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Surface Freight: Rail, Truck, and Intermodal

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Part 1
Railroad Operations

Tactical Planning for Coordinating Railroad Operations

PETER J. WONG, BJORN CONRAD, JEROME M. JOHNSON, AND
NICK LAY

Tactical (shift-by-shift) planning procedures for improving operations on the Grand Trunk Western Railroad are described. The tactical planning procedures are designed to improve the decision-making ability of dispatchers and yardmasters by explicitly requiring them to plan and coordinate their activities for the entire shift at the beginning of the shift. The procedures are centered around a systemwide nominal operating plan, which is adjusted during each shift on the basis of predictions of train and yard activities obtained from a simulation called the Dynamic Movement Predictor. Because of the systemwide planning and coordination inherent in these tactical planning procedures, the result should be improved labor productivity, car transit time, and trip reliability.

This paper describes tactical (short-term) planning procedures for improving the dispatching and yard operations of the Grand Trunk Western (GT) Railroad.

The decision makers who directly control the movement of cars on a railroad on an operational basis are the dispatchers and yardmasters. Dispatchers control the movement of trains on the line-haul portion of the railroad, and yardmasters control the movement of cars within a yard and terminal district. Dispatchers and yardmasters historically have had to react to problems and have not been able to plan the optimization of their own local operations and coordinate them with total systemwide operation. This lack of tactical planning and systemwide coordination contributes to the problems of low labor productivity, inefficient use of the physical plant, excessive car transit times, trip unreliability, and low car utilization.

The tactical planning process requires accurate current and predictive data on yard inventory, train consist, and train movement. These data are provided by GT's Railroad Automated Identification Location System (RAILS), which uses the advanced technologies of automatic-car-identification (ACI) scanners and advanced computer and communications hardware to instrument and monitor the entire GT railroad (1). Predictive yard-inventory, train-consist, and train-movement data are provided by the Dynamic Movement Predictor (DMP), which is a systemwide railroad simulation model constructed by Stanford Research Institute International to interface with RAILS and to run sufficiently fast to be useful in a tactical operating environment (2).

OVERVIEW OF TACTICAL PLANNING PROCESS

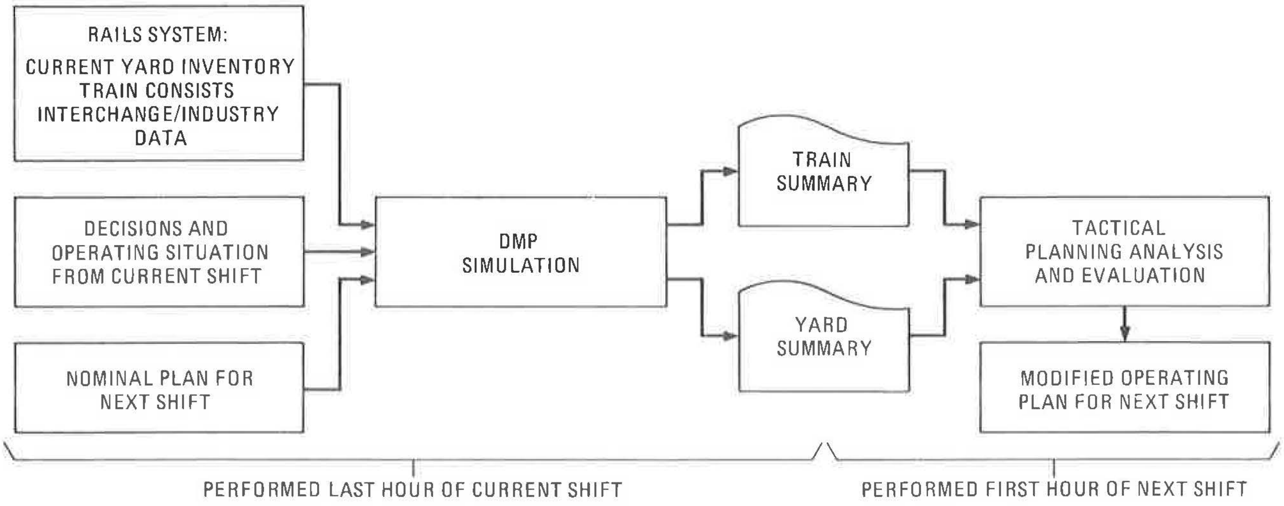
Figure 1 shows an overview of the tactical planning process. The DMP simulation is run at the end of each shift so that the outputs can be ready for evaluation at the beginning of the next shift. This requires that, at the end of each shift, the following information be input to the DMP:

1. RAILS data on current yard inventory and train consists and predictive interchange and industry data,
2. Decisions and operating situations from the current shift, and
3. Nominal schedule of operations for the next shift.

Much of the RAILS data will be automatically input to the DMP; a large amount of the interchange and industry data will be obtained manually via telephone calls to appropriate yards or foreign roads. The DMP simulation requires information on the current operation of trains that will still be in operation during the next shift and on any abnormal system problems (e.g., track outages and slow orders). The DMP also requires a nominal schedule of operations for the next shift (essentially a forecast of how the next shift should be run).

The DMP simulation will process the above inputs and produce the train summary and yard summary as outputs. These outputs, which are presented to the dispatchers and yardmasters for tactical planning at the beginning of the next shift, predict what the yard inventories and train consists would be if the nominal operating plan were actually implemented. Each dispatcher and yardmaster develops a plan of his or her own local activities at the beginning of the shift on the basis of an attempt to implement a systemwide nominal operating plan. Changes in the nominal operating plan, based on examination of the

Figure 1. Tactical planning process for dispatching.



DMP predictions of yard inventory and train consists, are determined early in the shift and negotiated between the dispatchers and yardmasters as the need arises. Modifications to the nominal plan may result from traffic conditions, operating constraints, and plant conditions not accounted for in the nominal plan.

In this manner, the nominal operating plan provides the central mechanism for ensuring that local decisions are made with a systemwide perspective. Decisions to deviate from the nominal plan are efficiently communicated and coordinated as modifications or exceptions to the plan. As a consequence, the planning process allows dispatchers and yardmasters to

1. React to daily traffic and operating variabilities in a coordinated manner,
2. Consider the systemwide consequences of decisions,
3. Provide a basis for more precise coordination between the dispatching and yardmastering operations, and
4. Consider the impact of current decisions on future events.

TACTICAL PLANNING PROCESS FOR DISPATCHING

General

The main intent of the tactical planning process for dispatching is to provide the dispatching function with an operating plan for the next shift. Such a plan should expedite the movement of traffic from a systemwide viewpoint, keep yards from becoming congested, and allow efficient use of dispatching resources (e.g., engines and crews) and of yard resources.

At the beginning of the shift, the dispatching office is presented with DMP predictions on train and yard activities based on a nominal operating plan. The dispatching planner analyzes these predictions to determine whether modification to the nominal plan should be made to account for day-specific traffic levels and operating conditions, such as light or heavy traffic demand, shortages of locomotives or crews, and track repair and outages.

In the case of light traffic demand, some trains must be canceled, and the work of these canceled trains must be reassigned to other train crews (subject to the federal regulation that the operating crew can work for a period of not more than 12 h). The starting time of trains whose work is reassigned may be rescheduled to accommodate the new traffic. In the case of heavy traffic demand, extra trains may be added, and trains may run heavy, which slows them down. The work of these heavy trains may have to be reassigned so that they will carry fewer blocks (groups of cars classified for movement to the same yard or terminal).

If the traffic increases unexpectedly or if there is an unexpected number of locomotive failures, a shortage of locomotives and crews may occur in the short term. Under the circumstances, trains may be heavy and therefore run more slowly. Changes to the nominal plan may be made to minimize the systemwide impacts of these shortages by reblocking trains so that they run more heavily and the priority traffic is moved on time.

Frequently, portions of track are out of use or there are orders to slow down for varying amounts of time due to track repairs. These track disruptions can significantly affect the running times of trains. The scheduled departure time may have to be adjusted to account for these track conditions.

In general, the dispatching planner can modify the nominal plan by

1. Canceling trains or adding extra trains,
2. Changing the starting time of a train,
3. Adding or canceling scheduled stops of trains, and
4. Changing the blocks (classifications) picked up or set out at the stops.

There are fundamental constraints on the degree of modification to which the nominal operating plan can be subjected on a daily basis, after the work rules, the 12-h law, the nature of the train, terminal restrictions, and traffic priorities have been taken into consideration. Because decisions about individual trains affect other trains, these decisions should be planned and orchestrated from a systemwide viewpoint. In the tactical planning procedure for dispatching, the modifications to the nominal plan should be finished by the dispatching planner approximately one hour into the next shift; this modified plan is then given to the dispatcher for implementation.

DMP Predictions

At the beginning of each shift, the dispatching office receives the DMP predictions for an initial nominal operating plan for the shift. The predictions of train activities and yard activities are in the form of train-summary and yard-summary reports, respectively. Trains are designated by a three-digit number (e.g., 391); an extra section of the train is designated by placing the number 2 in front of the usual train number (e.g., 2391). Yards and stations are coded with a three-digit number, and blocks are coded with a two-digit number.

A sample train summary is shown in Figure 2. "Yard number" indicates the scheduled yard stops. For each train and each yard stop, the train summary provides the following information:

1. The arrival time, the day (Julian date, which is the number of days elapsed in the year), and the number of cars that arrived on the train;
2. The number of cars that have been set out for each block;
3. The number of cars that have been picked up for each block;
4. The departure time, the day (Julian date), and the number of cars that departed on the train; and
5. The gross tons and car miles accumulated by the train up to that stop.

A sample yard summary for Battle Creek Yard (Yard 837) is shown in Figure 3. Similar outputs are available for all yards in the system. The blocks are listed in the first column. The arrival and departure of trains and the time and Julian date of the arrival or departure are given across the top of the summary. For each train arrival or departure, the net change in the number of cars in each block is indicated and the cumulative total of cars that remain in the block is noted. Traffic not brought to the yard by a GT main-line train but from interchange or local industry is treated like a train arrival but would be denoted "Traffic."

Development of a Modified Nominal Plan

To produce an operating plan, the dispatching planner analyzes the train-summary and yard-summary reports in a manner similar to the following:

1. For each yard in the yard summary, the time at

which priority blocks become exceptionally large is circled, and the time at which the yard is expected to be congested is marked.

2. Trains predicted to be light, heavy, or late are circled and noted on the train summary.

3. Trains identified as running light are reviewed to see whether they can carry some of the large blocks in the congested yards that were

Figure 2. Train summary.

```
TRAIN    YARD    ARRIVAL   WITH   ******** SETOUT *********   ******** PICKUP *********   DEPARTURE  WITH  GROSS   CAR
NUMBER  NUMBER  TIME  DAY  CARS   NO. OF CARS (BLOCK NO.)     NO. OF CARS (BLOCK NO.)     TIME  DAY  CARS  TONS   MILES

 371     837       0    0           0( 0)    0( 0)    0( 0)   52( 5)    0( 0)    0( 0)   1400  209   52   2149       0

         842       0    0   52                                                           1430  209   52   2149    1138

         903       0    0   52                                                           1540  209   52   2149    4102

         913       0    0   52                                                           1625  209   52   2149    5990

         918       0    0   52                                                           1659  209   52   2149    7436

         951       0    0   52                                                           1712  209   52   2149    8002

         952       0    0   52                                                           1716  209   52   2149    8106

         954    1722  209   52     52( 5)    0( 0)    0( 0)    0( 0)    0( 0)    0( 0)      0    0    0      0    8268



TRAIN    YARD    ARRIVAL   WITH   ******** SETOUT *********   ******** PICKUP *********   DEPARTURE  WITH  GROSS   CAR
NUMBER  NUMBER  TIME  DAY  CARS   NO. OF CARS (BLOCK NO.)     NO. OF CARS (BLOCK NO.)     TIME  DAY  CARS  TONS   MILES

 385     811       0    0                                                                 600  209   26   1302    1128

         815     625  209   26      0( 0)    0( 0)    0( 0)    6(18)    3( 1)    2( 5)    725  209   61   3002    1643
                                                               3( 7)    8( 8)    8(10)
                                                               5(11)    0( 0)    0( 0)

         819       0    0   61                                                            725  209   61   3002    1649

         827     745  209   61      3(21)    5(23)    1(24)   18( 1)    1( 2)   13( 5)    835  209  140   5486    2387
                                    1(25)    1(27)    0( 0)    5( 7)   11( 8)    9(10)
                                    0( 0)    0( 0)    0( 0)   16(11)    1(12)    7(13)
                                    0( 0)    0( 0)    0( 0)    1(14)    1(15)    7(17)

         830       0    0  140                                                            933  209  140   5486    7021

         831       0    0  140                                                           1009  209  140   5486    7035

         837    1120  209  140     21( 1)    1( 2)   15( 5)    0( 0)    0( 0)    0( 0)      0    0    0      0   12859
                                    8( 7)   19( 8)   17(10)
                                   29(11)    3(12)    7(13)
                                    1(14)    1(15)   11(17)
                                    6(18)    1(44)    0( 0)
```

