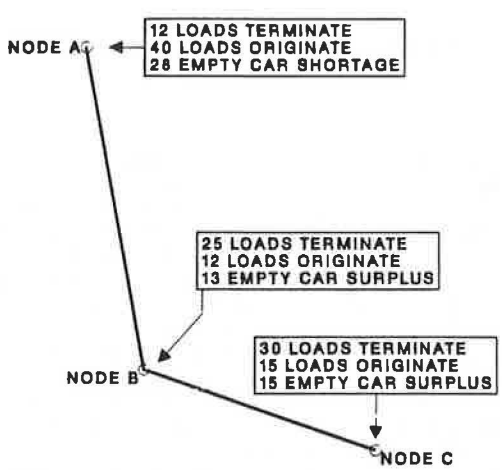

FIGURE 4 An example for the proposed method.

TABLE 1 Loaded Car Movements

To	From A	From B	From C	Total Terminations
A	0	2	10	12
B	20	0	5	25
C	20	10	0	30
Total orginations	40	12	15	67

TABLE 2 Transportation Costs ($)

	Tare	Gross	Net
C to B	400	550	150
C to A	700	1,050	350
B to A	300	500	200

If there were an additional empty car at B, the cost incurred by one empty car movement from C to A ($700) could be avoided. However, the cost of moving the additional car at B up to A ($300) would be incurred. The value of an additional empty car at B would be the $700 cost that would be saved less the $300 cost than would be incurred (i.e., $400). There would be no value to having an additional empty at C. C is the highest cost supplier of empties to A. Thus the values assigned to the nodes would be

Node	Value ($)
A	700
B	400
C	0

Loaded car trips would be assigned empty car costs as shown in Table 3. This method assigns backhaul credits for loaded trips moving from B to A and from C to A. This is appropriate because backhaul moves save the railroad money.

The total amount of empty car costs that would be assigned in this example is shown in Table 4. This sum is the same as the amount of empty car cost incurred. The proposed method for allocating empty car costs to loaded car trips will always result in al-

TABLE 3 Costs Assigned per Loaded Car ($)

From	To	Loaded Cost	Origin	Termination	Net	Total Cost Assigned
C	B	500	700	400	300	800
B	A	500	400	700	-300	200
A	C	1,050	700	0	700	1,750
C	A	1,050	0	700	-700	350
B	C	550	400	0	400	950
C	A	550	0	400	-400	150

TABLE 4 Total Empty Costs Assigned

From	To	No. of Trips	Empty Costs ($)	Total ($)
A	B	20	300	6,000
B	A	2	-300	600
A	C	20	700	14,000
C	A	10	-700	-7,000
B	C	10	400	4,000
C	B	5	-400	-2,000
Net cost assigned				14,400

located empty car costs that exactly equal actual empty car costs incurred if three conditions are met:

- Actual car distribution is optimal;
- Loaded moves occur in a repeating pattern; and
- There is no slack (i.e., there are only just enough empty cars to satisfy demand).

The first condition would have been violated in the example if an empty car had been moved from B to C and then to A. This would appear foolish in the example; but on more complex networks, when loaded demand cannot be perfectly predicted in advance, such suboptimal moves do occur. These moves are the result of imperfect knowledge and do not necessarily reflect badly on the skill of car distributors.

The second condition, assumed to occur in the example, also will not exactly occur in the real world. Although railroads do experience consistent loaded movement patterns, an exact car-for-car repeat is not likely to occur. Exclusion of slack, the third condition, requires the same number of loads in each period. This is also unlikely.

To summarize, the method proposed in this section meets the two criteria established previously. The proposed method provides the appropriate network view, which reflects the implications of both the empty supply and return of the loaded move. This formulation of a network model is achieved by assigning opportunity costs as empty car values at each node. The method also provides the appropriate backhaul credits because the cost assigned, the difference between nodes, will be negative when a load moves from a low-value node to a high-value node. However, the proposed method has two potential problems:

- The development of opportunity costs requires a thought process that may be difficult to apply to large networks, and
- The allocated empty car costs will not exactly equal the empty car cost actually incurred, except under ideal circumstances.