Figure 3. Sample yard summary: Battle Creek Yard (Yard 837).

```
              398        511        513        500        387       -386        512        385        391        433
CLASS       ARRIVES    DEPARTS    DEPARTS    DEPARTS    ARRIVES    DEPARTS    ARRIVES    ARRIVES    ARRIVES    ARRIVES
            547/209    615/209    745/209    800/209    811/209   1000/209   1019/209   1120/209   1121/209   1127/209
--------------------------------------------------------------------------------------------------------------------------
CHICAGO      0(  88)    0(  88)    0(  38)    0(  88)    0(  88)    0(  88)    0(  88)   22( 110)   35( 145)   21( 166)
CHGO CNW     0(  19)    0(  19)    0(  19)    0(  19)    0(  19)    0(  19)    0(  19)    0(  19)    0(  19)    4(  23)
RAILPORT     0(   7)    0(   7)    0(   7)    0(   7)    0(   7)    0(   7)    0(   7)    0(   7)    4(  11)    0(  11)
BISL CNW     0(  29)    0(  29)    0(  29)    0(  29)    0(  29)    0(  29)    0(  29)   15(  44)    1(  45)    7(  52)
BLUE I.      0(  14)    0(  14)  -14(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)
ROCK I.      0(  48)    0(  48)    0(  48)    0(  48)    0(  48)    0(  48)    0(  48)    8(  56)    7(  63)    7(  70)
MILW         0(  33)    0(  33)    0(  33)    0(  33)    0(  33)    0(  33)    0(  33)   19(  52)    0(  52)   12(  64)
HARVEY       0(  20)    0(  20)    0(  20)    0(  20)    0(  20)    0(  20)    1(  21)   17(  38)    3(  41)    8(  49)
THORNTON     0( 113)    0( 113)    0( 113)    0( 113)    3( 116)    0( 116)    1( 117)   29( 146)    8( 154)    7( 161)
GRIFFITH     0(  44)    0(  44)  -44(   0)    0(   0)    0(   0)    0(   0)    0(   0)    3(   3)    4(   7)    2(   9)
HASKELLS     0(  17)    0(  17)  -16(   1)    0(   1)    0(   1)    0(   1)    0(   1)    7(   8)    0(   8)    2(  10)
S BEND       0(  11)  -10(   1)    0(   1)    0(   1)    0(   1)    0(   1)    0(   1)    1(   2)    0(   2)    3(   5)
K'ZOO        5(  68)  -49(  19)    0(  19)    0(  19)    1(  20)    0(  20)    0(  20)    1(  21)    1(  22)    5(  27)
S BEND E     0(  15)  -15(   0)    0(   0)    0(   0)    1(   1)    0(   1)    1(   2)    0(   2)    0(   2)    2(   4)
B CREEK      3(   3)    0(   3)    0(   3)    0(   3)   10(  13)    0(  13)    9(  22)   11(  33)   26(  59)   16(  75)
BC CR        0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    6(   6)    0(   6)    0(   6)
FLINT W      0(  11)    0(  11)    0(  11)    0(  11)    0(  11)    0(  11)    0(  11)    0(  11)    0(  11)    3(  14)
LANSING      7(  67)    0(  67)    0(  67)    0(  67)    0(  67)    0(  67)   17(  84)    0(  84)    0(  84)    0(  84)
DURAND       1(  15)    0(  15)    0(  15)  -13(   2)    0(   2)    0(   2)    9(  11)    0(  11)    0(  11)    0(  11)
HOLLY N      0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    1(   1)    0(   1)    0(   1)    0(   1)
GR RAPD      1(   5)    0(   5)    0(   5)   -4(   1)    0(   1)    0(   1)    3(   4)    0(   4)    0(   4)    0(   4)
FLINT        6( 121)    0( 121)    0( 121)    0( 121)    0( 121)    0( 121)   12( 133)    0( 133)    0( 133)    0( 133)
FLINT E      0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)
PT HURON     1(  12)    0(  12)    0(  12)    0(  12)    0(  12)  -11(   1)    1(   2)    0(   2)    0(   2)    0(   2)
SARNIA X    15(  36)    0(  36)    0(  36)    0(  36)    0(  36)  -21(  15)    0(  15)    0(  15)    0(  15)    0(  15)
CNT          3(  73)    0(  73)    0(  73)    0(  73)    0(  73)  -58(  15)    1(  16)    0(  16)    0(  16)    0(  16)
CNB          0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    0(   0)    6(   6)    0(   6)    0(   6)    0(   6)
CNP          0(   2)    0(   2)    0(   2)    0(   2)    0(   2)    0(   2)    2(   4)    0(   4)    0(   4)    0(   4)
CN SAND      0(   6)    0(   6)    0(   6)    0(   6)    0(   6)    0(   6)   11(  17)    0(  17)    0(  17)    0(  17)
PONTIAC      4(  45)    0(  45)    0(  45)    0(  45)    0(  45)    0(  45)    1(  46)    0(  46)    0(  46)    0(  46)
DETROIT      6(  97)    0(  97)    0(  97)    0(  97)    0(  97)    0(  97)    1(  98)    1(  99)    0(  99)    0(  99)
TOLEDO       0(  22)    0(  22)    0(  22)    0(  22)    0(  22)    0(  22)    0(  22)    0(  22)    0(  22)    0(  22)
DET CR       0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)    0(   3)
OVER AGE     0( 263)    0( 263)    0( 263)    0( 263)    0( 263)    0( 263)    0( 263)    0( 263)    0( 263)    0( 263)
--------------------------------------------------------------------------------------------------------------------------
TOTAL       52(1310)  -74(1236)  -74(1162)  -17(1145)   15(1160)  -90(1070)   77(1147)  140(1287)   89(1376)   99(1475)
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identified in step 1. If so, these light trains are reassigned to pick up extra traffic. The starting time of reassigned trains may have to be changed to pick up the extra traffic; the expected time at which this reassigned block is ready for pickup can be estimated by using the yard summary. In particular, the yard summary indicates for each block the net change in size of the block and the block size as a function of time. By noting when cars enter the yard for the block and by estimating the time necessary to switch the cars, estimates can be made of when the block is ready for pickup.

4. If there are no more trains available to relieve the congested yards identified in step 1, extra trains must be scheduled; their starting times are scheduled to relieve yard congestion before the predicted congestion time.

5. For those trains predicted to be both heavy and late (identified in step 2), a scheduled pickup of a block can be canceled and rescheduled for pickup by a light train. The train summary can indicate blocks (and their size) that may be canceled from heavy trains and potential light trains that may pick up the block. If a suitable light train is identified, the work is reassigned. The starting time of reassigned trains may have to change to wait for reassigned traffic; the expected time at which this reassigned block is ready for pickup can be estimated by using the yard summary and the process discussed in step 3.

6. If yards are uncongested and a substantial number of trains are running light (as identified in steps 1 and 2), the pool, or low-priority, trains on a train summary may be canceled one at a time and their work may be reassigned to the preferred, or higher-priority, trains until all the trains are at capacity. Some trains that have reassigned work may have their starting times set back while they wait for traffic; the expected time by which this reassignment is ready for pickup can be estimated by using the yard summary and the process discussed in step 3.

In the process of analyzing the train and yard summaries, any decisions to deviate from the nominal operating plan are communicated and coordinated with the affected yards.

The output of the tactical planning process is a modified operating plan that is used to aid the on-line dispatching process. This operating plan is recorded on a work sheet called the train instruction sheet. On this work sheet, the planned call and departure times are noted for each train. Next the planned stops for the train are specified. For each stop, the number of cars of each classification to be picked up or set out is noted.

The modified nominal plan in the form of the train instruction sheet should be completed approximately one hour after the beginning of the shift. The modified plan is given to the dispatchers as a guide to their decision making.

TACTICAL PLANNING PROCESS FOR YARDS

General

The new tactical planning process for yards is designed to enhance a yardmaster's ability to plan the activities for the entire shift at the beginning of the shift. By properly organizing and presenting RAILS-DMP data, more planning time will be available so that better sequencing decisions can be made on work assignments. In the new procedure, a work sheet is used to show which connections all cars in the yard and cars projected to be in the yard must make. The procedure makes the effect of alternative sequences of work more evident to yard managers than it has been in the past. The new procedure has been designed to anticipate line-haul power and crew availability, to smooth shift-turnover transition by providing an orderly transfer of knowledge to the next shift, and to train more-skilled yardmasters to impart their knowledge to less-skilled yardmasters.

Yardmasters affect the performance of yard operations by the sequence of tasks for switch-engine crews, by the change of classification track assignments, and by the negotiation with the dispatcher of departure time, classifications, and size of outbound trains to be made up at the yard. The purpose of the new yard-planning process is to provide yardmasters with an operating methodology that improves yard performance within the context of a systemwide operating plan.

Yard-Planning Work Sheet

The details of the tactical planning process for yards are shown on the sample work sheet for Battle Creek Yard in Figure 4. The format of the left-hand and right-hand columns of the work sheet is described below.

1. The upper part of the left-hand column (Battle Creek East Yard) contains information on the yard's turnover; the status of the yard at the end of the previous shift is detailed for the new yardmaster at the beginning of the next shift. Specifically listed are the number and type of cars on each track.
2. The lower part of the left-hand column (Engine Delays and Failures) contains the factors and times that the switch engines were unavailable for work.
3. The upper part of the right-hand column (Estimated Train and Blocks Outbound) lists the outbound trains expected to run, their expected call times, the expected blocks to be put on the train, and the expected number of cars in each block. An initial estimate of this information is provided by the nominal operating plan. The information is continually refined during the yard-planning process and through negotiation with the dispatcher.
4. The middle part of the right-hand column (Dangerous Cars) provides information about the location of dangerous cars in the yard and which crews have been notified of this fact before the dangerous cars are moved.
5. The lower part of the right-hand column (Hot Cars, Transfer, Special Moves) contains special instructions for priority movement of cars, blocks, or trains. Hot cars are those cars that must make certain connections.

The column headings across the top of the middle portion of the work sheet give the various outbound classifications and their station numbers. The following information can be entered in the column for each classification:

1. The total number of cars that have already been switched [Total Ready to Move (Switched)] is listed in the first row; the number of cars already switched that are considered overage is noted. This information is obtained from the yard summary. The next rows (In Yard to Be Switched) list the number of cars for each classification for each train received in the yard but not yet switched. This information is obtained from switch lists.
2. The row below these (Total to Be Switched) totals the cars in the yard to be switched (i.e., the sum of the entries under In Yard to Be Switched). Below this (Inbound This Shift) the number of cars expected for each future train to be received in the yard during the shift is noted.

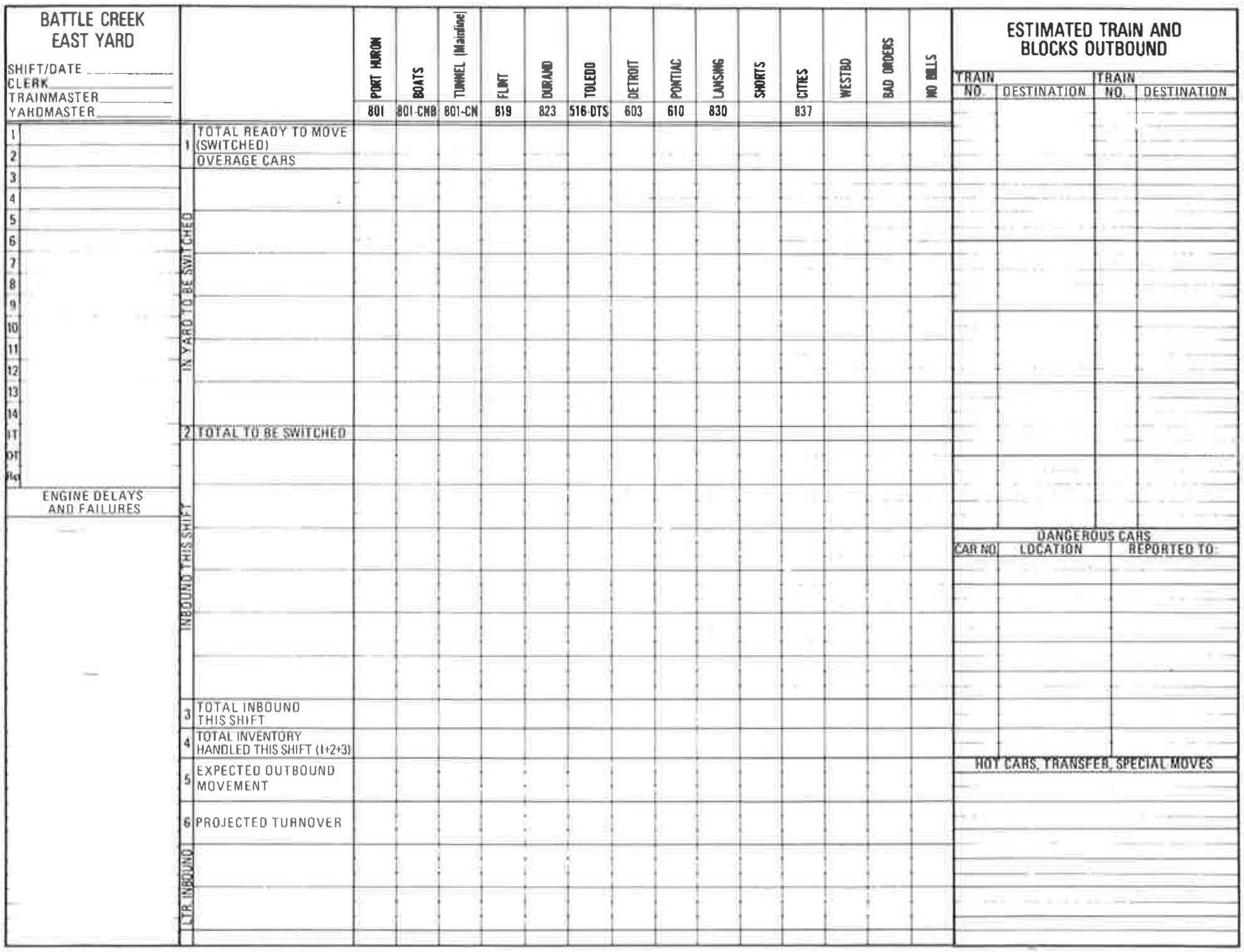

Figure 4. Yard-planning work sheet.

BATTLE CREEK
EAST YARD
SHIFT/DATE ________
CLERK ________
TRAINMASTER ________
YARDMASTER ________

1 2 3 4 5 6 7 8 9 10 11 12 13 14 IT OT Rq

ENGINE DELAYS AND FAILURES

		PORT HURON	BOATS	TUNNEL (Mainline)	FLINT	DURAND	TOLEDO	DETROIT	PONTIAC	LANSING	SHORTS	CITIES	WESTBD	BAD ORDERS	NO BILLS
		801	801-CNB	801-CN	819	823	516-DTS	603	610	830		837			
1	TOTAL READY TO MOVE (SWITCHED)														
	OVERAGE CARS														
IN YARD TO BE SWITCHED															
2	TOTAL TO BE SWITCHED														
INBOUND THIS SHIFT															
3	TOTAL INBOUND THIS SHIFT														
4	TOTAL INVENTORY HANDLED THIS SHIFT (1+2+3)														
5	EXPECTED OUTBOUND MOVEMENT														
6	PROJECTED TURNOVER														
LTR INBOUND															

ESTIMATED TRAIN AND BLOCKS OUTBOUND

TRAIN NO.	DESTINATION	TRAIN NO.	DESTINATION

DANGEROUS CARS

CAR NO	LOCATION	REPORTED TO

HOT CARS, TRANSFER, SPECIAL MOVES

Advanced consist information from RAILS is used for trains that have already departed from a neighboring yard and are to arrive in the near future. DMP projections are used for trains not yet made up.

3. The row below that (Total Inbound This Shift) totals the cars not currently in the yard that are expected to be switched during the shift (i.e., the sum of the entries under Inbound This Shift).

4. Next, Total Inventory Handled This Shift gives the total number of cars already switched plus the cars expected to be switched during the shift (i.e., the sum of rows 1, 2, and 3).

5. Expected Outbound Movement gives the totals for each classification that are expected to leave the yard during the shift. This information is obtained from the number under Estimated Train and Blocks Outbound in the upper right-hand column of the work sheet.

6. Projected Turnover gives the number of cars by classification expected to be in the yard (i.e., row 5 subtracted from row 4).

7. The last entries (Later Inbound) give the number of cars expected for each classification for trains expected to arrive during subsequent shifts. This information would come from DMP projections and is mainly advisory for the current shift.

Details for Use of Yard-Planning Work Sheet

The tactical planning procedure for yards begins toward the end of a shift. On the work sheet, the inbound-traffic demand on a yard is organized from RAILS advanced consists and DMP projections so that it can be scanned to detect major trends or special problems. Assignment to scheduled trains of nominal connections of blocks of cars can be achieved, and the need for any additional trains far in advance of their required call times can be anticipated. When the yardmaster comes on duty for the next shift, the work sheet is scanned, it is discussed with the trainmaster if necessary, and the specific standing inventory lists of cars then in the yard is reviewed. By using these data, the yardmaster can annotate the worksheet with actual connections and assign work to the switch crews to balance transit-time considerations and car-handling factors. The work sheet can be continually annotated throughout a shift and thus be used as an evaluation and planning device. Because the yard-planning work sheet is the focal point of the tactical planning procedure for the yard, the steps in the planning procedure that involve the work sheet are described below.

Step 1

A yardmaster assistant uses a RAILS terminal and yardmaster work assignments to fill out data required for yard planning on the work sheet. These data are as follows:

1. The projected yard turnover, which consists of the content of each track in the form of either number of cars and their classifications or an

inbound or outbound train number and number of cars, is placed in the upper part of the left-hand column (Battle Creek East Yard).

2. The number of classified cars for each block that are already switched is entered under Total Ready to Move. This information is obtained from RAILS, adjusted for the cars that will be added to or deleted from the track by switching that is assigned by the yardmaster by means of switch lists that have been issued through RAILS.

3. The number of unswitched cars for each block for each unswitched received train is entered under In Yard to Be Switched. Each grouping is identified by train number, interchange source, or other grouping, such as crossovers or industrial movements. These block counts will be available from previous planning sheets for long-standing trains from advanced-consist summary reports transmitted by RAILS.

4. The number of cars for each block on each known inbound train is listed by train number, interchange, or industrial connection and entered under Total Inbound This Shift. Advanced-consist summaries and lists from RAILS are required to obtain these data. Occasionally critical data must be obtained by telephone or estimated (estimated data should be followed by the notation "est").

Step 2

A yardmaster fills in the upper part of the right-hand column, Estimated Train and Blocks Outbound, with the numbers of scheduled outbound trains (including any specials or extras) called by the dispatcher. The times and the preferred classifications for those trains are filled in, a preliminary assignment of blocks to those trains is made, and any particularly short connection times or train-sizing problems are noted. The number of cars for each destination would not be filled in initially. However, during the planning process, the sum for each classification on each train would be estimated and noted beside each outbound train; these estimates would be continually refined.

Step 3

The incoming yardmaster reviews the planning sheet. If potential schedule or connection problems are spotted, they are immediately noted and the dispatcher or trainmaster or both are contacted to negotiate possible changes or anticipated problems.

Step 4

The yardmaster gives switching assignments to the crews by annotating the work sheet. As estimates of the classifications and numbers of cars making outbound trains become clear, they are written for each outbound train in the section labeled Estimated Train and Blocks Outbound. At this time, the number of cars either switched or to be switched for each classification specified in the middle rows is also annotated with the connecting outbound train number.

Step 5

The yardmaster continues to annotate the work sheet throughout the shift in the manner described in step 4. Information on later inbounds is added throughout the day from RAILS advanced-consist summaries.

Step 6

The yardmaster continually projects train and other requirements for 12 h or so in advance and notifies the trainmaster or dispatcher of the desirability of potential operating changes to the nominal plan. Factors that could modify the nominal plan for the yard's viewpoint include

1. Unacceptable bunching of inbound trains,
2. Unacceptable (e.g., too-large) sizing of inbound trains,
3. Unusual block buildups (e.g., too few or too many of a given classification for a train or track),
4. Unusual car distributions on a train (e.g., 20 cars for Flint, Michigan, already blocked on a train that can leave on a through track and be added to other cars for Flint already in the yard),
5. Desirability of running extra trains or canceling scheduled trains, and
6. Desirability of mine-running certain traffic from or through the yard (i.e., not sorting the cars on the train).

Step 7

The yardmaster assistant continues to monitor and update the work sheet. Actual connections and train composition should be annotated when a train leaves.

Step 8

A yardmaster assistant uses the work sheet for the next shift by extrapolating turnovers and by copying unswitched-inventory information.

Step 9

The work sheets are stored and saved for evaluation of schedule and operating policy on a regular basis.

Step 10

Yardmasters compare DMP yard projections with actual operating plans. Discussions between dispatchers and yardmasters center around exceptions to the nominal plan.

CONCLUDING REMARKS

The operational demonstration took place during the week of July 25, 1977. This demonstration included a period of 48 consecutive hours during which the GT railroad was operated by using the tactical planning procedures developed during the project. Tactical planning of train and yard operations 8-12 h into the future was routinely accomplished; for certain trains the planning horizon was extended from 16 to 20 h. On the basis of a shift's tactical plan, dispatching and yard operations, power scheduling, and crew assignments could be coordinated. These procedures have now been implemented on the entire GT Chicago Division, which extends from Port Huron in Michigan to Elsdon in Illinois.

ACKNOWLEDGMENT

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Determination of the Effectiveness of Railroad-Car-Distribution Decision Making

CRAIG E. PHILIP AND JOSEPH M. SUSSMAN

Most railroad organizations have defined and divided functions narrowly—around their visible physical activities such as moving trains, switching cars, and setting prices—because it appeared to be the most efficient way to manage such a complex production process. Unfortunately, adoption of such a structure has meant that the level of service provided to shippers and the use of the railroad's capital assets are the indirect result of numerous and often unrelated decisions rather than the focus of managerial activity. To understand this problem, a single function—car distribution—has been chosen for detailed investigation because it is an important determinant of both level of service and use of the freight-car fleet. Numerous operations research studies of car distribution have been conducted in recent years, but most have defined car distribution narrowly and ignored the broader organizational context within which car distribution actually functions. A framework is developed that is used to structure the analysis in a manner that permits consideration of both the physical elements of the production process and the managerial elements required to control it. Car-distribution organization, information, and decision structures are described and analyzed. Eight major areas in which improvement appears to be necessary are identified, and the direction of future research in this area is briefly discussed.

The railroads pioneered the development of organizational structures and practices to permit the management of large industrial concerns (1, p. 87), yet today there is a growing awareness that these decision-making and organizational structures (which have been used by the railroad industry for the last 100 years) may require change if the industry is to remain competitive with other transportation modes. This is no small task. Drucker, in his most recent text on the problems of management (2, pp. 590-591), cites railroads as one of the few businesses "for which we do not possess an adequate principle of organization"; he notes in particular the dilemma that faces managers responsible for the major capital assets--cars and locomotives--who must decentralize to attain efficiency but centralize to ensure effectiveness.

The solutions to this problem that have surfaced most recently focus principally on the form and structure of the organization as a whole (3, p. 176). While useful, such prescriptions may not address the problem at the level of the individual decision maker, whose behavior requires change. This study demonstrates that a focus on individual decision making is helpful in understanding the relevant organizational, information, and decision support systems of the transportation firm where the production process itself is complex.

To illustrate the proposed methodology, a single function--car distribution--has been selected as the subject of this decision-making diagnosis and design study. Car distribution was selected because

1. It is a function that has high leverage; even small improvements will have a major financial impact due to the rapidly increasing value of the freight-car fleet;
2. It is a relatively well-defined activity in the organization that has identifiable actors and procedures;
3. It has been the subject of numerous studies by operations researchers, who have adopted a traditional engineering view of the problem;
4. Institutional changes within the industry, which include the Clearinghouse (a mechanism to allocate equipment between railroads), hourly car hire, and the dramatic increase in the number of cars provided by third-party investors, have a significant impact on car distribution; and
5. Change is likely to be forced on it by external pressures--significant deregulation will remove many of the barriers that now constrain distribution activities and force a reassessment of policies and practices.

Car-distribution activity concerns the transfer of emptied cars from their unloading points to the next prospective shipper. Usually defined as an operating function, it is a support task to the primary productive activity of the railroad, which is to move loaded freight cars from shippers to receivers.

Car distribution is defined by car distributors themselves to be the process of identifying destination points for empty cars, given an available supply and potential demands, in a manner that minimizes cost. Defined in this way, the only problem faced by the car distributor is the matching of a given set of available empty cars with a given set of specified destinations. Most operations research studies have focused on the problem as defined in this way, since solutions can be generated by a variety of mathematical programming techniques. A review of attempts to apply mathematical programming to the car-distribution problem may be found elsewhere (4).

A main tenet of this study is that it is more fruitful to investigate the role of car distribution in the context of the railroad's total production function. This requires that the focus be not on a narrow interpretation of what car distribution produces--the movements of empty cars--but on the interdependencies that necessarily exist between car distribution and the rest of the railroad organization. From this perspective it is clear that (a) the choice of the empty cars to be distributed from those available and (b) the selection of which demands are to be satisfied are themselves problematic and interdependent decisions that must also be considered, and extensive observation of car distributors at work confirms that they are actively involved in these decisions. Thus, an operational definition must account for all the roles actually played by car distributors in the organization.

Part of the reason for this incongruity between definition and action can be explained by the constraints that have historically impinged on the car-distribution activity. From a political perspective, a narrow definition of the car-distribution activity provides insulation from the Interstate Commerce Commission (ICC) and from other departments of the railroad. The ICC's Common Carrier Obligation is usually interpreted to require equitable treatment of all shippers, so car distributors may be réluctant to admit that their actions have a substantive impact on shipper car supply.

More fundamentally, this difference in definition is a reflection of a problem that many consider to be at the heart of the industry's current difficulties. The organizational structure adopted by most railroads has tended to define positions narrowly--around visible physical activities such as moving trains, switching cars, repairing track, and setting rates--and not around the coordinated control of these interdependent activities to produce profitable transportation service. The established decision-making structure often does not acknowledge these coordinating functions and so obscures the interdependencies between decisions.

It is thus not sufficient to examine the present organization in terms of the acknowledged decisions and decision processes employed. To effectively assess or change any of these activities requires a framework that relates the function or functions that are being investigated to the relevant organizational context.

A framework that can be used to analyze the management processes at work within a transportation firm is described in the next section. The framework selected is based on ideas found in control theory.

In the second section, the car-distribution process will be formulated as a control problem, and in the third section the car-distribution management process found on several railroads examined during the study will be described by using the framework to organize the description.

Finally, a preliminary diagnosis of the management process will be described in terms of major areas of potential improvement to the organizational, information, and decision-making structures relevant to car distribution.

FRAMEWORK FOR ANALYSIS

In this section a framework will be described that can be used to guide an assessment of a transportation organization's decision processes and structure. The framework developed is similar to that used to analyze control problems in physical systems in that it explicitly distinguishes between state and control variables. It differs to the extent that explicit consideration is given to the fact that constraints and objectives for each part of the organization are usually derived in a complex fashion from the entire organization's constraints and objectives. Feedback and evaluation are also considered separate definable processes, since these too often present problems.

What Are We Trying to Analyze?

Analysts of transportation systems are often seduced by the complexity of the technology employed. In analyzing the car-distribution activity, for example, it is possible to look only at what might be called the physics of the problem, searching for a mathematical representation of the equipment flows and trying to find optimal solutions to the problem. Such approaches assume a single decision maker, who has complete information about the problem and an unambiguous objective. While each assumption may represent an appropriate normative ideal, none is reasonable as a description of the actual problem-solving environment.

The context within which the decisions are actually made almost always involves more than one decision maker; each has a limited amount of information that concerns both the environment and the activities of others, and each responds to multiple and conflicting objectives or constraints. To understand why decisions are made as they are and to prescribe changes that are likely to be feasible and effective, the analysis must account for this organizational context.

But what is an organization and how can it best be analyzed? Schein provides a definition that is typical of those found in the literature (5, p. 9):

> An organization is the rational coordination of the activities of a number of people for the achievement of some common explicit purpose or goal, through the division of labor and function, and through the hierarchy of authority and responsibility.

The specifics of this definition are less important than its identification of the essential elements of an organization: a group of people, some of whom are responsible for the coordination of work by others, who have divided a task to achieve some objective. Our study of the car-distribution function will therefore focus not only on the task itself but also on how that task has been divided, how each subtask is performed, and how they are coordinated to achieve a desired result. A framework based on control theory in physical systems is proposed in the remainder of this section to relate these organizational aspects of the problem to its physical structure.

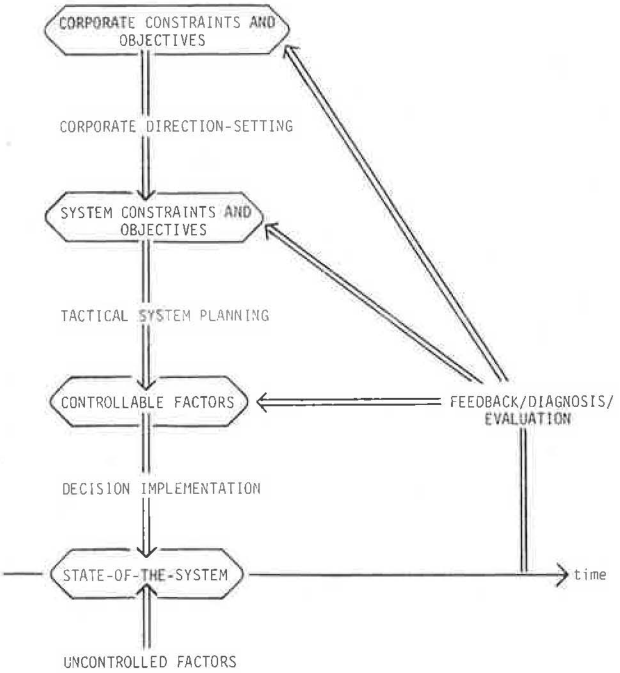
Defining the Concept of Control

The word "control" is one of those terms used in a wide variety of contexts. Anthony defines management control as "the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives" (6, p. 14). From this definition it is clear that most managerial activities (organizing, analyzing, and communicating) are undertaken to achieve control, but the word is often used in a much more limited context. For example, Tricker (7) states that "the purpose of any management control system is to establish criteria of performance for units in an organization." Control is often equated with budgets and performance measures, as though these activities alone would be sufficient to achieve control.

We are primarily interested in the control of managerial systems, but the term finds its most precise meaning and usage when applied to physical problems. In this context, the control system has four elements:

1. State variables, which characterize the attributes of the system believed to be most relevant;
2. Control variables, which characterize the

Figure 1. Management analysis framework.



known choices or decisions that can be made to alter the system;

3. Equations of motion, which describe the impact that control variables are believed to have on state variables; and
4. Objective function, which describes the desired state of the system.

For those engineering problems that can be so characterized (e.g., setting a missile's trajectory), the solution process is devoted to the formal specification of the equations of motion, which, when combined with an appropriately defined objective function, can often be solved for the optimal setting of the control variables. Although it is unlikely that problems of control in social or managerial systems could be formally modeled or solved in this way, it is interesting to note that the physical control problem implied by the structure above is similar to the definition of management control proposed by Anthony.

The framework used for physical systems analysis provides a useful point of departure for a framework to analyze managerial systems. Most important is the explicit distinction made between the state variables, which characterize the system, and the control variables, which represent those activities about which managers make choices to influence the state of the system. Explicit consideration of the relationships among these variables establishes the most important link between the physical and the managerial structures of the problem.

The Framework Defined

The main dimension of this framework for managerial analysis is based on the hypothesis that control is a principal task of management. The structure described below and illustrated in Figure 1 is motivated by that used to assess physical systems but modified to reflect the important differences between physical and social systems.

The physical-system framework focuses on the variables that characterize a system and the equations that characterize the relationships between variables. In an equivalent fashion, we will distinguish between elements and processes that act on the elements.

Control Elements

Control elements are defined as follows:

1. The state of the system is defined by a set of selected state variables. "System" refers here to that portion of the organization's productive activity that is the responsibility of the functional area or areas being analyzed. For example, in analyzing the car-distribution function, the state of the system will be defined by variables that relate to the location and status of the empty fleet.
2. Controllable factors are those variables that can be altered by managers to change the state of the system. Car distributors, for example, can decide which cars should be kept for reloading.
3. Uncontrollable factors are those variables that influence the state of the system but are controlled by others in the organization or by forces outside the organization. Shipper orders, for example, cannot be controlled by the car distributors in the short run.
4. System constraints and objectives are the limits and goals that restrict and motivate the actions taken relevant to the system. For example, car distribution may have as an objective to maximize filled orders but may also be constrained by the ICC to allocate the available fleet equitably.
5. Corporate constraints and objectives are the organization's constraints and objectives that are relevant to the system. A railroad, for example, may have an objective to maximize the profit contribution of its car fleet.

Control Processes

Control processes are defined as follows:

1. Decision implementation is the application of decisions made with respect to control variables. For example, car distributors may decide to reload foreign equipment (cars from other railroads) and must see that their decisions are actually executed.
2. Tactical system planning is the translation of system constraints and objectives into plans that specify how controllable factors are to be manipulated. Car distribution, for example, translates car service orders into rules that govern the selection of foreign cars for reloading.
3. Corporate direction setting is the translation of corporate constraints and objectives into constraints and objectives relevant to the system. For example, a corporate objective to reduce the number of cars owned may be translated into a system objective to increase foreign-car reloading.
4. Feedback, evaluation, and diagnosis is the comparison of actual system behavior over time with expected behavior. For example, a system objective to use all available foreign cars could be evaluated by measuring the foreign cars actually reloaded.

The relationships between control elements and processes are shown graphically in Figure 1. The most important difference between this structure and the one described for physical systems is the explicit recognition that the definition of constraints and objectives in a social organization and the translation of these into specific ones that can guide actions in any single part of the organization is a potentially complicated and problematic area.

Managerial Dimensions

The managerial activities (e.g., tactical system planning) required to control a particular physical process (e.g., moving empty cars) were identified in the previous section. The ability of the firm to execute these activities is determined by the organizational, information, and decision structures adopted by the firm. Key elements of each will now be described.

Organizational Structure

The most important distinguishing characteristics of any organization are the divisions of labor and responsibility used to achieve its objective or purpose. In this context, four characterizations of the structure are possible:

1. Personnel authority relationships: Individuals are grouped together under other individuals who have authority over their actions.
2. Task authority relationships: Individuals are given the right to carry out certain tasks.
3. Accountability relationships: Individuals are held responsible for the performance of tasks, for the activities of specific individuals, or for both; this requires that a manager's actions be accompanied by a prediction or expectation of the outcome and that the actual outcome be measured and subsequently compared with this prediction.
4. Motivational relationships: Within the context of their authorities and responsibilities, managerial behavior is prompted by inducements or incentives structured by the organization.

The traditional organization chart, which specifies reporting relationships among positions, partly reveals the first two relationships. To understand the task authority and accountability relationships, however, the individual activities of managers should be related to the control processes identified earlier.

Motivational relationships need to be examined, because social systems are largely volitional: Individuals must be motivated to choose the behavior thought to be appropriate by the organization. In some cases, parts of the motivational structure may be explicitly stated in terms of incentive pay systems, performance evaluation schemes, etc. Often, however, implicit codes of individual behavior and performance will exist that may or may not be tied to organizational objectives.

Information Structure

One popular approach to organizational analysis begins with the assumption that organizations can be characterized and understood as information-processing networks. This approach focuses on the channels of communication that exist between senders and receivers of information, in which the sender selects, encodes, and transmits information to a receiver who detects and decodes the message. Based on this framework, three issues are relevant: (a) who originates what information relevant to the elements of the system, (b) how the information is packaged and transmitted, and (c) who receives what information and in what form.

The analysis of the information structure must embody both the formal management information system and the informal communication channels that exist among members of the organization. The former is likely to be highly structured and documented, and the latter may be informal and discovered only through observation of participants.

Decision Structure

Decision making may be said to occur whenever a choice among different potential actions is required. The individual or group that is to make the choice (and to some degree their motivation in the selection process) will be determined by the organizing structure. The information system will define the data available to support the decision.

The process used will be determined by the tools available to synthesize the information, which may be informal and involve training appropriate individuals or structured in the form of computer programs and systems. In either case, the decision structure can be broken down and analyzed in terms of the way it supports the three stages of decision making (8, p. 47):

1. Knowledge: Searching the environment for conditions that call for a decision;
2. Design: Inventing, developing, and analyzing possible courses of action; and
3. Choice: Selecting a course of action from those available.

In many cases, it may be difficult to identify precisely the decisions that are made or the three phases of decision making noted above. In fact, there is substantial evidence from behavioral studies of decision making that the more important the decision, the less structured the process. In such cases, a principal benefit of the analysis may be to reveal the structure implied by the actual decision-making process.

Use of the Framework for Analysis of Managerial Systems

This framework makes it possible to systematically analyze the management of a particular function or set of functions performed by a transportation firm. The function is first formulated as a control process that reveals the essential managerial activities and their relationships to each other. The execution of these activities can then be assessed in terms of the organizational, information, and decision structures adopted. Car distribution will now be analyzed in this manner.

CAR DISTRIBUTION AS A CONTROL PROCESS

The framework described in the previous section will be used to define the control elements and processes required by the physical characteristics of car distribution and its role within the organization. Particular emphasis is given here to the interdependencies involved.

System-State Variables

The primary productive activity of a railroad is, of course, to move loaded freight cars from shippers to receivers. An additional task is usually necessary if this productive activity is to be accomplished, namely, the movement of emptied cars from the unloading point to the next prospective shipper. The state of the car-distribution system may thus be described by equations defining three variables:

$$E^t = \sum_i (I_i^t + P_i^t) \qquad (1)$$

where

E^t = empty cars in the sytem to be used for loading,

I_i^t = cars waiting at supply point (any point where they can enter or exit from the distribution system), and

P_i^t = cars moving from one supply point to another.

$$D^t = \sum_i D_i^t \qquad (2)$$

where D^t = cars applied to orders.

$$U^t = \sum_i (0_i^t - D_i^t) \qquad (3)$$

where U^t = unfilled demand and 0_i^t = empty-car orders at point i.

Controllable and Uncontrollable Factors

The system as defined by Equations 1-3 is determined by both controllable and uncontrollable factors, which are listed below:

1. Controllable Factors

   F_i^t = empty cars sent to other system supply points from i,

   J_i^t = empty cars sent off line from i, and

   D_i^t = empty cars applied to orders at i.

2. Partly Controllable Factors

   A_i^t = empty cars arriving at i from other system supply points,

   P_i^t = empty cars in the pipeline to i from other supply points (arrivals and pipeline volume are in the part determined by operating-department decisions that determine travel time), and

   R_i^t = empty cars received from interchange at point i (empty interchange receipts will be determined in part by foreign-carrier decisions).

3. Uncontrollable Factors

   S_i^t = empty cars released from industry at point i and

   0_i^t = empty car orders at point i (both. these factors are determined by marketing decisions).

The state variable in Equation 1 (E^t) is a function of controllable, partly controllable, and uncontrollable factors:

$$I_i^t = I_i^{t-1} - F_i^{t-1} - J_i^{t-1} - D_i^{t-1} + A_i^{t-1} + R_i^{t-1} + S_i^{t-1} \qquad (4)$$

$$P_i^t = P_i^{t-1} + \sum_j F_{ji}^{t-1} - A_i^{t-1} \qquad (5)$$

Both state variables in Equations 2 and 3 are a function of D_i^t, a controllable variable, but the degree of control is constrained by uncontrollable factors, since $I_i^t \geqslant D_i^t \leqslant 0_i^t$. In other words, it is obvious the number of cars applied to orders cannot be greater than the order but, which is more important, it cannot be larger than the number of cars available (I_i^t). This reflects the high degree of interdependence caused by the fact that controllable and uncontrollable factors simultaneously affect all the state variables.

Corporate Direction Setting

Car-distribution decisions determine the car orders actually satisfied, which directly affects the railroad's revenue level, and these same decisions determine the empty-car and movement costs required to support this revenue.

Yet car distribution cannot possibly determine the best revenue and cost levels. For its decisions to be made in a manner consistent with corporate objectives, the other departments with more direct control and responsibility for revenue and cost levels must define the set of corporate objectives and constraints relevant to car distribution. Marketing should provide a market plan that includes anticipated levels of loaded movement (0_i and S_i for all i) and a priority ranking of these demands, operations should provide an operating plan that includes level-of-service expectations, and finance should provide a car plan that projects the system fleet size.

These plans must be translated into a set of specific plans for car distribution, which specify realizable performance targets and guidelines for action. The two most important of these are the loading plan and the empty movement plan, both of which are described below.

The loading plan specifies expectations with respect to the car placement activity:

$$D_i = \begin{cases} 0_i & \text{if } E > E^* \\ \alpha_i 0_i & \text{if } E < E^* \end{cases} \qquad (6)$$

where

$E^* = \sum_i [0_i^*(I_i + P_i)/L_i]$,

α_i = shortage allocation factor (between 0 and 1), and

E^* = number of empty cars required to satisfy all orders, given the movement plan, which is represented here by $(I_i + P_i)/L_i$ (car days/load).

When available car supply E_i is less than E^*, the shortage allocation factors (α_i) determine which supply points will receive the largest percentage of available supply.

The empty movement plan translates the car supply and demand forecasts into expected movement patterns. J_i, A_i, and F_i are determined such that

$$(D_i + J_i) - (S_i + R_i) + (A_i - F_i) = 0 \qquad (7)$$

$$(F_{ij}C_{ij}) + (J_iC_i') \qquad (8)$$

is minimized where

C_{ij} = movement cost for empty car from i to j,

C_i' = movement cost for empty car from i to interchange, and

$F_i = \sum_j F_{ij} + A_i = \sum_j F_{ji}$.

Equation 7 expresses the requirement that distribution pick a plan that balances network car supply (through J_i) and local car supply (through A_i and F_i) with demand. Equation 8 reflects the desire to achieve this in a manner that minimizes cost.

It is important to recognize the interdependence between the two plans. The loading plan depends on both demand forecasts and the movement plan, while the movement plan depends on the car plan, the market plan, and the level of demand specified in the loading plan. It is this interdependence between activities within car distribution and between car distribution and the other departments on the railroad that makes this direction-setting process necessary and makes a simple mathematical programming approach to car-distribution planning untenable.

Tactical Direction Setting

The loading and movement plans set overall goals for the car-distribution function. To be effective, these goals must be made operational in terms of specific sets of rules for the control variables that can be manipulated.

Order application rules should be derived directly from the loading plan so that, on a daily basis, the percentage of orders to be satisfied at an individual supply point (i) is determined by the level of car supply compared with that needed by the system.

Foreign-reloading rules are derived from both the loading and the movement plans; i.e., if $D_i^t = 0_i^t$ for all i, set J_i's to minimize movement expenses; if $D_i^t < 0_i^t$, set J_i's so that $D_i = \alpha_i 0_i$. Thus, when there is a car surplus, foreign cars should be used rather than being sent off line only if this reduces empty costs, but when there is a car shortage, foreign cars should be used to satisfy marketing targets.

Finally, movement flow rules are developed from the movement plan:

$$F_i^t = (0_i^t + J_i^t + A_i^t) - (S_i^t + R_i^t) \qquad (9)$$

with F_{ij} calculated to satisfy

$$F_i^t = \sum_j F_{ij} \qquad E(A_j) = \sum_i F_{ij} \qquad (10)$$

These three sets of rules make the system car-distribution plans operational by relating them directly to the control variables. They are designed to guide decision implementation.

In summary, car distribution is a necessary and complicated part of the railroad production process. Based on an understanding of the car-distribution activity and of its relationship to the rest of the organization, a description structured by the framework for analysis has been presented. Figure 2 displays the relationship of these elements and processes to each other. This figure identifies the variables that characterize the state of the system, the controllable and uncontrollable factors that determine the state of the system, and the corporate and system direction-setting processes necessary to guide car distribution. By using this description, it is possible to analyze a railroad's car-distribution activities.

CAR-DISTRIBUTION MANAGEMENT PRACTICES

The framework for analysis already presented was developed so that the managerial activities related to car distribution could be understood and analyzed. During the past year, several major U.S. railroads have been visited and interviews have been conducted with personnel responsible for the car-distribution activity. In addition, the results of a survey of industry car-distribution practices conducted by the Association of American Railroad's Freight Car Utilization Program have been reviewed and the results have been synthesized. Although practices differ, there is a substantial degree of commonality. The following description is based on a composite view of the characteristics found most often on the carriers studied.

As suggested in the preceding, the description that follows will focus on the organizational, information, and decision structures used to carry out the car-distribution activities already defined.

Organizational Structure

In analyzing the division of tasks among individuals, we will focus on three important structural characteristics: (a) the division of personnel authority (who reports to whom), (b) the division of task authority (who carries out which tasks), and (c) the division of task accountability (who is responsible for the outcome of specific tasks). The first is embodied in the departmental structure adopted by the organization; the second and third are revealed through an analysis of organizational behavior.

Personnel Authority Structure

Most major railroads in the United States today are functionally organized; Figure 3 illustrates the division of the major functions relevant to car distribution.

The operations department is divided functionally: The mechanical, engineering, and transportation departments have tended toward centralization, whereas most operating organizations have remained geographically decentralized. Car distribution is typically one of the functions of the transportation department.

The traffic department is also organized along functional lines; the principal division is between sales and marketing. Within marketing, pricing, equipment and service planning, and market development are the main subdivisions. All are centralized.

The organization of the transportation department itself differs somewhat from one railroad to another. Some have district or division superintendents responsible for particular regions of the railroad to whom regional car distributors report. Others have system car distributors who are responsible for the entire railroad.

Also in the operations department, the local agency personnel play a major role in the car-distribution function. The agents report through the operations organization to the district general managers.

In addition to the functional relationships described above, one or more car committees often exist to coordinate some car decisions, particularly those concerned with acquisitions. Members of each of the major functional areas are represented and, although the committees usually do not have staff or budgets of their own, they do facilitate communication between functional areas affected by car decisions.

Task Authority Structure

The tasks carried out by individuals in the organization are not specifically identified by the organizational chart or the personnel relationships shown in it. The major managerial activities associated with car distribution have been identified; it is possible to identify the individuals who have authority to carry out each activity shown in Figure 4.

The car distributors are largely concerned with the day-to-day implementation of car distribution.

Figure 2. Car-distribution control task hierarchy.

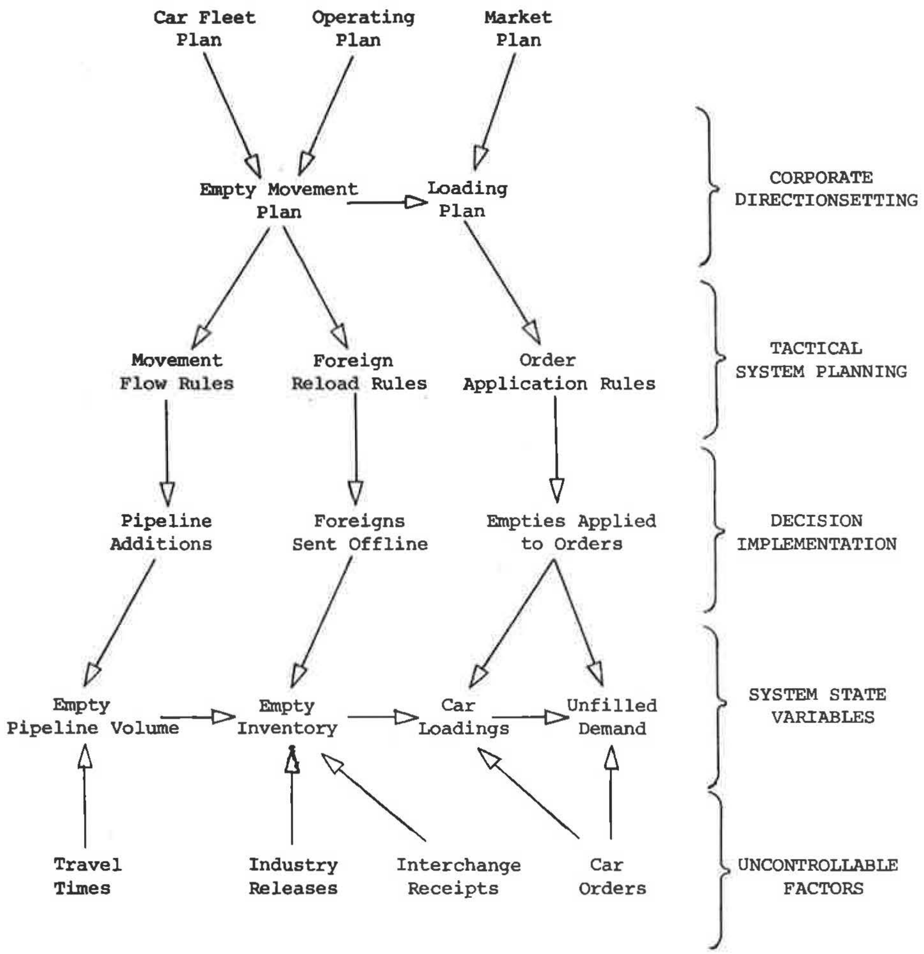


Figure 3. Departmental organization relevant to car distribution.

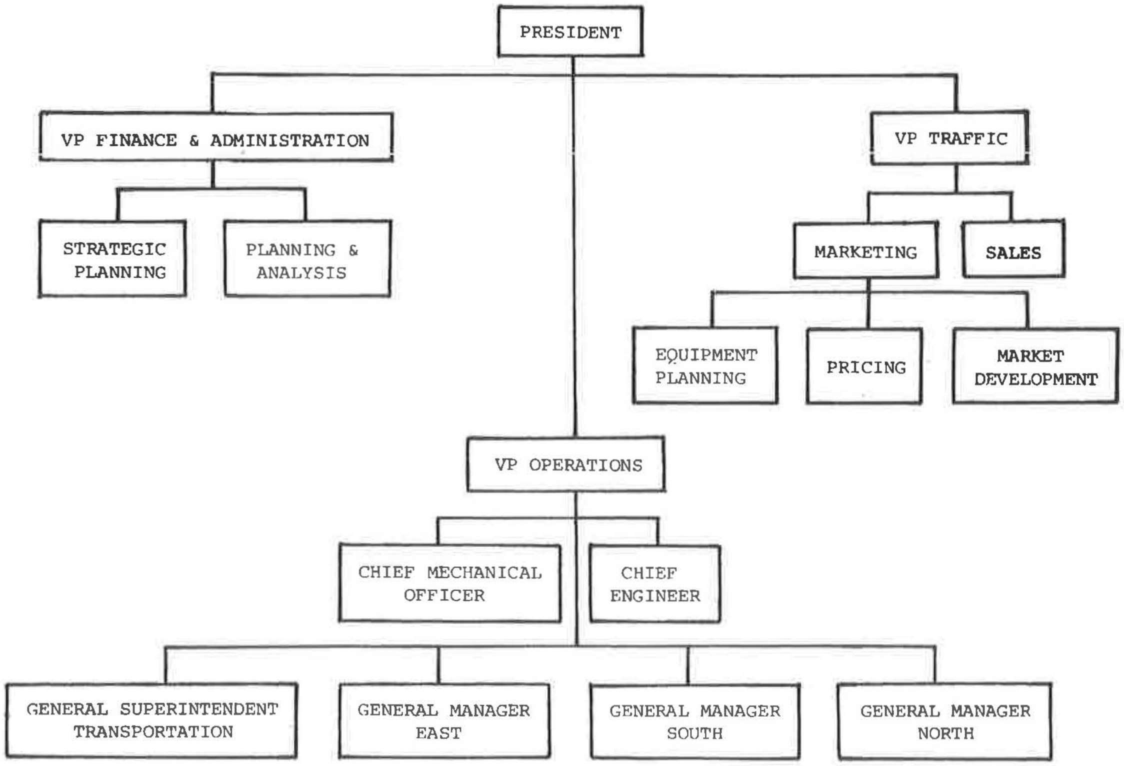
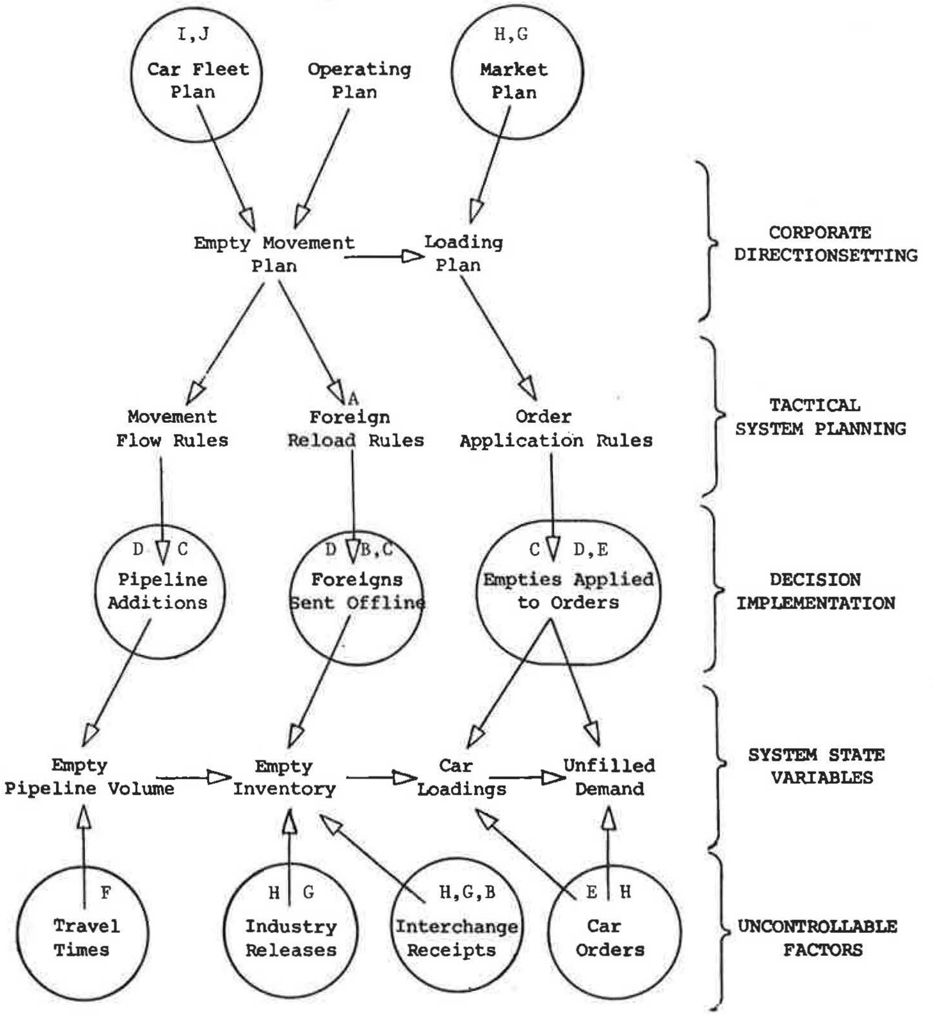


Figure 4. Task authority structure.



A = General Superintendent of Transportation

B = Director of Transportation Services

C = Director of Freight Car Utilization

D = Car-Distribution Managers

E = Local Agents

F = Operating Department

G = Market Managers

H = Sales Department

I = Equipment Planning

J = Planning and Analysis

They are the first line of defense between the railroad operating organization and both the customer and the commercial departments on the railroad. When problems arise with respect to equipment availability (even when the problems are caused by events not controllable by car distribution), the car distributors must respond to the crisis.

There is no one to perform the activities necessary to assure that these actions taken by the car distributor are consistent with the objectives of the firm. There is no regular preparation of movement or loading plans or of the movement, foreign-reload, or order-application rules necessary to guide car-distribution implementation decisions. Car fleet and market plans are prepared by other groups in the organization, but no one is formally authorized to translate these plans into constraints and objectives for the car-distribution activity. Tactical planning to guide daily implementation decisions is not evident.

Task Accountability Structure

Authority, accountability, and responsibility are often considered interchangeable, but we have defined accountability more precisely to refer to those actions where the result or impact is measured and explicitly compared with the result predicted. Thus, a manager may have authority to undertake some task but not be accountable and likewise may be accountable even though not authorized to take the action. Task accountability defined in this way requires that a manager's actions associated with the task be accompanied by a prediction of the outcome and that the actual outcome be measured and subsequently compared with this prediction.

Given this definition, no one is typically accountable for car-distribution decisions. The general superintendent may be responsible for net car hire, but an estimate of what net car hire ought to be is seldom made and in any case it is only indirectly related to car-distribution performance.

To some degree the implementation decisions of the car-distribution managers can be deduced from historical data on their decisions, but these decisions are not evaluated against the resulting empty flows in any formal way.

In general, the motivational philosophy that is relevant to the major actors in car distribution has tended to be behavioral rather than quantitative. In other words, judgments about the performance of the car-distribution managers are related primarily to their ability to behave like car distributors and are not based on any formal measure of output.

Information Structure

The proliferation of sophisticated computer-based information systems complicates the task of understanding what information actually supports decision making in any area of the railroad organization. Car distribution is particularly affected because it must use car data from both the real-time operating system and shipper information from the local agencies.

An enormous amount of car-location and status data are collected and manipulated by a railroad's management information system, and much of this information is potentially relevant to the car-distribution activity since distribution decisions are based on the number and location of available empty cars. In addition to this car- oriented information, shipper-order data are also gathered, usually by local agents in the field, and periodically transmitted to the car distributors.

The collection, manipulation, and reporting of these data about the system-state, controllable, and uncontrollable variables were different on each of the railroads investigated. Yet, although the format of the specific reports differed, the type of information available to the car distributors was similar. Car distributors typically do a substantial amount of manual data manipulation to supplement that provided by the computer system. This is particularly true of data concerned with car orders, which are often telephoned to the car distributor by agents in the field and not entered into the computer directly.

The types of information most often found in the car-distribution reports and the relevant time frames within which the reporting occurs are shown below. The tabulation does not show whether the report formats are useful, but it provides an indication of what coverage is available for the factors relevant to car distribution.

Type of Information	Time Frame	
	Real Time	Historical
State variables		
Empty inventory	x	
Empty pipeline	x	x
Cars loaded	x	x
Unfilled demand		
Controllable factors		
Pipeline additions	x	
Empties off line	x	x
Orders filled		
Uncontrollable factors		
Industry releases	x	x
Interchange receipts	x	x
Car orders	x	
Travel time		

Decision Structure

The organizational structure describes who will make which decisions, and the information structure determines what data will be available about the problem. Here, the processes used by the decision maker about car distribution will be described. As proposed earlier in the paper, the description will examine three aspects of each decision process: knowledge, design, and choice.

In analyzing the organizational structure, it was discovered that car distribution is involved in three areas of decision: pipeline additions, foreign empties sent off line, and empties applied to orders. In practice, the first two of these are handled as part of the same decision process. We will thus focus on two major decisions--establishing empty-car disposition instructions and applying cars to orders.

Establishing Empty-Car Disposition Instructions

Knowledge

When car distributors were asked what event or events caused them to make disposition decisions, the most common response was a customer order for cars or an unanticipated problem on the railroad. These events were, in fact, found to trigger the decision-making process in many cases.

However, it often appeared that decisions were made whenever cars became available. This might be called origin- or car-oriented behavior, and it seemed especially typical in times of car shortage. This is a logical approach because, of course, even if there are many car orders, it is impossible to make disposition decisions if there are no cars available.

Design and Choice

Despite extensive observation of car distributors at work, in general it was not possible to distinguish between the process used to find alternatives and the process of criteria used in selection. The literature on the behavior of decision makers supports this finding (9, p. 32). It has been hypothesized that decision making involves an often-undirected search, which stops once a feasible solution has been found. The aspects of design and choice will therefore be treated together.

Before adoption of real-time management information systems on railroads, freight-car distribution was accomplished on a disaggregate basis. Local car distributors would make an assignment decision for every car that became empty within their territory; this process could not possibly account for the interdependencies among disposition decisions.

As their information systems have improved, most railroads have, to some degree, centralized the car-distribution activity and attempted to develop mechanisms that would allow car distributors to make decisions about groups of cars and to leave to the computer the application of the decision to specific cars. The car distributors use a set of well-defined computer instructions that specify the desired pattern of empty-car movements, and the computer determines which instruction is relevant for each car. Two types of typical instructions are (a) movement instructions (MI's), which are used to assign destinations to a specific number of cars of a particular type from a specific origin, and (b) control orders (CO's), which assign a destination to cars at a specific origin that are not covered by any operative movement instruction.

There may also be an option to specify either instruction as absolute (the car is to be assigned as indicated by the instructions whether it is needed locally or not) or permissive (local needs are satisfied first). By making the instructions absolute, the car distributor can attempt to control local inventories as well as flows between points.

These instructions are used by the car-distribution managers to make disposition decisions such as the following: (a) when a car becomes empty on the system, the computer scans the MI and CO files and matches the car's specifications with those contained in one of the control orders; and (b) if the car is a foreign car and is not to be reloaded (or if car service rules prohibit reloading), the computer automatically selects the nearest junction as its destination.

If each origin area were assigned a single MI and CO, there would be little ambiguity about the plan and its execution would be straightforward. In many cases, however, a single origin area may supply cars to many destination areas. In this case the MI's and CO's must be assigned priorities, so that the destinations that actually receive cars will be dependent on the number available in the origin area.

These instructions (or ones like them) are used by car distributors to implement their decisions. What is not clear is how the specific instructions ultimately implemented are selected. There are few formal mechanisms, reports, or analytical tools available to help the car-distribution manager create and test alternatives on most railroads and no well-specified objective or goal to support the selection process.

There is an interesting paradox in all of this. There is little evidence to suggest that car distributors struggle to cope with the numerous options that are, in theory, available to them; without too much difficulty, they manage to make decisions--in fact, they make many every day. Yet the principal reason given for not using analytical problem-solving techniques has been the overwhelming complexity of the car-distribution problem.

Applying Cars to Orders

Knowledge

Car orders from shippers initiate this decision process; these orders are accumulated by local agents, who transmit them once or more each day to the car distributors.

Design and Choice

The car distributors and the local agents share responsibility for the process of applying cars to orders. In some cases, MI's are used to direct specific cars of a particular type to specific shippers from distant terminals. Most often, however, the local agents choose which cars to apply to which orders. It again is very difficult to determine how or why the decisions are made.

In some respects, the local agency is involved in both commercial and operating activities, and feelings of alienation from both the railroad and shipper are evident in the attitudes expressed by local agency personnel. There is a feeling that shippers require the personal contact afforded by the personnel at the local agency, yet this may inevitably lead local agents to make decisions that are in the best interest of the shipper but not the railroad. The commercial and operating roles played by the local agency need to be clarified.

In summary, the managerial tasks necessary to carry out car-distribution activities in a manner consistent with corporate objectives have been identified and the organizational, information, and decision structures adopted to carry out these tasks have been described. Last, the use of the framework for analysis to identify areas where improvement is needed will be demonstrated.

IDENTIFYING AREAS OF POTENTIAL IMPROVEMENT

The description of the car-distribution process provided earlier is a rather strong normative statement about the way car distribution ought to be managed. The main underlying hypothesis is that, given the interdependencies that exist among parts of all transportation firms, substantial management time and effort must be given to the process of ensuring that all actions are coordinated and consistent, especially since the advances in the information and decision systems have improved our ability to achieve such coordination and consistency.

Actual management practices employed to control the car-distribution activity have been described in a way that facilitates diagnosis of the weaknesses in current practice. To this end, those aspects of the organizational, information, and decision structures that appear to be susceptible to improvement are described briefly below.

<u>Organizational Structure</u>

Lack of Interaction Between Car-Distribution and Other Departments

The functional structure adopted by most railroads tends to inhibit interdepartmental participation. A freight-car committee overcomes this problem to some degree, but its principal activities at present are in the area of long-term investment decisions. Interaction to support tactical implementation activities like car distribution is not easily accomplished by committees that meet infrequently.

Lack of Authorized Planner of Car-Distribution Activities

When the organization was analyzed in terms of the task authority structure, it became clear that car distribution is an action-oriented group; the planning that is required to guide the execution process is often absent.

A continuous planning effort is required to reconcile the conflicting constraints and objectives that each major department of the railroad might wish to impose on car distribution and then to translate an agreed-on plan into rules that can guide day-to-day performance. The activities that would be performed by a car-distribution planning group are those that were specified in Figure 4 under corporate direction setting and tactical system planning.

Inadequate Output Control of Car-Distribution Activities

In identifying the accountability relationships relevant to the car-distribution activities, it became clear that the motivational philosophy relevant to the major actors has tended to focus on behavioral control rather than output control. The results of car-distribution activities are not measured and used in the evaluation of individual decision makers; instead, their ability to behave like car distributors seems to be more important.

Behavior control of this type is used most frequently when the output is difficult to measure and attribute to specific decisions. However, the assessment of available information suggests that it is certainly possible to measure the output of car-distribution activities. To use output control, it is also necessary to specify what the desired output is. A more formal planning process to support car distribution would be needed to achieve this.

Information Structure

Lack of Predictive Information to Support Decision Making

Since movement between points on the railroad is time consuming, car-distribution disposition instructions are always based on estimates of future activities. Unfortunately, the information system provides few forecast data helpful to car-distribution decision makers.

Inadequate Car-Order and Percentage-Demand-Fill Information

Car-distribution decisions are instigated by order information, yet the information is collected in an informal manner and is never accumulated systematically. The effectiveness of car-distribution decisions is inherently limited by the quality of the car-order information, and the ability to evaluate car-distribution actions is limited by the quality of the historical car-order data.

The lack of reliable and organized information about car orders from shippers also means that the railroad as a whole is unable to determine what the demand for their product (or service) really is. For example, tonnage and revenue forecasts are typically based on historical car loadings, even though true demand may have been quite different from actual car loadings.

Inadequate Travel-Time or Movement-Cost Information

One objective that is certainly important to car distribution is the minimization of transportation costs required to execute whatever plan is chosen, yet there is little formal cost information in the form of either travel times or movement expenses provided to decision makers in car distribution.

Decision Structure

Lack of Documented Car-Distribution Decisions

Historical data that document empty-car movements are collected and disseminated, but the decisions actually made by the car distributors are not similarly documented. This problem relates in part to the structure of the computer instructions, which do not always define an unambiguous course of action. It also reflects the very technical orientation of the car distributors themselves.

Lack of Alternative Decisions

Despite the fact that the number of alternative possible disposition decisions is enormous, there is no systematic effort to create and evaluate even a few different alternatives. In general, the tools and information provided car distributors do not facilitate the testing of alternative actions. In addition, because those actions that are perceived as most important are in response to some form of crisis, there often is no time to consider alternatives.

The eight aspects of the organizational, information, and decision structures that require improvement have been identified by comparing actual managerial practices with a normative description developed by analyzing the physical process of car distribution and its role within the railroad. By using this approach, it has been possible to diagnose the problem in a manner that accounts for the realities of the decision-making environment. Future research will seek to use the diagnosis results to guide the development of decision support systems for transportation managers.

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Use of Computer Graphics for the Display and Analysis of Railroad Traffic Flows

ALAIN L. KORNHAUSER AND RICHARD ANTUSH

This paper summarizes efforts to (a) obtain commodity-specific traffic volume data for all lines of the U.S. railroad system, (b) display those data on a national scale, and (c) analyze and better understand the absolute and relative distribution of the flow of these commodities. The procedure used to generate these data was a standard traffic assignment of historical traffic data contained in the Federal Railroad Administration (FRA) carload waybill statistics. For the purpose of this study, the 1976 waybill statistics report was expanded to match total annual terminating carloads by railroad and commodity as reported in the 1976 quarterly commodity statistics. Princeton University's Railroad Network Model, an enhanced version of the FRA network model, was used to assign these data to the (most likely) path actually traversed by each carload on the U.S. system. The traffic volume assigned to each link by direction of travel and commodity subgroup was accumulated over all carload records. Graphic displays of some of these accumulated volumes are presented.

The traffic-density chart has long been a useful management information tool. Operational and marketing personnel rely on the density chart to gauge past performance, to plan improvements, and to predict future traffic trends. With an increasing responsibility for financing and planning, the Federal Railroad Administration (FRA) also requires this same information, but on a national rather than a corporate level.

This paper summarizes efforts to (a) obtain commodity-specific traffic volume data for all lines of the U.S. railroad system, (b) display those data on a national scale, and (c) analyze and better understand the absolute and relative distribution of the flow of those commodities.

The 1976 FRA carload waybill statistics report was expanded to match the report of total annual terminating carloads by railroad and commodity in the 1976 quarterly commodity statistics. The data base provides a 1 percent sample of all loaded movement on the U.S. railroad system and furnishes the historical distribution patterns of origin to junction to destination that are characteristic of the U.S. railroad system. This data base was then used as an input for a standard historical traffic assignment by using the Princeton University Railroad Network Model, an enhanced version of the FRA network model.

The model assigns traffic volume to each link in the 17 000-link U.S. railroad system by direction of travel and commodity group. This information is then presented as the standard carload-density chart for the entire U.S. railroad system.

These density charts provide corporate, state, and federal rail planners with a valuable overview of rail movements previously not available.

DATA BASE

The 1976 carload waybill sample formed the base traffic data used to generate the commodity-specific link volumes. These data represent roughly 1 percent of the railroad traffic for the year 1976. They are collected by the Interstate Commerce Commission (ICC), and the sampled waybills are converted to machine-readable form by FRA and are enhanced by researchers at Princeton University. Additional documentation on the 1973-1977 carload waybill statistics is presented elsewhere (1-3).

The 1976 statistics were expanded to represent total annual traffic for that year. The sampling process used in accumulating the waybill statistics centers about a reporting requirement placed on the railroad that terminates the carload. Most of the bias in the sample is caused by uneven reporting by terminating railroads. To reduce the reporting bias, commodity- and railroad-specific expansion factors were developed (all commodity-specific expansion factors for 1976 are on tape IVOLID 3424, at Princeton). The factors expanded the waybill sample to equal total carloads terminated--by commodity [defined by standard transportation commodity code (STCC)] and by railroad--as reported in the quarterly commodity statistics (QCS) for 1976. The expansion factors ranged from 85 to 135; an example of the expanded statistics for railroad 190 of the Consolidated Rail Corporation (Conrail) is presented in Table 1.

Traffic assignments were produced for 19 unique commodity groupings plus a special grouping of all trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) traffic and total traffic. Table 2 lists each of the commodity subgroups used in this study (based on the 1977 ICC STCC tariff 1-F).

PATH-FINDING AND TRAFFIC ASSIGNMENT ALGORITHMS

The algorithmic procedure used to transform the basic route data contained in each waybill record into carload volumes by direction on each link (segment) of the U.S. railroad system is encompassed within the Princeton Railroad Network Model. This model was developed by Princeton University through research contracts funded by both FRA and the ICC Rail Services Planning Office; it is kept on Princeton University's computer system. A more-complete description of the model is presented elsewhere (4).

The Princeton Railroad Network Model is, in fact, an enhanced version of the FRA network model. It consists of five basic elements: the link-node network, railroad traffic assignment model, computer-graphics module, cross-reference files, and submodels.

Link-Node Network

A machine-readable link-node description of the U.S. railroad system is the first basic element of the enhanced FRA network model. This link-node depiction of the railroad system has been enhanced to represent the actual U.S. railroad system more closely. Elements such as trackage rights are included, and all corporate railroad networks are connected. Also included are current versions of the networks for Conrail, Delaware and Hudson Railway Company, and National Railroad Passenger Corporation (Amtrak), as well as for all other class I railroads. The basic characteristics for the network links and nodes included in the network data base are presented below ("503 code" is the FRA Section 503 main-line--branch-line code, "SPLC list" is the standard-point-location-code list, and "FSAC list" is the freight-station-accounting-code list):

Link	Node
A-line node number	Number

Table 1. Example of commodity-specific expansion factor for 1976 terminated traffic.

Three-Digit STCC	1976 QCS Carloads	1976 Waybill Carloads	QCS/Waybill Ratio
11	63 981	705	90.753
12	13 375	164	81.55
13	20 987	252	83.282
14	994	12	82.833
19	607	7	86.714
84	144	11	131.273
86	64	0	0.0
91	135	2	67.5
101	188 931	1816	104.037

Table 2. Commodity subgroups.

Stratified Commodity Subgroup	STCC Number	Commodity
1	01	Farm products, field crops
2	10	Metallic ores
3	11	Coal
4	142, 144	Crushed stone, gravel and sand
5	09, 14 (except 142 and 144)	Fresh fish or other marine products, nonmetallic minerals NEC
6	204	Grain mill products
7	20 (except 204)	Food or kindred products NEC
8	08, 241	Forest products, primary forest products
9	24 (except 241)	Lumber or wood products NEC except furniture
10	26	Pulp, paper, and allied products
11	19, 28	Ordnance or accessories, chemicals or allied products
12	13, 29	Crude petroleum, natural gas, or gasoline; petroleum or coal products
13	32	Stone, clay, concrete, or glass products
14	33, 34	Primary metal products, fabricated metal products
15	37	Transportation equipment
16	40	Waste or scrap materials
17	41, 42, 44, 45, 46, 47	Miscellaneous freight shipments (41), containers, shipping, returned empty (42), freight forwarder traffic (44), shipper association or similar traffic (45), miscellaneous mixed shipments (46), small package freight shipments (47)
18	35, 36	Nonelectrical machinery, electrical machinery
19	NEC 21, 22, 23, 25, 27, 30, 31, 38, 39	Tobacco products (21), textile mill products (22), apparel products (23), furniture (25), printed matter (27), rubber or miscellaneous plastics products (30), leather products (31), instruments or photographic goods (38), miscellaneous manufactured products (39)

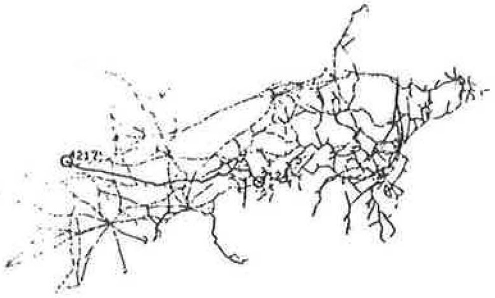
Note: NEC = not elsewhere classified.

Link	Node
B-line node number	Name, county, state
Distance	x-coordinate
Owner	y-coordinate
Track rights	Yard type
503 code	TOFC ramp (yes, no)
	SPLC list
	FSAC list

Table 3. Structure of record input to railroad traffic assignment model termed ABSORT.

Field Number	Field Length	Description	Typical Value
1	3	Railroad	22 (Atchison, Topeka, and Santa Fe)
2	5	On-railroad node	4217 (Chicago)
3	5	Off-railroad node	1623 (Los Angeles)
4	5	Carloads farm products	3
5	5	Carloads metallic ores	12
6	5	Carloads coal	0
.	.	.	.
.	.	.	.
.	.	.	.
23	5	Carloads TOFC	1

Figure 1. Examples of computed best path between Pittsburgh and Chicago on Conrail.



Railroad Traffic Assignment Model

This is the basic algorithm of the Princeton Railroad Network Model. It requires that the locations (network node numbers) at which traffic originated and left a particular railroad and a vector that contains the characteristics of the traffic that is traveling between any two nodes be input. The vector of characteristics can include a wide variety of items, such as total carloads, tonnage, revenue, TOFC cars, cars of flammable liquids (STCC 4910), covered hoppers, covered hoppers that carry grain, and covered hoppers owned by the Southern Railway Company that carry grain. For the purposes of this study, the vector of characteristics was total carloads of traffic in each of the four-digit STCC hazardous subclasses. The structure of the record input to the railroad traffic assignment model is presented in Table 3. The input data are normally obtained from waybill samples. The route contained in each waybill record is separated into segments unique to each railroad that participated in the carload movement. The origin, destination, and interline junction fields are used to define the on- and off-railroad nodes for each segment of the move. Other waybill data elements define the unique characteristic of the shipment and the quantity to be entered into the appropriate field of the input file. The file created from the waybill data (ABPAIR) is sorted by railroad number to segregate all movements handled by each railroad. This sorted file is termed ABSORT. The railroad traffic assignment model operates on all records for any one railroad at one time. For each record the algorithm finds the best (minimum-impedance) path on the railroad network in question. While any analytic impedance measure can be used, the model uses a simple measure,

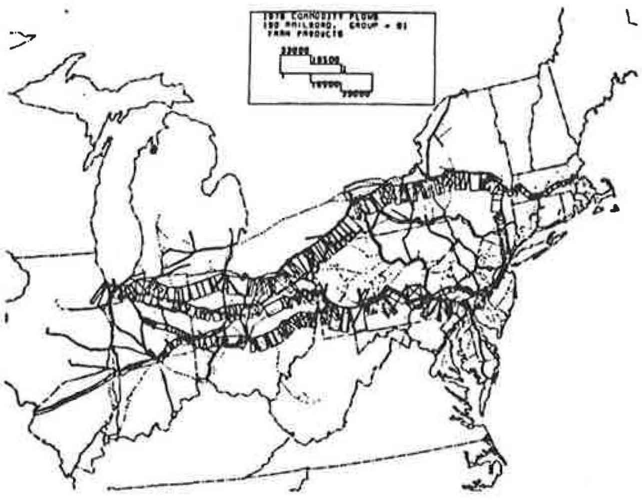
$$\sum_{k \in P} D_k MLC_k$$

where D_k = distance on link k, MLC_k is the FRA Section 503 main-line--branch-line code of link k (1 = A main line, 2 = B main line, 3 = A branch line, 4 = B branch line), and the sum is taken over the links that make up path P on the railroad in question. The best path P* is the path that minimizes the sum. An example of such a path computed on Conrail between Pittsburgh and Chicago is shown in Figure 1. Once the path P* has been

Table 4. Output file of railroad traffic assignment model specific to flow of 19 commodity subgroups.

Field Number	Field Length	Description	Typical Value
1	3	Railroad	22 (Atchison, Topeka, and Santa Fe)
2	5	Link number	11 632
3	5	A-line node	14 371
4	5	B-line node	14 370
5	5	Carload volume A-B farm products	82
6	5	Carload volume B-A farm products	47
⋮	⋮	⋮	⋮
43	5	Carload volume A-B TOFC	2
44	5	Carload volume B-A TOFC	4
45	7	Carload volume A-B total 1976	4632
46	7	Carload volume B-A total 1976	2573

Figure 2. Commodity flows: farm products (1976).



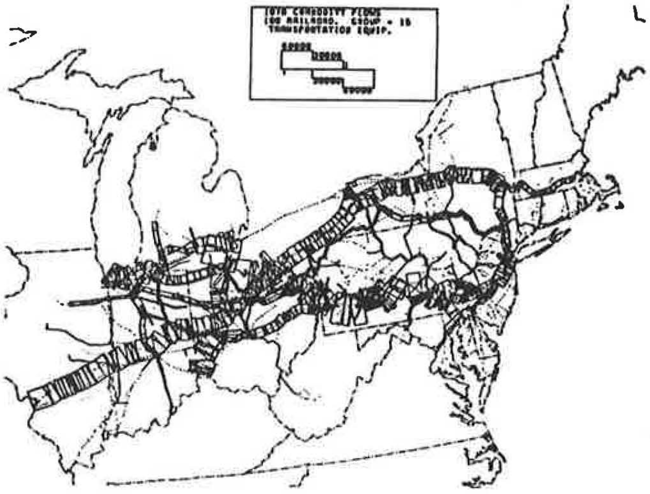
found, the algorithm increments direction-specific volume entries for each of the k links of path P*. The amount of the increment is the value of each flow characteristic.

The railroad traffic assignment model is extremely efficient in these computations. It takes advantage of an efficient algorithm that generates minimum spanning trees and a data-restructuring procedure that minimizes the number of times that the tree-generation routine is executed.

The output file of the railroad traffic assignment model contains total link and volume data for each railroad, as presented in Table 4. [The output files produced by this project were delivered to the Transportation Systems Center of the U.S. Department of Transportation in Cambridge, Massachusetts. The tape version is called 3424, the disk version of which is stored at Princeton University (MTH204, files 404, 405).]

Because a number of segments of the U.S. railroad system are used jointly by two or more railroads, the following process is used to obtain total link volumes. To calculate total characteristic volumes on a link, a separate buffer is created that contains two vectors 17 000 links long for each flow characteristic. By cycling through the volume data for each railroad and increasing the appropriate elements of the buffer, total volumes on each link are progressively accumulated. Thus, both railroad-specific and total link volumes, by direction, for each characteristic are computed for each link in the U.S. railroad system.

Figure 3. Commodity flows: transportation equipment (1976).



Computer-Graphics Module

The Princeton Railroad Network Model includes a battery of computer-graphic processors that provide rapid graphic displays of the input and output data. The graphic processor allows for the display of the railroad network in its entirety, by individual railroad, or by other specification. State and county boundaries, link volumes that use rectangles the depth of which is proportional to volume by direction (the rectangles are drawn on each side of the link to represent the flow in each direction), node volumes, and alphabetic characters are examples of other graphic displays. Copies of the graphics can be produced on cathode-ray-tube hard-copy units or by multicolor Calcomp plotters.

Two examples of railroad-specific traffic volumes are presented (Figures 2 and 3). They were computer drawn on a Tektronix 4015 terminal from which instant hard copies were made, which are shown here. Different types of lines were used for state boundaries, railroad links, and directional volumes. Figure 2 shows the flow of farm products on Conrail. Two principal routes are used, the so-called "water-level route" and the former Pennsylvania Railroad main line. The traffic volume on both is about equal. Note the almost total absence of traffic in the Northeast Corridor. In comparison, Figure 3 shows the flow of transportation equipment. The focus is Detroit, from which a large amount of southbound traffic goes to the Cincinnati gateway and westbound traffic to the St. Louis gateway. Good directional balance in flow exists on the water-level route west of Buffalo; however, east of Buffalo the flow is exclusively eastbound. The former Pennsylvania Railroad main line has a well-balanced flow, and the New Jersey portion of the Northeast Corridor has significant traffic volume.

Cross-Reference Files

The Princeton Railroad Network Model contains

Figure 4. Estimated carload volumes: farm products (1976).

Figure 5. Estimated carload volumes: metallic ores (1976).

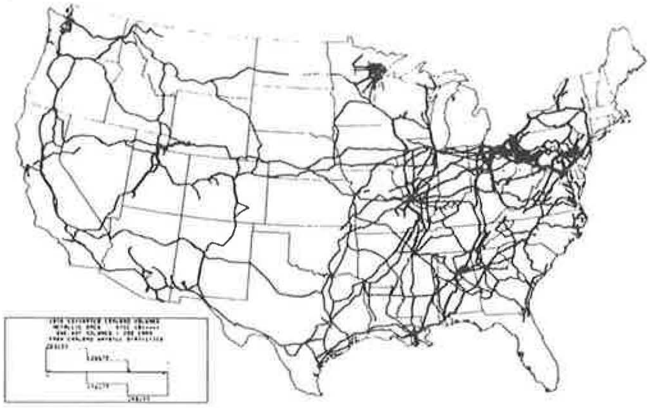
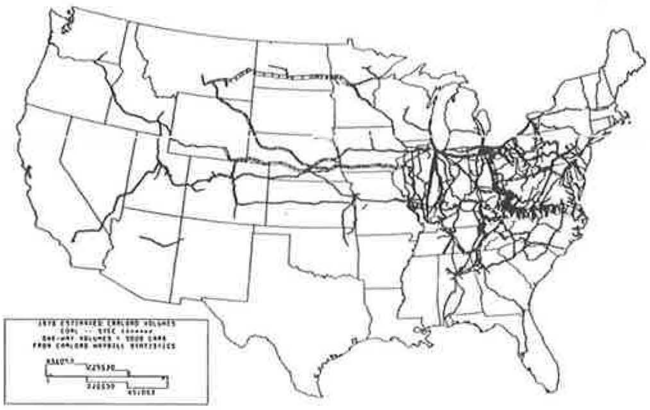


Figure 6. Estimated carload volumes: coal (1976).



cross-reference files that permit the translation of socioeconomic and railroad operations data so that they can be displayed graphically. Cross-reference files exist for correlation between network node numbers and the following data: the SPLCs, the Association of American Railroads mandatory rule 260 junctions (5), Amtrak station abbreviations, railroad accident record locations, and TOFC stations.

Submodels

Submodels included in the Princeton Railroad Network Model are an analytic division formula for allocating revenue to each carrier, an elementary cost model, and network and data editing modules that use computer graphics.

Figure 7. Estimated carload volumes: grain mill products (1976).

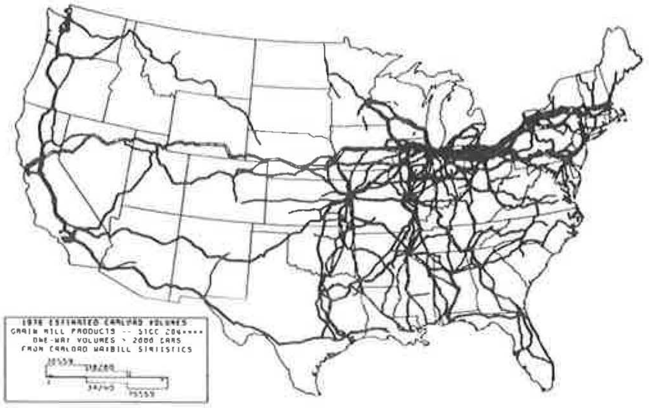


Figure 8. Estimated carload volumes: forest products (1976).

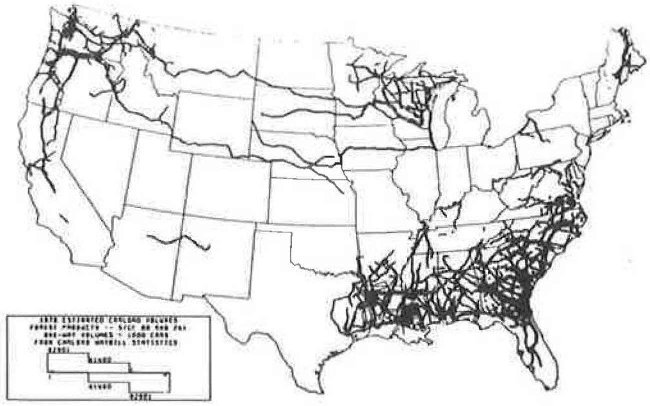


Figure 9. Estimated carload volumes: pulp and paper (1976).

GRAPHIC DISPLAYS OF EXAMPLES OF CARLOAD VOLUMES

Figures 4 through 13 are examples of graphic displays of traffic volumes for some of the 19 all-inclusive commodity classes, for the TOFC volume, and for estimated total carload volume across the United States. Each map is drawn by using an autoscale function that selects the scale

Figure 10. Estimated carload volumes: ordnance and chemicals (1976).

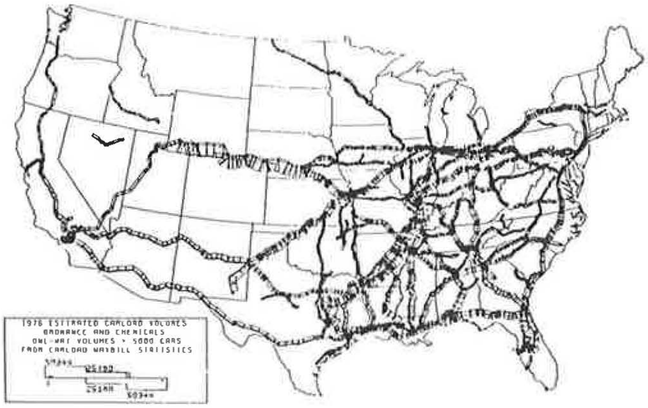


Figure 11. Estimated carload volumes: transportation equipment (1976).

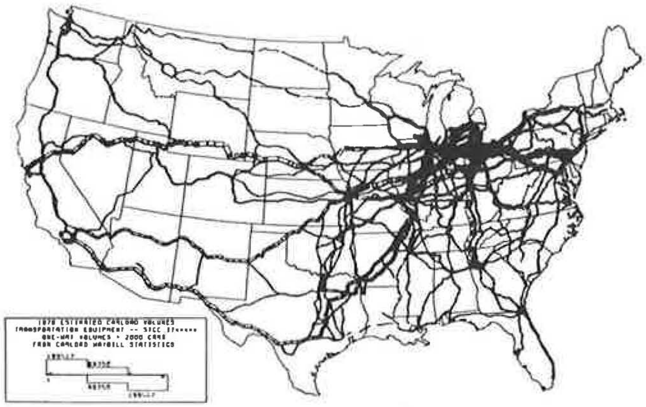


Figure 12. Estimated carload volumes: TOFC (1976).

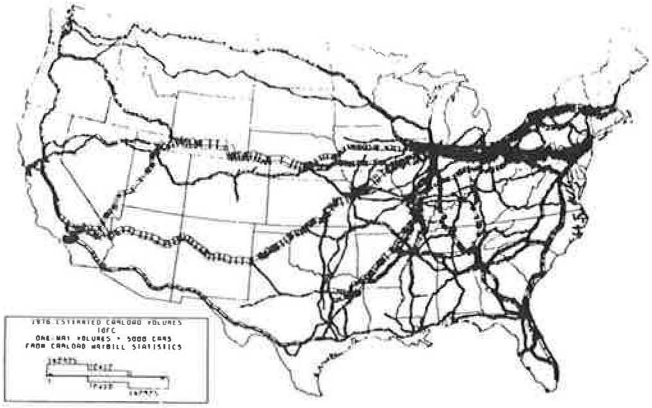
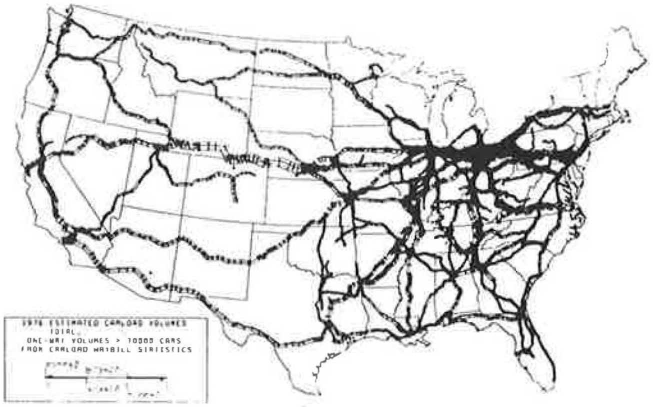


Figure 13. Estimated total carload volumes: (1976).



as a function of the traffic volume on the most heavily used link. Thus, one gets maximum resolution on each map; however, one cannot compare the volume on one map with that on another without careful consideration of the scale given in the legend of each map. Even with autoscaling it is impractical to display all 17 000 links of the network. Thus, only the most heavily used segments are displayed. Each legend describes the car volume threshold used to select those links that would be displayed. In general, each map displays approximately 5000 of the 17 000 links.

Each map relays a great deal of information about the flow of each commodity subgroup across the U.S. railroad system. Absolute as well as relative traffic densities are displayed. Direction of movement, directional balance and imbalance, and major production and consumption points are clearly identifiable. For example, farm products (Figure 4) are clearly westbound and southbound. The Union Pacific main line seems to be the most heavily used line for this commodity, whereas there are very large southbound flows to the ports of Houston and New Orleans, and the ports of Duluth-Superior and Norfolk also exhibit significant terminating volumes.

Metallic ores (Figure 5) exhibit totally different traffic patterns; there exist extremely large (and short-haul) traffic volumes around Duluth and the Louisiana panhandle and moderate flow in Pennsylvania and from Salt Lake City to Wyoming. The rest of the country has a relatively sparse volume of this kind of traffic.

TOFC traffic, on the other hand (Figure 12), is fairly well distributed and exhibits good directional balance. The former Pennsylvania Railroad main line, Conrail water-level routes, and the Union Pacific main line seem to be the most heavily used corridors for TOFC traffic. The Atchison, Topeka, and Santa Fe Railway and the Missouri Pacific Lines serve the southwest to Chicago, and the Seaboard Coast Line and the Louisville and Nashville Railroad Company (Family Lines) are the most heavily used in the corridor from the southeast to the northeast.

Total estimated carload volumes are displayed in Figure 13. The former Pennsylvania Railroad main line, the Conrail water-level route, the Union Pacific main line, and the Norfolk and Western line to Point Lambert, which carries coal downhill from Kentucky and West Virginia, are in the most heavily used corridors. Many other aspects and characteristics of the movement of railroad traffic are evident from the study of these computer-graphic maps.

ACKNOWLEDGMENT

This work was sponsored by the Transportation Systems Center and monitored by Walter Maling.

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Analysis of Brokerage Feasibility for Unit-Coal-Train Shipments to the Midwest

RITA KNORR, STEPHEN VEZERIS, AND KURT WILKIE

The purpose of this paper is to determine the feasibility of aggregating industrial and utility demands for coal and of serving the demands through a local brokerage operation to reduce transportation cost. This cost saving is associated with the economy of scale of unit-train shipments. The delivered price of western coal is calculated for local users in a given Midwest subregion based on current utility and industrial coal demands. The broker operation would consist of unit-train hauls from western mines, a receiving and storage terminal, local truck or rail transportation from the terminal to each user, and possible transshipment to distant waterfront users. The research focuses on the area of Green Bay-Kewaunee in Wisconsin. Applicability of this brokerage concept to other areas that receive western coal shipments is also discussed.

In order to decrease U.S. dependence on foreign energy products used by utilities and industries, the Carter Administration has mandated an increase in the share of coal-fired industrial and utility boilers. This will create the need for more coal that is capable of meeting clean-air standards. Western mines are the obvious source due to the plentiful amount of low-sulfur coals. These mines have entered into long-term contracts with many large utilities (1). These long-term commitments allow for reduced cost of delivery of the coal, largely due to the use of unit trains. Users of small amounts are unable to capture these reduced costs because of their low-volume shipments. As more utilities want to convert to western coal and as industrial coal-fired boilers become more prevalent, alternative distribution methods may be required to make coal a more cost-effective energy alternative for these users.

The objective of this paper is to present a concept called coal brokerage, by which the coal demand of an area is aggregated and served through a single facility in order to achieve the high volumes necessary to justify unit-train service. Once such a system is initiated, it is conjectured that those users whose orders are too small to receive unit trains individually can begin to capture the cost savings associated with unit-train service.

In order to analyze the coal-brokerage concept, the region of Green Bay-Kewaunee in Wisconsin was chosen as the site for analysis because (a) there had been speculation by lower-peninsula Michigan utilities about a Wisconsin transshipment site for western coal, (b) the area's paper industry uses a large amount of coal, (c) the Wisconsin Energy Office has researched coal consumption in depth and has an available data base for industrial boilers and their fuel type, (d) line-haul rail routes allow for adequate access from western mines to utility and industrial coal users, and (e) there is no single user or facility currently large enough to handle unit-train shipments.

In this paper, the existing geographical traits of the Green Bay-Kewaunee region, including the local transportation network, are detailed. Alternative brokerage setups and operational strategies are discussed. Total coal demand necessary to substantiate a brokerage and transshipment site is estimated. A detailed description of the current prices of line-haul rail, terminal and transshipment, and local distribution is given in order to calculate the total cost of coal to the subscribers of a brokerage operation, and these figures are compared with current local coal prices. Finally, the advantages and disadvantages of the brokerage concept are outlined, and their application to other sites and to bulk commodities is summarized.

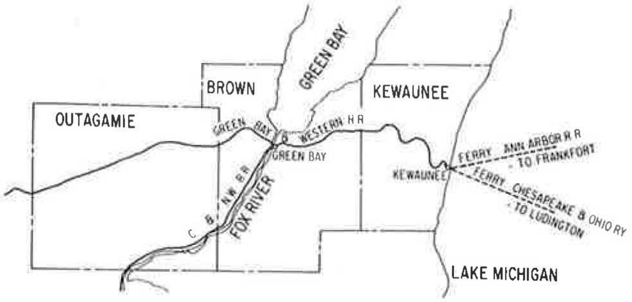
SITE DESCRIPTION

The Green Bay-Kewaunee region is in northeastern Wisconsin and includes Outagamie, Brown, and Kewaunee counties. The area is delimited by Lake Michigan, Green Bay, and the Fox River, as shown in Figure 1. The Fox River is navigable only six miles upriver from the bay, where the port facilities and major industries are located. The industry in Green Bay primarily revolves around paper products. The paper and pulp mills are located along the riverfront due to their needs for coal shipments and for water. No significant industry is located in Kewaunee.

The industry of the area is relatively stable; no major growth trends are evident. No riverfront land is readily available for new industries, and the navigation aspects of the river channel restrict the use of larger vessels now under construction. However, a vacant industrial area along the bay not far from the river, called Bayport, is available for new industry and is the most likely location for a coal-brokerage terminal. The present industrial area has been declared an environmental nonattainment area, which means that air-pollution levels may force any new industries to locate farther away from the present industrial core.

Northeastern Wisconsin's transportation system consists of three railroad companies, adequate highways and streets, and port facilities for Great Lakes shipping. The Chicago and North Western

Figure 1. Green Bay-Kewaunee region.



Transportation Company (CNW) and the Chicago, Milwaukee, St. Paul, and Pacific Railroad Company are major railroads serving Green Bay. The Green Bay and Western Railroad Company (GBW) serves points west to the Mississippi River, where it connects with the Burlington Northern, and a transshipment point at Kewaunee to the east. Figure 1 shows the rail lines that would play a role in increased coal traffic. Potential problems of increased coal traffic are (a) greater use of an old GBW bridge over the Fox River that is regularly out of service, (b) the need for heavier rail on the GBW main line, and (c) increased rail traffic in certain residential areas. These problems can be resolved by rerouting and investment.

Green Bay is served by highways that link it with Fox River Valley cities, points along the Lake Michigan shoreline, including Kewaunee, and the upper peninsula of Michigan. Three highways form a divided-highway belt around the city. The street system is a basic grid adapted to the Fox River; adequate arterials through main corridors serve the industrial areas well.

Kewaunee and Green Bay both serve as Great Lakes ports, and each offers potential advantages as coal-transshipment points. The port of Kewaunee is capable of year-round operations and offers a more-direct route to Michigan utilities than does Green Bay. The port and its surrounding area have an acreage constraint that affects coal storage and track layout due to the Kewaunee River wetlands, which are protected by the Wisconsin Department of Natural Resources, and steep bluffs that rise to 50 ft. The Green Bay area has an adequate transshipment site (Bayport), which has ample available land for a coal terminal. The port of Green Bay is planning to build an L-shaped peninsula into the bay to serve larger ships now unable to navigate the Fox River, but environmental questions about impacts on the bay and nearby wetlands have been raised. A disadvantage of a Green Bay site is that the port is closed for three to four months of the year due to ice conditions.

THE COAL BROKERAGE

The coal-brokerage concept focuses on aggregating user demands and on using high-volume transportation and handling to meet those demands. The concept of consolidating bulk commodity shipping is not new, but its application to coal delivery is uncommon. In agriculture, terminals collect grain from farms for transfer onto rail or barge. In the eastern coal industry, individual carloads of coal from area mines are collected to form unit trains. The coal-brokerage concept differs in that coal from one source is distributed to several users, as opposed to the collection of commodities from several points and their transportation to one user. The high output of western coal mines allows the use of one source.

The coal-brokerage operation centers on a bulk-handling facility. A terminal is necessary for receiving high-volume line-haul shipments, for storing these shipments, and for distributing them to local users. Storage is necessary to smooth out the disparity between batch arrival and continuous use of coal. Therefore the operation consists of (a) high-volume transportation from the mine, (b) a receiving and storage terminal, and (c) transportation from the terminal to the user.

Terminals may be arranged in a variety of ways depending on site advantages and constraints. A train-unloading system is necessary; this can be done by bottom dumping, in which hopper cars are emptied from the bottom into a coal pit beneath the track, or by rotary dumping, in which cars are individually turned over and the coal is dumped into a bin. A track layout that minimizes switching and uncoupling is most efficient, but land constraints may require a less-favorable layout. A track loop is preferred to parallel holding tracks because of its continuous operating capabilities. A stacking and reclaiming system is needed to move coal from the dumping area onto a stockpile (stacking) and to remove it from the stockpile (reclaiming). These tasks can be accomplished by a single stacker-reclaimer, which both dumps and removes coal from the top of the stockpile, or by a system that dumps coal from the top and reclaims it from tunnels beneath the stockpile. Last, equipment is needed for transfer to other modes; such equipment as stationary shovelers or mobile front-end loaders are needed for trucks, and rail cars and dock-mounted ship loaders are needed for transshipment. Conveyor belts typically connect the unloading, stacking-reclaiming, and loading systems.

BROKERAGE ALTERNATIVES

The relative advantages and disadvantages of brokerage sites at Kewaunee and Green Bay, as well as their potential as transshipment sites, created the need for various brokerage alternatives. Each alternative is a type of operation and terminal setup that could conceivably serve coal demand by using the brokerage concept.

The first alternative consists of a major bulk terminal at the Bayport site in Green Bay. Unit-train coal would be stockpiled and distributed locally by rail or truck and also loaded onto lake vessels for delivery to lower-peninsula utilities. Advantages of a Green Bay site include nearness to users (many within a 3-mile radius) and plentiful land for efficient train unloading and stockpiling. A disadvantage includes the suspension of transshipment during the winter months, which requires stockpiling by the Michigan users.

Another alternative is to send a portion of unit trains to a Kewaunee facility. This would exploit the advantages of year-round shipping from Kewaunee. For example, unit-train deliveries might alternate between Kewaunee and Green Bay. The second alternative would therefore include building two smaller terminals. The Green Bay site would receive, store, and distribute coal as before, but without transshipment. The Kewaunee site would receive, store, and transship the coal to Michigan utilities. Disadvantages include the loss of scale economies from the use of two smaller terminals and limited land for storage at the Kewaunee site.

A third alternative is a modification of the second and addresses the storage problem at Kewaunee. The need for storage can be eliminated if coal is loaded directly onto a vessel from the unit

Table 1. Projected coal demand of industries and utilities.

	Coal Tonnage (000 000s)			
		Projected Year		
Site	Base Year 1978	1980	1985	2000
Wisconsin				
Green Bay industries	810	810	810	810
Pulliam utility	767	767	767	767
Michigan				
Muskegon utility	1366	3308	3308	3308
West Olive utility	1416	1416	1416	1416
Holland utility	146	146	146	146
Grand Haven utility	0	0	212	212
Total	4505	6647	6659	6659

Note: Data are from Asbury and others (1) and Wisconsin Energy Office.

Table 2. Estimated costs of western coal for three alternative locations.

	Cost by Location ($/ton)		
Item	Green Bay	Green Bay-Kewaunee	Green Bay-Kewaunee (no storage)
Component costs			
FOB mine	11.00	11.00	11.00
Unit train	10.00-14.00	10.00-14.00	10.00-14.00
Brokerage facility			
Green Bay	1.50-2.25	1.50-2.25	1.50-2.25
Kewaunee		1.50-2.25	0.50-0.85
Great Lakes shipping			
Green Bay-Michigan	1.11		
Kewaunee-Michigan		0.63	0.63
Local distribution			
Rail	1.68-2.84	1.68-2.84	1.68-2.84
Truck	1.00-1.50	1.00-2.50	1.00-2.50
Delivered price			
Wisconsin by local rail	24.18-30.09	24.18-30.09	24.18-30.09
Wisconsin by local truck	23.50-28.75	23.50-28.75	23.50-28.75
Pulliam	22.50-27.25	22.50-27.25	22.50-27.25
Michigan	23.61-28.36	23.13-27.88	22.13-26.48

train. Less equipment and less land are needed in this setup. A disadvantage is the requirement of accurate timing between rail and vessel arrivals.

Other alternatives were considered but rejected for various reasons. A single central facility in Kewaunee was rejected because of the storage problem and because of the 35-mile westward backtrack from Kewaunee to the Green Bay users. The distance is not economically wise for a large-volume trucking operation and could cause serious local roadway maintenance and environmental problems. Another idea was to have the unit train drop off a specified number of full hopper cars in Green Bay on its way to Kewaunee. The cars would be distributed locally without the need for a terminal facility in Green Bay while the rest of the train was unloaded at a Kewaunee facility. The major problem here is that unit-train rates would not apply due to the breaking of the train.

UTILITY AND INDUSTRIAL COAL USE

The utilities in Wisconsin and Michigan that will be most likely to benefit from any new western coal distribution from the Green Bay-Kewaunee area are Pulliam in Wisconsin and Muskegon, West Olive, Holland, and a new power plant to be sited in Grand Haven on Michigan's lower peninsula. Demand data for 1972-1978 use of coal by utilities and data obtained by telephone on the new power plant formed the basis of an estimation of base-year and projected coal use for each utility site (1). The data consist of a listing of all coal-using utilities, their sources of coal, the type of haul, and coal heat content, sulfur emissions, and price.

Wisconsin utility coal demand was studied at the Pulliam plant in Green Bay. Coal demand was relatively constant throughout the 1972-1978 period. No new boilers have come on line, and it is expected that this will be the case in the future due to the stable nature of the area's economy. Table 1 shows the present demand at the Pulliam plant and the projected demand based on no new boilers or increase in coal demand.

The present and projected coal-tonnage requirements for the Michigan plants are also shown in Table 1, in which growth is seen only at the Muskegon site, where additional facilities are under construction. The new Grand Haven power plant is scheduled to be operational by 1982.

Projected industrial coal use in Green Bay shown in Table 1 is about 810 000 tons/year based on Wisconsin Energy Office data. The industrial coal demand, generated largely by paper and pulp mills, is projected to remain constant.

Boiler conversions from oil and natural gas to coal may occur as a result of price decontrol for these fuels. Location will play a role in the extent of conversions due to the designation of the industrial core as a nonattainment area. Users that are potentially the strongest candidates for conversions will not alter the aggregate industrial demand substantially.

COST ANALYSIS

Brokerage Cost Components

An important aspect of brokerage feasibility is its cost competitiveness with present coal-delivery operations. If the delivered price of western coal to users via a broker is not competitive with present prices, the brokerage will not be economically feasible. A way of deriving the delivered price is to identify the cost of each component for a mine-to-user journey. Such components include freight-on-board (FOB) mine costs, unit-train rates, brokerage-facility costs, local-distribution costs, and Great Lakes shipping costs for Michigan users. Estimates of these costs by the alternatives are shown in Table 2; they were obtained by surveying similar current operations.

FOB mine cost is the price charged for mining coal and loading it onto a rail car. This price is primarily dependent on the type of mine and the amount of coal purchased. Since our interest centers on western coal, the FOB mine cost shown is for the Decker Mines of Montana and assumes the purchase of 4 000 000 tons/year (2). The total demands of Green Bay utilities and industry and of eastern Lake Michigan utilities are likely to exceed this amount.

Unit-train rates are dependent on distance traveled and annual tonnage. It is difficult to obtain a point estimate for a given distance and tonnage, so rate ranges are shown in Table 2. These data apply to a 1031-mile Decker-Superior route and are used due to geographical similarities to a Decker-Green Bay route (2). The latter route is roughly 100 miles longer and is not likely to affect this rate range significantly.

Handling costs at the brokerage facility depend on the capacity and capabilities of the terminal. The transshipment cost of $1.50/ton shown in Table 2 has been confirmed by a coal-terminal engineering firm as an industry standard (according to J. Norwood of Dravo Corporation) for a facility of medium to high capacity (10 000 000 tons/year or

Table 3. Price of coal delivered to Wisconsin and Michigan utilities.

Utility Site	Current Price[a]	Estimated Delivered Price ($/1 000 000 Btus) Green Bay	Green Bay-Kewaunee	Green Bay-Kewaunee (no storage)
Wisconsin				
Pulliam	1.22-1.33	1.17-1.42	1.17-1.42	1.17-1.42
Michigan				
Muskegon	0.98-1.35	1.23-1.48	1.20-1.45	1.15-1.38
West Olive	1.15-1.64	1.23-1.48	1.20-1.45	1.15-1.38
Holland	1.69	1.23-1.48	1.20-1.45	1.15-1.38

[a] Assumes 12 000 Btu/lb.

Table 4. Price of coal delivered to Green Bay industries.

Amount Used per Year (tons 000s)	Current Price[a]	Estimated Delivered Price ($/1 000 000 Btus) Green Bay	Green Bay-Kewaunee	Green Bay-Kewaunee (no storage)
0-50	1.87-2.08	1.22-1.56	1.22-1.56	1.22-1.56
51-100	1.66-1.87	1.22-1.56	1.22-1.56	1.22-1.56

[a] Assumes 12 000 Btu/lb.

more) that has rail-dumping, storage, and ship-loading capabilities (2). Such a facility would be required for the first alternative, in which the brokerage operation would be located in Green Bay. The second alternative requires two smaller terminals, and the throughput cost rises as expected. A $1.95/ton price is interpolated from estimates of $1.50 for a 10 000 000-ton/year facility and $2.25/ton for a 2 000 000-ton/year facility, assuming the need for a 5 000 000-ton/year facility at each site (according to J. Norwood, Dravo Corporation). A range of $0.50-0.85/ton for direct rail-to-water transfer without storage capability is shown under the third alternative. The price of $0.85/ton was quoted by an Illinois mining company (according to G. Roberts, Freeman United Coal Company) and by a New York utility (according to D. Vrooman, Niagara Mohawk Power Corporation).

Transshipment of coal to Michigan utilities involves a Great Lakes shipment from the brokerage site. The figures in Table 2 assume $0.006/ton-mile for an average trip length of 105 miles from Kewaunee to Michigan and 185 miles from Green Bay to Michigan (2,3). The Michigan utilities considered are on lakefront sites, and the assumption is made that there is no need for local truck or rail transfer. The cost of unloading is assumed to be included in the Great Lakes shipping costs.

Local rail and trucking prices were obtained from conversations with local railroads and paper companies, since such rates are site specific. The tariff ranges from $1.68/ton for a local switch by the GBW to $2.84/ton for a 20-mile shipment between Green Bay and Kimberly, Wisconsin, by the CNW (ICC tariff 17104-C, item 234; ICC tariff 6639, item 570). The two rates thus set a range for local rail distribution. The local truck-haul rate paid is $1.00/ton for a truck haul of 2-3 miles (according to C. Prince of Proctor and Gamble Company).

Cost Comparison

The delivered prices for the various delivery modes and destinations are obtained by adding the appropriate price components. For example, the delivered price to Green Bay by rail (Table 2, Wisconsin by local rail) is the sum of FOB-mine, unit-train, Green Bay brokerage-facility, and local-rail costs, while the delivered price to Michigan utilities is the sum of FOB-mine, unit-train, Kewaunee or Green Bay brokerage-facility, and Great Lakes shipping costs. The Pulliam price is a special case; the utility's location next to the brokerage site decreases or eliminates local distribution costs.

Before a comparison of present prices and estimated broker prices can be made, a conversion is necessary. Eastern and western coals differ in their heat content, so examining prices paid per ton of coal is not an accurate way to compare prices paid for energy. The estimated delivered prices from Table 2 have been converted to dollars per million British thermal units; a heat content of 9600 Btu/lb for Decker coal was assumed (2). These prices and the current prices paid by Wisconsin and Michigan utilities and Green Bay industries are shown in Tables 3 and 4 (1); the current prices were obtained by assuming 12 000 Btu/lb for the eastern and midwestern coal now used.

In a comparison between prices and estimated broker prices, several observations can be made. Broker prices to the Pulliam generating plant in Green Bay are within the range of prices now paid (Table 3). This means that western coal prices via a broker do not offer substantial cost savings for the plant but are competitive. However, it would cost more than the current price for the Michigan utilities to obtain western coal through a Wisconsin terminal (Table 3).

It is understandable that brokered coal does not offer substantial cost savings to utilities because the volumes of coal used are relatively high and have already enabled high-volume purchases and forms of delivery. However, industrial users are more likely to realize cost savings from a brokerage due to the higher purchase and transportation prices paid for lower volumes of coal. For example, the Pulliam plant pays $30-35/ton for eastern coal, whereas Green Bay industries that use less than 50 000 tons/year pay $45-50/ton. Table 4 shows that a coal brokerage would indeed provide substantial cost savings to Green Bay industries. The magnitude of possible savings can be illustrated by the fact that a saving of $0.50/1 000 000 Btu for a plant now burning 50 000 tons of eastern coal per year will result in a total saving of $600 000/year.

FINDINGS

A cost analysis of brokerage alternatives shows that western coal via a broker can offer significant savings for the Green Bay industrial users. Prices of brokered coal are competitive with prices now paid at the Pulliam plant in Green Bay; however, the brokerage coal does not seem to be cost competitive for Michigan utilities.

The Michigan utility demands make up a significant portion of the total demand (Table 1) and are important in supporting the volume assumed in the cost analysis. Therefore, the feasibility of a brokerage in this area appears to be contingent on a decision by Michigan utilities whether to use western coal despite the price disadvantage.

Air-quality standards play a large role in the decision and will favor western coal if they are not relaxed. It is likely that Michigan utilities may favor western coal due to its slower price escalation, since eastern coal prices have risen faster than western coal prices due to labor demands and mining techniques. These factors suggest that western-coal use on the lower peninsula of Michigan may well become widespread enough to justify the volumes assumed in this study.

Other issues and assumptions underlie the above conclusions of this study: (a) Demand projections have been based on present stringent air-quality standards; (b) it has been assumed that all coal users are capable of using western coal; (c) infrastructure issues affect the feasibility of a brokerage and have not been addressed (e.g., the owner or operator of a brokerage could be a utility, coal company, shipping company, or railroad company, which could affect the type of operation, location, and prices charged); and (d) pricing policies, such as pricing based on quantity purchased, have not been examined.