The following section addresses these potential problems. It shows how opportunity costs can be easily derived and it provides an estimate of the error introduced by not exactly satisfying the conditions for assuring that allocated costs exactly equal actual costs.

APPLICATION TO MOVEMENT OF INTERMODAL TRAILERS

The opportunity costs for the three-node network were readily derived without the use of a computer. Most railroads, however, have more complex networks and could not easily derive the necessary opportunity costs. It is therefore proposed that the dual values from the linear programming optimization of car distribution be used to provide estimates of the railroads' actual opportunity costs. This section explains how the dual values can be obtained and reports the results of an application of the proposed empty car cost allocation method to a railroad's intermodal dry trailers.

Linear programming will generate the appropriate empty car values to assign to each node. The dual solution to a linear programming formulation of an empty car distribution problem also provides the opportunity costs for the nodes (shadow prices). The dual values represent the benefit of having additional empty cars at the nodes. Thus, the dual values are the opportunity costs required for the proposed empty car costing method. The only necessary assumption for these values to be accurate is that the railroad's actual car distribution closely approximates the ideal (optimal) distribution.

To formulate the linear program that would be used for the example discussed above, the node relationships must be redefined in terms of matrix variables as follows:

	To		
From	A	B	C
A	X(1,1)	X(1,2)	X(1,3)
B	X(2,1)	X(2,2)	X(2,3)
C	X(3,1)	X(3,2)	X(3,3)

The linear programming formula is

$$\begin{aligned} \text{Minimize } Z = {} & 0\,X(1,1) + 300\,X(1,2) + 700\,X(1,3) \\ & + 300\,X(2,1) + 0\,X(2,2) + 400\,X(2,3) \\ & + 700\,X(3,1) + 400\,X(3,2) + 0\,X(3,3) \end{aligned}$$

subject to:

Supply

$X(1,1) + X(1,2) + X(1,3) \leq 12$

$X(2,1) + X(2,2) + X(2,3) \leq 25$

$X(3,1) + X(3,2) + X(3,3) \leq 30$

Demand

$X(1,1) + X(2,1) + X(3,1) \geq 40$

$X(1,2) + X(2,2) + X(3,2) \geq 12$

$X(1,3) + X(2,3) + X(3,3) \geq 15$

The resulting dual values are

Supply Equations

A	700
B	400
C	0

Demand Equations

A	-700
B	-400
C	0

The dual values for the supply equations can be interpreted to represent the cost reduction that could be obtained if additional cars were available at the nodes. These values are the same as the opportunity costs in the previous section. As expected, linear programming produces the same values as the opportunity costs developed previously. The dual values for the demand equations are equal in magnitude but opposite in sign to the dual values for the supply equations. This is because the demand equation dual values represent the increase in cost that would occur if more empties were needed at the nodes.

The proposed method was applied to a railroad's intermodal dry trailers. The three-node linear programming formulation was expanded to 14 nodes to represent the railroad's 14 major intermodal ramping areas. The supply and demand constraints were developed from actual April 1983 loaded trailer moves. Loaded trailers originating in an area were counted as demand for trailers and loaded trailer terminations were counted as supply. Loaded trailers received from other railroads at interchanges were excluded from the demand count and interchange-forwarded loads were excluded from the supply count. Empties received at interchanges and empties forwarded at interchanges were added to the supply and demand counts, respectively.

The costs for the objective function were developed from 6 months of historical data; and when available, the average cost of empty movement for the node pair was used. The costs were direction specific. When no observations existed for a node pair, costs from other corridors were extrapolated.

After the dual values were obtained from the solution of the linear programming model they were applied back to the loaded trips as costs at origins that were reduced by the value of empty cars at terminations. Interchange traffic received a 0 value at the interchange point. Thus, the empty cost allocated to a load that was received at an interchange was zero minus the value of an empty at the terminating location.

This method was able to allocate 79 percent of the empty trailer cost that had actually been incurred in April. The 21 percent of empty cost that was not captured by this method was attributed to three factors: the time frame used in the study, uncertainty of supply and demand, and operating decisions unrelated to cost.