FURTHER CONSIDERATIONS

The criteria for evaluating the feasibility of a coal-delivery system, such as the brokerage operation, include more than the delivered prices per unit of coal. Environmental, economic, land-use, and regulatory considerations also need to be explored.

By allowing for unit-train movement, western low-sulfur coal can be made available to users of small amounts. Depending on federal policy, the use of low-sulfur coal can be an alternative to large investments in high-cost scrubbing equipment. By burning the low-sulfur coal, government-imposed air-quality standards are more easily met, which possibly could increase coal use even in nonattainment areas.

The broker-terminal operation simplifies the process of contracting for coal supplies for certain firms (particularly utilities). Rather than contract volumes and rates separately with the mine, the railroad or line-haul mode, and the intermodal facilities, the firm need only deal with the brokerage representative, who will have made these separate contracts as part of the operation and include them in the single rate negotiated and agreed on.

Since all coal users will be served by a local high-volume broker, there is less need for individual firms to stockpile coal at their respective plant sites. The single local storage location of coal would allow local plants to use land currently set aside for on-site coal storage more productively. In those regions where land rents are high or the availability of vacant land is restricted, this can allow a firm to expand its plant without being hampered by local land constraints.

There are some disadvantages to aggregating the demands of a number of relatively low-volume coal users and serving them through a single broker. In order to justify unit-train service and for the terminal to receive and locally distribute the coal, some commitments must be made by large-volume users to ensure that minimum volumes can be achieved. Without such support, the establishment of a broker operation is too risky an investment. Low-volume users, on the other hand, may not be willing to commit themselves to one source of coal; they may prefer instead to buy coal on the spot market in hopes of purchasing it at the lowest current rates.

To achieve the necessary volumes for cost savings, one coal broker should be the sole distributor to a region. The local supply of coal to the region's industries and utilities will be tied closely to the operation of the broker system. If any component fails or closes down for any number of reasons (equipment breakdowns, weather, strikes, etc.), the local economy may be affected. The lack of any individual-firm storage of coal, although it means that the land can be put to more-productive uses, also means that coal supply is tied directly to the smooth operation of the brokerage. Service interrupted for even a day could conceivably lead to a disruption of plant operation. Measures must be taken to ensure that such a relationship does not exist and that the local economy will be protected from short-term interruptions.

Depending on the organizational infrastructure of the brokerage, a monopoly or cartel on coal for the subregion results. Although the economies of scale and their resulting cost savings are achieved, small-volume local users may not be able to achieve a corresponding price reduction if the broker decides to price as a monopolist and maximize the profits.

The brokerage concept is applicable to other regions and commodities as well. An area with a total coal demand that is high enough to justify unit-train delivery can be considered a candidate for a brokerage operation. Other necessary attributes include adequate rail access to western coal mines, moderate concentration of coal users to minimize distribution costs, adequate roadway or rail access to local users, adequate land for coal storage, and minimal environmental impacts of site development. Access to waterborne transportation is desirable because the ability to serve distant coal users on waterfront sites will increase the volume handled and enable further cost reductions associated with such higher volumes. A brokerage can also serve other commodities as long as an area's transportation, location, and demand attributes are similar to those mentioned above.

A trend is developing in new terminals that indicates potential growth of the brokerage concept. New terminals are being designed for several users or commodities or both. For example, the Hall Street Coal Terminal in St. Louis was designed to use excess handling capacity for customers other than its primary customer and is capable of storing several types of coal separately. Also, Detroit Edison is seeking coal customers to buy excess capacity at its new Lake Superior terminal. The emergence of such multiuser bulk-terminal facilities indicates a growing interest in exploiting the scale advantages of large shipments and terminals.

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Benefit-Cost Analysis in Rail Branch-Line Evaluation

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Section 5 of the Department of Transportation Act of 1966, as amended by the Local Rail Service Assistance Act of 1978, requires that a "methodology for determining the ratio of benefits to costs of projects" be included in state rail plans. This paper discusses some of the key issues that should be addressed in these methodologies. First, common errors are identified that occur in branch-line benefit-cost analyses that are submitted to the Office of State Assistance Programs of the Federal Railroad Administration. Techniques for avoiding these errors are suggested. A basic analytical framework for the evaluation of branch-line projects is presented that is then extended to cases in which projects are expected to (a) affect related transportation services and (b) produce improvements in the quality of branch-line service. Problems that arise from the relocation of capital and labor are also discussed.

Under Section 5 of the Department of Transportation Act of 1966, as amended by the Local Rail Service Assistance Act (LRSA) of 1978, federal funds are available to the states for enhancing the viability of lignt-density rail lines or for mitigating the effects of abandonment of such lines. The financial assistance can be used in any of the five ways enumerated in the act--subsidy, acquisition, rehabilitation, substitute service (e.g., construction of new connections or team tracks), or new construction.

One of the major purposes of LRSA was to alter the eligibility criteria under state assistance programs so that railroad lines do not have to be already abandoned to be eligible for assistance. In order to ensure that federal money is not used to perpetuate economically inefficient and unneeded railroad lines, the following provisions were made part of the legislation:

1. Section 803(a) of LRSA states that, in order to be eligible for funds, a state must have a rail plan that "includes . . . a methodology for determining the ratio of benefits to costs of projects . . ."; and
2. Section 803(b) states that, until such benefit-cost methodologies are developed, projects can be funded "on a case-by-case basis where [the Secretary] has determined, based upon analysis performed and documented by the state, that the public benefits associated with the project outweigh the public costs of such project."

Since the passage of this legislation, the terms "public benefits" and "public costs" have been defined in a variety of ways. Some analysts have assumed that public costs and benefits refer to funds that leave and arrive at the state treasury. However, the amount of money received by the state treasury has little if anything to do with public benefit. We argue below that public benefits and costs should be considered in the context of the economy of the nation, the individual states, and the local regions.

The objective of this paper is to aid the analyst in estimating the true economic benefits and costs of rail branch-line projects. Although it is conceded that economic measures of the contribution of proposed projects to the efficiency of the state or national economy do not constitute the complete set of desirable measures of project effectiveness, it is our contention that economic measures are essential and that they should be correct and not misleading.

The next section of this paper discusses some common errors in branch-line benefit-cost analyses submitted to the Office of State Assistance Programs of the Federal Railroad Administration (FRA) and suggests ways of avoiding them. Ways in which benefit-cost analysis can be applied to branch-line projects are then suggested under some typical scenarios to measure their efficiency benefits, i.e., real additions to the welfare of society. Space limitations do not permit discussion of the distributional consequences of projects for shippers, carriers, state and local governments, and different income groups. These are treated in an FRA publication (1), which also discusses intangible benefits and costs and environmental effects.

OVERCOMING COMMON MISTAKES AND MISCONCEPTIONS

Benefits

Since the passage of the Railroad Revitalization and Regulatory Reform Act of 1976, some state planning agencies have attempted to measure the benefits and costs of rail branch-line investments. Most of these analyses considered as benefits the annual transportation cost savings to shippers, tax revenues saved or generated, and decreased government spending (e.g., lower unemployment compensation payments) and compared them with the annual government costs of assisting the line. This approach is based on some misconceptions and produces misleading results.

One serious misconception is that the increases in government revenue are real benefits. A state could, at no cost to its government, simply double all taxes. From the viewpoint of the state government, the benefits of this policy far outweigh the costs. From the public's viewpoint (or the state-economy viewpoint), such an action could produce a substantial disbenefit. Thus, although it is important to know which parties (including the government) gain and lose from a project, increased tax revenues do not constitute a meaningful measure of benefits. Taxes are simply transfer payments within the economy. Tax payments neither reduce the inputs required to produce goods and services nor increase the output of goods and services. Clearly, then, taxes are not benefits.

Some analysts have taken the view that, if a business must close down due to a rail abandonment, all revenue currently received by the business is an accurate measure of the benefit to the public of saving the line. This approach, however, leads to benefit estimates that are too high. To measure the benefit of saving a business from failure, the analyst should estimate the market value of its products minus the opportunity costs of its labor and material inputs under the abandonment alternative. When the labor becomes unemployed and cannot be reemployed for some time, the opportunity cost of this labor becomes zero, and the disbenefit of the lost business is revenue minus the cost of material inputs (assuming that there is a ready market for these materials elsewhere). These benefits would normally accrue during the time that the labor remains unemployed. After all the labor has been reemployed, it should be assumed that the loss in the business affected is recovered by increased output of businesses that reemploy the labor. During the period of unemployment, the state government will pay unemployment compensation. From a statewide viewpoint, this is merely a transfer payment and does not affect net benefits. From a local viewpoint, this compensation decreases the impact of abandonment and should be subtracted from the disbenefits; this decreases the net benefit of avoiding abandonment.

The lack of a consistent viewpoint contributes to these misconceptions. By adding tax revenues, increased business revenues, and decreased shippers' cost of transportation, three different viewpoints are used. Thus, the quantities are not additive. Such an approach is similar to adding the grain price paid to the farmer by the miller, the flour price paid to the miller by the baker, and the bread price paid to the baker by the consumer and calling it total revenue to the grain industry. Obviously, much has been counted twice and much has been left out by not maintaining a consistent point of view.

Two important considerations often left out of rail benefit-cost analyses are the economic life of the project and the time value of money. Often, first-year benefits of saving a rail line are seen as remaining constant and unabated forever. Similarly, annual costs of maintaining service are expected to be perpetual. Such benefit-cost comparisons simply measure annual cash inflows against annual cash outflows. However, most of the time, a project will involve initial costs (usually for rehabilitation or construction) that must be amortized over an appropriate period of time. This period, the life of the project, should be consistent with the planning horizon. The planning horizon should not exceed the length of time that the line's operator agrees to continue service, even though the economic life of materials used in rehabilitation or new construction of a railroad could be as long as 15 years or more. The benefit stream should also be shown to stop at the end of the planning horizon. Decisions that involve time periods beyond the planning horizon are arrived at independently. In addition, benefits that accrue from preventing abandonment are not usually constant each year. If abandonment did occur, disbenefits would be high the first year but would decline significantly as adjustments were made.

A proper and reasonable method for handling varying amounts of benefit and cost over time is to calculate a present value for all costs and benefits by appropriately discounting their future flows. This raises the issue of what discount rate to use. The rates usually used reflect two components: (a) the opportunity cost of money and (b) inflation. Since most projections of future flows do not account for inflation, only the opportunity cost of money should be used (perhaps around 3 or 4 percent). Alternatively, inflation could be factored into future flows and the higher nominal rate could be used (which is currently 10-15 percent).

An illustration of these two approaches follows:

	Net Benefits	
Item	Constant $	Current $
Year		
1	1 200 000	1 284 000
2	600 000	686 940
3	300 000	367 513
4	150 000	196 619
5	75 000	105 191
6	37 500	56 277
7	18 750	30 108
8	9 375	16 108
Present value		
2.8 percent	2 265 450	
10 percent	1 996 355	2 265 450

The example assumes that the initial investment in rehabilitation will be $2 100 000 and that the benefits accrue due to abandonment avoidance. The first-year benefits are assumed to be $1 200 000 and to decrease by one-half each year. The third column shows the inflated benefit flows, by assuming inflation at 7 percent/year. Note that by using a 10 percent discount rate on the inflated-dollar figures, the present value of the benefits is $2 265 450, an amount large enough to justify the project. If, however, the 10 percent rate (which includes a 7 percent penalty for inflation) is applied to the constant-dollar benefits, the present value is only $1 996 355, an amount not large enough to justify the project. To perform the analysis by using constant-dollar benefits, the inflation penalty of 7 percent must be removed from the nominal interest rate, which leaves a 2.8 percent value [(1.1/1.07) - 1]. Use of a discount rate of 2.8 percent on the constant-dollar column yields a present value of benefits of $2 265 450, which is exactly the same as that obtained by projecting inflation. Thus, the project is sound. However, according to some procedures in use today, project benefits would be shown to be smaller than project costs.

The project may not be the best alternative, however, if the null or base alternative is not abandonment. Since LRSA allows funding of currently operating light-density lines regardless of the possibility of past, present, or future abandonment, the justification for the project may not be the avoidance of service loss. In this case, benefits in the category of reduced transportation costs, consumer (shipper) surplus, and producer (carrier) surplus must be considered. Reduced transportation costs can best be estimated by calculating the value of resources used in providing the service. Rate differences are often used instead. It should be recognized, however, that rates are often quite different from costs and not a good proxy for them.

In performing the analysis where abandonment is not a factor, the planner should be sure to include all benefits. Those most often excluded are the producer and consumer surpluses described below. If abandonment is probable but not certain as the null alternative, the benefits of avoiding abandonment should be multiplied by the probability that abandonment would occur in the absence of the project.

Costs

Examples of common mistakes in cost estimation are as follows:

1. Counting only forfeited loan interest: Some planners feel that when an interest-free loan is made to a railroad, only the lost interest is the cost to the public of the project. As the FRA benefit-cost guidelines (1) have argued, however, project evaluation requires the estimation of all social costs, particularly the present value of the opportunity costs of equipment, labor, and materials. These costs will be incurred regardless of the means by which they are financed. An interest-free loan implies only that more of a project is funded by the state and less of it by the railroad. This is a valid distributional consideration for state rail planners but should not affect the estimation of a project's social cost.
2. Counting only the federal share: This is often justified on the basis that, since the benefit-cost requirement is federally imposed, only the federal investment needs to be justified. It is true that the law is intended to prevent federal aid to uneconomical projects, but making a judgment

about the economic propriety of a project requires that all costs be considered.

3. Counting only the local match: This approach is often justified on the grounds that, since the federal money comes from an entitlement program, the federal share is essentially free. The only real investment, then, is the local match money; thus, only the local match needs to be justified. This line of reasoning is incorrect, because the federal funds that are used divert labor and material resources that could be used for other projects. In order to assure that only the best and most economical projects receive federal funds, it is important that all project costs be analyzed.
4. Ignoring the railroad contributions: Often, when the railroad puts up some of the money for a project, it is not included in the costs because it is not a public cost. Again, "public" is not synonymous with "government." Like federal and state funds, rail funds cause material and labor that could be used elsewhere to be tied up in the project.

A related problem concerns project definition. Sometimes a situation will arise in which a portion of a line will be rehabilitated by using LRSA funds, whereas rehabilitation of another portion is privately financed. In the analysis of this situation, one of two courses is acceptable:

1. Benefits of rehabilitating both portions could be compared with the costs of rehabilitating both portions (which includes private investment), so that the benefits that accrue from the two projects do not have to be separated; or
2. Benefits of both projects could be separated (this can be a formidable task), and the benefits of the LRSA project could be compared with its costs.

It is incorrect to compare the benefits of both rehabilitations with the costs of only the LRSA-funded part of the project.

CALCULATION OF BENEFITS AND COSTS

Primary Efficiency Benefits

Benefits that arise from different types of services provided by one investment alternative and not by another will be reflected in cost, rate, and quantity differences among alternatives. These in turn will bring about differential producer and consumer surpluses, which will measure the relative economic benefits of the various investment alternatives.

Figure 1 shows how these benefits are measured. The shaded area shows the producer and consumer surpluses for alternative 0. The hatched area shows the increase in producer and consumer surpluses that results from implementing alternative 1. As shown, the benefits can be divided into three subcategories: A, the decreased cost to provide service to the existing traffic [$q_0(c_0 - c_1)$]; B, producer surplus (economic profit) on new traffic [$(p_1 - c_1)(q_1 - q_0)$]; and C, consumer surplus on new traffic [$1/2(p_0 - p_1)(q_1 - q_0)$]. The expression for the total benefit is $q_0(c_0 - c_1) + (p_1 - c_1)(q_1 - q_0) + 1/2(p_0 - p_1) \times (q_1 - q_0)$.

In computing the decrease in cost to provide service, the analyst should be sure to calculate the actual change in economic resources required to move the commodities. It is also important that a clear distinction be made between these costs and the cost of the project alternative that is being evaluated. Elements within this category will vary with the project and the mode that is being analyzed but will normally include the following costs: maintenance; insurance; crew, driver, or operator; fuel; and other vehicle. Taxes levied on operations or properties are not properly considered as costs here, because they are transfer payments. However, any resources received in return for the tax payments made are costs. For example, truckers pay road-user taxes. These payments are not, as such, economic costs, but the expenditures required to provide and maintain the highways for the truck movements analyzed are costs (input resources). In truck travel, the taxes paid may be the best available measure of their share of the highway costs and therefore be an appropriate cost element. It should also be noted that, although rates would equal costs under perfect competition, this will not usually be the case for rail branch lines.

Estimating Traffic Increases

In computing the changes in producer and consumer surpluses on new traffic, the analyst first needs to forecast how much new traffic there will be. This can be done by estimating a demand curve and rate changes or possibly by doing a shipper survey. Many planners feel that a rate change would never occur with any improvement project. However, such a project may forestall a planned rate increase and, since a benefit-cost analysis compares different future scenarios, a rate difference would appear in the analysis. Also, if abandonment were the alternative to the project, rates would change substantially. Once new traffic quantities and rates are estimated, producer and consumer surpluses on the new traffic can be calculated. It should be noted that the change in the consumer surplus measures the economic value of any increased business activity of rail-using firms that results from the project.

Accounting for Effects on Related Transportation Services

In analyzing the impacts of a branch-line investment or subsidy, it is important to take into account its likely effects on competing and complementary modes of transportation. For example, in areas where truck transportation is an alternative to the shipment of commodities by rail, a branch-line investment that reduces costs and rates can be expected to induce at least some shippers to switch from truck to rail transport. In Figure 1, the increase in rail transport is shown by the distance q_0q_1 as a result of a movement along the demand function from E_0 to E_1. In Figure 2, the demand of shippers for truck transport is shown by D'_1. A decrease in the rail freight rate from p_0 to p_1 (Figure 1) might cause the demand for truck transport to shift to D'_2, so that $q'_1q'_2$ in Figure 2 equals q_0q_1 in Figure 1.

In this example, it is tempting to argue that the reduction in the original consumer and producer surpluses provided by truck transport should be subtracted from the gains depicted in Figure 1 in calculating the net social benefits contributed by the branch-line investment. This would be incorrect, however, because the reduction in demand for truck transport is merely the means by which shippers take advantage of the new, lower rail rates. It is true that the railroad will gain at the truckers' expense, but no shipper will be made worse off. If some resources of production that have been released from trucking remain unemployed, however, this must be reckoned as a social

Figure 1. Primary efficiency benefits.

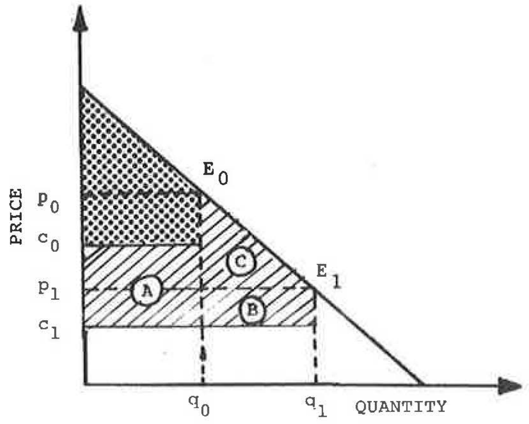
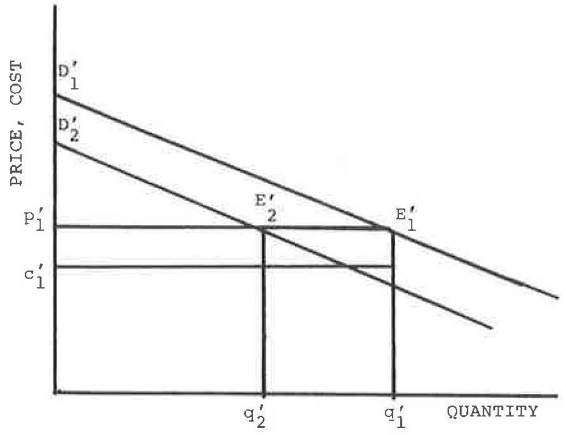


Figure 2. Project impacts on an alternative transportation service.



disbenefit. Measurement of this disbenefit is discussed below.

The foregoing analysis may require some refinement if truck owners respond to lower rail rates by decreasing their own rates in an attempt to recapture some of their lost market. Truck transport would then yield more consumer surplus, although at the expense of the producer surplus. To the extent that the lower trucking rates succeed in restoring some lost shipments, the demand for rail transport will decrease, and the measurement of area A + B + C in Figure 1 will have to be adjusted accordingly. These analytical refinements may be unnecessary, however, especially if secondary reactions to a decrease in rail rates are expected to be small.

Accounting for Benefits from Service Improvements

We have considered the case in which a branch-line investment or subsidy can be expected to yield lower rail costs and rates. We now turn to the possibility that the benefits are realized in the form of improved reliability of service, decreased loss and damage, or decreased time in transit without a decrease in rates and possibly not even in costs. There are at least three approaches to the measurement of these benefits.

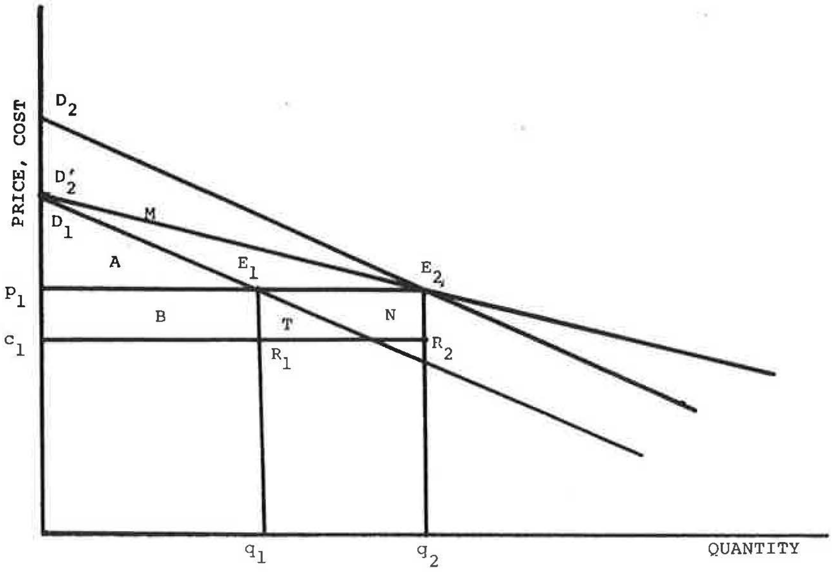
The most straightforward approach is to examine each benefit separately and to estimate its value to the shippers served by the branch line. Instead of using more-sophisticated, indirect methods, the analyst could discuss the anticipated benefits with shippers and ask them what the improvements in service would be worth to them in dollar terms. One disadvantage of this technique is that some shippers may be unwilling or unable to quantify the value of the benefits; another is that the shippers who would benefit from the branch-line improvements might be tempted to exaggerate their value in an attempt to promote the project. To safeguard against these possibilities, the analyst should arrive at an independent assessment of the anticipated improvements by considering the statements of shippers as indicative but not definitive.

A variation of the first approach is to regard uncertainty, loss and damage, and time in transit as costs borne by shippers. According to this view, the benefits calculated in the first approach can be interpreted as rate reductions. These can be translated into unit-rate reductions and applied to Figure 1. This approach has the advantage of being consistent with the valuation of projects that decrease costs and rates; i.e., the benefits of all projects that are considered will be measurable in terms of increases in consumer and producer surpluses.

An improvement in branch-line performance may also be thought of as the displacement of the existing quality service by higher-quality service. In Figure 3, D_1 is the original demand function, and D_2 is the demand for the improved transportation. Since the only point normally known on D_1 is E_1, some other point must be estimated, even if it can be assumed that D_1 is linear. The point that is perhaps the least difficult to estimate is the intercept of D_1 with the price-cost axis. The price at that point should be at the level that is just high enough to cause the last shipper to stop shipping. It is also the level that defines the highest price that a shipper is willing to pay to make a shipment. Depending on whether the shipment is defined as mode specific or not, reasonable estimates can be made.

In the absence of any evidence to the contrary, it is reasonable to assume that the new demand function is parallel to D_1. In some cases, however, it may be appropriate to assume that D_2 has the same intercept with the price-cost axis as does D_1. Such an assumption implies that in either case (with or without the improvement that is being evaluated), the highest price that anyone is willing to pay for the shipment is the same. The demand function D'_2 illustrates this case. The intercept of D_1 with the price-cost axis can be estimated by using the price for a competing mode, such as truck. This approach can be justified by the assumption that if the rail price (rate) should reach that level, all shipments would be made by some competing mode and none by rail. Whether the original and shifted demand functions are parallel or have a common price-cost axis intercept, the geometry of Figure 3 is illustrative of the benefit calculation. At the original rate p_1, the amount carried by the branch line is expected to increase from q_1 to q_2 because of improved service. The original amount of consumer and producer surpluses, area A + B, has been replaced by the larger area A + B + M + N + T. Thus, the area M + N + T measures the benefit yielded by the branch-line investment. This technique is attractive because of its conceptual simplicity; it requires only that the analyst be able to estimate the increase in branch-line traffic attracted by the improved service. It is not necessary to evaluate the benefits of improved reliability, decreased loss and damage, faster delivery, and so forth. A serious weakness of this approach is that the benefit

Figure 3. Benefits from service improvements.



calculation is highly sensitive to two factors, both of which are susceptible to considerable error. First, in arriving at an estimate of increased tonnage, the analyst may have little or no information to work with and thus be able to make little more than an educated guess. Second, the slope of the new demand function is unknown. In Figure 3, it is only assumed to be the same as the slope of the original demand function or to have the same intercept on the price-cost axis. A slight deviation of the estimated slope from the true (unknown) slope would be a source of inaccuracy in calculating area M + N + T (the increase in consumer and producer surpluses).

Secondary Efficiency Benefits

Secondary efficiency benefits usually result from avoiding abandonment. The variations among alternatives in modes and types of transportation services may cause companies to relocate and move onto or away from the branch line concerned. Such moves entail the relocation of resources such as labor and capital to different productive uses.

In many cases, these resources are shifted to new uses almost immediately, which offsets initial losses. Whenever there is a delay in shifting resources to new uses, there is a loss of production, which is a secondary efficiency disbenefit attributable to the alternative that caused it. Even when the offsetting change occurs, it may not be one that employs resources as effectively (i.e., it does not create as much producer and consumer surplus) as was the case originally. In such a case, the diminished surplus may be considered a disbenefit; however, such changes are probably small enough to be ignored.

Before the offsetting change occurs, labor, capital, and materials may remain idle. Until these resources are reemployed elsewhere, their value is lost. Prior to abandonment, such resources had a value equal to their opportunity costs; now that they remain unemployed, their opportunity cost is zero. Since the disbenefits are calculated as changes in opportunity costs, the disbenefit is equal to the previous opportunity cost of the resources. This disbenefit would decline over a period of time as the resources become reemployed.

When a business relocates, there would be moving costs involved. These moving costs can be added to the disbenefits of the alternative that caused the relocation.

The evaluation of secondary efficiency benefits depends on the point of view taken. If it is the national viewpoint, offsets to disruption of production should occur more rapidly than when a local point of view is adopted. When a local viewpoint is used, however, certain transfer payments become real benefits (or disbenefits). For example, unemployment compensation would normally be supplied by the state to residents of a local area who become unemployed. Since this is a transfer from outside the local area and the local area does not provide resources in return for the transfer, receipt of this compensation is a real benefit to the locality. Thus, the disbenefits of unemployment should be reduced by the amount of additional unemployment compensation received if a local viewpoint is adopted. From a state or national point of view, however, unemployment compensation is a transfer payment and can be ignored when net efficiency benefits are computed.

CONCLUSION

The comparison of public benefits and public costs as required by LRSA need not be a fearsome and mysterious chore. An ample amount of relevant theory and applications exists to provide the necessary framework and guidance for doing the required calculation. This paper is intended to increase the communication on the subject among all interested parties.

Benefit-cost comparisons of this type should be embedded in a broader-based evaluation scheme. They are intended to measure the economic value of the projects concerned. In this particular instance, measurement of public benefits against the required public costs is mandated by the federal legislation that continues the Rail Branch Line Continuation Assistance Program. Analysis of the distribution or incidence of the economic and noneconomic effects of each project is essential to the broader-based evaluation.

Adherence to the principles in this paper and avoidance of the pitfalls that it points out will go a considerable way toward production of meaningful benefit-cost comparisons.

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REFERENCE

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Theory for Estimating Traffic Diversions on a Restructured U.S. Railroad System

ALAIN L. KORNHAUSER, MARK HORNUNG, AND REGGIE J. CAUDILL

Each proposal to restructure the U.S. railroad system involves an analysis of the extent to which traffic will shift from existing routes to new routes offered by the restructured network. Classically, this exercise was conducted manually by traffic clerks and marketing personnel; however, the recent availability of machine-readable nationwide railroad traffic data enables these analyses to be done efficiently by a computer. An elementary model of traffic diversions suitable for estimating traffic diversions that result from a limited restructuring of the U.S. railroad system (i.e., individual mergers such as the Burlington Northern and the St. Louis-San Francisco Railway Company) is based on the redistribution of traffic among existing routes and new routes on the merged railroads. However, if all or most of the railroads are merging or changing configuration, all or most of the existing routes will be modified and therefore all new routes must be generated; this is termed the advanced model. This paper develops in detail the underlying theory for estimating traffic diversions on a vastly restructured railroad system. Historical shipper behavior data are presented to justify route selection and traffic assignment procedures. A stepwise application of the method is described and results are presented.

At present, the railroad industry is besieged with proposals that call for the restructuring of the operating jurisdictions of its various constituent companies. Proposals to merge, acquire, abandon, provide direct service, or otherwise consolidate are being forwarded by the railroad industry as well as by government agencies such as the Interstate Commerce Commission (ICC), the Federal Railroad Administration (FRA), the United States Railway Association, and the New England Regional Commission of the U.S. Department of Commerce. This jostling for position is not new. The railroad industry has undergone a continual restructuring of its geographical operating territory during its 150-year life. The current trend was, in a sense, spurred by the bankruptcy of the Penn Central Transportation Company and the enactment of the 1976 Railroad Reorganization and Regulatory Reform (4R) Act, but it is also simply the newest cycle of railroad geopolitics. A previous cycle founded the Penn Central, the Burlington Northern, the Seaboard Coast Line and the Louisville and Nashville Railroad Company (Family Lines), and the Chesapeake and Ohio, Baltimore and Ohio, and Western Maryland Railway Companies (the Chessie System). The present cycle may lead to mergers of the Burlington Northern and St. Louis-San Francisco Railway Company; the Chessie System and Family Lines (CSX); Missouri Pacific and Union Pacific; the Boston and Maine Corporation, Maine Central Railroad Company, and the Bangor and Aroostook Railroad Company (New England Rail Company); Core-Consolidated Rail Corporation (Core-Conrail); Core-Chicago, Milwaukee, St. Paul and Pacific Railroad Company (Core-Milwaukee); controlled liquidation of the Chicago, Rock Island, and Pacific Railroad Company; and a host of abandoned lines. Each proposal has either been formally presented to the ICC or is under active study by government agencies. Other restructuring of conventional and bureaucratic interests go as far as to include consolidations that would lead to a U.S. railroad system composed of only several east-west and north-south railroads.

A major impact of these consolidations is that the shippers who patronize the railroad industry will be faced with a significantly different logistic environment and with different intramodal as well as intermodal competition. This will cause the shippers to rethink their logistic patterns and thus there will be a significant effect on the distribution of traffic, which will affect the fundamental operation and validity of economics of each member carrier of the restructured railroad system.

The purpose of this paper is to describe a computer-based analytical method for estimating the shipper's logistic response to a vastly restructured system of railroad networks and thus its impact on traffic distribution, revenue potential, and costs of each railroad. In a recent publication, Kornhauser (1) described a method for estimating the effect on traffic flow of a limited restructuring of the U.S. railroad system, i.e., the evaluation of the traffic impact of a single merger or a single abandonment. This elementary theory of traffic diversions is based on the premise that a shipper will need to make only incremental changes in logistics patterns as the result of a single merger. Thus, routing decisions are heavily biased toward historical routing patterns. This premise allows for the reliance on historical traffic data and the creation of new routes only in those markets in which new single-carrier service is created by the merger. Otherwise, traffic is assumed to be shifted among existing routes.

Faced with a vastly restructured railroad system, shippers will generally not have old routes to choose from and will be faced with a completely new set of logistic choices. Accurate assessments of the impact of each consolidation must include accurate forecasts of the shipper's response to these choices. Although it is appropriate to assume that shippers will select routes that are consistent with their historical choice patterns, the historical routes may, in general, no longer be the preferred routes. New routes must therefore be generated that are consistent with the behavior of shippers in selecting routes.

Traffic diversion analyses have been part of all merger applications and serious consolidation proposals for at least the last 60 years. However, these analyses have always been done manually by using teams of traffic clerks and marketing personnel. The procedure generally consists of the evaluation of each market through the use of expert judgment. This method leads to the inclusion of all kinds of qualitative factors in the traffic diversion process, which can lend greater accuracy to the forecasts than is possible in a rigid analytical framework. However, this process is extremely costly in terms of time and personnel, cannot be audited, is in general not consistent or repeatable, and provides no sensitivity information. The computer-based method described here tends to overcome these drawbacks.

The purpose of this paper is to describe a method for forecasting the distribution of traffic over a vastly restructured U.S. railroad system. The method itself has been termed the advanced theory of traffic diversions. This theory uses a three-dimensional visualization of the U.S. railroad network, the Quanta-Net Intercarrier Route-Choice Model, which attempts to replicate shipper behavior. The model's data requirements and applications are described.

ELEMENTS OF THE ADVANCED MODEL OF TRAFFIC DIVERSIONS

As described above, the advanced theory of traffic diversions assumes that only the origin, destination, and tariff of railroad traffic of various commodities are known. It is the objective of the method to identify the route or routes over which that traffic will flow. Once all traffic is routed, the traffic captured by each railroad, its distribution over various segments, commodity breakdown, gross revenues, and even costs may be computed.

The method depends on (a) two primary models, a route-choice model (the Quanta-Net Intercarrier Route-Choice Model, an extension of the Intracarrier Route-Generation Model) and a market-share model; (b) traffic demand data, which are assumed to provide the origin, destination, and tariff of all railroad traffic in the forecast time frame; and (c) network data, which are link-node characteristic data of each railroad configuration in the forecast time frame.

Network Data

The railroad network data required for the model must give information on (a) the nodes, which are the locations at which traffic can be originated, terminated, and interchanged between railroads, and (b) the links, which are the connecting segments. These data are now available in the Princeton Railroad Network Model, which contains all fundamental node and link characteristics of the U.S. railroad network. The basic network consists of some 16 373 Net-3 nodes and 17 874 links that connect these nodes. Characteristics for each node include (a) x,y-coordinates that permit geographic display of the network and correlation with any geographic data such as political boundaries and socioeconomic statistics (e.g., population) and (b) translation tables between Net-3 node numbers and station name, the standard point location code (SPLC), freight station acounting code (FSAC) (2), Association of American Railroads (AAR) Rule-260 interline junction code (3), FRA 1975-1978 accident statistics (4), trailer-on-flatcar (TOFC) ramp file (5), the FRA yard file, and National Railroad Passenger Corporation (Amtrak) stations. The FSAC, SPLC, and junction translation tables allow for the conversion of all pertinent traffic-generation and route data contained in the carload waybill statistics so that they can be correlated with the network data. The most important of these correlations enables the traffic data to be assigned to the network in a classical traffic assignment process and displayed geographically.

The link data consist of characteristics that identify the ownership, trackage rights (if any), distance, and FRA Section 503 code for the main line and branch line of each link. The link data base also includes speed, grade, curvature, signal system, and number of tracks of many (but not all) links.

Information that is not contained in the data base includes the location of specific shippers, travel time, and travel-time reliability. It would be beneficial to have the travel-time data; however, it is believed that distance and route impedance measures based on the Section 503 codes for the main lines and branch lines serve as adequate surrogates.

Traffic Data: Carload Waybill Statistics

Under the terms of ICC Order 49 (Code of Federal Regulations, Section 1244), line-haul railroads that have operating revenues of more than $3 million are required to submit a sample of audited waybills to FRA. The waybills submitted are to be those that terminate on the submitting railroad and end in the numbers 01. FRA converts these waybills to machine-readable form. Each year's sample represents slightly less than a 1 percent sample of the year's carload movements (between 175 000 and 200 000 carloads/year for 1973-1978). Each waybill contains fundamental data that identify the shipment (e.g., number of cars, net tons, commodity, car type, car owner and number, and total revenue) and fundamental route data (origin, origin railroad, destination, destination railroad, and, since 1973, each overhead railroad and interline junction). The fundamental route data base has been enhanced by researchers at Princeton University (6, Chapter 7) to (a) reconstruct many of the defaulted junction codes; (b) include Net-3 numbers, which facilitate the use of the data in conjunction with the network data base; (c) estimate mileage for each railroad segment of the route; and (d) calculate the impedance of each route segment, which is equal to the sum of the impedances of all links that make up the route (the impedance of a link is equal to its distance times its Section 503 code for main line and branch line. The impedance, distance, and number of interline junctions provide surrogate measures for the quality of the waybill's route.

Although the carload waybill statistics are an imperfect sample (7-9), some of the imperfections have been corrected, and they are (in our opinion) the best data available for any mode of freight transportation. The data are certainly adequate for purposes of strategic planning and policy and market analysis.

Intracarrier Route-Generation Model

The waybill data described above provide a basis for observing shipper route choice and thus for constructing a behavioral route-choice model. It is the shipper's (consigner's) responsibility to specify the railroad-interline junction sequence for each carload, although this is often done in conjunction with or by sales representatives of the originating railroad. It is the responsibility of the operating department of each railroad to route the shipment from the point at which it receives or originates the shipment to its forwarding or terminating location. Railroad operations are based on yard-to-yard blocking patterns and train schedules. At present no algorithm exists that can efficiently reconstruct such patterns; however, one consequence of such patterns is that major yards are located along or at intersections of main lines, and traffic tends to flow along main lines and avoid branch lines. Thus the traffic-flow impacts of railroad operations can be embodied in an algorithm that tends to route traffic along the shortest main lines and uses branch lines only for continuity or to avoid very circuitous alternate routes. These observations suggest that a simple minimum-impedance route-finding algorithm whose impedance measure is distance weighted by main-line--branch-line classification may lead to an adequate method for reconstructing intracarrier routes. The particular impedance measure used in the Princeton Intracarrier Route-Generation Model is simply the sum of the impedance on each link (I_j) of route k:

$$I^k = \sum_{j \in k} I_j \tag{1}$$

The impedance of link j is

$$I_j = D_j MLC_j \tag{2}$$

where D_j = the distance on link j and MLC_j = the Section 503 main-line--branch-line code for link j. MLC_j = 1, 2, 3, or 4 depending on whether link j is an A main line, B main line, A branch line, or B branch line, respectively. This impedance measure has the effect of greatly discouraging routes that use branch lines and of forcing the traffic (if reasonable) to flow on main lines, as is observed in practice.

No rigorous analytical calibration of the impedance formula has been performed; however, an extensive qualitative validation has been undertaken (10). Many minimum-impedance routes have been analyzed graphically by operations personnel of many major railroads. In all but a few instances, the routes generated correspond to actual routings used. The traffic does flow through major yards and on main lines, and the algorithm does reconstruct aggregate operational practices.

Elements of Shipper Route-Choice Behavior

The Intracarrier Route-Generation Model is an integral part of the Quanta-Net Intercarrier Route-Choice Model discussed in the following section. It is also an essential element for studying the elements of shipper route-choice behavior. When applied to historical data, it provides additional performance measures about shippers' observed routing patterns. Studies of these patterns of route choice (11,12) indicate that

1. Single-carrier service is preferred overwhelmingly over multiple-carrier service, except in markets more than 1000 miles distant where only run-through routes obtain sizeable (but rarely dominant) market shares;
2. Routes that have fewer carriers are generally preferred;
3. Relative impedance is a better measure than distance for identifying dominant market-share routes when each route uses an equal number of railroads; and
4. If given a choice of interline junctions, the originating carrier tends to get the long haul.

These historical route-choice patterns define shipper behavior and also suggest an analytical framework for forecasting routes over a restructured railroad system. By including an impedance for each interline transfer, a minimum-impedance route-choice model would tend to find routes that minimize the number of interline transfers. By using a constant unilateral discount for the impedance on all links of the originating railroad, minimum-impedance routes would tend to use the originating railroad as far as possible; thus the long-haul principle would be simulated. Finding the discount for the originating carrier's link impedance is straightforward. Consideration of junction impedance requires the reformulation of the network node-link data by using the three-dimensional quantum-network concept, the Quanta-Net Intercarrier Route-Choice Model.

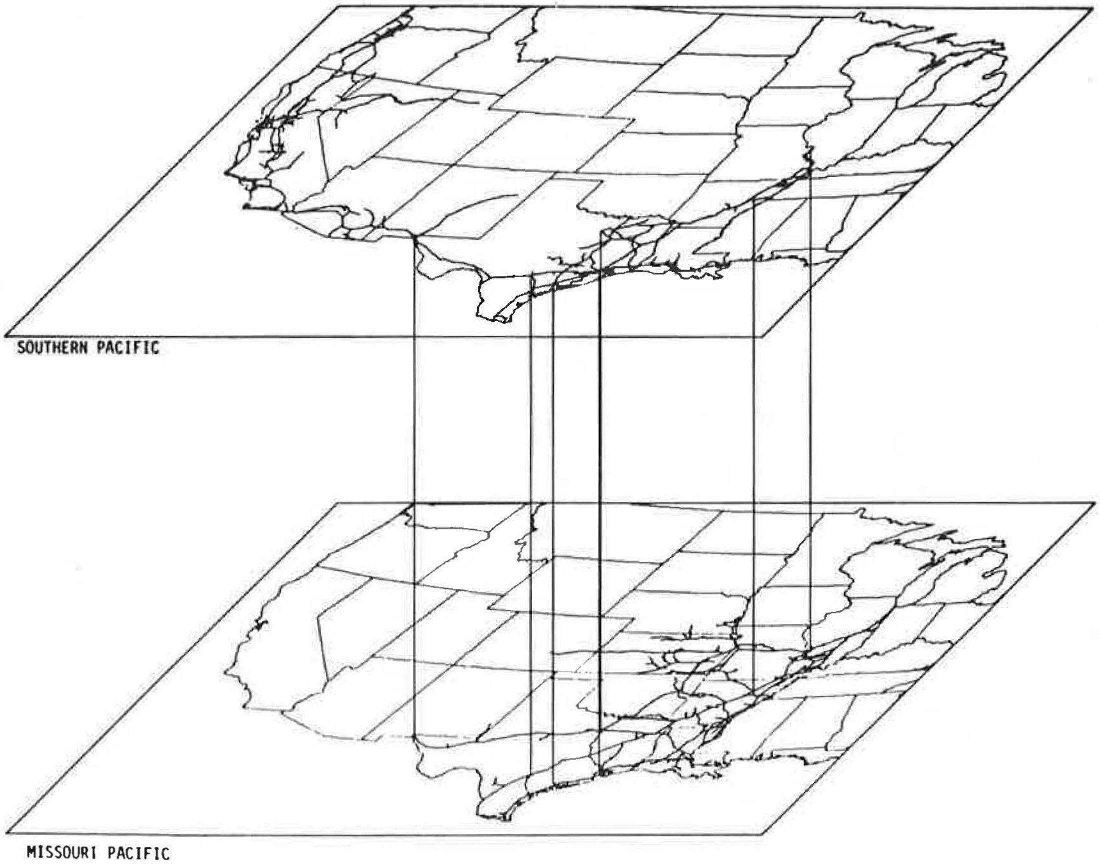
Quanta-Net Intercarrier Route-Choice Model

Concept of the Model

One method of generating multicarrier routes in a way commensurate with shipper behavior is to conceive of each carrier's network as a distinct entity connected to other carriers at certain points by junction links (instead of nodes), where each junction link has an appropriate impedance (13). The realization of this concept requires a redefinition of the network data so that each node (as well as each link) of the quantum network is unique to a (single) carrier and so that additional links are added to the network data to serve as jumps between unique carriers. Thus each carrier can be considered to operate on a unique plane, or quantum level. Jumps to another quantum level (carrier) can only occur by junction links in which an impedance penalty is incurred during the transfer from one energy level to another. This concept can be visualized in Figure 1, which shows the Missouri Pacific on one plane and the Southern Pacific on another. Junction links are shown at the major junctions between these railroads. Special interline operational efficiencies such as run-through operations may be simulated by reducing the impedance at those junctions, while junctions that have poor facilities or unmatched schedules can be replicated by increasing the junction impedance. If the distance between the quantum levels is to be proportional to the nearby junction impedance, Figure 1 would need to be modified so that each railroad occupied a surface warped by the relative value of the junction impedance.

The quantum-network configuration can be constructed through a sequential enumeration and translation of the nodes and links of each carrier and the manual definition of the Net-3 location of each junction and its interchange carrier. Hornung (14), in one definition of a quantum network, identified the 408 most-active junctions in the United States (those junctions that have an average of at least 10 carloads/day of interchange traffic). This configuration of the 41 largest railroad companies is made up of a network of 17 172 unique nodes,

Figure 1. Quanta-Net structure between Southern Pacific and Missouri Pacific railroads.



18 175 carrier links, and 408 junction links.

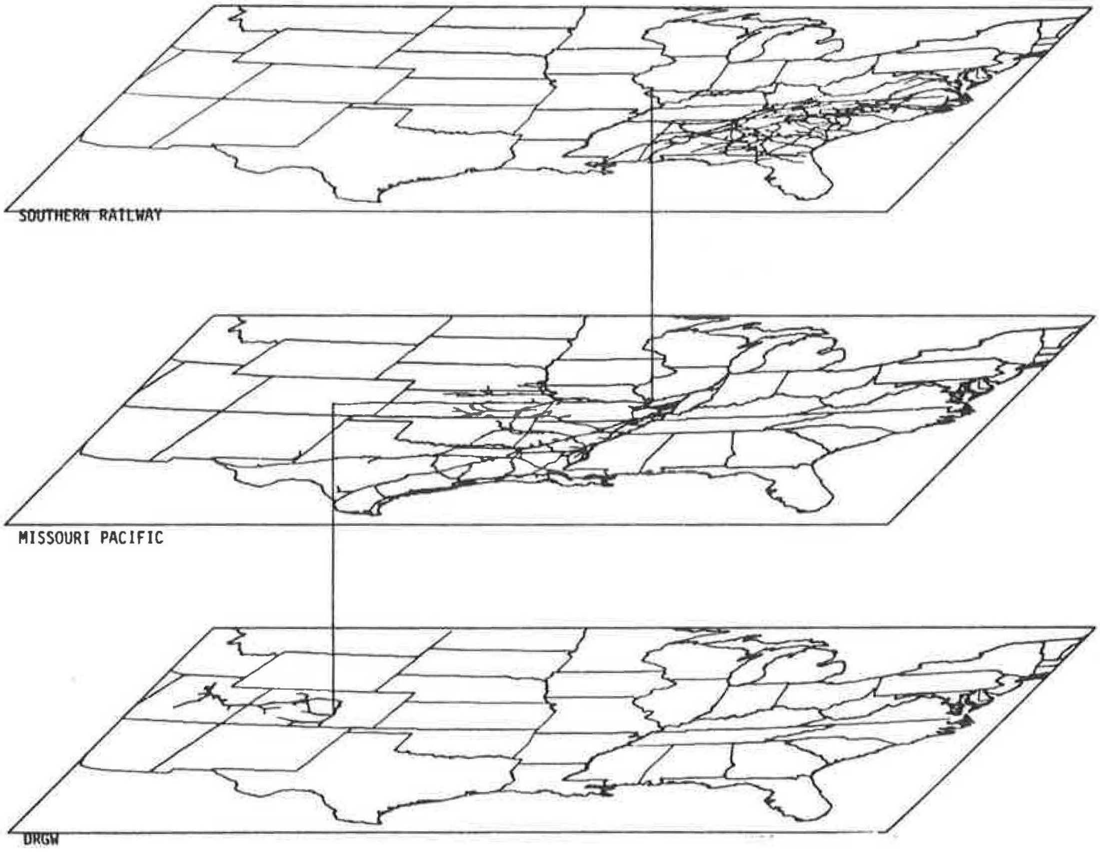
When applied to the restructured quantum network, the Intracarrier Route-Generation Model described earlier yields the route from any quantum-network origin (a unique origin location and originating railroad) to all quantum-network destinations (unique destination location and destination railroad). Since the originating railroad is specified by the quantum-network origin node (each quantum-network node is unique to one carrier), it is trivial algorithmically to consider discounts for the links of the originating railroad; thus, long-haul shipper behavior is simulated. Appropriate differential values of junction impedance will simulate biases between junctions. An example of a minimum-impedance three-carrier route between a Southern Railway Company origin in Atlanta and a Denver and Rio Grande Western Railroad Company (DRGW) termination in Denver is shown in Figure 2. The route forecast involves an interchange at St. Louis with the Missouri Pacific, which interchanges in Pueblo with the DRGW. This route conforms with historical routings.

Calibration of the Long-Haul Discount Factor

Through the application of the Quanta-Net Intercarrier Route-Choice Model to a historical (say, 1977) railroad network configuration in which shipper choices are known through the carload waybill statistics, one can calibrate the values of both the long-haul discount factor and the junction impedance so that the model best replicates observed shipper behavior. Such a calibration can provide insight into fundamental shipper behavior and can also reflect the effectiveness of railroad sales and marketing departments and interline operation. Preliminary investigations of the long-haul discount factor focused on its sensitivity, variability between railroads, and varibility between origins on the same railroad. An experiment was designed to provide a first insight into these characteristics, in which routings generated by the quantum model were compared with historical routings. The experiment consisted of two parts. In the first, routings from origins on several different railroads were investigated to determine the sensitivity of the discount factor and its variability between railroads. For simplicity (and to isolate this experiment as much as possible from the effects of various values of junction impedance), only two-carrier waybill movements were investigated. The junction impedance was set at the arbitrarily large value of 1000 miles of A main line. The two-carrier portion of the 1977 carload waybill sample was extracted as a historical reference, and the origin on each railroad in the sample that had the largest number of destinations was found. This provided a group of source nodes with a relatively high number of historical records for the largest sample size for each quantum-network minimum-impedance tree generated.

Five railroad origin locations were chosen for investigation from the above group. Three were on carriers thought to have strong marketing departments and long first hauls: Atlanta, Georgia, on Southern Railway Company (which serves 86 destinations); Houston, Texas, on Southern Pacific (131 destinations); and Golden, Colorado, on Burlington Northern (53 destinations). The others were on carriers thought to be less successful at achieving a long first haul: Bayonne, New Jersey,

Figure 2. Minimum-impedance Quanta-Net route between Denver on Denver and Rio Grande Western and Atlanta on Southern Railway.



on Conrail (86 destinations) and Birmingham, Alabama, on Family Lines (84 destinations). The initial discount factors chosen to be investigated were 0.6, 0.8, 1.0, and 1.2; several others were added for the Atlanta origin on Southern Railway in order to obtain a more-detailed profile of a single origin. Comparisons were to be made both with all historical records and with only those records that had junctions in the set of 408 coded on the network. The following measures of the merit of the various discount factors were to be taken:

1. Number of movement-group (unique origin-destination groups) records reproduced exactly,
2. Number of carloads routed exactly (on the theory that those markets that have low volume would be more likely to have unusual routings not predictable by the model),
3. Average difference in the length of the first haul between the generated and historical waybills, and
4. Standard deviation of the difference in distance (as a measure of variability).

An example of the results is shown in Table 1 for the Atlanta-Southern route. Figure 3 shows a plot of long-haul discount factors versus mean mileage differences (generated minus historical). The following general observations can be made:

1. The best estimate of long-haul discount (in which the mean mileage difference is zero) varies widely among the railroads tested, from 0.58 for Southern Railway from Atlanta to about 1.38 for Family Lines from Birmingham. The values do seem to correspond to the generally accepted impressions of the different railroads' ability to capture the long haul.
2. The percentage of carloads routed correctly for records with coded junctions varies for the best long-haul discount from 67 percent for Family Lines to 81 percent for Southern Railway. In general, one can expect to replicate the route of 75 percent of the carloads exactly.
3. The standard deviation of mileage differences is quite high in most cases, usually more than 100 miles. It does seem to be reduced in the vicinity of the best long-haul discount, however.
4. The accuracy of routings is fairly insensitive to the value of long-haul discount in the range studied here. This implies that, for many movement groups, there exists one best choice of junction and all other junctions are seen to be vastly inferior.

The second part of the long-haul calibration experiment examined two additional origins, one on Family Lines and one on Southern, to determine the intrarailroad variation. Origin locations were exchanged (Birmingham on Southern Railway and Atlanta on Seaboard Coast Line) so that geographical differences would not enter into the results. In general, the results indicate that the long-haul discount factor is fairly constant within a railroad; however, more experiments are needed to reach a definite conclusion.

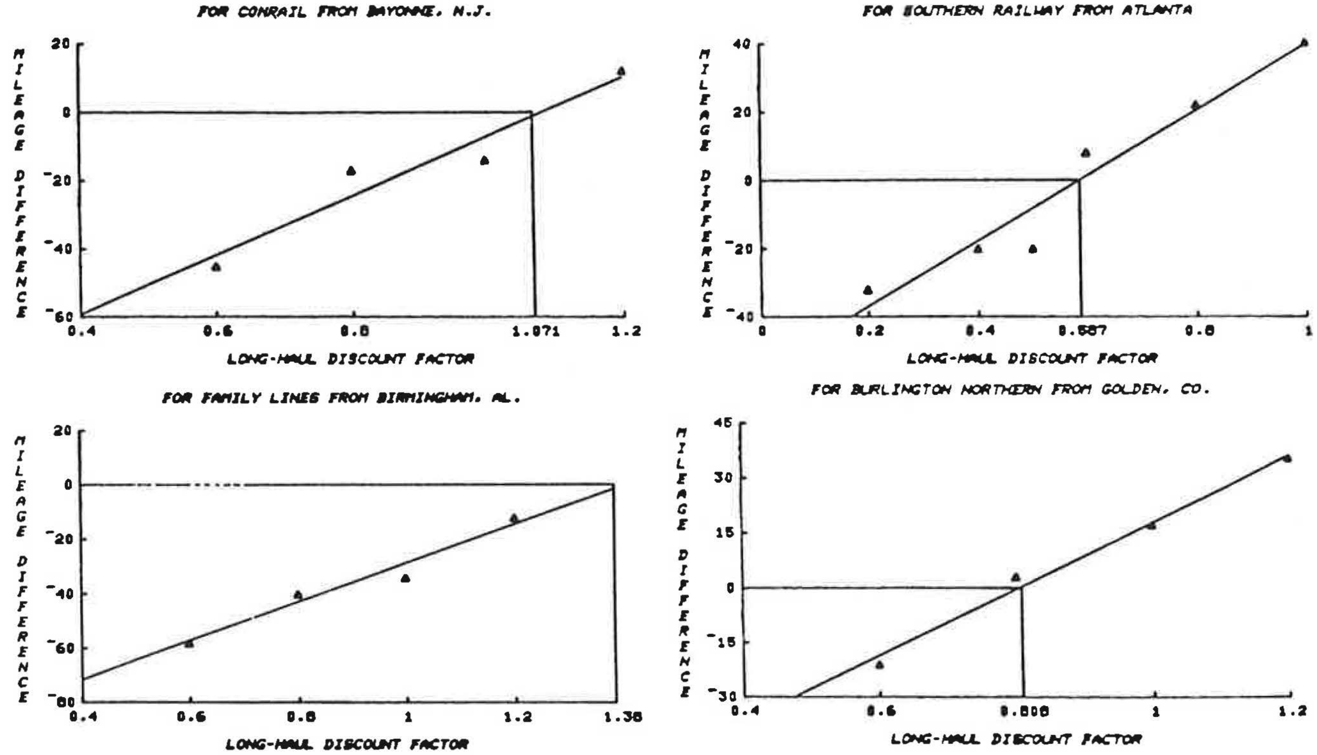
A thorough calibration of appropriate values of junction impedances is still under study; however, very high values are indicated. This solidifies the observation that shippers are more inclined to choose routes that require the minimum number of intercarrier transfers.

Table 1. Results of experiment 1: Southern Railway originating in Atlanta.

							For All Records		For Records with Coded Junctions	
Long-Haul Discount	Junctions Found Exactly	N (%)	P (%)	Carloads Routed Exactly	NC (%)	PC (%)	Mean Mileage Difference	SD	Mean Mileage Difference	SD
0.2	59	69	73	197	77	80	-32	119	-32	120
0.4	62	72	77	200	78	81	-20	109	-20	109
0.5	62	72	77	200	78	81	-19	111	-20	109
0.6	57	66	70	180	70	73	8	137	8	137
0.8	56	65	69	179	70	72	21	135	22	135
1.0	55	64	68	172	67	70	45	131	40	132

Note: N = number of movement groups (86); P = number of movement groups with coded junctions (81); NC = number of cars (256); PC = corresponding number of cars (247).

Figure 3. Calibration of long-haul discount factors.



Market-Share Model

The market-share model is a user-specific model based on relative distance, impedance, and intercarrier transfers on competing routes in the same market (origin-destination pairs). Competing routes exist for all markets served either by competitive originating railroads or by competitive terminating railroads. The Quanta-Net Intercarrier Route-Choice Model will forecast a single route for each unique combination of origin railroad and destination railroad; the model cannot provide for competitive overhead carrier routes. All other routes are assumed to serve none of the market's traffic. However, traffic must be distributed over the competitive routes generated. Some of those routes should be assigned zero market share because the originating or terminating carrier provides only a zero-length haul. These routes are generated as a requirement of completeness among the unique origin-destination railroad combinations. For example, for the market on the East Coast to Memphis, the quantum-network model would specify routes where the Chicago, Rock Island, and Pacific Railroad Company terminates the traffic. In each of these routes another railroad brings the shipment to Memphis and switches to the Rock Island, which terminates the movement. The assumption is that all railroads that serve Memphis have access to all shippers; thus there is no need for a switching movement and in fact shippers would not select such routes. Shares among the market's other routes could be assigned by using the judgment of expert witnesses or possibly by a calibrated multidimensional logit model that is a function of the relative impedance (combination of line and junction) and relative distance between the various best routes such as that shown below (research at Princeton is continuing in an attempt to calibrate such a model):

$$MS_k = \exp(I_k)/\sum_j \exp(I_j) \qquad (3)$$

where MS_k = market share of route k and I_k = impedance of route k.

STRUCTURE FOR APPLYING THE ADVANCED MODEL OF TRAFFIC DIVERSIONS

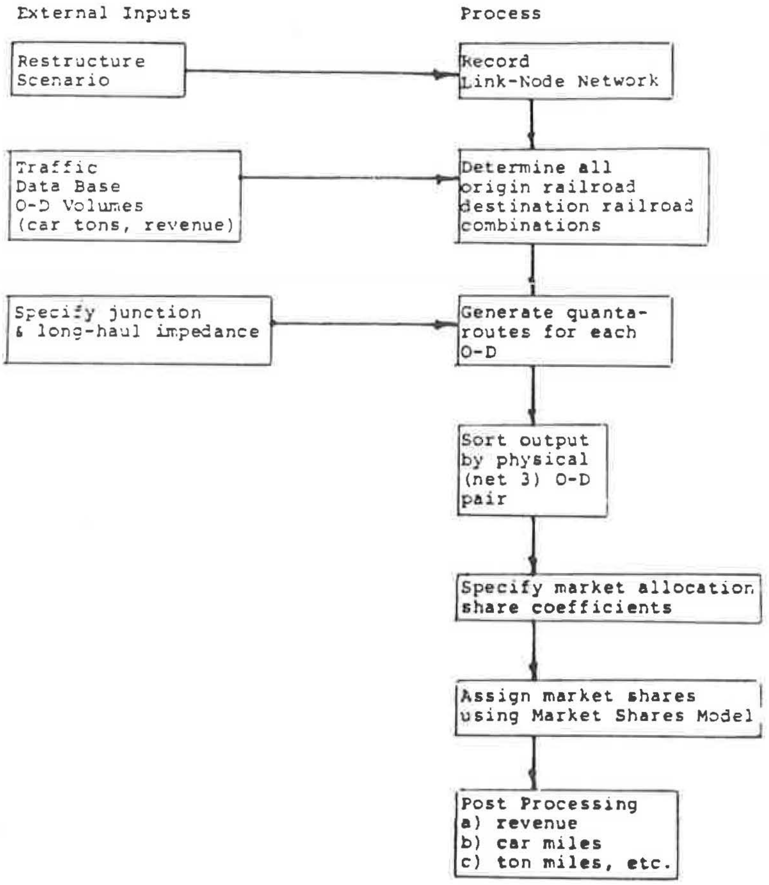
After having described each of the elements that make up the advanced model of traffic diversions, we now show how the elements may be sequenced for a particular application. The discussion uses the following example: Suppose that the Rock Island discontinued all service and that the ICC issued directed service orders to various railroads that required them to provide service over specified portions of the Rock Island. [Johnson (15) describes a method that indicates which railroad is most suitable to operate and acquire which portion.] Given that these railroads eventually acquire these portions, the model is to assess the long-term impact of these acquisitions on the distribution of traffic in that area.

Computational Procedure

In the short term the status quo would continue; however, in the long term new competitive patterns would emerge, and some traffic would travel over new routes. The forecasting of these traffic shifts could proceed as follows (see Figure 4):

1. Record link-node network: The various portions would be merged into their appropriate acquirers by using interactive computer-graphic techniques.
2. Select traffic data base: This may be one or several years of carload waybill statistics or forecast-year FSAC-to-FSAC demand data.
3. Determine all combinations: For each market contained in step 2, the combinations of origin railroad and destination railroad should be determined. Each railroad that serves each node of the restructured network can be determined from the node data in step 1.
4. Generate quantum routes: For each origin and destination, a unique record of origin-origin railroad (unique quantum-network node) to destination-destination railroad would be created. This record would be a unique quantum-network node pair. Appended to each record should be the first origin-destination Net-3 number.
5. Choose values of junction impedance and long-haul discount factors: These values could be historical values or values modified by anticipated interline junction agreements and shifts in marketing and sales efforts.
6. Generate minimum-impedance quantum-network routes: For each record produced in step 4, the railroad-junction-railroad sequence of each route would be appended, as well as the mileage of each railroad segment, the total mileage, and the total impedance.
7. Sort output by actual (Net-3) origin-destination pairs: For the file created in step 6, this will coalesce all quantum-network routes for each actual market. Each route will have distance and impedance values.
8. Identify market-share coefficients: These should be specified for the market-share model.
9. Assign market shares: These are determined for each quantum-network route in each market by using the market-share model.
10. Perform postprocessing steps: These steps

Figure 4. Computation of procedure for advanced diversion model.



are to determine (a) revenue--use formula for prorating mileage to compute revenue for each carrier and accumulate data for each railroad; (b) car miles--multiply carrier mileage by cars on each record and accumulate data for each railroad; (c) ton miles--use same process as that for car miles; (d) traffic distribution--use intracarrier route-choice model to accumulate car and ton assignments on each link and plot car and ton density charts for each railroad; (e) cost--use car-mile and ton-mile statistics to obtain rough value of costs by using unit-cost method; and (f) sensitivity analysis--compare values from (a) to (e) with historical value or values by using different network configurations, traffic data bases, or impedance values.

Reflections on the Method

Each element of the method described in the previous section has been carried out for several independent studies; however, the entire method has not been executed in a unified application. Some of the elements are rather simple and straightforward. Some are complicated and consume time and personnel and computer resources. The development of a restructured scenario can become a very involved process by itself. Johnson (15) has provided some analytical suggestions. The recording of links and nodes is made very efficient by using interactive computer-graphic techniques. A scenario such as the one discussed above can be coded in less than three person days. Step 2, selection of the traffic data bases, is simple if one chooses to use the carload waybill statistics but can become most expensive if one attempts to put together total traffic data from individual railroads. Commodity statistics from the Bureau of Economic Affairs tend to be too aggregated geographically to be used by themselves. They can be used to factor waybill statistics to a forecast year. In any application, not all traffic would be analyzed; possibly only the markets that represent, say, 85 percent of the affected traffic would be surveyed. Such an assumption reduces the number of movement groups by about 40 percent. Steps 3 and 4, finding all combinations of origin-destination railroads, is a straightforward operation by using the network node data. These steps form an intermediate output provided during the formation of the quantum network. Step 5, specification of impedance values, requires a great deal of subjective judgment, but the analysis is not overly sensitive to the choice of these values. Step 6, generation of quantum routes, is a straightforward but a very computer-time-consuming process. The computation time to generate all routes from a single (Net-3) origin (one tree) is about 2.5 s of central processing unit (CPU) time on an IBM 3033, by using a machine-language algorithm. Although this is quite fast, when one considers that several thousand trees will be generated for a single analysis, the cost is considerable. A mechanism to generate routes on intermediate tree branches does allow a saving of one-half to two-thirds. Work is continuing to try to further reduce the computer time. Step 7, sorting of the output, is trivial, but the specification of market shares in step 8 is probably the most sensitive and subjective element of the analysis. Step 9, the assignment of market shares, simply uses the intracarrier traffic-assignment model, with which there has been a great deal of experience. For all railroads, this step should consume less than 20 min of CPU time on an IBM 3033. Step 10 is simply a post-data-processing step that is tailor-made for each application. The only difficult element is the estimation of costs. There are serious questions as to the accuracy of any existing macroscale cost models.

In summary, the model does have a strong theoretical base; it needs a more computationally efficient quantum route-generation algorithm; it is not overly sensitive to assumptions except in the specification of route-share coefficients; and it does provide the traffic impacts on all carriers.

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Part 2
Motor Carrier Operations

Analysis of the Costs of Truckload Freight Operations

DENNIS R. JANSEN

This paper examines the impacts on truck costs of the most-critical financial and operational variables in long-haul, truckload freight movements. By using a truck cost model developed by the Association of American Railroads (AAR), the paper analyzes the sensitivity of truck costs to changes in fuel price, cost of capital, driver wages, tractor price, trailer price, depreciation method, and insurance cost. The effects of changes in operational factors such as truck speed, annual mileage, cargo weight, equipment type, fuel mileage, and percentage of empty backhaul are also shown. Data are drawn from various sources, which include truck-auctioneer data, truck-leasing company reports, U.S. government publications, and the AAR's field survey of rail-competitive truck movements. The principal finding of the analysis is that a reasonable minimum for mid-1979 rail-competitive truck costs is $0.83/revenue (loaded) mile and $0.055/ton-mile. It is also shown that marketing intelligence is of critical importance for making cost estimates, particularly with respect to equipment price and use, fuel price and mileage, and driver type and wages. Recent cost increases in these three areas (particularly in fuel prices) have reopened some freight markets to rail competition.

Recent rapid increases in the cost of operating tractor trailers in long-haul intercity freight markets have dramatically altered the setting in which trucks and railroads compete for freight. This paper presents the results of ongoing research that is being conducted by the Research Division of the Economics and Finance Department of the Association of American Railroads (AAR) in the area of truckload freight costs. Two basic areas are addressed in the paper: (a) what the factors are that are most critical in influencing truckload freight costs and (b) what the strategies are that truckers are using to offset cost increases.

Average mid-1979 costs by truckload operation carrier type are presented. These are followed by sensitivity analyses on the numerous factors that affect the costs of a base-case operation (an owner-operator leased to an irregular-route common carrier). This base case was selected in order to focus the analysis on a representative type of truckload freight operation. The sensitivity analysis uses a computerized truck cost model developed by the AAR (1) that employs mid-1979 truck cost components and inputs.

Several major findings result from the research:

1. The base-case truckload freight operation costs about $0.79/running mile and $0.053/ton-mile. After average empty mileage has been factored in, these figures are $0.93 and $0.062, respectively. A sizable portion of these costs are fixed or semifixed costs, which require some payment whether the truck is moving or not.
2. Three major strategies exist for offsetting cost increases: increased equipment use over time, improved fuel efficiency, and use of less-expensive tractors.
3. If the average gross revenue per loaded mile is $1.20, the owner-operator must drive in excess of 115 000 miles annually in order to earn $20 000 and meet operating costs (including brokerage fees and empty-mileage costs).

The next section of this paper documents the data sources and the truck cost model used in the research. Then average costs are presented for several classifications of motor carriers (excluding regular-route common carriage and agricultural cooperatives). A review of the base-case results and significant sensitivity analyses run on model input variables is given next, and the last section presents findings and conclusions.

TRUCK COST-MODEL DESCRIPTION AND DATA SOURCES

The AAR has revised and updated the computerized truck cost model it uses in marketing research and policy analysis. The model estimates total line-haul costs for any set of financial, operating, and equipment factors that the user specifies. It is oriented toward long-haul (more than 150 miles) truckload freight movements that are rail competitive and does not include terminal costs or pickup and delivery costs usually associated with less-than-truckload (LTL) operations.

There are two approaches to truck costing. One is to assign costs to a fixed period of time (such as one year) and then divide by annual mileage to obtain costs per mile. The other is to assign various costs on a mileage-related (variable-with-output) basis and sum to obtain a total cost-per-mile figure. The AAR model combines the two methods by assigning most costs on a time-related (fixed- or semifixed-cost) basis and some on a mileage-related (variable-cost) basis.

In owner-operator truckload freight operations, there are three major cost divisions: direct vehicle operating cost, costs associated with empty mileage, and overhead (agency or brokerage fees associated with leasing). The first two are accounted for by the model; the last is not and is more easily incorporated by viewing it as a reduction of the freight rate. It applies only to owner-operators.

Model Inputs and Output

The 36 input variables required in the model for the van base case are listed in Table 1. The variables fall into several groups:

1. Driver factors: wages (or residual, in the owner-operator case) and living expenses;
2. Capital costing factors: cost of capital (or loan rate, if an owner-operator is involved), investment tax credit, income tax rate, depreciation method, salvage values, useful life, tax life, and tractor and trailer purchase prices;
3. Operating costs: fuel cost and mileage, tire cost and life, maintenance cost per mile, overhead cost per year, insurance cost per year, and various user taxes and permit costs; and
4. Operating factors: owner of vehicle (driver or company), trailer type, miles per year, length of haul, and payload.

The operational data for the truck cost-model runs used in this paper are from a large field survey of intercity truck movements (2). The survey involves 31 000 personal interviews with intercity truck drivers made at 20 key locations around the country since 1977 (7000 in 1979). The interviews are conducted at a random time of day, day of the week, and time of the month. Each driver is asked to respond to questions about current and previous hauls, operation, and personal driving characteristics. Included are questions about legal status (carrier type), equipment, origins and destinations, and driver productivity. The sample has an intended bias against regular-route common carriers (LTL freight) and intracity local cartage.

The model's output includes cost per mile, per trip, per hundredweight, and per ton-mile. The sensitivity of trip costs to the amount of empty (nonrevenue) mileage assignable to a particular trip is also computed and output in tabular form.

Model Characteristics and Methodology

The model is designed to produce average cost figures that are applicable in costing out specific hauls. Marketing intelligence must be gathered in order to use the model successfully. The critical operational variables (miles per year, length of haul, equipment type, vehicle owner, and cargo weight) must be closely estimated, since they have significant impact on costs.

Table 1. Sample AAR truck cost-model inputs (van base case).

Variable	Name of Variable	Value
C1	Owner of capital assets	Driver
C2	Cost of after-tax capital (%)	12.5
C3	Investment tax credit (%)	10
C4	Marginal income-tax rate (%)	46
C5	Depreciation method	Straight line
C6	Interest rate on financing (used only for owner-operator cases)	15
C9	Insurance cost per year including cargo ($)	5000
D1	Driver wages per year including benefits ($)	19 600
D2	Driver expense per year ($)	3500
F1	Fuel price (cents per gallon)	90
F2	Fuel mileage (miles per gallon)	4.7
	Trailer	
L1	Purchase price including tires and sales tax ($)	11 500
L2	Economic life (years)	8
L3	Salvage value ($)	3750
L4	Tax life (years)	8
L5	Tax salvage value (%)	10
L6	Tire purchase price ($)	1150
L7	Tire life (miles)	170 000
L8	Maintenance cost (cents per mile)	1.5
M1	Miscellaneous expenses per year ($)	3500
	Tractor	
R1	Purchase price including tires and sales tax ($)	60 000
R2	Economic life (years)	5
R3	Salvage value ($)	12 000
R4	Tax life (years)	4
R5	Tax salvage value ($)	10
R6	Tire purchase price (set of 10)	1700
R7	Tire life (miles)	200 000
R8	Maintenance cost (cents per mile)	9
U1	Miles operated per year	115 000
U2	Miles operated per round trip	2600
U3	Miles operated per trip (headhaul)	1300
U4	Average payload/trip (headhaul)	15
X1	License and permit cost per year ($)	1200
X2	Third structure tax per mile (cents)	0.5
X3	Federal highway user tax per year ($)	210
X4	Equipment type	1

Capital costing in the model involves the use of net present-value analysis, which discounts depreciation, interest, investment tax credit, and salvage-value cash flows into a present-value figure. This figure is than divided by the economic life of the vehicle to obtain equal annual capital outlays. (Note that all capital cost computations are made separately for tractors and trailers to allow for differing economic life, salvage value, tax credit, etc.) This capital outlay and other time-related expenses (notably driver wages and expenses, insurance, and overhead) are divided by annual mileage to obtain a cost-per-mile figure. Other mileage-related expenses are then added to these to obtain the total cost per mile.

AVERAGE COSTS BY TYPE OF CARRIER

Rail-competitive trucking encompasses a broad spectrum of operating characteristics (3). There are numerous possible combinations of carrier legal types (common, private, contract, or exempt), trailer types [van, refrigerated van (reefer), or flatbed], and driver arrangements (union or nonunion, owner-operator, or company driver). This section focuses on variations in truck costs that exist across carrier types.

Table 2 presents results of truck cost-model runs based on interviews from the data base described above. Inputs of such averages as annual mileage, length of haul, cargo weight, fuel mileage, and driver wage were varied according to data derived from interviews. Truck movements that involved multiple-drop shipments, sleeper teams, or household goods were eliminated because they are unique operations that are not well suited to averaging. Since trailer prices, maintenance costs, and, most importantly, length of haul and annual mileage vary across equipment types, only van equipment interviews were selected, to ensure similarity and comparability.

Results in Table 2 and elsewhere indicate that company-operated trucks produce cost figures that are comparable with those from owner-operated trucks (4-6). The data indicate that company trucks have lower capital and fuel costs but higher wage and overhead costs. Trucking companies often obtain fleet purchase discounts (up to 20 percent) and certainly have a lower cost of capital than do owner-operators. They also get favorable prices on fuel, due to volume purchasing, and are more inclined to install fuel-saving devices than their capital-weak counterparts. Higher wage costs stem largely from the upward pressure of union

Table 2. Average van-trailer line-haul costs by carrier type.

Carrier Type	Annual Mileage	Cargo Weight (tons)	Length of Haul (miles)	Driver Wage per Mile (cents)	Total Cost per Mile (cents)	Total Cost per Ton-Mile (cents)
Irregular-route common carrier						
Owner-operators	115 000	15	1300	17.0	79	5.2
Company drivers	114 000	18	900	19.3	76	4.2
Private carrier[a]						
Company drivers	109 000	16	1100	20.2	80	4.9
Contract carrier						
Owner-operators	118 000	17	1300	17.0	81	4.7
Company drivers	121 000	14	1000	18.1	78	5.2
Exempt carrier						
Owner-operators	130 000	20	1300	17.4	75	3.8
Company drivers	125 000	20	1000	17.6	73	3.6

[a] Private carriers rarely lease owner-operators.

driver-wage and fringe-benefit requirements, estimated to be 25 percent of straight wages.

Although moderately higher annual mileages for owner-operators are indicated by the data, nothing conclusive is shown about cargo weights. As is commonly asserted, owner-operators must drive more to make competitive wages, even with their tax advantages.

BASE-CASE RESULTS AND SENSITIVITY ANALYSES

This section presents results from truck cost-model runs by using the base case mentioned above and describes the sensitivity of these base-case truck costs to changes in critical variables. The variables addressed include trailer type, driver factors, capital costing factors, fuel-price and fuel-economy factors, and several operational factors, including annual mileage and cargo weight.

Table 3. Input data for truck cost model.

	Value		
Variable[a]	Van	Reefer	Flatbed
C1	Driver-owned	Driver-owned	Driver-owned
C5	Straight-line	Straight-line	Straight-line
U1 (miles)	115 000	130 000	100 000
U2 (miles)	2600	3500	2500
U3 (miles)	1300	1700	1150
U4 (tons)	15	19	19
X4	Van	Reefer	Flatbed
F1 (cents/gal)	90.0	90.0	90.0
F2 (miles/gal)	4.8	4.7	4.9

[a] See Table 1 for names of variables.

Trailer-Type Cost Differences

The model was run by using input values for three trailer types--vans, reefers, and flatbeds. Inputs and results are shown in Tables 3 and 4. The results indicate that, despite higher capital and operating costs, reefer operations produce unit costs equal to or below those of van or flatbed operations. This is due to the longer hauls and higher annual mileage productivity regularly achieved by reefer operators and to their lower ratio of empty to total miles. Note, however, that flatbeds achieve the lowest cost per hundredweight, due to higher average cargo weights and shorter hauls.

The van base case, which serves as the basis for further sensitivity analyses (see Table 5), operates at \$0.79/running mile and \$0.053/ton-mile (Table 4). The cost-per-mile formula that results from the base-case run is

$$TCM = \$0.30 + (\$55\ 000/M),$$

where TCM = total cost per running mile and M = annual mileage. This equation is estimated to be valid between approximately 50 000 and 180 000 miles/year. Mileages outside this range significantly alter the proportions of fixed to variable truck costs, especially driver wages, capital costs, and maintenance costs.

Impact of Driver Wages

Driver wages constitute 22 percent of the total van base-case operating costs per mile (\$0.17/\$0.79) and more than one-third of the fixed cost component (\$19 600/\$55 000). Table 2 shows that wages can

Table 4. Truck cost-model output for van, reefer, and flatbed base case.

Operating Cost (cents/mile)

	Value		
Item	Van	Reefer	Flatbed
Driver	17.0	18.0	17.8
Driver expense	3.0	2.7	3.5
Capital cost	19.2	20.0	21.9
Fuel cost	18.7	19.1	18.4
Maintenance cost	10.5	11.0	10.5
Tire cost	1.5	1.5	1.5
Licenses and permits	1.0	0.9	1.2
Third structure tax	0.5	0.5	0.5
Federal highway user tax	0.2	0.2	0.2
Insurance cost	4.3	3.8	5.0
Miscellaneous expenses	3.0	2.7	3.5
Total[a]	79.1	80.5	84.1

Operating Cost per Trip ($)

	Value		
Item	Van	Reefer	Flatbed
Cost per round trip	2057	2817	2102
Cost of headhaul	1029	1368	967
Cost per ton-mile	0.053	0.042	0.044
Cost per hundredweight	3.429	3.601	2.544

[a] Totals are not exact due to rounding of figures.

Table 5. Sensitivity analyses on percentage of loaded mileage for three cost-model cases.

	Van		Reefer		Flatbed	
Loaded Miles as a Percentage of Total Miles	Total Cost per Loaded Mile (cents)	Total Cost This Load ($)	Total Cost per Loaded Mile (cents)	Total Cost This Load ($)	Total Cost per Loaded Mile (cents)	Total Cost This Load ($)
1.0	79.1	1029	80.5	1368	84.1	967
0.9	87.9	1143	89.4	1520	93.4	1074
0.85	93.1	1210	94.7	1610	98.9	1137
0.8	98.9	1286	100.6	1710	105.1	1208
0.7	113.0	1470	115.0	1955	120.1	1381
0.6	131.9	1715	134.2	2281	140.1	1611
0.5	158.3	2057	161.0	2737	168.1	1934

range up to about 30 percent of costs in the private-carrier case. The labor component could conceivably reach 35 percent of costs if driver expenses (lodging and food) are included and if union drivers are used. Basically, for every additional $1000 of compensation, truck costs per mile rise about $0.01.

Base-case driver earnings are $19 600/year. This figure is actually not a salary per se but represents a residual of the freight revenue. Gross freight revenue data obtained in the survey indicate that $1.20/mile (including Interstate Commerce Commission fuel surcharges) was appropriate for this type of operation in mid-1979. The $1.20/mile gross revenue is reduced by the leasing fee paid to the carrier and by empty mileage, as shown below, which leaves $0.17 for the driver and $0.61 for vehicle operating cost (1-2):

Item	Cost ($)	Percentage of Gross Revenue
Carrier leasing fee	0.29	24
Empty mileage factor	0.13	15
Driver residual	0.17	17
Direct vehicle operating cost	0.61	44

Residuals in the exempt owner-operator sector appear to be comparable but, since annual mileage is so much higher, annual incomes are higher also.

Nonunion company drivers also report per-mile earnings of $0.17-0.19. However, their employers frequently pay approximately 25 percent more than that for Social Security and unemployment taxes, health and welfare benefits, holidays and sick leave, and workmen's compensation. This raises company driver wages to about $0.21-0.24/mile, or $21 000-$26 000/year (based on 100 000-110 000 miles/year). Teamster's wages are even higher. (The 1979 National Master Freight Agreement ratified in mid-1979 provides hourly wages of $10.65 and fringe benefits of $3.25, or a total of $13.90/h. A 2080-h workyear yields $28 912 annually. Teamsters paid by the mile are compensated more than $0.30/mile.)

Capital Costing Factors

Capital ownership costs constitute 24 percent of total line-haul costs in the van base case and 40 percent of fixed costs. The $60 000 tractor input into the model (7,8) accounts for $0.16/mile on its own, while the $11 500 van trailer only makes up $0.025/mile. Note that the useful life of the tractor is assumed (Table 1) to be five years and that of the trailer is eight years.

Table 6 shows capital cost changes when variations are introduced in several of the 16 input variables that enter the capital costing formulas. Variables selected for analysis include investment tax credit rates, depreciation methods, interest rates on the truck loan, and several others.

Significant changes were found when the interest rate on the owner-operator's truck loan was altered. Each additional percentage point of interest is shown to add about $0.008/mile over the life of the truck. The use of an accelerated depreciation schedule is shown to save the trucker only slightly more than $0.01/mile; similarly, trailer price and trailer economic-life changes have only a small impact on total costs. (Trailer-related costs make up only about 7 percent of total operating costs in the base case.)

Without question, the single most important factor in determining truck capital costs is the price of the tractor. As noted above, tractor capitalization alone constitutes $0.167/mile, or 21 percent of the total costs (36 percent if tractor insurance, tires, and maintenance are added). A change of $10 000 in the initial capital outlay for a tractor can change operating cost per mile by almost $0.03 (with salvage value raised or lowered concurrently by $2000).

Changes in tractor economic life combined with changes in economic salvage (resale) value produced similarly significant results. Many factors come into play when changing these variables, however, because maintenance costs and the investment tax credit allowed also change with economic and tax life, respectively.

Strategies for capital cost reduction center around high equipment use and reductions in initial outlay. New entrants into the industry are more likely to succeed if they resist the temptation to splurge on a tractor that has excessive horsepower and all the glamorous options. A reduction of $0.03/mile in operating costs can translate into $3500/year in the base case, or a present value of $13 000 ($3500/year for five years at 10 percent). The effect of high equipment use is discussed in the section on annual mileage.

Fuel Price and Fuel Economy

One of the most pressing issues in the trucking industry is that of fuel prices and fuel economy. While the 55-mph speed limit sponsored by the U.S. Department of Transportation was directed primarily at the trade-off between speed and fuel mileage, this section will address the impact that fuel cost and fuel mileage have on total trucking costs.

Fuel costs have grown from about 15 percent of total truck line-haul costs per mile in 1977 to more than 23 percent today. Paxson has shown (9) that the cost impact of fuel price increases on trucks is nearly double that on rail. Table 7 shows that price increases of $0.30/gal (33 percent) yield increases of $0.063 in cost per mile (8 percent). Such a price increase computes to $7200/year in the base case. Fuel-mileage changes yield similarly dramatic results. An improvement of 1 mile/gal can save $0.032/mile or $3700/year in the base case.

Strategies for fuel-cost reduction are numerous. They include the installation and use of fuel-saving engines, wind deflectors, radial tires, special gearing, lightweight accessories, and synthetic lubricants. The savings that accrue to the trucker seem to outweigh the small incremental costs of using these items. Most fleet operators are moving ahead rapidly with such fuel-saving measures, but owner-operators are not aggressively pursuing these strategies, probably due to shortage of capital or concern about the appearance of their trucks and their powerful engines.

Annual Mileage, Length of Haul, and Truck Speed

The final general area of analysis is that of the effect of operating changes on truck line-haul costs. It is shown that annual mileage, length of haul, truck speed, cargo weight, and empty mileage are critical inputs in truck costing.

Annual Mileage

The single most important variable in determining truck line-haul cost per mile is annual mileage (Table 8) (1,2). This is due to the fact that the fixed and semifixed portions of truck costs--capital costs, insurance costs, licenses and fees, overhead, and driver wages--are becoming so prohibitively large. The annual Hertz truck cost study (5) cited

Table 6. Truck cost sensitivities to capital costing factors (van base case).

Variable	Base-Case Value	Change	Capital Cost per Mile (cents)	Total Cost per Mile (cents)	Change from Base Case (cents)
C3 (%)	10.0		19.2	79.0	
		12.5	18.8	78.7	-0.3
		7.5	19.4	79.4	+0.4
C5	Straight-line		19.2	79.0	
		Double-declining balance	17.9	77.7	-1.3
C6 (%)	15		19.2	79.0	
		19	22.5	82.3	+3.3
		11	16.1	75.9	-3.1
L1 ($) and L3 ($)	11 500 and 3750		19.2	79.0	
		13 500 and 3950	19.7	79.5	+0.5
		9 500 and 3550	18.8	78.6	-0.4
R1 ($) and R3 ($)	60 000 and 12 000		19.2	79.0	
		70 000 and 14 000	21.9	81.8	+2.8
		50 000 and 10 000	16.3	76.3	-2.7
R2 (years) and R3 ($)	5 and 12 000		19.2	79.0	
		7 and 10 000	16.6	76.5	-2.5
		3^a and 14 000	24.2	84.1	+5.1

[a] Tractor tax life is equal to three years.

Table 7. Truck cost sensitivities to fuel cost and mileage (van base case).

Variable	Base Value	Change	Fuel Cost per Mile (cents)	Total Cost per Mile (cents)	Change from Base Case	
					Cents	Percent
Fuel cost ($/gal)	0.90		18.7	79.0		
		1.50	31.3	91.6	+12.6	+16
		1.20	25.0	85.3	+ 6.3	+ 8
		0.60	12.5	72.8	− 6.3	− 8
Fuel mileage (miles/gal)	4.8					
		5.8	15.5	75.8	-3.2	− 4
		3.8	23.7	84.0	+5.0	+ 6

Table 8. Impact of annual mileage on truck costs and driver compensation.

	Truck Costs		Driver Compensation	
Annual Mileage	Per Mile (cents)	Total ($)	Per Mile (cents)	Total ($)
90 000	71	63 900	7	6 300
115 000	61	70 200	17	19 600
140 000	57	79 800	21	29 400

insurance as the fastest-rising component of truck operating costs.

Table 8 shows the sensitivity of truck costs per mile and driver income to annual mileage changes. A per-mile cost reduction of 7 percent is obtainable by driving 140 000 miles/year as opposed to 115 000 miles. Note also that the driver's effective mileage wage increases to $0.21/mile at this level. In essence, the driver has paid his fixed costs, so that more of the freight revenue accrues to him and not to the truck manufacturer or the insurance company.

As fixed costs increase, there is a greater penalty for idle time and empty mileage. Hence, the incentive for increased equipment use (and for hours-of-service violations) becomes stronger, and drivers redouble their efforts to keep their trucks loaded and moving as much as possible.

Length of Haul

Length of haul is critical to truck unit costs, mainly because there is a correlation between length of haul and annual mileage. Data from AAR and the U.S. Department of Agriculture (10) support the assertion that, in general, longer hauls correspond to greater annual mileage and hence lower unit costs. (AAR data show that movements in the range of 250-500 miles average 99 000 miles/year, those of 500-750 miles yield 105 000 miles/year, those of 750-1000 miles yield 112 000 miles/year, etc., up to those of 2500-2750 miles, which yield 127 000 miles/year. On the average, an increase by one length-of-haul increment translates into an additional 3000 miles/year.)

Truck Speed

Variations in overall truck speed also have a dramatic effect on annual mileage and unit costs. Increases of 5 mph on a schedule of 300 days at 11 h/day translate into 16 500 additional miles annually. The unit-cost effect of such a productivity increase would be slightly offset, however, by slight increases in fuel consumption, wear and tear on the truck, and possibly fines for speeding.

Cargo Weight

Cargo weight affects truck costs most noticeably by increasing the wear on tires, trailer, and engine and by increasing third-structure taxes (in some states) and fuel consumption. However, the total difference between running with 15 tons and running empty is less than $0.05/mile. AAR data indicate that two-thirds of the movements weigh between 9 and 21 tons. In the table below, fuel mileage changes of 0.2 mile/gal were assigned for every 3-ton change.

Cargo (tons)	Cost per Ton-Mile ($)	Cost per Hundredweight ($)
9	0.088	5.72
12	0.067	4.35
15	0.053	3.49
18	0.046	2.96
21	0.040	2.58

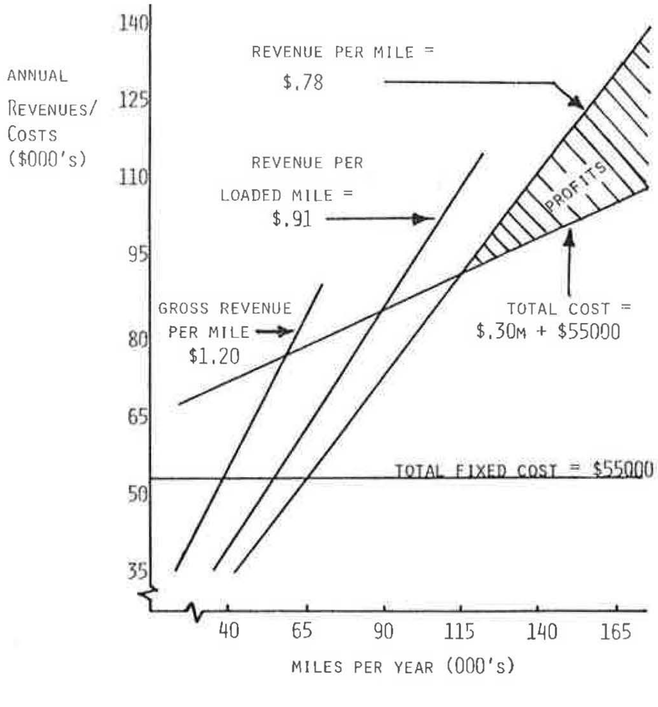
A ton-mile cost reduction of up to 30 percent is possible with a load of 21 tons compared with the base-case haul of 15 tons. There is a strong incentive for carrying overweight loads, especially when the chances of detection are perceived to be slight (11).

Empty Mileage

Finally, empty mileage is a very important variable in determining truck cost levels. AAR statistics show an average of 15 percent empty mileage associated with base-case operations. A sensitivity analysis for empty mileage for the van base case showed truck costs of $0.93/mile and $0.062/ton-mile at 85 percent of capacity.

Actually, empty mileage is best accounted for by adjusting revenues rather than cost figures, which change only slightly when the truck is empty. This concept is shown in Figure 1. This break-even analysis assumes an average revenue per loaded mile of $1.20 and a brokerage fee of 24 percent. The effect of the 15 percent average empty mileage is to reduce the overall net revenue per running mile. Net revenue per loaded mile is $0.91 ($1.20 x 0.76). Each additional percentage point of empty mileage to total mileage results in a need to drive 2000 additional miles/year to break even. The base-case driver would break even at about 90 000 miles if empty miles could be reduced to zero; however, with 15 percent empty miles, 25 000 miles more must be driven to break even.

Figure 1. Mid-1979 base-case break-even analysis.



SUMMARY AND CONCLUSIONS

This paper presents findings from research conducted on the average costs of truckload freight operations. A base case was selected and sensitivities were run to determine potential variations in average costs; potential strategies used to offset cost increases were discussed. Base-case costs were $0.79/running mile and $0.053/ton-mile. When average ratios of loaded to empty mileage are factored in, these costs increase to $0.93/running mile and $0.062/ton-mile.

Several major strategies emerged from the sensitivity analyses. First, by decreasing tractor purchase price, truck costs can be decreased as much as $0.03/mile, or $0.002/ton-mile. Increasing fuel mileage by 1 mile/gal achieves similar cost reductions. Increases in annual mileage productivity can yield a 7 percent reduction in per-mile costs. Cargo weight increases can reduce ton-mile costs to about $0.04.

Combinations of the above strategies produce a reasonable minimum for rail-competitive truck costs of $0.71/running mile and $0.04/ton-mile (by using a driver wage of $0.19/mile and 150 000 miles/year). The factoring in of 15 percent empty mileage raises these costs to $0.83/running mile and $0.055/ton-mile.

The massive cost increases that rail-competitive truckers are experiencing create definite incentives for violating hours-of-service regulations, for overloading trucks, and for speeding. It has been shown that by doing these things, the base-case operation can reduce per-mile costs up to 10 percent and ton-mile costs up to 25 percent.

The cost increases also place the truck operators in the position of requiring rate increases that may open up marketing opportunities for U.S. railroads. Recently, some of the movement of fresh fruits and vegetables that are shipped east from California has been recaptured by several railroads after the market had long been dominated by trucks. Although the final impetus for this traffic diversion was the nearly simultaneous occurrence of the independent truckers' strike and rail-rate deregulation on fresh fruits and vegetables, the railroads have retained much of this traffic since the end of the strike. Future diesel-fuel, driver-wage, and truck-price increases could intensify and expand such marketing opportunities for rail.

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Marketing Advantages of Size in the General-Freight Motor Carrier Industry

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This paper focuses on a hypothesis that has been offered as an alternative explanation for the increasing concentration observed in the general-freight motor carrier industry. Although economic research on this question has traditionally been directed to the cost structure of the industry, this paper addresses a demand-side explanation, namely, the hypothesis that general-freight carriers with extensive terminal networks possess important marketing and service advantages over small firms. A formal test of the hypothesis that size affects marketing advantages, based on city-pair market data collected from carriers that offer single-line service in selected transcontinental markets, provided the following results. Those carriers with the largest route networks, whether measured by the number of terminals or by the number of standard-metropolitan-statistical-area (SMSA) points served, did not (other things being equal) possess the largest share of overall less-than-truckload (LTL) revenue in the lanes studied. Indeed, other factors, such as a carrier's relative financial health and regional identification, appeared to play a greater role in explaining market share than did network size. Nevertheless, carriers with extensive networks did earn higher average LTL revenue per shipment pound than did carriers that served a smaller number of terminals or SMSA points. These results, although based on a limited sample of city pairs, indicated that carriers with extensive terminal networks have balanced market-share objectives against other objectives such as shipment yield. Moreover, such carriers have been more successful in competing for high-rated traffic than have smaller carriers. The results thus suggest that, under the present regulatory system, large interregional general-freight carriers possess significant marketing advantages in soliciting high-rated freight and that these advantages have contributed to the high relative growth and profitability of such carriers.

This paper examines the hypothesis that large general-freight carriers that serve many points enjoy important marketing or service advantages over smaller firms (1-3). According to this hypothesis, carriers that offer regular service to many points will (other things being equal) win the greatest market shares in any given city-pair market. This hypothesis is supported by informal observations of shipper behavior in selecting motor carriers, which indicate that shippers have a strong preference for minimizing the number of carriers with which they deal and do so by selecting carriers that provide the greatest route coverage. Such a practice minimizes the number of interactions between shipper personnel and carriers, minimizes congestion at the shipper's loading docks, and concentrates the shipper's bargaining power, e.g., in negotiating special commodity or point-to-point rates.

The hypothesis of the marketing advantages of size is of particular interest in view of the controversy that surrounds the economics of the general-freight or less-than-truckload (LTL) segment of the motor carrier industry. This debate has focused on whether the increasing concentration observed in LTL transportation is the product of Interstate Commerce Commission (ICC) regulation or of structural economic factors.

Traditionally, research on this question has been directed to the cost side of the industry, i.e., to the issue of cost economies of scale. Over the past 20 years a number of studies have attempted to estimate the most efficient size for a general-freight carrier. The results of these studies suggested that economies of scale (if they exist at all) are achieved only by certain regional carriers, while interregional carriers are characterized by constant returns to scale (4-5).

Economists have interpreted the cost-study evidence as indicating that any given market should be able to support substantially more carriers than it currently does and accordingly that high concentration ratios reflect artificial regulatory restrictions on entry into the market. In contrast, members of the general-freight carrier industry have argued that concentration trends are explained by the nature of demand for LTL transportation, i.e., by the marketing advantages that accrue to large carriers that serve many points. They argue that, in the absence of regulation, the industry would come to be dominated by a few large firms. Given the importance of this question, this paper presents a formal test of the marketing-advantages hypothesis.

The next section of the paper discusses general-freight carrier marketing and service strategies as they have evolved under ICC regulation. Next, an empirical investigation of the relationship between the major dimensions of carrier service--route coverage, quality of service, and marketing effort--and carrier market performance in 18 transcontinental lanes is presented. A summary of the study's conclusions ends the paper.

Table 1. General-freight carriers that offer single-line service in study lane markets, 1973.

Study Lane Market	Mileage[a]	Carriers[b]
Chicago-Los Angeles	2087	A-L
Chicago-San Francisco	2169	A-K
Chicago-Portland	2095	A, B, D, G, H, K, L
Minneapolis-Los Angeles	1889	A, E, J-M
Minneapolis-San Francisco	1940	A, E, J-M
Minneapolis-Portland	1678	A, K-M
St. Louis-Los Angeles	1848	A, B, D-G, I-L
St. Louis-San Francisco	2089	A, B, D-K
St. Louis-Portland	2060	A, B, D, G, H, K, L

Note: A = Consolidated Freightways; B = East Texas Motor Freight; C = Illinois-California Express; D = IML Freight; E = Lee Way Motor Freight; F = Navaho Freight Lines; G = T.I.M.E.-DC; H = Transcon Lines; I = Western Gillette; J = Yellow Freight System; K = Pacific Intermountain Express; L = Ringsby Truck Lines; M = Garrett Freightlines.

[a] Derived from Household Goods' Carriers Tariff Bureau, Agent Mileage Guide 9, MC-ICC 140. For rate-making purposes, these mileages are increased by 6 percent for circuity.

[b] General-freight carriers that advertise in the National Highway Carriers Directory publication (8).

IMPLICATIONS OF ICC RATE REGULATION

As in other industries in which prices are regulated and entry is restricted, competition among interregional freight carriers has focused on service, i.e., the building of market advantage through the provision of fast, reliable transportation over an extensive route network. Given the ICC's relatively permissive policy toward mergers that offer improved service, such competition has escalated in recent years as carriers have expanded their terminal-point coverage through end-to-end mergers and acquisitions of operating rights. In addition, many carriers have been aggressive in opening secondary or satellite terminals along existing routes.

However, at the same time, the fact that under the current regulated rate structure not all classes of traffic and shipment sizes are equally compensatory provides carriers with an incentive to engage in selective marketing. Attracting or marketing high-rated freight is generally regarded as a strategic factor in building a competitive advantage in the general-freight transportation business. For example, in a statement on the current motor carrier rate structure in ICC Ex Parte MC-98, one industry member observed (6):

> Further use of present structures will lead, through the simple thrust of economics, to an oligopoly in motor transportation. The remaining oligopolistic carriers may certainly not have been the more efficient carriers in terms of productivity; but assuming arguendo that all trucking management were equally efficient, there would still be carriers eminently more profitable than others due purely to operating environment.
>
> When I speak of operating environment, I do not mean differences in trucks and terminals; for in truth, the entire industry uses roughly the same tools of physical productivity. When I talk of operating environment, I mean the traffic environment--things that affect traffic environment such as short haul vs. long haul, on-line vs. interchange, low class vs. high class, head haul vs. back haul, etc.
>
> This environment is controlled not by management, but by rate bureau averages, classification board averages, ICC and intrastate operating authority, interline concurrences or lack of same, carrier traffic costing with computers or the lack of it, and, last but not least, the alteration of the environment through traffic selectivity. The game called profit in the trucking industry is not won on operating efficiency, but on operating environment manipulation; or simply knowing and understanding the inequities in the rate structure, and through environmental change making them work for you (emphasis added).

Carrier traffic selectivity takes a number of forms. Negative expressions of selectivity by carriers include avoidance of commodities considered to be undesirable traffic as the result of physical characteristics or volume, refusal to accept interline traffic in certain circumstances, refusal to accept traffic destined for cities or areas that do not generate large amounts of backhaul traffic, withdrawal of service from low-traffic-density points after merger, and bypassing of communities not served by the Interstate highway system. In such cases, the justification usually given by a carrier for its refusal to accept less-desirable traffic is that its facilities are overloaded and that the article tendered for transportation might be damaged or lost if held over until a slack period is reached.

On the other hand, positive expressions of traffic selectivity--service rivalry and marketing efforts aimed at attracting desirable freight--take on added importance in the presence of cross subsidization. For example, the Yellow Freight System believes that a major contributor to the success of its marketing program is a single-minded focus on a specific class of business. The essence of Yellow Freight's approach is careful allocation of salesmen's efforts on key accounts, as determined by the volume and length of haul of the LTL traffic that the account offers. Salesmen attempt to get the most-attractive business from customers as well as a balanced flow of traffic in and out and the optimum mix of high- and low-density shipments (7).

EMPIRICAL ANALYSIS OF MARKETING ADVANTAGES OF SIZE

This section provides an empirical investigation of the relation between the major dimensions of carrier service--route coverage, quality, and marketing effort--and carrier market outcomes in a number of major transcontinental traffic lanes between the Midwest and the Pacific Coast. Practical considerations dictated the selection of transcontinental corridors; because of the length of these corridors, the number of carriers from which data would be required (carriers with single-line authority) was held to manageable proportions. The lanes selected for analysis and the carriers that offer direct service in each are shown in Table 1.

Seven of the carriers that serve the lanes listed in Table 1 were able to provide 1973 data on origin-destination LTL and truckload (TL) revenue, shipments, and tonnage for each pair of cities in which they had authority: Consolidated Freightways, East Texas Motor Freight, Garrett Freightlines, Illinois-California Express, IML Freight, Pacific Intermountain Express, and Yellow Freight System. Because not all carriers that offer single-line service in the study lanes were able to provide data, it was necessary to estimate the total LTL and TL traffic base in each lane. This was done by using city-to-city traffic-flow reports prepared by the Rocky Mountain Motor Tariff Bureau (RMB) from its Continuous Traffic Study waybill samples.

Market Hypotheses

As discussed above, under the present regulatory system, carriers will not necessarily seek to maximize overall market share but rather will attempt to maximize share in selected high-rated traffic segments. Given these conditions, carrier service rivalry will be directed to market share and shipment yield, although nothing can be said about the form of this rivalry a priori. These hypotheses thus yield the following models:

$$R_i^j = f(M_i^j, Q_i^j, A_i^j, e_i^j) \quad f_1 = ?, f_2 > 0, f_3 > 0 \tag{1}$$

$$Y_i^j = f(M_i^j, Q_i^j, A_i^j, S_i^j, e_i^j) \quad f_1 > 0, f_2 > 0, f_3 > 0, f_4 < 0 \tag{2}$$

where

R_i^j = ratio of the actual LTL revenue market share of firm j in market i to the expected market share if the market had been divided equally,

Y_i^j = average LTL revenue per pound of firm j in market i,

M_i^j = ratio of the number of markets served by carrier j to the average number of markets served by all carriers with authority in market i,

Q_i^j = ratio of the service-quality ranking for carrier j to the average-quality ranking of all carriers with authority to serve market i,

A_i^j = ratio of marketing effort for carrier j to the average marketing effort of all carriers with authority to serve market i,

S_i^j = average LTL shipment size of firm j in market i, and

e_i^j = random error term.

The process of transforming the qualitative factors suggested above into explicitly defined quantifiable variables is constrained by data availability. The definitions of the variables used in this analysis (and their shortcomings) are outlined below.

Network Coverage

One of the key explanatory variables suggested by the marketing-advantages hypothesis is the extensiveness of a carrier's route network. In this study this variable (TERM) is defined as the number of terminals operated by the carrier as listed in the spring 1974 National Highway Carriers guide (8). Since the number of terminals does not necessarily indicate the marketing significance of a carrier's system in terms of population served, an alternative measure, SMSA, i.e., the number of standard metropolitan statistical areas served by a carrier, was tested.

Service Quality

Published data on carrier service quality do not exist. However, shippers increasingly use carrier profile and rating systems, which suggest that carrier financial condition is a good proxy for service quality. Indeed, there is general agreement in the motor carrier industry that a company's stability and service tend to be impaired when its operating ratio rises to more than 95 percent. For example, in shippers' carrier rating profiles, the use of the financial-condition yardstick has been explained as based on the premise that a carrier reacts either positively or negatively because of financial condition. It is reasoned that a carrier in financial difficulty may lack the incentive to deal equitably with the shipper on claims, rates, services, etc. Further, if a carrier's financial condition leads to bankruptcy, a shipper may be exposed to financial loss. In any event, bankruptcy proceedings necessitate the use of a new carrier.

In this analysis, service quality is proxied by the carrier's average operating ratio for 1970-1972 (ORAVG). Because origin-destination traffic in the 18 study lane markets represents a relatively small portion of the study carriers' overall traffic, this measure may be considered exogenous to particular markets. (In no sample lane did a study carrier's origin-destination LTL revenues exceed 4 percent of its systemwide LTL revenues. Indeed, in nearly all cases, the ratio of carrier-lane LTL revenues to systemwide LTL revenues was less than 1 percent.)

Sales Effort

No data that pertained to carrier marketing budgets, sales staff, or sales policies in individual citypair markets were available. An alternative system variable, number of salespersons per SMSA (SALES), was used as a proxy measure for a carrier's marketing effort.

Dummy Variables for Network Characteristics

Several additional carrier network characteristics may be relevant to shipper carrier choice, i.e., whether or not a carrier is operating in a home market or in a market in which its regional identification factor is high or low. The following dummy variables were included to represent these factors: HOMEMKT, which had a value of 1.0 if a carrier's corporate headquarters was located at the point of origin in a city-pair market and zero otherwise; NORTHREG, which had a value of 1.0 for a predominantly northern carrier that competed on a route served primarily by southern carriers and zero otherwise; and SOUTHREG, which had a value of 1.0 for a predominantly southern carrier that competed on a route served primarily by northern carriers and zero otherwise.

Dummy Variables for Firm Effects