The time frame is a problem of static analysis. By aggregating 30 days of demands and supplies into 1 month of data, the linear programming model did not have to face momentary supply imbalances that actually occurred. Examination of the actual flows of empties over the month showed empties being sent from A to B as well as from B to A, which appeared at first glance to be inefficient and nonsensical. However, these movements were not due to faulty empty car distribution decisions but rather to a surplus at A at the start of the month and a deficit at A later in the month.

The second factor, uncertainty of supply and demand, is discussed by Jordan (11). Decisions regarding the distribution of empties must be made before complete information is available regarding the availability of empties and the need for empties. A model using historical information can always efficiently distribute empties.

The third factor, operating decisions not rigorously based on cost criteria, mostly relates to car distribution decisions based on customer relations rather than cost efficiency. When an important customer is ready to load, distribution may be based on satisfying that customer first and not striving for optimal car movement on the network. Although a slight delay may result in additional loaded terminations providing empties in close proximity to the customer, customer satisfaction takes priority over waiting for these potential economies to develop.

To complete the test application, the 21 percent of actual empty trailer cost not allocated by the method was applied as a flat charge to each trailer. Statistics on profitability by corridor were then calculated using this new allocation of empty trailer costs and compared with the results of more traditional methods.

This new proposed allocation appeared to provide the best ordinal ranking of corridor profitability. However, costs for individual loaded moves ranged from the cost of the tare weight of the loaded move to many times that amount. Although it was agreed that these costs accurately represented the economics of the moves, the large swings in cost for similar distance moves was startling. (Specific cost information is proprietary and cannot be presented here.)

CONCLUSIONS

This paper presented a new use for the linear programming formulation of empty car distribution. Although previous research efforts using linear programming have focused on car distribution itself, this paper assumes that car distribution is adequate and attempts to allocate the associated costs to loaded trips. Current cost allocation schemes do not reflect empty cost incurrence adequately. The proposed method appears to reflect cost incurrence correctly in ideal circumstances and was shown to approximate closely actual cost incurrence of a railroad's intermodal trailers.

Empty car costs are a significant portion of a trip's variable cost and can have a dramatic effect on profitability studies and pricing decisions. As railroads have more flexibility in pricing because of deregulation, they need more precise cost analysis of traffic segments. The proposed method of allocating the cost of empty cars has theoretical appeal. It resolves the conflict between empty supply and empty return and it provides backhaul credits. As was shown, the method can be computerized using linear programming.

Although this paper reported the application of the proposed method to intermodal dry trailers, the method can also be used for any car type. However, each car type should be modeled separately. Because distribution patterns vary considerably by car type, an aggregation of all car types would provide meaningless results.

This method allocates the line-haul portion of empty car costs. The cost of local train gathering and distribution of empty cars should be costed separately. It is suggested that through train crew change points serve as nodes. This results in more accurate modeling of actual car distribution decisions and also reduces the size of the linear programming formulation. Thus, although a railroad may have many thousands of stations, only approximately 50 nodes are used to apply this technique to car types. For intermodal trailers, as previously discussed, only 14 nodes were required.

Any railroad could use this method by adding a linear programming capability to their computer system. The railroad would only need to know the origination points and termination points of its loaded moves and the nodes and volume of interchange traffic. If route-specific costs were not available, a railroad could use for the objective function a system average-per-mile line-haul cost multiplied by mileage; however, some concerns remain regarding this method:

1. Use of this method provides startling results compared with average cost data. However, if the ordinal ranking of costs is accepted, this ranking could be preserved while modifying the values.
2. Calculation of shadow prices is based on a 1-month snapshop of supply and demand when actual car distribution is limited to a much smaller time frame.
3. Calculation of shadow prices is based on discrete time periods for supply and demand when a moving window in time would more accurately reflect railroad operations.
4. Backhaul credits are applied to all loaded trips into empty car deficit nodes. This definition of backhaul may be too broad.

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.E. 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