As candidates for inclusion in an equation geared toward explaining differences in carrier market share and shipment yield on the city-pair level, the quantifiable variables outlined above have some obvious intuitive appeal. However, other important explanatory variables have undoubtedly been missed in this selection of variables. Some of these influences might be picked up by the inclusion of an additional dummy variable for each carrier. This variable would carry a value of 1.0 for the carrier associated with the variable and a value of zero for all the other firms in the market. By using the technique of introducing dummy variables into the regression equation, any previously unidentified, constant, and persistent factor that influences an individual carrier's lane-market performance should be picked up and highlighted by the dummy variable designed to characterize the firm effect of the carrier in the regression equation. (A long list of factors thought to influence shippers must go unmeasured in this analysis: actual transit time; consistency of meeting transit time; schedule of pickup, delivery, or pickup-and-delivery service; availability of equipment; capability of tracing; frequency of claims; settlement policies for claims; incidence of billing or rating errors; ability to expedite; willingness to negotiate special commodity

Table 2. Carrier system characteristics, 1973.

Characteristic	Carrier A	B	C	D	J	K	M
Number of terminals	191	52	31	48	147	85	64
Number of SMSAs served	99	36	20	35	94	64	14
Number of the 50 largest SMSAs served	44	19	12	24	40	33	9
Average operating ratio 1970-1972 (%)	92.4	96.3	92.4	93.3	90.3	95.2	92.8
Number of salespersons	401	83	68	115	225	184	52

Note: Carriers are identified in Table 1.

Table 3. LTL revenue market-share estimates.

	Dependent Variable = logLTLREV					
Item	A	B	C	D	E	F
Constant	-0.027 91	-0.017 63	-0.921 82	-0.026 85	-0.044 48	0.228 18
logTERM	-0.215 32	-0.664 86^a	-2.698 2^b			
	(0.193 62)	(0.201 34)	(1.373 9)			
logSMSA				-0.032 67	-0.308 37^b	-4.416 2^a
				(0.162 24)	(0.164 39)	(1.589 6)
logORAVG	-15.214^a	-20.915^a	-46.824^b	-12.806^a	-16.565^a	-32.894^b
	(5.353 3)	(4.805 5)	(25.795)	(5.096 4)	(4.741 7)	(15.109)
logSALES	1.680 0^a	1.381 0^a	17.313^b	1.581 6^a	1.110 7^a	8.949 7
	(0.469 77)	(0.420 72)	(9.143 6)	(0.467 47)	(0.449 89)	(5.135 9)
SOUTHREG		-0.657 69^a	-1.106 0^a		-0.540 95^a	-1.218 9)^a
		(0.134 67)	(0.119 34)		(0.133 62)	(0.126 60)
NORTHREG		0.074 73	0.009 23		0.146 35	-0.095 07
		(0.093 13)	(0.083 34)		(0.094 19)	(0.090 24)
HOMEMKT		0.150 51	0.122 05^b		0.097 62	0.113 24
		(0.121 05)	(0.071 20)		(0.126 37)	(0.069 50)
Firm 1			3.187 7			0.510 13
			(2.012 6)			(1.197 0)
Firm 2			-4.094 2^a			-3.224 2^a
			(0.395 14)			(1.257 6)
Firm 3			0.749 56			-0.673 40
			(0.538 70)			(0.875 06)
Firm 4			0.262 43			-0.992 00
			(0.464 71)			(0.644 76)
Firm 5			2.325 2^b			0.971 93
			(1.277 1)			(0.803 42)
Firm 6			3.274 9^b			1.727 6
			(1.715 2)			(1.039 4)
R^2	0.251 41	0.463 34	0.833 71	0.239 93	0.412 86	0.842 08
$\bar{R}^2$	0.222 62	0.420 41	0.804 79	0.210 70	0.365 89	0.814 62
F-Statistic	8.731 8	10.792	28.828	8.207 5	8.789 8	30.661
SE	0.359 62	0.310 52	0.180 21	0.362 36	0.324 79	0.175 61

Note: A = system variables; B = system variables plus network-characteristic dummy variables; C = system variables plus network-characteristic and firm-effect dummy variables; D = system variables with alternative scale variable SMSA; E = system variables with alternative scale variable SMSA plus network-characteristic dummy variables; F = system variables with alternative scale variable SMSA plus network-characteristic and firm-effect dummy variables. Values in parentheses are standard errors of the coefficients. N = 82.

[a] Significant at 0.01 level (two-tailed test).

[b] Significant at 0.05 level (two-tailed test).

rates; ability to provide rate and route information; and practices for credit, dunning, and collections.) The existence of strong firm effects would not result in the direct identification of additional variables that might be important in defining a firm's relative lane-market performance. However, if strong firm effects were observed, case studies might be undertaken to identify the causal factors at work.

Carrier system characteristics that correspond to these variables are shown in Table 2.

Empirical Results

Market Share

Since discussions of service rivalry in the general-freight motor carrier industry offer no precedents for functional form, three alternative functional forms--double-logarithmic, semi-logarithmic, and linear--were tested in analyzing the determinants of market share. This paper presents results for the double-logarithmic form [the results for the semilogarithmic and linear forms are given elsewhere (9)]:

$$\log LTLREV = b_0 + b_1 \log TERM + b_2 \log ORAVG + b_3 \log SALES + \text{dummy variables} \quad (3)$$

where LTLREV is defined as the ratio of actual carrier LTL revenue to expected LTL revenue if the market is divided equally among competing carriers, and the explanatory variables are as defined in the previous section. This model was also estimated with the alternative scale variable SMSA.

The market-share regression results are shown in Table 3. (The firm-effect dummy variables are not identified by company name in order to ensure the confidentiality of the carrier data.) Each of the estimated equations is statistically significant. As can be seen, however, comparison of the basic and expanded regression models indicates that inclusion of the dummy variables for regional and firm effects provides a more complete specification, which contributes significantly to the explanatory power of

Table 4. LTL shipment-yield estimates.

	Dependent Variable = LTLREVLB					
Item	A	B	C	D	E	F
Constant	0.053 85	0.044 41	-0.574 20	0.060 61	0.045 71	-0.391 78
LTLSIZE	-0.000 03^a	-0.000 04^a	-0.000 04^a	-0.000 04^a	-0.000 04^a	-0.000 04^a
	(0.000 01)	(0.000 01)	(0.000 01)	(0.000 01)	(0.000 01)	(0.000 01)
TERM	0.005 19^a	0.006 14^a	0.021 45			
	(0.001 75)	(0.002 02)	(0.012 82)			
SMSA				0.005 68^a	0.006 74^a	0.022 79
				(0.001 86)	(0.002 15)	(0.019 71)
ORAVG	0.055 12	0.063 17	0.831 08	0.044 31	0.056 44	0.475 10
	(0.062 76)	(0.065 60)	(0.445 59)	(0.060 41)	(0.063 71)	(0.335 78)
SALES	-0.005 69	-0.005 88	-0.142 43	-0.001 22	-0.000 21	-0.002 34
	(0.005 68)	(0.005 89)	(0.160 15)	(0.005 40)	(0.005 73)	(0.114 55)
SOUTHREG		0.004 25	0.007 32		0.004 55	0.007 50
		(0.003 70)	(0.005 68)		(0.003 70)	(0.005 89)
NORTHREG		0.001 36	0.000 42		0.000 28	-0.001 49
		(0.002 75)	(0.003 83)		(0.002 67)	(0.003 90)
HOMEMKT		-0.000 34	0.000 05		-0.000 60	0.000 46
		(0.003 47)	(0.003 50)		(0.003 47)	(0.003 52)
Firm 1			-0.075 63			0.002 49
			(0.081 34)			(0.056 90)
Firm 2			0.002 20			0.023 72
			(0.012 41)			(0.026 24)
Firm 3			0.005 21			0.023 79
			(0.017 24)			(0.023 50)
Firm 4			-0.006 18			0.019 94
			(0.024 68)			(0.023 74)
Firm 5			-0.049 60			-0.001 57
			(0.055 43)			(0.041 27)
Firm 6			-0.041 52			0.010 69
			(0.065 13)			(0.049 92)
R^2	0.258 72	0.272 09	0.352 57	0.262 45	0.277 60	0.338 93
$\bar{R}^2$	0.220 22	0.203 23	0.228 79	0.224 13	0.209 26	0.212 54
F-Statistic	6.718 7	3.951 5	2.848 5	6.849 8	4.062 3	2.681 8
SE	0.008 83	0.008 93	0.008 78	0.008 81	0.008 90	0.008 88

Note: A = system variables; B = system variables plus network-characteristic dummy variables; C = system variables plus network-characteristic and firm-effect dummy variables; D = system variables with alternative scale variable SMSA; E = system variables with alternative scale variable SMSA plus network-characteristic dummy variables; F = system variables with alternative scale variable SMSA plus network-characteristic and firm-effect dummy variables. Values in parentheses are standard errors of the coefficients. N = 82.

[a]Significant at 0.01 level (two-tailed test).

the model in each of the alternative functional forms.

The network-coverage variable (TERM) and its alternative (SMSA) showed a negative and generally significant association with market share in each of the alternative specifications. Although the marketing-advantages hypothesis suggests that a carrier wins consideration based on the extensiveness of network coverage, the results presented here indicate that, in the presence of rate cross-subsidization, the largest carriers (measured by number of terminal or SMSA points served) do not necessarily seek to maximize overall market share in a lane.

The coefficient on the service proxy variable (ORAVG) is negative and statistically significant across alternative specifications. This result indicates that, other things being equal, the more precarious a carrier's financial condition is (the higher the average operating ratio in the previous three years), the lower is the ratio of actual to expected market share. To the extent that a carrier's financial condition is an indicator of reputation for efficient operations and for service quality, this result supports the hypothesis that service quality (in the absence of price competition) is one key to building market share.

The marketing effort proxy (SALES) possesses a positive and statistically significant coefficient in all but one of the market-share regression specifications. Again, this is the expected result.

Finally, the inclusion of dummy variables for the network characteristics and firm effects as a group added significantly to the explanatory power of the market-share regressions. However, not all the dummy variables were statistically significant. For example, although the HOMEMKT coefficient had the expected positive sign in all the specifications, it was generally not statistically significant. Accordingly, it cannot be concluded that carriers operating in a home market enjoy a competitive advantage over other carriers in winning market share.

The coefficient on the dummy variable SOUTHREG, which represents southern carriers that operate on a northern route, was negative and statistically significant in nearly all cases. This result suggests that, other things being equal, carriers that have southern-based terminal networks appear to be at a competitive disadvantage on northern routes. In contrast, the coefficient on the dummy variable NORTHREG was positive in most cases, although it was never statistically different from zero. It is thus interesting to note that, in general, northern-based carriers do not appear to be at a competitive disadvantage on southern routes.

The signs and significance of the dummy variables for the firm effects varied across specifications due to relatively high collinearity between some of the dummy variables and system-characteristics variables. Nevertheless, three of these variables contributed significantly to the explanatory power of the market-share regressions. This result invites further investigation to determine whether unidentified systematic factors are at work.

LTL Revenue Yield

Three alternative functional forms were also tested in analyzing the determinants of average carrier revenue per shipment pound in a lane. This paper presents results for the linear form [the results for double-logarithmic and semilogarithmic forms have been reported elsewhere (9)]:

$$\text{LTLREVLB} = b_0 + b_1\,\text{LTLSIZE} + b_2\,\text{TERM} + b_3\,\text{ORAVG} + b_4\,\text{SALES} + \text{dummy variables} \qquad (4)$$

where LTLREVLB is defined as carrier average revenue per shipment pound in a lane and LTLSIZE is defined as carrier average LTL shipment size in a lane. (With the exception of minimum-charge shipments, the LTL class rate structure is based on weight.) The remaining variables are as defined above. The shipment-yield regression results are shown in Table 4.

Each of the estimated equations is statistically significant. In contrast to the market-share estimates, the inclusion of the network-characteristic and firm-effect dummy variables lowered the significance of the relations, i.e., it did not contribute to explaining the variation in carrier shipment yield.

Although the estimated coefficients on the service-quality proxy (ORAVG) and marketing-effort proxy (SALES) were statistically insignificant in all cases, the coefficients of the network-coverage variable (TERM) and its alternative (SMSA) were positive and statistically significant in all but two cases. That is, carriers that had more-extensive terminal networks generally earned higher average LTL revenue per hundredweight than did carriers that served a smaller number of terminals. This result suggests that carriers that have large route networks have been more successful in winning high-rated traffic than have other carriers.

CONCLUSION

The analysis provided some interesting results. Those carriers with the largest route networks, measured either by the number of terminal points served or by SMSA points served, did not, other things being equal, possess the largest share of overall LTL revenue in the study lanes. Indeed, other factors, such as a carrier's relative financial health (a proxy for service quality) and regional identification, appeared to play a greater role in explaining market share than did network size. Nevertheless, carriers with extensive networks did earn higher average LTL revenue per shipment pound than did carriers that served a smaller number of terminals or SMSAs.

These results, although based on a limited sample of city pairs, indicate that, under the existing regulatory environment, carriers with extensive terminal networks have balanced market-share objectives against other factors such as shipment yield. Such carriers have been more successful in competing for high-rated traffic than have smaller carriers.

Through pursuit of selective marketing strategies, the largest carriers appear to have made the differential profit opportunities inherent in the LTL class rate structure work to their advantage. The results presented here thus suggest that large interregional general-freight carriers do possess marketing advantages in soliciting high-rated freight and that these advantages are important in explaining the high relative growth and profitability of such carriers.

At the same time, the results present a number of additional questions: Do carriers with extensive route networks possess marketing advantages relevant to all shippers or to only certain shippers? What service strategies would be pursued by different groups of carriers in the absence of regulation? Would selective service strategies remain viable or would all carriers pursue a generalist strategy? What role would price competition play? Finally, what impact would historical market strategies and positions have in shaping postregulation strategies and performance? These questions invite further research, especially case studies of carrier service and marketing strategies.

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Consequences of Regulatory Reform on the Owner-Operator Segment

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Since owner-operators provide approximately 25-40 percent of the intercity truck transportation in the United States, any major disruptions to this sector that result from deregulation would seriously impair motor carrier operations. As a result, informed policy decisions about deregulation must assess its impact on owner-operators. This paper presents four alternative scenarios for the owner-operator sector in a deregulated environment. Data gathered from a two-year study of owner-operators are then used to assess the likelihood of occurrence for each scenario. The four scenarios range from a prediction of cutthroat competition among owner-operators to one of relative stability and increased earnings. Due to the already depressed level of owner-operator earnings, their current high turnover rates, and their increased options that stem from deregulation, it is unlikely that the former prediction will be realized. A more likely possibility is that deregulation will benefit the owner-operators. However, their increased benefits will be in direct proportion to their bargaining power. Multiple-vehicle fleet owners will have more bargaining power in dealing with carriers, shippers, or brokers and, as a result, will benefit more from deregulation than will the single-vehicle owner.

The nation is in the midst of a thorough review of current regulatory policy toward motor carriers. Various proposals have been introduced in Congress that provide for substantial regulatory change that involves either the total motor carrier industry or selected segments of it. The truckload segment of the industry, in which owner-operators are principally involved, has received particular attention in most of the proposals. This segment of the industry focuses on the movement of commodities in full-truckload lots between shippers and receivers. This paper addresses the impact on owner-operators of a proposal to remove both entry and pricing controls from the truckload segment of the motor carrier industry.

Specifically, this paper presents four alternative scenarios for owner-operator behavior under deregulation. Next, relevant information from recent owner-operator studies is detailed, since it is the thesis of this paper that, in order to understand owner-operator behavior under deregulation, it is critical to define it under the current regulatory climate. Last, data from the owner-operator studies are directly related to each of the scenarios as a guide to making an informed judgment about which course of events is most likely to occur under deregulation.

SCENARIOS FOR OWNER-OPERATORS UNDER DEREGULATION

The impact that deregulation will have on the owner-operator sector of the motor carrier industry is a critical aspect of the policy review of motor carrier regulation, since owner-operators provide approximately 25-40 percent of the intercity truck transportation in the United States (1). Thus, any major disruptions to this sector brought about by deregulation would seriously impair the motor carrier industry. As a result, policymakers should be aware of the potential consequences of deregulation on the owner-operator sector.

This section presents four scenarios for owner-operator behavior under deregulation. In the next section, data from a recent owner-operator study are presented as a basis for making a more-informed judgment about which of the scenarios is most likely to occur under deregulation.

Scenario 1

Scenario 1 predicts that cutthroat competition will prevail among owner-operators in the aftermath of deregulation. The reasoning behind this outlook is that owner-operators tend to be unsophisticated entrepreneurs, unaware of their costs of doing business. As a result, they currently suffer from low earnings, and a high percentage of them experience business failure each year. However, there are some prevailing standards that govern the level of compensation paid by carriers regulated by the Interstate Commerce Commission (ICC) to their owner-operators under lease arrangements (usually a specified percentage of the total freight revenue charged to the shipper) that have proved to be sufficient for many owner-operators to continue in business.

Deregulation, in contrast, will exacerbate the existing plight of owner-operators by allowing them to compete directly against one another and against motor carrier firms for the shippers' business by eliminating the requirement of obtaining an operating certificate from the ICC before services are provided. Unaware of their costs of operation and no longer under a prevailing standard for their level of compensation, owner-operators will have a tendency, especially in direct negotiations with shippers, to bid down their revenue to levels that will make it impossible for them to meet expenses in the long term. The result, of course, will be a substantial acceleration in the owner-operator turnover rate and greater fluctuations in and concern about their supply.

According to the logic of this scenario, then, shippers will experience varying transportation costs, depending on availability of owner-operators, and an erratic quality of service. The owner-operator segment will suffer irreparable harm as a consequence of cutthroat competition.

Scenario 2

In this account, owner-operators will use the improved bargaining position that results from deregulation to increase their share of the total revenue received from shippers. This scenario is in direct contrast to the first one. It argues that deregulation will improve the bargaining position of owner-operators by giving them the option of dealing directly with shippers for business rather than by requiring them to operate under lease to a motor carrier that possesses the required ICC operating certificate.

However, if they use their new option to engage in competition with one another in direct negotiations with shippers, the potential exists for shippers to obtain rate concessions from the owner-operators and to decrease their freight bills. Although owner-operators who engage in such direct negotiations would not have to share their revenue with a motor carrier, they would be receiving 100 percent of a smaller total and would likely find little or no improvement in their revenue situation.

However, according to this scenario,

owner-operators will recognize such potential dangers and will find it in their best interests to continue to work through motor carriers rather than to approach shippers directly. Nevertheless, the owner-operators will use the new option that results from deregulation to demand from the carriers a greater share of the revenue than they now receive. It is anticipated that owner-operators who possess a large number of vehicles will have more bargaining power with the carrier in such situations than will owner-operators who have a single vehicle. Such differences in bargaining power should be reflected in a higher compensation for owner-operators who have more than one truck or tractor (multiple-vehicle fleets).

This scenario, unlike the first one, does not foresee that wide fluctuations in rates to shippers or an erratic quality of service will stem from deregulation. Instead, it anticipates that, although rates paid by shippers will reflect only general inflationary trends, revenue to owner-operators will increase as a consequence of their improved bargaining position.

Scenario 3

Scenario 3 projects that shippers will use the increased transport options that result from deregulation to lower their freight costs and simultaneously to augment the revenue of owner-operators. Shippers will have additional transport options as a consequence of deregulation because they will no longer be restricted to those carriers who possess ICC operating certificates.

According to this scenario, shippers will contact owner-operators directly and offer them greater compensation than they currently receive under lease arrangements with ICC-regulated carriers but not as much as shippers now pay the regulated carriers for transportation services rendered.

This scenario envisions that owner-operators and shippers will split in some fashion the portion of the total revenue that regulated carriers now receive under lease arrangements with owner-operators. The exact division of this revenue between the owner-operators and the shippers will be determined by the relative bargaining power of the respective groups. Again, as in scenario 2, it is anticipated that owner-operators who possess multiple-vehicle fleets will have greater bargaining power than will the owner-operator who has a single vehicle. Owner-operators with multiple-vehicle fleets can provide shippers with a greater portion of their total transportation requirements and assure a continuity in supply. As a consequence of these advantages, shippers may be willing to increase the compensation to owner-operators who have multiple-vehicle fleets.

The reasoning of this scenario is that shippers will be willing to pay owner-operators more than they now receive in order to guarantee stability in the supply of dependable owner-operators. In addition, their freight bill will be lower so long as increases in payments to owner-operators do not raise their total costs above the level currently paid to regulated carriers. Owner-operators will benefit from an increase in their revenues and from the stability that stems from their agreements with shippers.

Scenarios 2 and 3, then, anticipate stability under deregulation. Both scenarios envision an increase in revenues to owner-operators rather than a situation of great instability among owner-operators as predicted in scenario 1. Scenario 3, unlike scenario 2, anticipates that shippers and owner-operators will benefit from deregulation, while the regulated carriers will bear the brunt of the readjustments.

Scenario 4

Scenario 4 envisions that truck brokers, who now function primarily in arranging exempt loads for owner-operators, will assume a much greater role under deregulation. Under deregulation, truck brokers will no longer be restricted to the exempt-commodity sector because they lack the required ICC operating certificates for transporting regulated commodities; the broker will be able to contact shippers directly to arrange loads for owner-operators.

Since truck brokers in the exempt sector usually take a significantly smaller percentage of the total revenue from the owner-operator than do the regulated carriers, it is anticipated that owner-operators will be attracted to the arrangement of loads of previously regulated commodities by truck brokers so long as the brokers' charges do not rise to the level of those assessed currently by the regulated carriers. Again, the exact manner in which truck brokers and owner-operators split the percentage of revenue now deducted by regulated carriers from the owner-operators' pay will be determined by the respective bargaining power of the two groups. It is also expected that owner-operators who have multiple-vehicle fleets will have more bargaining power than will the owner-operator who has with a single vehicle.

Scenario 4 predicts stability in the aftermath of deregulation rather than the instability anticipated in scenario 1. It suggests that the major beneficiaries of deregulation will be the owner-operators (especially those who have multiple-vehicle fleets) and truck brokers. In contrast to scenario 3, it does not foresee that shippers will benefit from deregulation in the form of reduced rates.

Each scenario presented has made assumptions about owner-operator behavior under deregulation. It is the premise of this paper that such predictions would be more accurate if based on a knowledge of the actions of owner-operators in the current regulatory environment.

Fortunately, information about owner-operators has been enhanced as a result of a two-year study of their behavior conducted by researchers at the ICC. In the winter of 1978, approximately 500 owner-operators responded to questionnaires about their leasing arrangements with regulated carriers. One questionnaire concerned owner-operators under permanent leases to regulated carriers and one concerned those who were under trip leases to regulated carriers. [Under the terms of a permanent lease, owner-operators lease their equipment to a regulated carrier for at least 30 days; under the trip-lease terms, owner-operators arrange a one-way trip (only the return to their base of operations) with a regulated carrier.] One year later, ICC researchers requested the same owner-operators to respond to follow-up questionnaires that covered a wider range of subjects than the initial ones did; such issues as their revenues, costs, income, and methods of operation and equipment financing were included. The response rate to both surveys was exceptionally high. In the initial effort, the response rate from the permanent-lease sample was 88 percent and from the trip-lease sample, 74 percent. In the follow-up study, the response rate decreased by only 10 percent for each sample. These response rates were only achieved by a vigorous telephone follow-up to the initially mailed questionnaire (2,3).

In the section that follows, information from the ICC data base that is critical in making informed judgments about likely owner-operator behavior under deregulation is discussed.

EXISTING SITUATION OF OWNER-OPERATORS

Certain aspects of current owner-operator behavior, it is believed, will influence their future activities if the existing regulatory restrictions on operating certificates and rates are lifted as is contemplated in various deregulation proposals. The following areas of existing owner-operator behavior have particular relevance in assessing the prospective actions of this group: (a) the impact that owner-operators have on the level of compensation they currently receive, (b) the present level of earnings from the owner-operator business, and (c) the rate of business failures among owner-operators. Data from the ICC owner-operator studies that concern each of these three areas are presented below.

Impact That Owner-Operators Have on Their Current Level of Compensation

In order to anticipate owner-operator behavior under deregulation, it is instructive to understand the impact that owner-operators currently have on their level of compensation. The ICC studies provide relevant data on this issue for both permanent-lease and trip-lease owner-operators.

Permanent-Lease Owner-Operators

A major issue that faces owner-operators concerns control over both their work assignments and their level of compensation. The public often views owner-operators as having the freedom and flexibility that result from being their own boss. The term "last American cowboy" is symbolic of this public image. However, data from the ICC surveys are at substantial variance with this image. In the follow-up owner-operator survey, respondents under permanent lease were asked specific questions about trip leases, exempt loads, or both. The responses delineate some important limitations to their freedoms.

Owner-operators of only 59 percent of the vehicles that were under permanent lease on October 31, 1977 (the reference date for the initial ICC survey), were allowed by the regulated carrier to whom they were under permanent lease to also arrange trip leases. However, even those owner-operators who were allowed to trip-lease were not, in most instances, themselves responsible for arranging the trip. Indeed, the carrier who held the permanent lease was responsible for arranging the most-recent trip for 56 percent of the owner-operator vehicles still under permanent lease on October 31, 1978, whereas the owner-operators themselves (by personally contacting a regulated carrier) arranged the most-recent trip for only 34 percent of the vehicles.

The carrier who held the permanent lease also dominated in arranging exempt loads for the owner-operators. The survey showed that 72 percent of the owner-operator vehicles still under permanent lease in 1978 carried exempt loads. Of all the exempt loads carried, the carrier who held the permanent lease arranged the most-recent load for 62 percent of the owner-operator vehicles still under permanent lease in 1978, and truck brokers arranged the most-recent exempt load for another 12 percent. In contrast, the owner-operators themselves arranged the most-recent exempt load for only 24 percent of the vehicles. Thus, carriers who held permanent leases restricted the activities of most of their leased owner-operators either by refusing to allow them to arrange trip leases or by arranging both the trip lease and the exempt load, if permitted.

In addition, the carrier who holds the permanent lease takes, in most instances, a portion of the revenue that an owner-operator receives from both the trip lease and the exempt loads. In fact, respondents who had 88 percent of the vehicles still under permanent lease in 1978 said that the carrier who held their lease took a portion of the trip-lease revenue, whereas the corresponding figure for exempt loads was 84 percent of the vehicles. In both cases, these percentages are substantially higher than the corresponding ones in which carriers who held permanent leases arranged the trips. This indicates that, even if the lease-holding carriers do not arrange the trips, they are likely to take a portion of the owner-operator's revenue. Thus, the lease-holding carrier exerts strong control over the trip-leasing and exempt-hauling activities of the owner-operators who represent an overwhelming majority of the vehicles under permanent lease.

Traditionally, workers have sought to counterbalance such employer power through concerted activities such as the formation of unions to represent grievances to the employers and to bargain collectively with them. However, owner-operators who account for the vast majority of vehicles under permanent lease do not belong to a union. In fact, the owner-operators of 16 percent of the vehicles no longer under permanent lease on October 31, 1978, belonged to a union, while the comparable number of vehicles still under lease was 24 percent.

In addition to the issue of union membership, the survey asked respondents whether the compensation they received was directly affected by a union agreement. Again, those who owned only 13 percent of the vehicles still under lease and only 22 percent of those no longer under lease replied that union membership affected their compensation.

Trip-Lease Owner-Operators

The ICC surveys also focused on trip leases between regulated carriers and owner-operators. As noted in the previous subsection, many owner-operators under permanent lease to a regulated carrier also trip-lease. In addition, some owner-operators trip-lease with regulated carriers primarily for backhauls in association with the transportation of exempt agricultural commodities. The ICC took a sample of trip leases with regulated carriers during one particular month (October 1977) and sent a questionnaire to the owner-operators who had the trip leases. One year later, the ICC resurveyed the same owner-operators. The surveys contained data pertinent to the issue of the control exercised by the owner-operators who had trip leases over their activities and compensation.

Owner-operators in the trip-lease sample played a more important role in arranging both their trip leases and their exempt loads than did those in the base sample of those under permenent leases. In fact, owner-operators still in business on October 31, 1978, who had 59 percent of the trip leases arranged their most-recent trip lease by personally contacting a regulated carrier, and those who had 49 percent of these trip leases arranged their most-recent exempt load by personally contacting the shipper. In contrast, carriers who held permanent leases had a much smaller role in arranging trip leases and exempt loads for the owner-operators in the trip-lease sample than they had for the sample of those under permanent leases. The survey showed that the carrier arranged the most-recent trip leases for owner-operators still in business on the survey date who had only 28 percent of the leases and the most-recent exempt loads for those who had only 18 percent of the leases. Truck brokers also had a significant role in arranging exempt loads for owner-operators in the trip-lease sample. Brokers arranged trip leases for the most-recent exempt loads for owner-operators still in business who had 28 percent of the leases.

The explanation for the reduced role of carriers that hold permanent leases for owner-operators in the trip-lease sample as opposed to their role in the permenent-lease sample is that the former sample includes both owner-operators not under permanent lease and those still under permanent lease. Obviously, owner-operators in the former category (with no lease-holding carrier to arrange their loads) may contact a regulated carrier directly to arrange a load.

However, the mere fact that owner-operators arrange their trip leases, exempt hauls, or both does not necessarily imply that they exercise control over the level of their compensation. Owner-operators still in business who had 29 percent of the trip leases said they engaged in negotiations with truck brokers or shippers to determine the compensation for the exempt shipment. In contrast, those who had 49 percent of the trip leases had to accept what truck brokers or shippers offered and did not negotiate with them, and those who handled 12 percent of the leases said that trucking rate sheets with fixed levels of compensation were consulted to determine their rates. Therefore, in the trip-lease sample, owner-operator control in the form of negotiations for wages was substantially less likely to occur than control in the form of arranging the exempt load, trip lease, or both.

In the trip-lease sample, there was also very little evidence that owner-operator compensation was affected by a union agreement. No owner-operators in the trip-lease sample said that their exempt-commodity revenue was affected by a union agreement, whereas those owner-operators still in business in 1978 who had only 8 percent of the trip leases said that their trip-lease revenue was affected by a union agreement.

In short, owner-operators in the trip-lease and permanent-lease samples exercised little control over the level of their compensation for exempt loads and trip leases. The trip-lease sample, in contrast to the permanent-lease sample, however, showed that owner-operators had greater control in arranging their trips. Yet this greater control over trip arrangements was not equivalent to influence over the level of their compensation. For both samples, the option of joining unions to improve bargaining power has not yet been exercised by the majority of owner-operators.

Level of Earnings for Owner-Operators

Data that concern owner-operator earnings under the existing regulatory system are valuable in assessing their response to changes brought about by deregulation. In addition to the question of specific earnings, it is also important to know whether or not owner-operators make accurate estimates of their business costs. The answer to the latter question would give an indication of their strategy in negotiations with carriers, shippers, or both for their compensation in a deregulated environment. The ICC owner-operator surveys covered these issues for both owner-operators under permanent lease and those who trip-lease.

Owner-Operators Under Permanent Lease

In order for businesses to be successful, their managers must have accurate data about the costs of operation so that the prices charged for their product or service will cover those costs. In the follow-up owner-operator survey, respondents were asked specific questions about their cost records.

Owner-operators under permanent lease were questioned about whether they kept cost records adequate to permit them to make realistic estimates of the ability of their revenue from a particular load to cover their costs. The owner-operators under permanent lease were divided into three categories based on whether, on October 31, 1978, they were no longer under permanent lease, under permanent lease to the same carrier, or under lease to a different carrier. In all three categories, at least 83 percent of the owner-operators said they kept adequate cost records. However, the adequacy of these cost records is seriously questioned because a subsequent survey question asked whether the cost estimate included some amount for equipment replacement. In all three categories, owner-operators who had a significantly small percentage of vehicles responded affirmatively to the second question. For example, although 93 percent of the owner-operators who had vehicles still under permanent lease to the same carrier said that they kept cost records, only 61 percent of these owner-operators said that their estimates included equipment-replacement costs. Thus, there is serious doubt about the adequacy of cost estimates by owner-operators who represent a substantial portion of the vehicles under permanent lease, since they exclude equipment-replacement costs--a major expense category for owner-operators.

In view of recent attention from the media to owner-operator problems as well as the inadequacy of the cost estimates, data presented in Table 1 about owner-operator net income before taxes are not surprising. It should be noted that the net income figures given are those reported by the owner-operators themselves; hence they are not objective measures but are their perceptions of the net income situation. These perceptions are more valuable for the purposes of this study, since they form the basis for future decisions by the owner-operators. By October 31, 1978, 70 percent of those owner-operators no longer under permanent lease and 67 percent of those under permanent lease to a different carrier had earned less than $10 000 in 1977, while the comparable figure of owner-operators still under permanent lease to the same carrier was only 36 percent. Owner-operators who had a higher percentage of vehicles under lease to the same carrier earned higher levels of income than did those whose vehicles were no longer under lease or were under lease to a different carrier. It should be observed that the income figures in Table 1 are not adjusted for the number of tractors owned by the owner-operators. The basic message, however, is that the earnings of the owner-operators under permanent leases were seriously depressed in 1977.

Trip-Lease Owner-Operators

The trip-lease survey covered the same relevant issues as did the permanent-lease survey. Of the owner-operators still in business in 1978, those who had 84 percent of the trip leases said that they kept cost records adequate to make a realistic estimate of whether a particular load would cover costs of operation; of those no longer in business in 1978, those who had 97 percent of the leases said

Table 1. Distribution of permanent leases as of October 31, 1978, on basis of net income to owner-operators before taxes.

Net Income Before Taxes During 1977 ($)	No Longer Under Lease[a] (%)	Still Under Lease to Same Carrier[b] (%)	Under Lease to a Different Carrier[c] (%)
Less than 10 000	70	36	67
10 000-14 999	23	25	5
15 000-19 999	3	13	9
20 000-24 999	2	9	14
25 000-29 999	2	7	5
30 000-34 999	0	2	0
35 000-39 999	0	1	0
40 000-49 999	0	1	0
50 000 and more	0	6	0

[a] Nonresponse, 5 percent.
[b] Nonresponse, 2 percent.
[c] Nonresponse, 4 percent.

Table 2. Distribution of trip leases as of October 31, 1978, on basis of net income to owner-operators before taxes.

Net Income Before Taxes During 1977 ($)	No Longer in Business in 1978[a] (%)	Still in Business in 1978[b] (%)
Less than 10 000	87	43
10 000-14 999	10	21
15 000-19 999	3	11
20 000-24 999	0	8
25 000-29 999	0	1
30 000-34 999	0	2
35 000-39 999	0	5
40 000-49 999	0	2
50 000-59 999	0	2
60 000 and more	0	5

[a] Nonresponse, 3 percent.
[b] Nonresponse, 2 percent.

that they had kept similar records. Again, however, many owner-operators did not include a major cost item--equipment replacement--in their estimates. For example, owner-operators no longer in business in 1978 who had handled only 30 percent of the trip leases in 1977 said that they had included equipment replacements in their cost estimates, while those still in business who had handled 63 percent of the trip leases had included such estimates.

The data in Table 2 about the net income of owner-operators in the trip-lease sample are comparable to those about owner-operators in the permanent-lease sample. Owner-operators no longer in business in 1978 who had handled 87 percent of the trip leases had earned less than $10 000, while the comparable figure for those still in business was 43 percent.

Net 1977 income figures for the owner-operators in the trip-lease sample who were still in business in 1978 are less depressed than the 1977 figures for those no longer in business in 1978. Indeed, those of the owner-operators still in business who handled 64 percent of the trip leases had earned less than $15 000 in 1977.

In sum, both the permanent- and trip-lease samples gave strong indications of depressed earnings in the owner-operator sector. These low-earning patterns were coupled with incomplete cost information, which further endangered the owner-operator position.

Turnover Rate for Owner-Operators

The lack of control over operations and compensation, coupled with incomplete cost data and low earnings, results (not unsurprisingly) in high labor turnover in the owner-operator sector. By following the same owner-operators over a two-year period, the ICC studies have documented owner-operator turnover for both the permanent-lease and trip-lease samples.

On October 31, 1978, 20 percent of the owner-operators who had been under permanent lease on October 31, 1977, were no longer under a permanent lease, whereas 72 percent of the owner-operators were still under permanent lease to the same carrier. The remaining owner-operators were under permanent lease to a different carrier on October 31, 1978.

Comparable turnover rates exist for owner-operators in the trip-lease sample. On October 31, 1978, those of the owner-operators in business in October 1977 who had handled 18 percent of the trip leases were no longer in business, whereas the remainder of the trip-lease owner-operators were still in business.

The interaction of problems that face the owner-operators produces turnover rates equalling approximately one-fifth of both the permanent-lease and trip-lease samples in one year. This instability has important implications for assessing the impact of deregulation on the owner-operator sector, as will be demonstrated in the following section.

RELATIONSHIP BETWEEN OWNER-OPERATOR DATA AND DEREGULATION SCENARIOS

This analysis draws on the empirical base developed in the previous section to assess each of the four deregulation scenarios. These data will improve our knowledge about the likelihood of occurrence for each of the scenarios. Such understanding is useful in assessing the implications of alternative regulatory reform proposals.

Scenario 1

A major assumption of this scenario was that the owner-operators would engage in destructive, cutthroat competition. This was in part because they were unaware of their costs of doing business and would unknowingly offer their services for an amount of revenue below their costs. The ICC survey data revealed that, although the vast majority of owner-operators make cost estimates, these cost estimates do not include a major owner-operator expense category--equipment-replacement costs. Thus, although the overwhelming majority of owner-operators have a close approximation of their out-of-pocket costs in the short term, these estimates are insufficient for covering equipment-replacement costs, which occur at three- to five-year intervals. In a directly competitive circumstance, then, the majority of owner-operators, aware of their short-term out-of-pocket costs but unaware of their longer-term needs, might be willing to go below their long-term costs in direct negotiations with shippers.

The likelihood of below-cost pricing would be greater, of course, if the supply of owner-operators were plentiful. Scenario 1, indeed, implies that the supply of owner-operators will be sufficient that shippers will be in a position to force the owner-operators to bid against one another and to drive down their revenues. However, the ICC data about the depressed level of owner-operator earnings and high turnover rates, which encompasses approximately one-fifth of both the permanent- and trip-lease samples, have serious implications for the supply assumptions of scenario 1. In addition, the owner-operators are faced with significantly higher entry costs due to increases in the price of tractors and extremely high interest rates. Thus, evidence to support the critical supply assumptions of scenario 1 is lacking.

Scenario 1 also implies that owner-operators will bid against one another in direct negotiations with shippers. However, the ICC data indicated that, except for exempt shippers, owner-operators have had little experience in direct negotiations with shippers. Even in dealing with exempt shippers, owner-operators were more likely to rely on the carrier who held their permanent lease (if they were under permanent lease) or a truck broker than to approach the shipper directly. Thus, past experience does not support the notion that, under deregulation, owner-operators will shift their current patterns for arranging trips and will deal directly with shippers.

In conclusion, the fact that owner-operators make incomplete cost estimates does provide the potential for cutthroat competition. However, due to depressed earnings and high turnover rates in the owner-operator sector, there is little likelihood that there will be a supply of owner-operators adequate for such a situation to develop. Finally, although the scenario suggests a major shift in owner-operator behavior from dealing primarily with carriers to dealing directly with shippers, there is no evidence to support the likelihood of such a shift.

Scenario 2

Scenario 2 implies that, under deregulation, owner-operators would continue to deal with carriers rather than approach shippers directly. Certainly, the ICC survey data support the contention that owner-operators are currently dependent on carriers to arrange their loads under permanent lease, under trip lease, and even for exempt trips. This pattern of close association between owner-operators and carriers is therefore well established.

However, scenario 2 suggests that, under deregulation, owner-operators will be able to approach the carriers from a position of strength (due to the option of direct carriage provided by deregulation) rather than from a position of weakness (due to the need to rely on the carriers who possess proper operating certificates). Scenario 2 states that owner-operators will be able to convert this improved bargaining position into financial gains. Obviously, the extent of these gains depends in part on the ability of owner-operators to organize effectively and to control supply. Nevertheless, the ICC survey data that indicated only approximately 20 percent of the permanent-lease sample had union membership cast serious doubt on the organizing ability of owner-operators. However, without some significant improvement in the bargaining strength of owner-operators, the likelihood is diminished that conditions described in scenario 2 will occur.

Yet the prospects for the occurrence of scenario 2 improve if the situation of owner-operators with multiple-vehicle fleets is considered. It can be argued that owner-operators who control vehicle fleets rather than a single vehicle would be in a better bargaining position than the single-vehicle owner in a deregulated environment. The ICC survey data provide some evidence that the multiple-vehicle fleet owners, indeed, have greater bargaining power under the present regulatory system than do the single-vehicle operators. In response to the question that concerns the method by which their rates for exempt loads were determined, owner-operators who owned between 6 and 10 vehicles and handled 63 percent of the trip leases and those who owned between 11 and 20 vehicles and handled 50 percent of the trip leases negotiated with either a broker or a shipper the rate they were to receive for hauling the exempt load. The comparable figures among the single-vehicle fleet owners and those who owned between 2 and 5 vehicles are only 18 and 20 percent, respectively.

These results indicate that the multiple-vehicle fleet owners currently have better control over their financial position than do the single-vehicle owners. It is anticipated under this scenario that the multiple-vehicle fleet owners would be in a better position to translate their increased bargaining power (which results from the option of direct carriage combined with the control of supply) into higher financial rewards. Thus, the likelihood of scenario 2 seems particularly appropriate for multiple-vehicle fleet owners.

Scenario 3

Unlike scenario 1, scenarios 2 and 3 assume increased bargaining power for owner-operators that results from the option of direct carriage, the existing depressed levels of owner-operator earnings, high turnover rates, and some control over supply (especially among the multiple-vehicle owners).

Under the conditions of scenario 2, carriers cognizant of the improved situation for owner-operators would be willing to increase the owner-operator's share of the revenue. In contrast, scenario 3 envisions that the shippers, bypassing the carriers, will actively seek owner-operators (who would no longer be required to lease to regulated carriers) directly. The incentives for shippers to act in this manner are real. Currently, regulated carriers take from 25 to 30 percent of the total freight revenue and give the rest to the owner-operators. Shippers who believe that they could secure owner-operators directly at less than 25-30 percent of their current freight revenue would pursue this course of action.

It should be recognized that if the shippers were able to secure owner-operators with a savings that equaled or exceeded the 25 percent share now taken by the carriers, scenario 3 would be equivalent to the cutthroat competitive conditions of scenario 1, since in both instances owner-operator revenues would be driven below costs. However, scenario 3 argues that shippers and owner-operators will split the percentage of the revenue now taken by the regulated carrier. The exact nature of that split would be a function of the bargaining power of the owner-operators--with the multiple-vehicle fleet owners in a better bargaining position than the single-vehicle owner.

This scenario assumes that shippers will devote substantial efforts in dealing with owner-operators directly. It assumes also that owner-operators will be willing to deal directly with shippers, although there is no past experience on which to base such an assumption.

Scenario 4

Scenario 4 is really an offshoot of scenarios 2 and 3. It foresees that the role of truck brokers in the exempt sector will expand as a consequence of deregulation. The incentives for owner-operators to rely on truck brokers to arrange their loads would be great, since the brokers generally take from 8 to 10 percent of the revenue in contrast to the 25-30 percent taken by regulated carriers. It should be emphasized, however, that there are differences in the level of services provided by the brokers and the carriers. Whether the additional services provided by the carriers account for the percentage of difference in fees is a subject of great controversy.

There would also be incentives for shippers to use the services of truck brokers if some of the reductions in commission percentages were passed on to them in the form of reduced rates. The shippers might also find that the services of truck brokers are less expensive than the costs of locating and dealing directly with owner-operators themselves.

CONCLUSIONS

This paper has presented four scenarios describing the impacts of deregulation on owner-operators in the truckload segment of the motor carrier industry. Some final remarks about the likelihood of each scenario, based on data from the ICC surveys, are appropriate.

Scenario 1 conditions are unlikely to develop due to the already depressed level of owner-operator earnings, the current high turnover rates among owner-operators, and their increased options that result from deregulation. Shippers recognize that scenario 1 conditions would endanger the transportation system and consequently would refrain from pursuing it.

There can be no question that owner-operator as well as shipper options will increase as a result of deregulation and the removal of operating-certificate restrictions. Under deregulation, carriers will no longer be able to take a share of the freight revenue that is not justified by the cost of services provided. If they attempt to do so, owner-operators will refuse to drive for them and select instead either the option of approaching the shipper directly or approaching a truck broker. Shippers as well will refuse to pay carrier freight revenues that reflect compensation to the carriers not justified by the cost of service.

The current depressed state of the owner-operator segment and the high turnover rates should be improved due to the increased options made available to the owner-operators as a result of deregulation. Improvement in the situation will vary among individual owner-operators in direct proportion to their bargaining power. It is believed that the multiple-vehicle fleet owners who have some control over supply will have more bargaining power in dealing with shippers, carriers, or brokers than will the single-vehicle owner. It is believed that the power of the multiple-vehicle fleet owner, although improved, will nevertheless be checked by the threat of new entrants, even though the costs of entry (especially for the single-vehicle owner) have increased substantially due to inflation and higher interest costs.

In sum, the consideration of the impact of deregulation on the owner-operator segment is a critical component of the current policy debate. Decisions should not be made without a definite familiarity with the existing conditions of owner-operators.

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Transportation System Management Options for Downtown Curbside Pickup and Delivery of Freight

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In downtown areas, freight is picked up and delivered primarily at curbside, either on main streets or on minor cross streets and in alleys. Where excessive demands for freight exist on main arteries, surface traffic problems can become severe. This paper presents operational strategies that address this situation: curb-space management, signal-timing adjustments, signing of curb use and enforcement, restriping of arterial, temporal control of curb lane, relocation of bus stops, control of turns, and land-use control. The tools for evaluation were developed in previous research and are only summarized here. The paper concludes by ranking strategies for effectiveness based on the severity of the traffic problems caused by pickups and deliveries on the arterial.

In downtown areas, freight is picked up and delivered primarily at curbside, either on main streets or on minor cross streets and in alleys. Due to the nature of the principal demand variables for downtown urban freight (primarily consumable products), the freight generators usually front on the main pedestrian arteries (which usually are also the main vehicle arteries). In the downtown areas in which alleys parallel these main arteries, the problems created by conflicts between freight traffic and pedestrian traffic can be minimized. However, when there are no spatial alternatives to solve a goods-movement problem, other measures become necessary.

In this paper I present and evaluate selected low-cost operational (transportation system management, or TSM) strategies directed toward improving traffic conditions while recognizing the need to deliver freight with little or no disruption in service. To date, traffic engineering measures for goods movement have met with limited success (in my opinion) mainly because of an underestimation of the pressure that carriers face to serve their customers efficiently. This paper is based on a project that developed techniques for predicting freight demand, for predicting when pickup-and-delivery (PUD) vehicles would double-park or park in a curbside moving lane, and for determining the impact of lane blockages on arterial level of service. The project used these background capabilities to develop and evaluate TSM strategies for downtown arterial streets, and the results of the efforts of that phase are summarized in this paper.

BASIC TOOLS FOR STRATEGY EVALUATION

In an effort to be brief, this presentation may mislead the reader on the depth of the analysis done to develop the necessary tools for the strategy evaluation. These tools, which are not presented in detail, are

1. Estimation of demand for curbside PUD trips,
2. Determination of how the vehicles will park, and
3. Determination of the impact of a lane blockage on arterial level of service.

Tables 1 and 2 summarize, respectively, the weekly and daily generation equations and hourly arrival patterns of curbside PUD vehicles for various land uses. Figure 1 shows the probability of double-parking as a function of percentage of the blockface devoted to truck space (loading zones, hydrant zones, bus stops, driveways). In addition, the research determined that, under random normal enforcement, 20-25 percent of PUD vehicles that arrive at a blockface will stop in a designated curbside moving lane. Figure 2 was developed to show the relationship between number of double-parkers (or blockages of curbside moving lane), street traffic volume, and expected resultant arterial level of service. Figure 2 gives data for one-way streets (left) and two-way streets (right). With the basic information presented above (plus more not deemed necessary to include here), various strategies will be outlined and analyzed for effectiveness in subsequent sections of this paper.

TSM STRATEGIES FOR IMPROVING ARTERIAL FLOW

First, it is necessary to define the objective of the analysis. For this type of analysis it appears that a specified level of service would be that objective. The recognition that curbside goods movement is a problem related to traffic flow occurs when the state of the traffic on a street approaches or is at that street's capacity. An arterial with freely flowing traffic does not appear (to the traffic engineer) to represent a problem, even though there is some speed reduction due to lane blockages. Therefore, the strategy objectives would be to obtain (a) an upper-limit service level C (C-D boundary) or (b) an upper-limit service level D (D-E boundary) on the arterial (see Figure 2). It is evident that different cities have different objectives in traffic control management; many cities view the D-E border as unsatisfactory, whereas others consider it a realistic level of downtown congestion. Therefore, both the C-D and D-E boundaries will be used as strategy objectives when appropriate, and the option will be available to the traffic engineer or planner to use one or the other as determined by local policy. The strategies addressed include curb-space management, signing of curb use and enforcement of it, signal-timing adjustments, temporal control of the curb lane, demand-reduction methods, and other traffic engineering techniques. These strategies will be applied to specific blocks where goods-movement problems have been determined to exist. It should again be stated that goods-movement problems, though in some cases severe, are isolated, and solutions to these problems should take this into account.

Curb-Space Management

The basic question to be addressed is, for a given traffic-volume level, how much curb space should be allocated as available for PUD use (or rather not available for usual automobile parking). It should be noted that PUD vehicles will look for bus stops, hydrant zones, driveways, or any other available space to load or unload freight, and therefore the existence of such space generally does act as loading-zone space. For a given PUD demand and a given traffic-volume level, curb space would be needed in amounts necessary to reduce conflicts. The data used in this analysis are from Figures 1 and 2. These relate to the estimated percentage of double-parkers for various amounts of allocated PUD curb space and the effects of these double-parkers on level of service of one-way and two-way arterial streets. Tables 3 and 4 show the results.

The procedure followed in the development of Tables 3 and 4 is to

1. Find the maximum number of double-parked PUD vehicles that can be tolerated for a specific traffic volume and level of service,
2. Find the estimated number of vehicles that will double-park for various demands and curb-space allocations, and
3. Select the curb space needed that reduces the number of double-parkers to the tolerable level.

Tables 3 and 4 show that there are traffic-volume levels below which there need not be any designated PUD curb space to obtain a desired level of service--650 vehicles/h of green/lane for level C and 950 vehicles/h of green/lane for level D. These tables also show that one-way streets generally require more total curb space than do two-way streets; this is primarily because of the different blockage patterns. The tables further identify the no-solution (NS) conditions, where all space is allocated and the desired level of service is still not

Table 1. PUD demand equations.

Land Use	Equations for Weekly Generation	Equations for Daily Generation	R^2	N
Office	WG = (0.80 x FA) + 2.0	DG = (0.16 x FA) + 0.4	0.93	48
Residential	WG = (0.15 x DU) + 2.27	DG = (0.032 x DU) + 0.45	0.94	87
Hotels	WG = (0.30 x RU) - 12.0	DG = (0.06 x RU) - 2.4	0.96	11
Retail and prepared foods	WG = (1.65 x FA) + (1.21 x E) + 5.2	DG = (0.33 x FA) + (0.242 x E) + 1.04	0.25	44
Light industry and warehousing	WG = (1.28 x FA) + (0.31 x E) + 11.96	DG = (0.26 x FA) + (0.06 x E) + 2.4	0.64	31
Retail and service	WG = (0.30 x E) + 8.2	DG = (0.06 x E) + 1.6	0.74	219

Note: WG = weekly generation; DG = mean daily generation; E = employment; FA = floor area (m^2 000s); DU = dwelling unit; RU = rental unit.

Table 2. Hourly PUD arrival distribution, by percentages.

Time	Land Use: Office	Residential and Hotel	Food	Industry and Warehousing	Retail and Service
6:00-7:00 a.m.	0.1	0.4	2.9	0.2	1.0
7:00-8:00 a.m.	1.4	8.0	7.3	2.4	2.8
8:00-9:00 a.m.	9.6	12.2	11.8	14.0	7.7
9:00-10:00 a.m.	14.4	18.7	19.4	15.4	16.5
10:00-11:00 a.m.	16.6	16.5	19.7	18.1	18.1
11:00 a.m.-12:00 noon	13.4	13.4	15.3	12.4	14.6
12:00-1:00 p.m.	11.0	8.7	7.6	8.6	11.0
1:00-2:00 p.m.	11.4	9.2	7.5	10.8	10.6
2:00-3:00 p.m.	11.9	7.0	4.3	10.0	10.4
3:00-4:00 p.m.	9.9	5.9	4.2	7.4	7.1
4:00-5:00 p.m.	0.3	—	—	0.5	0.2

Figure 1. Probability of double-parking by PUD vehicles.

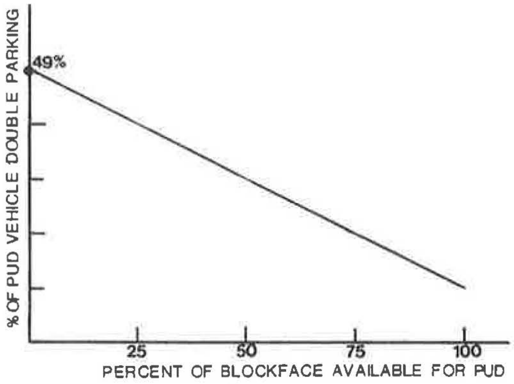

Figure 2. Relationship among number of double-parkers, street traffic volume, and expected arterial level of service.

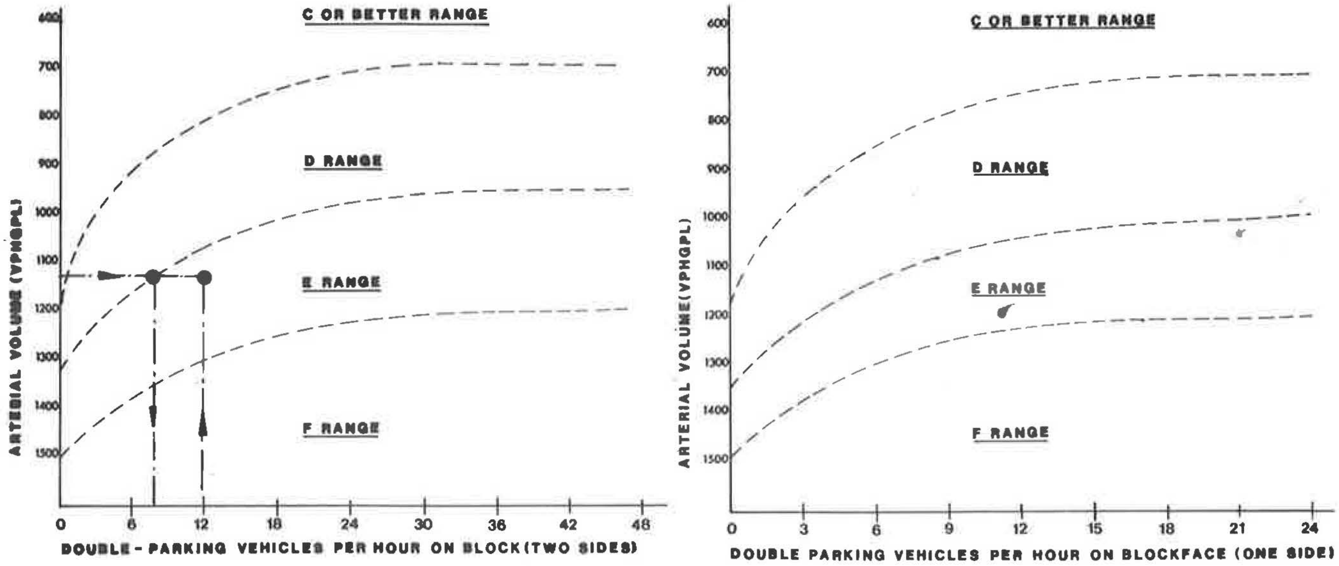

Table 3. Percentage of curb space needed on both sides of a one-way arterial.

Traffic Volume (vehicles/h of green/lane)	Level of Service	PUD Demand (vehicles/h) per Block[a]						
		10	20	30	40	50	60	70
700	C[b]	0	0	0	0	0	10	20
	D[b]	0	0	0	0	0	0	0
800	C	0	0	40	60	70	80	90
	D	0	0	0	0	0	0	0
900	C	0	60	80	90	100	100	NS
	D	0	0	0	0	0	0	0
1000	C	70	100	NS	NS	NS	NS	NS
	D	0	0	0	20	40	60	70
1100	C	100	NS	NS	NS	NS	NS	NS
	D	0	30	60	80	90	100	100
1200	C	NS	NS	NS	NS	NS	NS	NS
	D	50	80	100	NS	NS	NS	NS
1300	C	NS	NS	NS	NS	NS	NS	NS
	D	NS	NS	NS	NS	NS	NS	NS

Note: NS = no solution for conditions.

[a] Both sides of street. [b] Represents the upper limit of each level of service.

Table 4. Percentage of curb space needed on one side of a two-way arterial.

Traffic Volume (vehicles/h of green/lane)	Level of Service	PUD Demand (vehicles/h) per Block[a]						
		5	10	15	20	25	30	35
700	C[b]	0	0	0	0	0	10	30
	D[b]	0	0	0	0	0	0	0
800	C	0	0	20	40	60	70	80
	D	0	0	0	0	0	0	0
900	C	0	30	60	80	90	100	100
	D	0	0	0	0	0	0	0
1000	C	0	60	80	90	100	100	NS
	D	0	0	0	0	0	10	20
1100	C	70	100	NS	NS	NS	NS	NS
	D	0	0	10	30	50	60	70
1200	C	NS	NS	NS	NS	NS	NS	NS
	D	0	30	60	80	90	100	100
1300	C	NS	NS	NS	NS	NS	NS	NS
	D	70	100	NS	NS	NS	NS	NS

Note: NS = no solution for conditions.

[a] One side of street. [b] Represents the upper limit of each level of service.

obtained. Under such no-solution scenarios, additional strategies must be considered.

Example

The field conditions are as follows. The estimated PUD traffic to the block from 9:00 to 10:00 a.m. is 30 vehicles; the street is a one-way arterial that has three through lanes plus parking; the traffic volume is 1850 vehicles/h; arterial G/C = 0.55 (where G = green time and C = cycle time); there is 10 percent available PUD space on one side of the street; there is 30 percent available PUD space on the other side (due to a far-side bus stop); and the block length is 135 m.

To determine the present level of service and find the curb-space PUD needs necessary to achieve service-level-D operation on the arterial during that period, take the following steps:

1. Calculation of traffic volume in vehicles per hour of green per lane gives the following: (1850/3) x (1/0.55) = 1121 vehicles/h of green/lane.
2. By assuming an even distribution of PUD demand on both sides of the street, the estimated number of PUD double-parkers during the hour from Figure 2 is 12. Also, from Figure 2 it is seen that for 12 double-parkers/h and 1121 vehicles/h of green/lane, the one-way arterial operates in the service-level-E range.
3. The review of Figure 2 indicates that only a modest improvement is needed from 12 to 8 double-parkers to reach the service-level-D border. Table 3 shows that, for 30 PUD vehicles/h and 1121 vehicles/h of green/lane, the objective can be reached by providing 60 percent of curb space on both sides of the street for PUD use. Thus, to achieve this modest reduction in double-parkers, a sizeable amount of curb space is required.
4. The allocation of this space should be done on the basis of demand, in which the downstream ends of the block take the highest priority, the upstream ends take second priority, and the midblock section takes the lowest priority for allocation of space. In providing curb space for goods movement, ensuring that a lane blockage does not occur on the downstream approach to the intersection is of critical importance. Therefore space should be allocated there first for maximum effectiveness (1).

The example shown considers that there is about equal PUD demand on both sides of the street. If the PUD demand on one side is significantly higher than it is on the other side (more than 70 percent to 30 percent), the blockage pattern becomes similar to that of a two-way street and Table 4 would be more appropriate for analysis. In addition, the minimum-size curb-space allocation for PUD should be 14.5 m, except at corners, at which the minimum allocation acceptable would be 10 m.

The implementation of this curb-management strategy requires the acquisition of hourly PUD demand data either by using field observers or by using the generation equations and hourly arrival patterns developed with this report. In addition, traffic volumes and signal splits should be known, as well as the use of existing curb space (whether or not it is available for PUD use).

Signing of Curb Use and Enforcement

The conventional method of rationing curb space for PUD use is to designate that space as a truck loading zone by means of the appropriate signing. In New York City, the sign would read NO STANDING EXCEPT TRUCKS LOADING AND UNLOADING. Most cities would have similar signing, whereas some other cities would allocate the curb space just as a loading zone (and not differentiate passengers from freight). The objective of such signing is to provide curb space for the exclusive use of loading or unloading and to allow no parking for any other vehicles and no standing for any nonloading vehicles. There are two main problems with this type of signing that contribute to arterial conflicts, especially in off-peak traffic periods. First, the percentage of trucks in the total vehicle population is rising and is expected to continue to rise into the short-term future. The identification of a truck (except large ones) as a PUD vehicle is not obvious to a parking-enforcement agent, and non-PUD parking in the designated space will continue to occur. Second, when a PUD vehicle stops in a truck loading zone or any other parking space not "pressurized" by a parking meter or other such device, the total dwell time of the stop increases greatly (1). This increase is attributable only to the type of parking. Therefore, since there is increased time of occupancy, the loading zone is less effective.

An objective of curb-space management and control is to minimize the occupancy time of the designated users and eliminate (if possible) the nondesignated users. Elimination of all designated truck loading zones at a problem location appears to be a strategy capable of achieving the desired objective. Those areas intended for PUD use would be signed and controlled (enforced) as no-parking zones. PUD vehicles that are loading or unloading freight would be considered as standing (and therefore legally stopped), whereas all other vehicles would obviously be illegally stopped and subject to a summons. The table below summarizes the research findings with respect to PUD dwell time (1). The introduction of pressurized parking could reduce the mean dwell time in loading zones by about 30 percent and also reduce the non-PUD parking in those spaces. The combination of these improvements would directly result in less PUD double-parking. (The legally curb-parked mode includes truck loading zones.)

Parking Mode	Mean Dwell Time (min)	Sample Size
Double-parked in moving lane	11.5	1398
Curb-parked legally	19.5	5046
Curb-parked illegally	13.8	1697

The proposed strategy would only be implemented in the highest-density areas, and conventional loading-zone signing would remain in other areas. This dual system of signing areas as intended no-parking zones or as designated loading zones has two advantages. First, drivers of PUD vehicles would be able to recognize the existence of the designated spaces (signed LOADING ZONE) and therefore be less likely to use the no-parking zones. The second advantage is that, when drivers need time for personal reasons (coffee break, lunch, telephoning the terminal, etc.), the likelihood that they will take this time at a no-parking zone would be less than it would in a loading zone.

The major disadvantage of the no-parking-zone concept is the fact that all PUD vehicles could be ticketed if the driver is not with or close to the vehicle. However, it is the mere existence of such an enforcement option (even though it may rarely be exercised) that produces the expected operational benefits. The reduction in non-PUD truck parking would also be a positive benefit of the enforcement option.

A loading zone signed with no-parking signs would have at least 30 percent more capacity than a conventionally signed truck loading zone. For the example used in the curb-management section, it was determined that 60 percent PUD-available space was necessary to meet the level-of-service objective, a large increase over the existing 20 percent total. If the new 40 percent loading-zone space were to be signed with no-parking signs, only about 30 percent (40 percent divided by 1.3) would actually be necessary to achieve the desired objective.

The implementation of such a strategy should have the highest priority on main streets in the central business district (CBD) and on blockfaces where existing loading-zone space is fully used. The second priority would be in the CBD on cross streets where loading zones exist at the corners of a major arterial. The third priority would be on cross streets in the CBD where the curb space is designated for use by queued vehicles at loading docks. In all cases, the existence of conventionally signed, designated loading zones must be maintained in noncritical areas.

Signal-Timing Adjustments

The friction because of traffic problems caused by PUD vehicles and pedestrian traffic on a block reduces the intersection service volumes. For many arterials, there is a constant G/C, and for several intersections neither cross-street volume nor pedestrian needs can support this uniformity. The opportunity may therefore exist to increase arterial G/C in order to increase the service volume of a congested block or blocks to the level of upstream and downstream blocks.

The target of this strategy would be to determine the required arterial green per cycle in order to achieve a desired level of service on a problem segment. This level of service should logically be the same as that on the upstream blocks. The material developed in this research has consistently defined volume in vehicles per hour of green per lane. Therefore, the identification of a service volume at various levels of service can readily be translated into a G/C required if the actual traffic volume is known.

Table 5 was prepared to show the traffic volume at upper service levels C and D for various totals of PUD curbside generation and the percentage of available curb space for PUD vehicles. The traffic engineer or planner can therefore use this table to find the necessary amount of arterial green phase necessary to accommodate the actual traffic volume on the street at the desired level of service.

Example

For the same base conditions presented in the curb-management example, the traffic engineer wishes to provide service-level-D operation through signalization. The previous analysis concluded that 1121 vehicles/h of green/lane operated at service level E. The average amount of the block available for PUD use is 20 percent (average of 10 and 30 percent).

Table 5 shows that, for a demand of 30 PUD vehicles/h and 25 percent available PUD space, the service volume at service level D is 1025 vehicles/h of green/lane. Therefore, for an actual volume of 1850 vehicles/h on three through lanes (i.e., 617 vehicles/h of green/lane), the major-street green per cycle should be raised from 0.55 to 0.60 (617 ÷ 1025). In terms of solution scale, this G/C increase would be more attractive than an elaborate curb-space management plan.

There are various combinations of curb-management, signing, and signal adjustments that can produce the desired operating level of service. In order to implement such a signal strategy, it is necessary to inventory (or calculate) PUD hourly demand, count main-street traffic, and determine what curb space is already available for PUD use. These basic inputs will allow the determination of a target service volume from which the required split can be calculated. For computer-traffic-controlled signal systems, programming signal splits for specific periods of the day is facilitated.

Temporal Control of Curb Lane

The need to provide additional lanes to ease peak-period traffic flow is apparent in most downtown areas. The need to provide curbside express bus lanes (or contraflow lanes) is also present in many larger cities (generally those that also have goods-movement problems). In those cities where alleys parallel the main arterials, provision of the curb lane for non-PUD operations is greatly facilitated. In cities where no alternate PUD stopping space exists, the effectiveness of such a curb-lane strategy would be reduced, since all that is needed to disrupt flow is a single blockage per three-block segment. The research on this project also showed a marked variation among cities in terms of compliance

Table 5. Traffic volume (vehicles per hour of green per lane) at service levels C and D on one- and two-way arterials.

PUD Demand (vehicles/h)	Level of Service	PUD Space Available[a]				
		0	25%	50%	75%	100%
One-Way Arterials						
10	C^b	900	925	1000	1050	1125
	D^b	1125	1150	1175	1225	1275
20	C	850	875	900	950	1075
	D	1075	1075	1100	1150	1225
30	C	775	800	850	900	1025
	D	1000	1025	1050	1100	1200
40	C	750	775	800	850	975
	D	975	1000	1025	1075	1175
50	C	725	750	775	825	950
	D	975	1000	1000	1050	1150
60	C	700	750	775	800	925
	D	950	975	1000	1025	1125
70	C	700	725	750	775	900
	D	925	950	975	1025	1100
Two-Way Arterials						
5	C^b	975	1025	1075	1125	1175
	D^b	1250	1275	1300	1325	1350
10	C	850	925	950	1025	1125
	D	1150	1200	1225	1275	1325
15	C	800	825	875	975	1075
	D	1100	1125	1175	1225	1300
20	C	750	775	825	925	1025
	D	1050	1075	1125	1200	1275
30	C	700	725	775	850	975
	D	1000	1050	1075	1125	1250

[a] Averages for both sides or one side of the street, depending on whether street is one-way or two-way arterial, respectively.

[b] Represents upper limit of each level of service.

with a no-stopping curb-lane control.

The research has developed general guidelines for implementing a strategy for temporal displacement of the curb lane based on providing the carrier with the option of compliance without rendering the PUD process inefficient. These guidelines apply to cases in which no alley is available.

1. Since traffic does not generally peak in both directions at the same time, PUD operations in the nonpeak traffic direction should be encouraged through the provision of loading zones. This would apply to alternate parallel one-way arterials or to alternate-direction two-way arterials. It should be noted that PUD activity is negligible after 3:00 p.m. and therefore the morning peak period is the one to which the solution should be structured.
2. In addition, for blockfaces that normally generate 5-10 PUD operations/h, 15 m of available curb loading space should be provided at the corners of each cross street. Normal enforcement of parking regulations would suffice.
3. For blockfaces that normally generate more than 10 PUD operations/h during the strategy period, all above space requirements should be implemented, plus heavy enforcement (5-min coverage).
4. For an arterial segment that has more than 20 PUD operations/h on one or more blockfaces, the effectiveness of the strategy would be such that it should generally not be considered for implementation.

PUD Demand-Reduction Methods

The total number of possible conflicts between PUD traffic and pedestrians can also be reduced. This would be either by reducing the amount of curbside PUD operations in a problem period or by reducing the traffic volume in that period. The method generally available for PUD demand reduction is land-use control.

Land-use control is generally a long-term solution. On problem blocks, land use would be promoted that generated lower amounts of PUD trips, provided off-street loading for these trips, or both. For instance, the zoning of a warehousing section to permit loft residential dwelling would drastically reduce PUD demand on that block over time. Conversely, the zoning of that warehousing block to retail or commercial uses would increase PUD demand. An office building reconstructed to provide off-street loading facilities should also reduce curbside demand. The traffic planner should review zoning changes on principal arteries to evaluate their effect on PUD generation and curbside operations.

Short-term land-use control for PUD should concentrate on removing food establishments (retail and prepared) from principal arteries that have PUD-related congestion. The PUD arrival patterns and demand rates associated with this land use put it in direct conflict with the morning peak traffic period. It would be a land-use objective to not allow retail food establishments (supermarkets and drugstores) on principal arterials unless they are accessible from the rear. It would also be a land-use objective to restrict prepared-foods establishments on congested blocks unless access is available from a side street.

If the traffic planner can determine the expected reduction in PUD demand over time (during problem periods), the basic tables and figures presented in this paper will allow estimation of level-of-service changes.

Other Traffic Engineering Strategies

Three traffic engineering strategies are presented in this section: reduce arterial traffic, provide wider parking lanes, and relocate bus stops. Each is presented with a short description and a brief effectiveness evaluation.

Reduce Arterial Traffic

One option to reduce traffic-pedestrian conflicts on arterials is to reduce the number of vehicles without changing the goods-flow process. This can be done by diverting vehicles to parallel arterials by controlling turns in critical periods. That is, vehicles would be allowed to turn off but not onto the arterial in a problem segment. This technique, it is estimated, could reduce volume by 10-15 percent throughout the problem area. Figure 2 shows that such a reduction in volume can translate into real changes in level of service on the arterial. This traffic-reduction measure can be implemented independent of all strategies and therefore compound benefits. In the example being used throughout this paper, in order to achieve service-level-D operation, control of turns to reduce traffic from 1850 vehicles/h to 1780 vehicles/h (4 percent reduction) would be required. The traffic engineer would determine the method of achieving this reduction.

Provide Wider Parking Lanes

The lane striping on arterials could be used to diffuse traffic-pedestrian conflicts by increasing the size of one or both curb lanes to accommodate both the parked automobile and the double-parked PUD vehicle. Due to the fact that fewer than 1 in 20 PUD vehicles are tractor-trailers in the CBD, a 5-m curb lane can accommodate an automobile and an efficiently double-parked PUD vehicle. The increase in curb-lane width would be 2 m. It would be very rare to find an arterial wide enough so that 4 m (enough for two double-parking curb lanes) could be subtracted from the width of the through lanes without reducing the number of these lanes. However, it does appear feasible to provide the wider curb lane on one side of the arterial, the side that generates most of the PUD demand. For a two-way arterial, it would be the side that peaks in the morning. The following example shows the effectiveness of such a double-parking curb lane on one side of an arterial:

Suppose that there is an 18-m-wide one-way arterial with three through lanes and two parking lanes and each lane is 3.60 m. PUD demand in 1 h is 30 vehicles to both blockfaces, split 60-40 percent (18 on one side and 12 on the other), 20 percent of both blockfaces is available for PUD operations, and the volume is 1121 vehicles/h of green/lane. The problem is to find the existing level of service and resultant level of service of a double-parking lane.

Since this example is the same as that being used throughout this paper, the existing arterial operates at service level E. The proposed restriping plan would call for a 5-m double-parking curb lane, three 3.35-m travel lanes, and a 3.25-m parking lane. The 5-m lane would logically be placed on the side of the street with the 18-PUD/h demand. Therefore, the problem would now be reduced to having 12 PUD vehicles operate on one side of an arterial and no blockages on the other side (blockage pattern of a two-way arterial). Figure 2 shows that for a volume of 1121 vehicles/h of green/lane and five double-parkers per hour (12 PUD x 0.41; see Figure 1) the arterial would operate at service level D. Further, Table 4 shows that for a two-way arterial generating 12 PUD/h and at 1121 vehicles/h of green/lane, no curb space is needed to achieve service level D. Therefore, if that level of service is the strategy objective and if the 20 percent available PUD space is really a dedicated truck loading zone, as a part of implementing this strategy that dedicated space could be turned over to curbside automobile parking.

The implementation of such a double-parking lane strategy would produce more-effective results if the PUD demand is consistently biased toward one side of the arterial and would be rendered ineffective with radical shifting of PUD demand from one side to the other over the problem arterial segment. Therefore, a careful inventory of PUD demand should be a prerequisite to considering this strategy.

Relocate Bus Stops

Bus stops are generally placed every three or four blocks on an arterial. The placement of these bus stops is usually on the far side of an intersection, since this results in shorter lengths of required curb space. The use of bus stops for PUD operations is an ongoing process in downtown areas today. Therefore, the question becomes whether a bus-stop location can be coordinated with PUD curb-space needs. Research (1,2) has clearly shown that elimination of the downstream approach-lane double-parker would provide markedly higher benefits than reducing double-parking elsewhere on the blockface. Therefore the ideal placement for a bus stop from the PUD perspective would be at the near side of an intersection.

It can be argued that planning bus-stop space for PUD use is not good practice. However, because this bus-stop space is now being used in some areas and because the value of such space lessens in off-peak periods (when PUD operations peak), then in order to make better transportation use of existing facilities, near-side bus stops must be considered on arterials when PUD problems arise. In order to lessen the interference with right-turning traffic, near-side bus stops should be coordinated with the one-way pattern (if it exists) of the cross streets.

The quantitative effect of near-side versus far-side bus stops cannot be determined here because of the many non-PUD dependent variables, which include enforcement of bus-stop parking regulations, difference in bus drivers' habits in stopping at curbside (which may cause traffic interference), frequency of bus service, as well as the PUD variables such as demand and other available curb space. It is evident, however, that near-side bus stops will lower the probability of the PUD blockages that most adversely affect traffic operations, and therefore implementation of such a strategy would be beneficial to improving speed and level of service.

RANKING OF TSM STRATEGIES

It is clear that the specific problem situation in the field will dictate the most-effective strategy. The basic information provided in this paper allows the traffic engineer or planner to evaluate alternative options for improvement. The strategies presented in this paper are all of very low capital intensity, and the selection of a strategy would not generally be influenced by cost.

The research has pointed out that strategies that tolerate normal PUD characteristics are more effective than those that try to alter these characteristics. In the curb-management example, it was shown that excessive spatial requirements were necessary to achieve the level-of-service objective, whereas subsequent strategies achieved the objective in a more-efficient way. The following is a general ranking of strategies. The ranking is based on the expected effectiveness of the strategy under normal downtown conditions. However, field conditions should dictate to the traffic engineer which strategy is most effective. The ranking is segregated by severity of the problem; however, combinations of the various strategies are highly recommended.

Moderate PUD Problems	Severe PUD Problems
Change signal timing	Provide double-parking lane
Provide no-parking signing	Control turns
Provide double-parking lane	Manage curb space
Control turns	Provide no-parking signing
Relocate bus stops	Relocate bus stops
Manage curb space	Change signal timing

The development and evaluation of strategies by local planners and engineers will be tailored to specific cities and specific problem sites. The data, from which the findings were developed, showed that goods-movement problems are not the same in different parts of the country. The development density of the specific CBD as well as the characteristics of the arterial grid system are the principal differences. Other differences include traffic enforcement, PUD driver habits, and adherence to enforcement. The material presented in this paper is a first step toward understanding and improving the PUD problem; this can markedly improve the surface transportation system in the CBD.

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Part 3
Intermodalism

Trade-Offs Between Operations and Economics in Domestic Use of Containers

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Intermodal containers, as differentiated from piggyback trailers, have proved highly useful in international trade, primarily because they eliminate the reloading of cargo at each intermodal connection and the attendant delay, cost, damage, and opportunity for pilferage. However, physical constraints make containers less-economic transportation units per se than the individual modes that they replace—truck trailer, rail boxcar, break-bulk ship, etc. When standard intermodal containers are included in the U.S. domestic freight transportation system, their operating shortcomings outweigh any theoretical advantages that may accrue to either shippers or carriers. Such shortcomings include relatively high tare weights, limited cubic capacities, and requirements for sophisticated loading and transfer equipment. Proposals to develop and adopt a form of domestic container raise the same questions of standardization, interchangeability, and retrieval that plagued the international container industry in its early years. Further, the proposal raises the yet more-serious question of the rationality of allocating resources to develop a separate series of domestic containers that could not be interchanged with the existing fleet of more than 1.1 million international containers, with an estimated replacement value (including interface equipment) of $12.0 billion. This paper discusses the domestic operational restraints inherent in the use of international standardized containers and applies these to similar problems that might be anticipated for a variety of different domestic containers.

This discussion of operations will be limited throughout to containers as defined by the American National Standards Institute (ANSI) standard for closed van containers (ANSI MH 5.1.1M-1979):

> An article of transport equipment employed for the transportation of cargo in large unit loads which is strong enough for repeated use; designed for the carriage of goods by two or more modes of transport without intermediate reloading; equipped with features permitting its ready handling and transfer from one mode of transport to another.

In this context, containers do not include trailers or semitrailers used in trailer-on-flatcar (TOFC), or piggyback, intermodal truck-rail transport operations. In essence, containers are boxes without chassis or wheels for use in the highway mode that must be loaded and unloaded by using special handling equipment. In contrast, trailers may be transported on their wheels directly in the highway mode, and the same wheels may be used to load and unload the trailers from rail flatcars in the absence of special piggyback loading devices.

BACKGROUND

The origins of the so-called container revolution in intermodal transportation have been recounted many times. Suffice it to say that the concept of unit loading for intermodal international transport began to develop into a major submode less than 25 years ago. [Part of the following discussion of containers and container standards has been reported elsewhere (1).] Originally, several ocean carriers developed proprietary systems designed to avoid cargo handling at intermodal interfaces. Later, the advantages of standardization of sizes, fittings, load ratings, and strength testing led to what is today known as the International Standards Organization (ISO) standard container. However, some of the innovators are still operating with equipment that, although acceptable as defined by ANSI, is not in full compliance with ISO standards.

Experience over the past quarter of a century has shown that the maximum degree of equipment use and flexibility can be achieved with intermodal containers that are standardized at a number of points and thus may be handled and transported by the maximum number and type of transport and transfer modes. Thus, most of the 2 million or so intermodal containers in use throughout the world [which includes the 1.13 million that touch U.S. territory in the course of their movements (2)] conform totally or partly to the ISO standards for such units. In the Western world, only two firms use international intermodal containers (a total of approximately 85 000 units) that are not in basic conformity with the ISO standards (3).

DESCRIPTION OF CONTAINERS

Subject to refinements and improvements, standard containers represent a family of units that measure 605.8, 912.5, and 1214.2 cm (20, 30, and 40 ft) in overall length and 243.8 cm (8 ft) in overall width to meet U.S. highway limits. Heights vary from 243.8 to 259.1 cm (8.0-8.5 ft). In addition, containers that conform only to the U.S. standard may have lengths of 732.0 and 1066.8 cm (24 and 35 ft). Although van containers predominate, other body types are used. The methods used to lift and secure intermodal containers have also been standardized through upper and lower corner fittings and a system of locking devices. The ANSI standard likewise covers unit strengths, maximum loadings, and appropriate testing procedures.

Containers constructed to standard specifications may be mated, or carried, aboard ships equipped with container cells and guides, on rail cars fitted with appropriate devices to hold them in place [container-on-flatcar (COFC) type], in the highway mode on a standardized-frame trailer chassis with matching hold-down equipment, and in some instances on aircraft. Through standardization, units constructed in one nation may be transported by any of these modes in another country. Similarly, handling and transfer cranes and hoists can be used worldwide due to the standard sizes and fittings employed.

The present size and dispersion of the world's container fleet attests to the success of this method of freight handling. However, without the advantages of full interchangeability, much of this success would have been impossible, since each individual container system would be captive to its owner and operator. Since freight is virtually never balanced at any given point, the problems of retrieval of empty containers and their movement while empty would negate any efficiencies that might be achieved. Standardized containers permit maximum use of equipment through interchangeability among users. Today, almost all intermodal containers are owned by leasing and shipping companies (2) rather than by individual shippers.

LIMITATIONS TO CONTAINER USE

To place containerization in its proper perspective, it must be recognized that a large portion of total freight movements do not lend themselves to this method of unitized handling. Goods that move relatively short distances--less than at least 800 km (500 miles)--are not viewed as benefitting from containerization. Such movements may be made by highway on an overnight door-to-door basis by using standard highway trailers. In addition, many commodities do not lend themselves to containerization due to the nature of the freight, the equipment required, or both. These include such items as most bulk commodities, pipes, structural members, petroleum, ready-mix cement, and metal bars and coils.

The limitations of intermodal containerization are reflected in the present mix of standardized containers, of which approximately 90 percent are closed dry vans and the bulk of the balance are refrigerated vans (3). Another characteristic of containerized freight is its relatively high average density as indicated by the popularity of international containers 912.5 cm (30 ft) long. Almost two-thirds of all such containers are now of this length, as opposed to other lengths of up to 1214.2 cm (40 ft).

Containerization has sharply reduced time, handling, pilferage, and damage for international freight movements and thus, ultimately, costs. Freight may be loaded in containers anywhere in the world for transshipment by any transport mode to any other point in the world without further handling. Standardized handling and secured fittings, as well as standardized sizes, permit such interchanges at will. However, it is becoming apparent that containers per se are less-efficient units for transporting freight than are any of the individual modes that they have supplanted.

The explanation for this phenomenon is quite simple. The container box must be of a standardized size and strength in order to be accommodated by all transport modes. The strength requirements alone (dictated by the need to withstand wracking at sea, stacking, and transport by rail) require that the containers be so constructed that they weigh considerably more than, for example, the highway trailers that they replace. A 1214.2-cm (40-ft) container plus highway chassis has a tare weight approximately 1 metric ton (2200 lb) higher than that of a similar highway trailer.

Similarly, height restrictions of containers, dictated by the necessities of intermodal use, limit the container that is 1214.2 cm long to a cubic capacity that is as much as 30 percent less than the capacity of many now-popular 1397.5-cm (45-ft) highway trailers. These restrictions mean that containers carry less weight and less cubic capacity of freight than do highway trailers. It should be noted here that highway load weights in different states are based on total weight of the vehicle plus its load, and thus increased tare weights reduce the capacity to carry revenue freight.

Comparable losses of cubic and load capacity exist with regard to all other freight modes--rail, water, and air. Thus, the container achieves its efficiency not as a box per se, but rather as a means by which cargo rehandling at intermodal interface points may be eliminated.

Over the years, many thousands of containers have been injected into the U.S. domestic freight transportation systems in the course of moving such units to and from international interface points. For the most part, such movements have occurred over the highways with the container mated to a standardized chassis pulled by a truck tractor. Some use of containers has been made on the rails, as COFC or TOFC (by using a highway chassis), in the course of similar preinternational or postinternational movements or as part of a land bridge.

Motor carriers who have received intermodal containers have noted the reduced efficiencies associated with their use in these instances. Further, when the containers are reloaded, either for export or for so-called "free domestic" repositioning movements, the problems are repeated. Specifically, in comparing use of containers on trailers with use of standard highway trailers, the complaints relate to reduced interior heights and widths, reduced interior length, and reduced load-carrying capacity (within state weight limits). Also, use of containers both over the road and in TOFC operation effectively captures a container chassis, an expensive unit better used in positioning containers. The preferred ratio of chassis to containers is no more than one chassis for each five containers in service, and a prolonged mating results in a one-to-one ratio.

Rail operations with COFC are further restrained by a lack of the specialized handling equipment required to load and unload containers without chassis, especially at traffic points other than major ones. For this reason, most individual rail movements of containers are accomplished as TOFC, or piggyback.

The current fleet of international intermodal containers that operate into the United States has an estimated replacement value of $9.5 billion, and the associated highway chassis are estimated to have a replacement cost of $0.7 billion (2,4). Container and combination container-piggyback rail cars in service and on order for delivery by early 1980 have an estimated replacement value of $0.9 billion [based on 18 000 cars on order at an average current price of $48 000 (according to R. Brodeur of Trailer Train Company)]. An estimate of the replacement value of in-place container loading and handling equipment in the United States at the present time is approximately $1.0 billion. In total, therefore, the present value of containers and container transporting and handling equipment and facilities in the United States is approximately $12.0 billion.

Proposals to develop and adopt a domestic container system raise the same problems and questions of standardization, interchangeability, and retrieval that once existed with regard to the international intermodal containers. The idea of a separate domestic container system also raises what may be still more onerous questions concerning the rationality (and the resource allocation advisability) of developing a separate series of domestic containers that could not use the $12.0 billion replacement-cost investment in existing international container equipment.

However, no system that is not fully standardized (which would make it both intramodally and intermodally interchangeable) would have much national application or use. In fact, several of the present experimental domestic container systems suffer from exactly this problem. They are captive to the firms that have developed them and usually cannot be interchanged with other carriers in the same mode or with noncaptive equipment of other modes.

Although some of these developments may contain within them the embryo of a future standardized domestic intermodal container system, their present diversity (if continued unchecked) can only lead to a proliferation of individual proprietary systems. What is more alarming is that the proprietary systems, being captive, have reduced utility overall due to inherent problems of retrieval and return loads. This introduces a built-in inefficiency. Still further, there is the basic economic question whether a separate new series of domestic containers is really justified.

In this regard, there is no consensus of what size or shape such containers should assume. It would be logical to assume that, since most freight originates, terminates, or both via highway, highway size and weight limits should dictate the basic criteria. However, even here, highway limits are still developing, and the question whether domestic containers should follow present highway limitations or those envisioned for the future is apropos. The problems center around such limits as gross weight, which is currently 36 288 kg (80 000 lb) total in most states, and overall width, currently 2.44 m (8 ft).

If we assume current limits, a standardized system would then be locked in for the foreseeable future, especially with regard to dimensions. On the other hand, the assumption now of some future limits would require a careful determination of such limits and of the problem of making all existing equipment obsolete. Other questions and conflict areas abound. For example, current popular highway trailer lengths are 919.2, 1214.2, and 1397.5 cm (28, 40, and 45 ft). Each of these lengths is utile for one or more major types of freight movements. The shortest is used in twin or double-trailer combinations, while the two longer sizes are used for single-trailer movements of high- and low-density freight, respectively.

Aside from the physical limits of a domestic container series, there remain the questions of fittings and strength to withstand stacking and wracking loads. The existing ISO fittings and locking devices have been well proved in use. Moreover, existing expensive container lifting and transfer equipment has been designed around the ISO fittings. Thus, acceptance of the ISO-type system into a domestic container series would eliminate the need for development of a new approach and also provide for the use of existing handling equipment.

International intermodal containers are constructed to a high strength standard in order to withstand the rigors of use, which includes stacks of six loaded containers in the hold of a ship. When not more than two containers will be stacked and they will not be placed aboard ship, strength standards (and tare weight) may be reduced substantially. This has been done in the case of the special series of existing air-truck containers, which have a maximum capability of stacks two containers high. However, these air-truck containers cannot withstand the forces generated by rail transport.

CONCLUSION

When international intermodal containers are used in domestic freight transport within this country, they have been found to have a number of operational disadvantages in terms of transferability, weight, and cubic capacity, especially when operated in the highway mode. At the same time, these containers are virtually fully interchangeable on an intermodal basis due to a high degree of standardization of sizes and fittings.

A number of proprietary series of domestic intermodal containers are now being developed, none of which is fully compatible with the standardized physical and handling parameters of the existing fleet of more than 1.1 million international intermodal containers that operate into and through the United States. The actual need for a domestic container system must be viewed in terms of a fully compatible, interchangeable system in order to justify the costs and resource allocations involved. To date, none of the domestic container proposals has met these criteria.

In terms of maximum equipment and investment use, it is suggested that if any national series of domestic containers is developed, such a series, in order to gain acceptance from both transporters and shippers of freight, should

1. Have physical dimensions compatible with existing highway and rail equipment standards,
2. Have load-carrying capacity at least equal to that of present highway trailers,
3. Be equipped with corner fittings and locking and securing devices fully compatible with existing ISO standards for such equipment,
4. Be capable of withstanding loading forces imposed by rail and highway movements,
5. Be capable of being stacked two high when fully loaded,
6. Be physically distinguishable from international intermodal containers (to avoid accidental shipboard loading), and
7. Not require duplication of the $12.0 billion U.S. replacement-cost investment in ISO containers and container support equipment.

To meet these conditions for a series of domestic containers, it would appear that the best overall approach may lie in a program focused on ways to reduce the tare weight of the existing series of ISO international intermodal containers. In this way, one single container series could be used in both domestic and international trade, which would result in a very substantial saving in investment made in containers, chassis, and handling equipment.

Finally, it is believed that sunk cost requirements alone may dictate the fate of domestic containerization. Unless a domestic container series can use all or most of the existing equipment, duplication could cost at least another $12.0 billion. Such duplication would represent an economic waste and a misallocation of resources and could easily negate any benefits that might arise from freight containerization.

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Cost-Service Modeling: Theory and Practice

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Recent developments in transportation have increased the need for accurate microeconomic modeling. If it reflects situation-specific data, microeconomic modeling can be a valuable tool for shippers, carriers, and public policymakers. Reebie Associates has developed a unique cost-service modeling technique over the past 10 years. This paper outlines its theoretical structure and a recent application. The model described simulates carrier and shipper economics. The trade-off between cost and service is essential to both. A brief description, at the theoretical level, is given of the relationship between production costs and the service level for the carrier and that between transportation costs and distribution costs for the shipper. A graphic presentation is developed to describe them and their interrelationship. The theoretical construct is then employed to describe a recent market research project (conducted for the New York State Department of Transportation) that examined the feasibility of a new intermodal service. Three elements of that study—cost and service modeling, market segmentation, and shipper modal preference—are described briefly and related to the preceding theoretical construct. The paper ends with suggestions for further research.

The transportation environment is undergoing changes that are unprecedented in number, importance, and complexity. Carriers face increasingly stiff intermodal and intramodal competition. The increased importance of transportation- and distribution-related costs for many manufacturers has made the traffic department a key management function. Deregulation is another complicating factor in this increasingly uncertain environment for both carriers and shippers. This increased uncertainty can result in added risk, a very real cost felt by those unprepared to deal with the new environment (and indirectly by the rest of the economy as well).

Although economic regulation is being relaxed, direct government involvement in transportation is increasing. The continued instability of some modes and the growing awareness of the importance of a sound transportation infrastructure for regional economic competitiveness are catalysts for this development. Increasing direct government involvement has generated new areas of responsibility for public policy planners, responsibilities for which many are not prepared. Thus the uncertainties that concern the transportation market are now shared by public officials as well as private carriers and shippers.

Increased complexity and uncertainty in the transportation market have created a clear need for better understanding of transportation economics by shippers, carriers, and public policy planners. Applications-oriented microeconomics can be used by carriers to test their competitive environment; pricing and service strategies can be more effective if they are based on a solid understanding of demand sensitivity. Shippers armed with an understanding of carrier economics (and their own) can be better prepared for rate negotiations and better able to make short-term modal choice and longer-term facility planning decisions. Government policy planners, entrusted with major public expenditures for operating subsidies and transportation system investments, can be greatly assisted by microeconomic modeling, which can base their decisions more firmly on the marketplace and so ensure more-effective resource allocation.

Although the value of microeconomic modeling is evident, the area has not yet been adequately investigated. Several transportation researchers have attempted to model the transportation marketplace. However, theory often falls short of a reasonably accurate reflection of reality. Furthermore, practical applications of theory have tended to be at the higher policy levels rather than the operating level of decision making. Previous efforts in the field, such as those by Friedlaender (1) and by Meyer and others (2), focused on comparisons of simulated operating costs of competing modes. Considerable effort was given to defining the finest details of highly mechanized cost models. However, since they are based on broad system and nationwide averages, these models are frequently inappropriate for specific situations, which are often the cases where decision makers most need modeling support. Perhaps a more serious flaw of cost-oriented models is the slight consideration given the critical factor, service. Transportation is a service industry. Product quality is often more important than quantity. Although service is intangible, it is, nonetheless, a necessary component of a comprehensive model of the transportation marketplace.

More-recent models differ from their predecessors in that they attempt to incorporate service in the demand and supply equations. Roberts and his associates at the Massachusetts Institute of Technology (3) have modeled the shipper's purchase decision with their logistics analyzer. By pairing this simulator of shipper economics with carrier cost models, many transportation decisions can be simulated. This method has recently been used in the Federal Railroad Administration's Intermodal Freight Systems Study. Although service is an integral part of this modeling technique, the difficulties of relating nationwide averages to local situations remain. Another problem with this mechanized simulation of the shipper's transportation purchase decision is the assumption that the shipper's decision making is guided by a precise understanding of the economics. In fact, in decisions such as modal choice, a shipper's perceptions and biases are often more important than the actual logistics economics.

The cost-service model discussed in this paper builds on the research conducted in the past. The model differs from its predecessors in several respects. In recognition of the fact that a carrier or mode can offer a range of products to the market, the cost model has been used to estimate carrier cost profiles for several levels of service, i.e., several differentiated products. By incorporating the service capabilities of competing modes and carrier costs into the model, a more-complete representation of the supply equation is presented. By using survey techniques, shipper behavior is examined directly. Not only does this provide a more accurate picture of shipper preferences that actually drive the purchase decision, but it also ensures better applicability of the model to local situations.

Clearly, this is not the ultimate model. Many elements require further refinement. This paper will outline briefly the model's theoretical structure and its recent application in a research study conducted for the New York State Department of Transportation (NYSDOT).

COST AND SERVICE: THEORY

Models of the transportation environment are designed to replicate, in a simplified format, the choices available in the marketplace. As such, these models must simulate service and cost for the economics of both carriers and shippers. For the carrier, the service component represents the range of products that can be offered to the market. The cost component describes the carrier's costs associated with the production of those various levels of service, or products. In this model, shipping costs have been separated to isolate those directly paid to the carrier (i.e., transportation rates) and those implicit in the quality of the product purchased (e.g., inventory holding costs and packaging costs). The former describe the shipper's cost component; the latter, the service component.

Service Definition

On the simplest level, movement is the product of the transportation industry. How this movement is produced, packaged, and sold can vary markedly among modes. Furthermore, the importance of the quality of this movement varies among market segments as well. There are several components in the concept of service. Among them are transit speed, protective handling, delivery appointments, and billing procedures. Since the perceptions of capability and value for each component are so varied, each has a different level of importance for each shipper and carrier. For example, one shipper's purchase decision may take into account several elements of service--transit time, protective handling, and customer service. On the other hand, the entire strategy of a carrier may be focused on one service element, for example, fast transit time. Although service is an area of extreme complexity that is difficult to model, it cannot be ignored. To define the critical service dimension, it is necessary to introduce certain simplifying assumptions.

In numerous shipper surveys one factor, reliability, has repeatedly emerged as the most important determinant in modal choice. Reliability must be viewed separately, since it encompasses all elements of service, such as variability of transit time and levels of loss and damage. If a carrier establishes a service standard such as third-morning delivery, delivery appointments, and no more than 5 percent loss and damage, reliability will be measured by whether the performance meets these standards. Because of its importance, reliability should be given separate consideration in the development and application of service models.

In the discussion that follows, service has been portrayed as an aggregation of service elements on a one-dimensional continuum from low service to premium service. Low service level implies the minimum market-acceptable level for each service element; the premium level implies the maximum acceptable level. The intermediate service levels assume a graduated increase in each service element. In this context, low service should not be confused with poor service. Low service still implies an efficient operation. The low standards for such service elements as transit time and cargo handling are established by the carrier and clearly understood by the shipper. Although placing service on one dimension is a simplification, it enables many transportation decisions to be modeled and described by a two-dimensional graphic representation. For conceptual simplicity, an ordinal ranking from 1 (low) to 6 (premium) will be used to demarcate different levels of service.

Simulating Carrier Economics

Each carrier has a unique relationship between production costs and level of service generated--the trade-off between production cost and service level. Barge carriers, for example, can provide a low-service product (slow transit time, minimum cargo protection) at extremely low unit costs. However, the technological limitations of a barge operation would produce extremely high costs at substantially higher levels of service (for example, one that implies a 40-mile/h average transit speed). Conversely, the cost structure of motor carriers enables them to better serve customers who require higher levels of service. However, truckers cannot match the low unit costs of barges at the lower levels of service. Figure 1 gives conceptual curves that represent the contrasting cost-service tradeoffs of four modes: barge, rail, motor, and air.

The curves in Figure 1 are (of course) simplified. Not all carriers within any mode will have the same profile in a given situation. Moreover, the profile for any particular carrier can vary substantially in different markets. The value of these profiles is in the definition of the range of levels of service that a carrier (or mode) can produce. A carrier's product-line capability establishes the parameters of competitive capability. By referring again to the ordinal ranking of service levels, barge operators can produce service at levels 1, 2, and 3 before their costs become prohibitively high. However, their costs, even at level 3, are much higher than those for rail. Clearly, barge operators can compete only for market segments that will accept the lowest standards of service. Rail carriers, on the other hand, have a distinct advantage at level 3. However, they are on the margins of competitiveness at levels 2 and 4; these are the parameters of this mode's competitive capability. The identification of competitive parameters in terms of both production costs and service is vital to a carrier's real-world marketing strategy; it is also necessary in the construction of a representative model.

Simulating Shipper Economics

Each shipper has a set of distribution costs associated with different levels of service. (In this discussion, transportation costs are viewed separately from other distribution costs such as inventory-holding, lost-sales, and packaging costs. Total costs, including both transportation and distribution costs, are defined as total logistics costs.) For most commodities, an increase in transportation service can, to a point, be translated into a decrease in distribution costs. Delivery appointments can reduce labor costs at receiving facilities, faster transit time can lower inventory-holding costs, and better cargo handling can eliminate many packaging costs. The unique characteristics of each commodity and shipper mean that improved service can have quite different impacts on distribution costs from one situation to the next. For example, fast transit time in special protective equipment will have much more importance to a shipper of perishable goods than to one of plastics.

Since each shipper has a distinctive set of distribution costs that result from different levels of service, the willingness of each to pay for those services in increased transportation rates varies accordingly. In each purchase decision, there is a transportation-cost--distribution-cost trade-off. The objective of the rational traffic manager is to minimize total logistics costs (the sum of transportation and distribution costs). However, many traffic managers, with only a partial understanding of the distribution-cost implications of different levels of service, make trade-off decisions based on intuitive perceptions of total logistics costs rather than on precise economic comparisons. Allowances must be made in the research technique for such behavioral characteristics and for other factors such as imperfect information.

Figure 1. Curves that represent contrasting modal cost-service trade-offs.

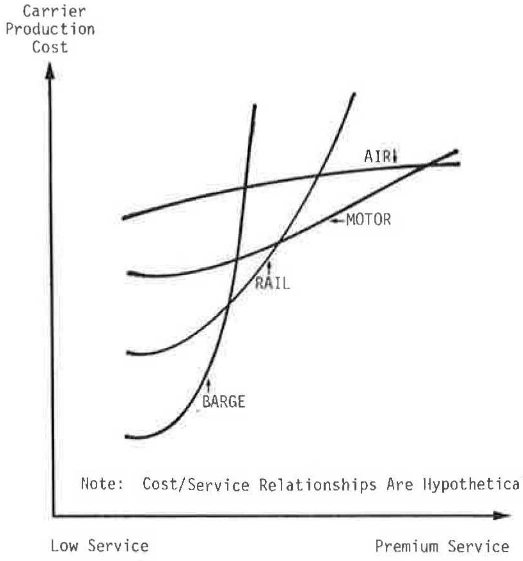
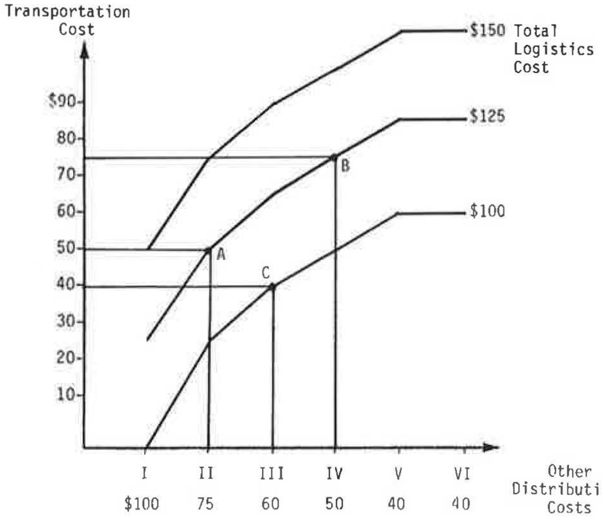


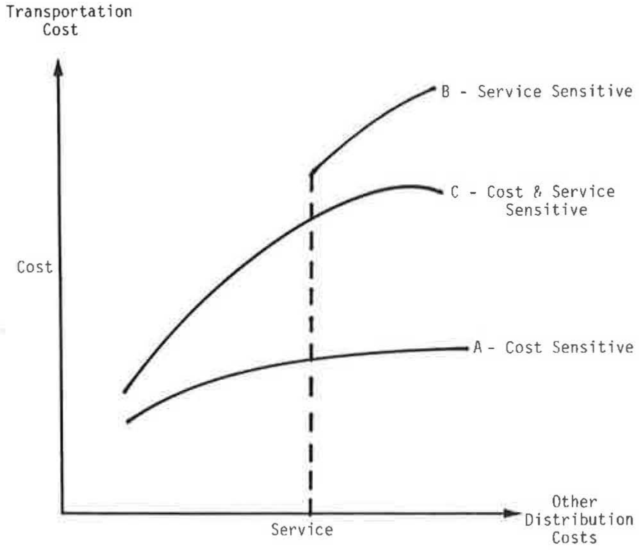
Figure 2. Family of isototal-logistics-cost (ITLC) curves for one hypothetical shipper.



Because there is a trade-off between transportation costs and distribution costs, total logistics costs can be identical for a number of combinations of transportation costs and service level. Figure 2 portrays the isototal-logistics-cost (ITLC) curves for one shipper. Each curve represents different combinations of transportation and distribution costs that produce the same total logistics cost. A rational shipper should be indifferent, over the long run, to any particular combination of cost and service that produces the same total logistics cost. These curves can be drawn for an infinite number of total logistics costs to form a family of indifference curves. The objective of the traffic manager should not be to hire a premium-service carrier without regard to cost nor to find the lowest rate. Rather the best combination of rate and service for the situation should be acquired and thus implicitly the move to the lowest possible ITLC curve will be made.

In Figure 2, point B describes a combination of a transportation cost of $75 and level 4 service that has distribution costs of $50 for this shipper. Total logistics cost is $125. At point A, the shipper has a lower transportation cost of $50, but higher distribution costs of $75. The total logistics cost at B ($125) is identical to that at A. The various combinations of transportation cost and service that produce the total logistics cost of $125 (including points A and B) describe an ITLC curve. On the other hand, point C has transportation and distribution costs that total $100. Logically, the shipper would prefer to be on the ITLC curve that includes point C.

Figure 3. Contrasting ITLC curves for three shippers.

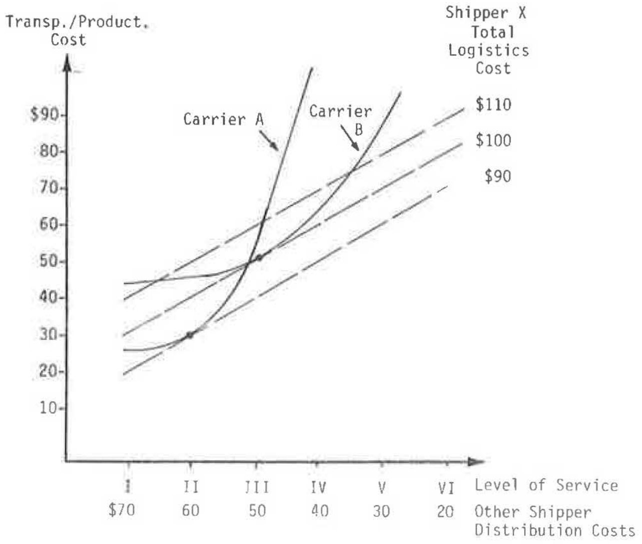


Each shipper has a family of identically sloped ITLC curves. Yet the exact shape of each shipper's curve is unique. This reflects the differing impacts of service on each shipper's distribution costs. Figure 3 shows a few representative curves. Shipper A manufactures a bulk commodity and has little need for more than base-level service; for this shipper, transportation cost is paramount. Shipper B ships perishable goods and finds low levels of service unacceptable; for B, premium service can be translated into substantially reduced spoilage and an increased market price. Shipper C represents the majority of the transportation market--improved service can reduce distribution costs but only to a point. Beyond that point, increased rates are not justified by lower distribution costs.

MATCHING SHIPPER AND CARRIER ECONOMICS

By themselves, the cost-service trade-off relationships of carriers and shippers have limited value. A carrier may have the advantage over competitors of producing much lower costs at all except the lowest levels of service. Yet, if the market in question is made up of shippers who are relatively service insensitive, that competitive advantage is diminished. Therefore, the trade-off between production cost and service level for carriers and the trade-offs between transportation cost and distribution cost for shippers must be combined into a single analytic framework. The X-axis of Figures 1 and 2 represents the service and distribution cost parameters for carriers and shippers, respectively. They can be placed on an equivalent basis by assuming (as was discussed earlier) that, as service levels change, shippers' total distribution costs are proportionately (although inversely) affected. How-

Figure 4. Comparison of shipper and carrier cost-service trade-off curves.



ever, since each shipper's value of service is unique, the proportion will vary accordingly.

Matching the Y-axis parameters of Figures 1 and 2 implicitly assumes that carrier rate levels (shipper transportation costs) are equivalent to their production costs. This is frequently not the case in the short run because of competitive pressure, regulatory constraints, market strategy, or an inaccurate cost measurement. Over the long run, however, carriers must earn sufficient revenues to cover their costs, which include an adequate return, if they are to continue to provide satisfactory service. If they are making excessively high earnings, other competitors can be expected to enter those markets (although this process may be slowed or limited by regulatory constraints) and bid the price down to a level nearer the cost of production. This long-run orientation is quite consistent with the planning functions for which the cost-service modeling is most effectively employed. As such, the equivalence of rates and carrier costs can be seen as a reasonable simplifying assumption.

By following these assumptions, the trade-offs for carriers and shippers shown in Figures 1 and 2 can be combined onto a single set of axes. Figure 4 gives the comparison of the requirements of one shipper (X) with the capabilities of two carriers (A and B).

For clarity, shipper X's ITLC curves have been made linear. Carrier A has a strong low-cost capability. However, A's competitiveness sharply deteriorates at higher levels of service. Carrier B is most competitive at higher levels of service. Of critical concern to both shipper and carrier are the points of intersection at which shipper X's ITLC curves cross each competing carrier's cost-service curves. Naturally, if only one carrier's curve crosses a lower ITLC curve, that carrier will have a significant competitive advantage. In this case, carrier B is capable of providing a product with total logistics costs of $100 for shipper X. Carrier A can offer shipper X a product on the $90 ITLC curve. This places carrier A in a dominant position for X's traffic and gives carrier A a wide margin of pricing flexibility.

As briefly described, one might conclude that the model is amenable to quantitative analysis. However, finding the fit in this discussion required several simplifications and assumptions. Cost-service trade-offs vary from shipper to shipper and from carrier to carrier. The use of nationwide, regional, and industry averages to simulate these trade-offs reduces the applicability of the model in specific situations. Furthermore, as a carrier's perception of competitive capability and a shipper's perception of the value of different levels of service may not be based on adequate information or a proper assessment of the information available, data on these behavioral characteristics that cannot be modeled mathematically must be introduced directly into an analysis. The theoretical framework has not been designed as an end in itself but rather as a guide for the conduct of a number of market-research assignments by Reebie Associates.

TRANSLATING THEORY INTO PRACTICE

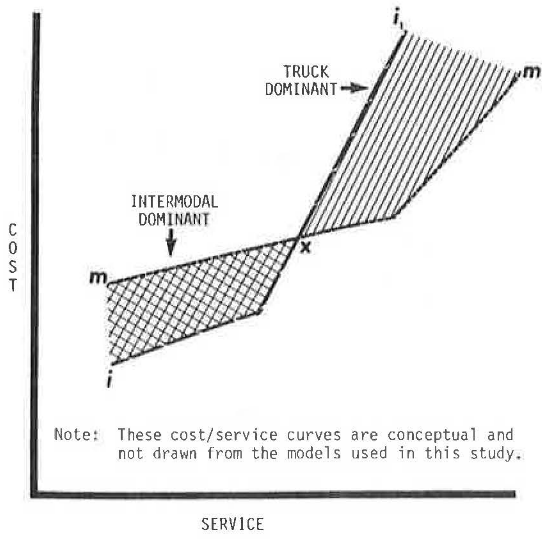
Many elements of cost-service modeling have been developed and tested in a number of Reebie Associates research and consulting projects. Since the principal objective of these studies was to analyze specific market situations to develop policy alternatives and recommendations and not simply to build elegant microeconomic models, not every facet of the cost-service trade-offs could be replicated in the fullest detail. However, the essence of its theoretical structure was preserved in recent applications. Cost-service modeling was a central element of a study conducted for the NYSDOT, which is a good example of the applicability and limitations of this technique.

This study was initiated to evaluate the economic feasibility of a new intermodal service to the New York City area, east of the Hudson River. Although intermodal service was available in New Jersey, its attractiveness for New York shippers is limited because of the low standard of reliability and long drayage hauls required. The state wished to know whether such a service would provide improvements in transportation costs and service for New York shippers and receivers, so that government investment, subsidy, or both would be justified. Cost-service modeling was used to estimate the potential economic viability of such a service. Although the feasibility of a project of this nature would also be determined by socioeconomic and environmental considerations, which are beyond the scope of this kind of modeling, the comparison between costs and service of competing modes describes the central economic question and therefore represents one of the most important tests for such a project.

In this analysis, two competing modes were examined--intermodal rail and motor carrier services, with the latter subdivided into a number of segments (regular and irregular-route common carriers and private and exempt-load truckers). Geographically, the base market was limited to that part of metropolitan New York City to the east of the Hudson River. Because of intermodal rail's inherent economics, the target market of the study was limited to New York's 25 largest traffic lanes (ones that were more than 400 miles long).

The analysis was conducted in three steps. The first established the nature of supply by identifying the cost and service characteristics of intermodal rail and motor carriers in New York and defined the zone of intermodal rail-truck competitiveness. To describe demand, the second step segmented the New York transportation market to isolate that traffic for which both modes could be competitive. In the final step, the demand characteristics of this competitive traffic base were measured against the capabilities of intermodal rail and motor carriers in New York, and the market potential for an intermodal rail service was projected.

Figure 5. Modal competitiveness: zones of dominance.



Note: These cost/service curves are conceptual and not drawn from the models used in this study.

Cost and Service Models

The first step of this analysis was designed to determine the production-cost--service-level trade-offs for intermodal rail and motor carriers. Figure 5 shows the conceptual representation of the cost-service trade-off curves for intermodal rail $(i-i_1)$ and motor carriers $(m-m_1)$. These curves describe, in general terms, the cost-service characteristics of each mode as found in this and previous studies. Intermodal rail, if operating at a high level of efficiency, can provide a superior cost profile at the lower levels of service. Because of the greater flexibility inherent in the highway mode, motor carriers tend to be more cost competitive at higher levels of service. These zones of dominance are defined in Figure 5 by the areas ixm for intermodal rail and i_1xm_1 for motor carriers. These zones describe price-service packages that cover a carrier's production costs yet are lower than any package offered by competing carriers.

To apply this relationship to the New York situation, models of carrier production costs and service capabilities, tailored to the specific transportation characteristics of the region, were developed. Although the costing model described only two modes, its construction remained a complex task. In this effort, a building-block approach was used. That is, each major cost component was developed by aggregating many subelement costs.

The carrier service model was (of necessity) simpler than the detailed cost model. Because of its overriding importance, reliability at the current truck standard was assumed for the new intermodal service. It was understood that unless an intermodal rail service provided such reliability, its prospects of success in New York would be minimal. To act as the surrogate for all other elements of service, transit time was made the key variable. (As identified in this and other studies, superior transit time seems to be closely correlated to superior performance for other service elements.) The service model produced transit times to the key markets for several variations of intermodal rail and truck service.

As noted previously, carriers' competitive capabilities will be influenced by their perceptions and biases. This behavioral consideration was not incorporated into this study, since there is not at present an intermodal carrier that serves New York City directly. If that had been the case, the intermodal cost and service models would have been modified appropriately. The results of the motor carrier models were tested in a survey of area truckers (and confirmed by area shippers).

By combining the results of the cost and service models, the boundaries of the competitive market were defined geographically. This market is made up of those traffic points at which intermodal rail is either currently competitive (to the west of Chicago) and points at which it could be potentially competitive with increased efficiency (primarily in the Midwest). Although the cost and service models indicated that there is a large potential zone of competitiveness, the true test is the market.

Market Segmentation

The New York transportation market is large and extremely complex. A fully comprehensive survey with an appropriate level of follow-up of the thousands of shippers in the city and its surrounding area was beyond the resources of this study. Reduction of the size of the survey to manageable proportions by focusing on that part of the New York transportation market for which intermodal and motor carriers could most directly compete was considered the most appropriate way to meet the demands for an adequate degree of market coverage and the budgetary constraints of the project. By using a comprehensive mail and telephone survey, those noncompetitive segments of the market were identified. This enabled a much more detailed in-person survey of the New York shippers who could use either intermodal or motor carrier service.

The New York transportation market was divided into three segments, each of which is displayed graphically. Figure 6 shows the relatively service-sensitive segment of the market that has a high standard of minimum service. In New York, this figure describes most less-than-truckload (LTL), short-haul, and damage-prone freight. Figure 7 represents the more cost-sensitive shippers, who do not significantly benefit from the higher-priced, premium-service alternatives. Since New York manufacturing is dominated by light industry, this segment is relatively small. In both cases, the shape of the ITLC curve is such that it passes through only one mode's zone of dominance. Thus, the shippers represented in Figure 6 will almost invariably rely on motor carriers (or a premium-service mode such as air cargo) because intermodal carriers cannot provide the minimum level of service required. The market segment represented in Figure 7 would rarely use motor carriers, since intermodal carriers (or another low-cost mode such as carload rail) can provide adequate service at lower cost than can motor carriers. These two groups of shippers represent those parts of the market that would be unlikely to divert between intermodal carriers and truckers.

Some New York shippers with economics similar to those in Figure 7 now use motor carriers or New Jersey intermodal carriers because there is not yet a New York-based intermodal service. Since these shippers would almost certainly divert to a new intermodal service, they were considered part of the intermodal service's assured market potential. Conversely, cost- and service-sensitive shippers (Figure 8) who would not use a new intermodal service were also not included in the later, more-detailed parts of the survey. Figure 8 shows the shipper with an ITLC curve that can cross both zones. This shipper was made the focus of the competitive analysis.

Figure 6. New York transportation market: service-sensitive shippers.

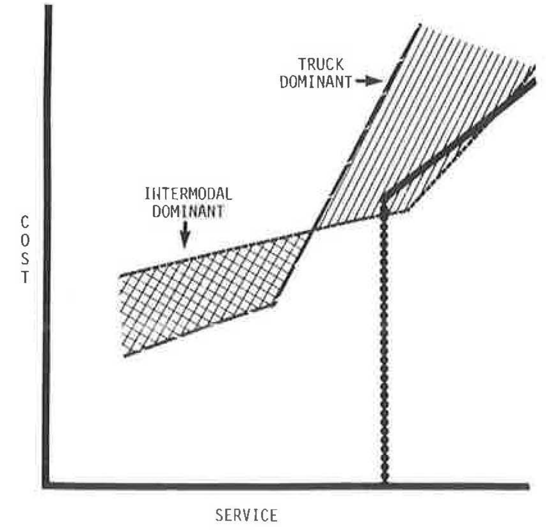


Figure 7. New York transportation market: cost-sensitive shippers.

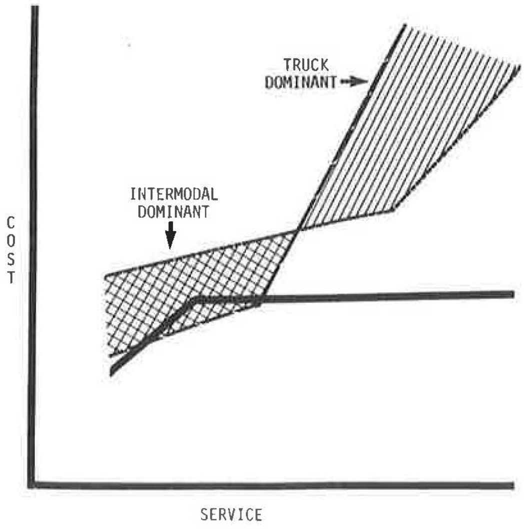
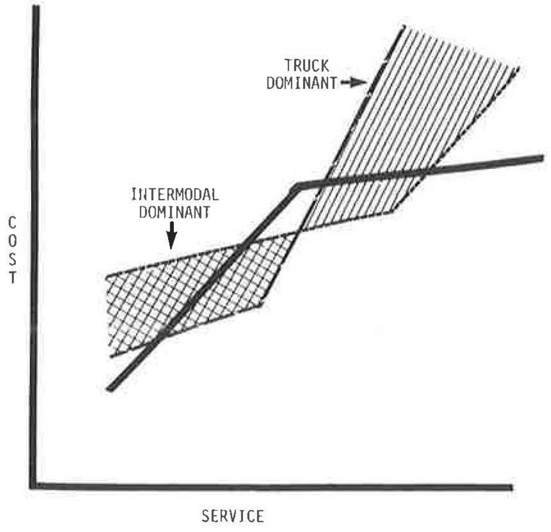


Figure 8. New York transportation market: cost- and service-sensitive shippers.



Competitive Analysis

In the New York study area, the competitive traffic base consists of not more than 200 major shippers and receivers. In the survey, almost every major shipper of outbound traffic and most important receivers were contacted. An emphasis was placed on outbound traffic because of the relatively intense competition for this traffic. New York's inbound-imbalance ratio of 2.5:1 makes this traffic crucial for a transportation service's success.

A diversion analysis technique (developed in earlier studies) was employed to estimate the shape of each target shipper's ITLC curve. In personal interviews, shippers were asked to estimate the diversion of traffic from their present carrier (almost invariably a motor carrier) to a new service and what this diversion would be for several different combinations of transit-time performance and transportation cost. Inherently, a significant diversion implies that the shipper is describing an indifference curve that is either equal to or lower than that of the carrier being used. The analysis was not designed to dissect the nature of the shippers' cost-service trade-off nor to understand their behavioral motivation. Rather it was intended to measure shippers' acceptance of a new modal option by asking them to simulate their cost-service trade-off decision. In this way, the reactions of shippers with widely varying distribution patterns could be aggregated. Furthermore, as biases, perceptions, and misinformation inevitably influenced the shippers' responses in the interviews, these unquantifiables were incorporated directly into the diversion analysis.

The survey identified many shippers (in the trucker's zone of dominance) who were unwilling to divert to intermodal service unless a substantial cost reduction or service improvement was promised. Others needed assurance of only a small cost reduction to switch their modal allegiance. These shippers represent the cost-sensitive market segment that should probably use any reliable intermodal service rather than motor carriers if there is one available. Several shippers were identified who would accept slower (although still reliable) transit time for a relatively small rate reduction. These shippers represent that part of the market served equally well by either intermodal or motor carriers.

The diversion analysis results indicated that a New York intermodal rail service could gain a significant share of the competitive market. Many New York shippers (within the target sample) have perceived ITLC curves that would seem to be best served by the cost-service profile that could be produced by an efficient intermodal alternative. A New York service could capture a substantial share of traffic to the Midwest, and market dominance in traffic lanes to the West would be likely. This projected traffic potential was the basis for the conclusion that an intermodal service could be a viable competitive force in the New York market.

SUMMARY

The model described in this paper is one of many attempts to apply transportation economics research in specific decision-making situations. Clearly this effort is in its very earliest stages and many of its components need further investigation and refinement.

Market-segmentation techniques employed in the consumer-goods industry can be profitably employed by researchers to tailor analytical techniques, such as the diversion analysis described above, to the unique distribution patterns of different industries and geographical regions. Survey techniques need to be developed in two directions: (a) more-economical and expeditious techniques to permit wider market coverage and (b) more-sophisticated, in-depth techniques to better understand the shippers' purchase decisions and to improve the reliability of survey results. Survey techniques and simulations can be complementary if they are developed in tandem. To realize the most value from both, their most-appropriate applications should be identified and linked. A shipper panel, established on a semipermanent basis along the lines of the Nielsen ratings for television, is one way to regularly gauge the impact of changes in shipper perceptions and environment on the purchase decision.

Product differentiation is becoming an increasingly important concern for both carriers and shippers. Costing techniques should be refined to better estimate the production-cost impact of providing different levels of sevice. Carrier costs have been the focus of a considerable amount of attention (perhaps too much). Costing techniques should be developed to better reflect local operating conditions and, more importantly, the perception of carrier management.

In sum, there are several areas that require further exploration for both cost and service and shippers and carriers. Clearly, this research will be most valuable if it reflects the decisions made in the marketplace and is designed to assist decision makers.

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Measuring Intermodal Profitability

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The profitability of intermodal operations provided by the rail industry and commonly known as trailer-on-flatcar (TOFC), or piggyback, service has been questioned in recent years. Although TOFC loadings have increased, the growth has not been as rapid as many believe possible; the industry's hesitancy to make the necessary investment and the reluctance of other modes to take advantage of rail line haul are indications of this situation. Although railroad-costing methodology has improved in the past decade, difficulties still exist in ascertaining profitability of any one segment of traffic. The difficulty of allocating costs prevents costing officials from accurately determining intermodal costs and hence profitability. It is this situation that confronts management with investment decisions and presents the Federal Railroad Administration (FRA) with problems in the promotion of intermodal operations in the rail industry. Congress provided funding for the FRA to partially offset operating losses in intermodal demonstrations under certain criteria; the most important of these are potentially profitable operations. In view of the problem with railroad-costing methodology, how should the profitability be measured? The FRA is funding research in two phases to develop an Intermodal Management Information System (IMIS). The first phase, an overview of rail information systems and a state-of-the art survey, confirmed the need for an IMIS and identified three modules that could be readily transferred to the industry. In various stages of development and testing are an Intermodal Management Equipment Control System (IMECS), which generates adequate records for detention billing and control of trailers, and a Repetitive Waybilling and Rating System (RWRS), which electronically maintains a comprehensive audit trail of waybill activity. Both these systems (and other sources) provide an automated collection of intermodal records to ascertain profitability for the rail carrier.

Since 1973, the ever-worsening fuel crisis and critical environmental problems have dramatized the need for truly efficient transportation. Each mode of transportation has individual characteristics of cost or service that are superior to those of competing modes depending on the distance and the function. When fuel was abundant and transportation modes were economically healthy, inefficiencies were tolerated in the name of laissez-faire competition. However, it has now become essential to encourage the combining of the best features of each mode into a total system; this cannot be accomplished by any one transportation company restricted to a single mode of operation.

In the case of domestic merchandise and perishable commodities, the ultimate solution may be a refinement of truck and rail piggyback service. This basic concept dates back many years and its use has been growing, but at a rate far slower than the true potential would justify. Investigation has disclosed numerous problem areas that impede the expansion of trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) traffic.

More important than fuel efficiency and environmental problems to the rail industry is that, in the continuing analysis of the industry by the Federal Railroad Administration (FRA), a conclusion was reached that improvement of intermodal services by the railroad industry may be able to recapture a substantial portion of the profitable market that has been diverted to competing modes.

The U.S. Department of Transportation (DOT) position on this issue is illustrated by Secretary Coleman's landmark statement of national transportation policy on September 17, 1975 (1): "The strength of our transportation system lies in its diversity, with each mode contributing its unique and inherent advantages.... A priority for reform is to encourage intermodal joint use of facilities [but] the potential of intermodal services remains for the most part unrealized." A transportation system based on policy outlined in the statement would provide "new, more cost-effective, energy-efficient and intermodal technology." These ideas were basically repeated in

Secretary Adams' 1977 policy statement on national transportation trends and choices (2).

Thus, DOT developed FRA's Intermodal Freight Program. The objectives are to develop the best marketing techniques, management and operating control systems, operating practices, and equipment concepts that can accelerate the growth of coordinated rail-highway merchandise service. Various alternatives are being tested and refined in actual service under a representative variety of operating conditions and market situations. Each demonstration project will address a distinct problem or combination of problems that defy simple solutions even on a long-term basis. DOT approval of a demonstration project specified that an important criterion of any demonstration is whether it has the potential for profitability, defined as 10 percent return on investment. How this is to be measured is the subject of this paper.

FRA INTERMODAL MANAGEMENT INFORMATION SYSTEM

An integral part of the Intermodal Freight Program is the development of a specialized Intermodal Management Information System (IMIS). Although the IMIS was introduced by FRA in order to improve the competitive situation of the TOFC mode (and consequently the railroad industry), there were other indications that such a system was needed. One was the National Intermodal Network Feasibility Study, which emphasized an IMIS as an essential feature of a successful TOFC system. Another study that reinforced FRA's belief that little attention had been given to the development of systems for intermodal use was an informal survey conducted in 1975, which concluded that the development of an IMIS would not result in a duplication of any existing, developing, or proposed system.

With the obvious industry need for an IMIS, the beginning of the FRA Intermodal Freight Program, and departmental approval of the program, a contract was awarded to Planning Research Corporation (PRC) in September 1977 to develop an intermodal information system with the following objectives:

1. To improve quality of service in (a) trailer handling in terminals and on trains and (b) loss and damage claims;
2. To improve productivity of labor (salesmen and personnel in terminals);
3. To increase revenue by (a) entering new markets through additional train, terminal, or equipment capacity and (b) assuring collection of all revenues due; and
4. To reduce expenses through improvement in use of certain kinds of labor and capital, which includes (a) tractor drivers and the labor and capital on ramps, (b) equipment such as trailers, cars, and other supplies, (c) terminals, and (d) trains.

STATE-OF-THE-ART SURVEY

The first task was a state-of-the-art survey to determine the extent to which systems that directly support intermodal service have been developed. The survey was designed to obtain information on a wide range of intermodal organizational, informational, and operational characteristics. It was intended to encompass not only the railroad industry, but also segments of the motor carrier and maritime industries.

The objectives of the survey were to determine the state of existing and planned systems that support any or all aspects of intermodal activity and to identify unmet needs. A sample of eight railroads was surveyed in detail. To be representative of the full range of industry practices, the sample selected included large and small carriers, differing intermodal organizations, integrated and independent motor carrier subsidiaries, and geographic balance. In addition, one common carrier, two trucking subsidiaries, and one international maritime carrier were included to further diversify the investigation of intermodal activities. Findings of the survey were verified by a search of pertinent literature and systems-related research.

The survey questionnaire was designed to capture characteristics of the intermodal operations, sales, marketing, pricing, costing, and data-processing environment with emphasis on the degree to which each functional area is capable of being automated. To solicit maximum cooperation, each rail carrier selected was initially contacted through the chairman of the Association of American Railroads (AAR) Intermodal Ad Hoc Steering Committee. The rail carriers were requested to complete the questionnaire and subsequently to review their responses with an on-site survey team. To coordinate the information collected, the carriers were asked to describe existing and planned systems for each intermodal function. In addition to responding to the survey, many carriers supplied reports now in use that support intermodal services.

Since the state-of-the-art survey deliberately limited the number of carriers, it was both appropriate and necessary to conduct a literature search to ensure that the study adequately reflected the current level of intermodal systems development, both in rail and in other transportation modes. In this way, information systems excluded from detailed examination by time and budget constraints could be documented if they were available through the literature review. Recent literature about management information systems in the intermodal area is sparse; it consists mainly of articles in trade publications and papers presented at conferences. The search concentrated on trade publications after 1970. As would be expected in publications intended for general readership, the articles described systems only in the most general terms, and the search revealed little that was not already included in the survey.

It was found that all railroads (except the smallest) now have some type of automated system in support of intermodal management and control. These vary widely in sophistication, in the degree to which mechanized processing is employed, and in the extent to which intermodal processing is involved within existing rail systems.

In the railroads surveyed, there were many consistent factors that related to intermodal data processing. At first glance, this consistency supports the premise that development of an intermodal system compatible to many would be a relatively simple task. Other factors, however, tend to make the task more complex. Key findings are discussed below.

Development Status

The intermodal component of the railroad industry is currently experiencing a surge of system design, development, and implementation activity unmatched in its history. This trend to enhance or develop systems in support of intermodal processing should be strongly encouraged, given the limited resources of most railroads and the relatively low priority attached to intermodal operations in general. Should the degree of system development for intermodal operations continue and actually increase, it is felt that future intermodal profitability would be significantly enhanced through improved management control and resource allocation.

Distinctive Intermodal Requirements

An independent IMIS that encompasses all aspects of intermodal activities does not exist. Several systems applicable to intermodal service were developed by converting or modifying (or both) conventional car systems. Intermodal requirements are met by these systems only to a limited extent, since they do not recognize certain distinctively intermodal needs. The need for certain approaches tailored to intermodal system design is beginning to be recognized, and some railroads are cautiously taking that approach.

Intermodal service has two characteristics that differentiate it from conventional carload traffic and result in unique information requirements. With intermodal service, the trailer is the revenue-earning unit comparable to the car. However, the trailer requires a car for movement on rail; the result is that two pieces of equipment are needed, whereas carload traffic requires only one. In addition, although cars are "married" to the rails, trailers frequently move out of railroad control, which requires that adequate records of street activity be maintained.

In general, a dichotomy in intermodal design activity was observed: Some railroads very successfully and easily converted or modified (or both) car systems to intermodal systems, whereas others found it more difficult to add intermodal capabilities to their existing systems.

Certain intermodal processing activities such as trailer control would be enhanced by independent development of intermodal systems applications in lieu of adapting conventional carload systems to meet the divergent intermodal requirements.

Trailer Control Systems

Most railroads surveyed consider an automated Intermodal Management Equipment Control System (IMECS) essential to future growth. An intermodal equipment control system, as defined here, primarily provides a real-time inventory of trailers and containers at the intermodal terminal that gives information such as the number out to a customer and the number of loads or empties in the yard. This type of intermodal processing was identified differently by the various railroads surveyed, which used terms such as Terminal Control System (TCS), Trailer Inventory Control (TIC), Van Inventory System Implementation Operating Network (VISION), and Intermodal Facility Inventory Control. Only one major railroad surveyed has implemented an intermodal equipment control system. This system is tightly interwoven with their car control system and their hardware and software configuration. This precludes it from being transferable. For most railroads, the automated status of the trailer is not carried any further than its arrival at the TOFC terminal on the rail car and is not recaptured until it is again loaded on a flatcar for movement. Several railroads are in the process of developing this capability, with implementation scheduled for the near future. In general, the intermodal organizations surveyed indicated that this application has a high priority and that other intermodal subsystems could be readily added subsequent to its implementation.

Repetitive Waybilling

The development of repetitive waybilling systems was considered essential by many intermodal departments. Most railroads surveyed had not yet implemented repetitive waybilling for intermodal traffic. Repetitive waybilling may be more suited to intermodal than to carload traffic, since a higher percentage of this traffic follows a repetitive pattern. The ancillary uses of an implemented repetitive waybilling system are numerous and perhaps represent the greatest long-term benefits.

Profitability Analysis

A common need throughout the industry is the automatic provision of more-specific performance measures in addition to the generation of dollars of costs and dollars of revenue on a more timely and accurate basis.

The only universal aspect of costing found in the survey was that all railroads perform cost studies. Each has designed its own costing methodology, which depends on its unique competitive, operational, or traffic pattern characteristics. Only one major railroad was found to have developed a regularly computer-produced profit-and-loss statement of intermodal movements by terminal, by city pairs, or by equipment type. Several of the carriers produced such a report manually by using settled revenues and average costs. Although many of them saw enormous benefit in such a report on a regular basis, differing management styles and lack of data base precluded any immediate plans to implement one. Most automated cost reports are generated from responsibility accounting systems and contain some average (allocated) costs. The accuracy of allocation methods used for general overhead, loss, damage, and several other costs is often a source of contention between intermodal and other functional areas of the organization.

Automated Detention Billing

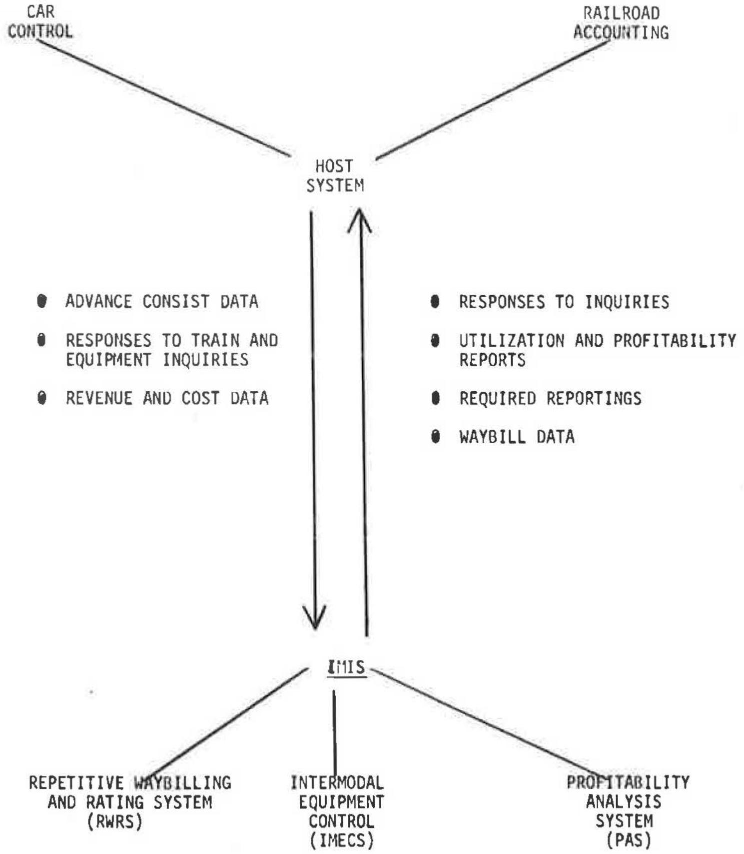
None of the railroads surveyed has totally automated detention billing. It was described as a very difficult procedure to automate, since it is dependent on numerous variables not readily obtained. The current clerical effort to rate and produce bills varies widely from railroad to railroad. With the advent of on-line intermodal equipment control systems, the automation of detention should logically follow, since the necessary data will be captured.

DEVELOPMENT OF THE BASELINE SYSTEM

With the survey findings outlined above, FRA decided to enter into phase 3 of the IMIS project and contracted with PRC to develop the system. The baseline system consists of intermodal equipment control, repetitive waybilling and rating (which is a reflection of revenue), and associated responsibility cost data. When combined with equipment data, the revenue and cost information is a profitability-analysis tool. Together these items form the IMIS, but (more importantly) they provide the foundation and data base for expansion into many other areas; hence, they form a baseline system. The IMIS will support equipment distribution and inventory, budget control, management by objective, and, in short, increased profitability.

By the previous designation of the components of the baseline system, it may seem that the marketing and pricing and the sales functions have been

Figure 1. Relationship of Intermodal Management Information System (IMIS) to existing railroad systems.



overlooked. To the contrary, many of the organizations surveyed that were concerned with these functions considered intermodal operations as a major informational source. Reports of cars loaded or empty and of the balance between the two direct the attention of sales and marketing departments to areas of imbalanced traffic, and comparative reports of customer activity can be drawn from historical data of trailer movement. Specific information on the intermodal operations functions is of more-immediate importance than that for use solely by marketing, pricing, or sales. For this reason, the marketing, pricing, and sales functions have received a lower priority for specific development than the baseline system components. By providing the baseline data base, these other functions can also be served, and there is the added advantage of laying a foundation for their future expansion within the IMIS.

It is important to realize that the baseline system is essential; it provides a broad, substantial foundation that immediately addresses critical intermodal information requirements. It is simpler and less costly to develop and implement a variety of reports without a baseline system and corresponding data base, but such an approach does not provide the railroads with the means to add and expand for long-term capabilities. The primary criteria for developing the baseline system are modularity and transferability--modularity to accommodate current needs as well as future expansion and transferability to allow maximum use by the intermodal organizations of the railroad industry.

Approaching the design from the top and working down enforces modularity. Transferability is fostered by developing an IMIS that is largely independent of existing railroad systems but still linked to those systems to avoid redundant efforts. The baseline system begins where those systems cease their control of intermodal activities and in turn terminates its scope where existing rail systems again take over. This relationship of the IMIS to existing railroad systems is shown in Figure 1.

The initial task was to specify the development of a baseline system. Each of the major components (intermodal equipment control, repetitive waybilling and rating, and profitability analysis) will be further refined into its component parts and supported definitions of functions, inputs, outputs, and transformations. The baseline system specification includes (a) purpose and scope; (b) design concepts and assumptions; (c) functional system description overview; (d) detailed specifications, i.e., IMECS, Repetitive Waybilling and Rating System (RWRS), and Profitability-Analysis System (PAS); (e) computer resource requirements; (f) software interfaces; (g) user input parameters; (h) output report layouts; and (i) data base definition.

Intermodal Equipment Control System

The foundation of the baseline system is IMECS. Not only does it provide data for profitability and performance analyses but, by its provision of real-time inventories of trailer location and status, it supports greater control of terminals and improved use of intermodal equipment. Possible equipment status is shown in Table 1.

On-line inquiries provide a good basis for terminal management personnel to make necessary adjustments to their daily operations. However, control of terminals includes not only tracking the trailer within the intermodal terminal, but also monitoring trailer detention by the customer and

Table 1. Possible equipment status as shown by IMECS.

Status	Flatcar	Van or Container
Ramp placement	X	X
Ramp departure	X	X
Bad order	X	X
En route	X	X
Available empty	X	X
Assigned empty	X	X
Gate arrival		X
Gate departure		X
Interchange delivered		X
Interchange received		X
Grounded		X
Notified		X
Picked up		X
Returned		X
Delivered to customer		X
Released by customer		X
Loaded on flatcar		X
Manifested		X
Stored on per diem relief		X
Released from per diem relief		X
Stored	X	X
Disposed of old equipment	X	X
Receipt of new equipment	X	X
Tendered	X	X

recording interchange by truck with other carriers. Reports on equipment overdue from maintenance shops and patrons, or idle for extended periods of time without being stored, identify areas for improving turnaround times. Due to the recording of status and location changes, detention times are available. From the state-of-the-art survey, it is known that detention rating systems vary from railroad to railroad. However, with the implementation of an externally supplied rate table, detention billing becomes feasible.

At the system level, current situation reports should provide for more-efficient distribution of empty equipment; this makes it possible to achieve an important reduction in empty trailer miles. In addition to real-time inventory conditions, the intermodal-management and home-office personnel would have access to historical data compiled by IMECS. All the data to produce an analysis of the facility's cycle of activities are available, and it is possible to automate a morning report that gives a synopsis of yesterday's activities for each intermodal terminal and hence for the system.

A detailed list of inquiries and reports should be produced by the general design specification; however, the following should be included: (a) inquiries about trailers by means of equipment identification; (b) summaries of trailers by a subset of available data elements, especially loaded versus empty, plan number, equipment type, and status (this provides the on-line situation report); (c) inquiries about outstanding customer notifications; (d) daily situation report at system level (i.e., aggregation of individual reports); (e) morning report; (f) report of overdue or idle equipment; (g) per-diem relief summaries; (h) analysis of facility's cycle of activities; and (i) detention summaries and bills.

This is not meant to be a definitive list of all the reports because it is important to remember that the baseline IMECS provides a comprehensive data base capable of producing a variety of reports. It is intended that the baseline system produce a few reports considered basic to any intermodal operation. In addition, each railroad can use the data base to yield reports that reflect its own operating emphasis and particular interest.

The host computer system (the railroad's on-line operations control system) will provide advance consist data, which include estimated time of arrival and waybill information for the conveying flatcar and for all the vans or containers it carries. These data will allow IMECS to automatically create inventory records of that equipment whose current status is "en route." If data on a given railroad's consist are not sufficient for our purposes, advance consist data can be entered manually. The host system also provides responses to inquiries about the various trains and equipment that it is currently supporting. The intent is to maximize the use of existing systems. IMECS will not capture these types of data for its files but will switch the host responses to a cathode-ray tube or printer for use in the advanced-planning process at the intermodal terminal.

Since each railroad's requirements for data will vary, so will the amount of data that flows from IMECS to the host system. This is why the modular approach is so important to the design. Inquiries on IMECS files should be allowed from the host and from any other user. Additional reports that may be required will have to be developed separately for each railroad.

Given the integrated data base provided by IMECS, other functions can be provided in succeeding phases of implementation, such as customer orders, blocking of trailers and cars, flatcar matching, and crew work assignments.

Repetitive Waybilling and Rating

The RWRS greatly simplifies the billing process and provides a timely and accurate revenue data base. The system complies with standards currently in existence for repetitive waybilling and rating yet provides for distinctively intermodal requirements in the revenue-capturing process. The general approach was to capitalize on prior development characteristics of similar systems for carload and intermodal traffic and to tailor existing design criteria for the baseline IMIS. Waybill preparation for the intermodal traffic that the railroad originates or controls (i.e., local traffic, interline forwarded traffic, and miscellaneous charges) is approached in a fashion typical within the industry. The source data-entry system uses proven concepts in which, in a typical case, the billing clerk calls out a pattern (the waybill profile) and then fills in any blanks. The hard-copy bill will be produced when requested, the billing data (extract information) are forwarded to other functional areas that require such data (central accounting and movement systems, for example), and these data are retained on the local system for subsequent recall, correction, embellishment, or other use. The process by which the waybill information is retained is especially critical to intermodal traffic. Time-saving automated techniques are built into the RWRS to aid the movement of either paired or unpaired trailers. The variable input data will be edited by interactive graphics to verify format and consistency with trailer inventory.

Within the RWRS component of the baseline system, the following four subfunctions have been developed:

1. Interactive capture and printing of the waybill,
2. Real-time rating of waybills through application of repetitive rate structures,
3. Generation of freight bill information when appropriate, and
4. Provision for a revenue data base that will include all repetitive shipments.

The system has been developed in a modular fashion to permit both those railroads that have already implemented a repetitive-based system and those railroads that can provide revenue via another method to tie in with other components of the IMIS. In addition, the system operates in conjunction with existing railroad accounting procedures and car movement systems. Transportation Data Coordinating Committee specifications have been adhered to so that the system can provide for the electronic interchange of waybilling information.

Baseline system development for profitability analysis has focused on providing a data base of information that concerns the profitability of intermodal services performed by the railroad. Two aspects of data definition are critical to the development of profitability analysis as a tool for many users. First, data elements must be identified that are conducive to effective profit measurement and performance evaluation. Second, a data base must be defined to maintain these elements at a level of detail compatible with extraction and aggregation of the information for differing levels of management organization. Three general categories of data elements are essential: movement, revenue, and costs.

Movement

Data for monitoring van or container movement and equipment use are furnished for profitability analysis by the IMECS of the recommended baseline system. IMECS will supply the key elements of time and movement of individual trailers or containers. Several identifying characteristics associated with the movement of intermodal equipment are included in the profitability-analysis data base so that the movement information can be extracted and summarized in various ways. For example, all records that contain the same customer identity could be selected and aggregated to provide information by customer. The most common displays of information noted during the state-of-the-art survey visits were by terminal, origin or destination, customer, commodity, plan, and equipment type.

Revenue

The state-of-the-art survey also noted that a high percentage of intermodal traffic (as much as 95 percent) follows a repetitive pattern. A substantial portion of the revenue for intermodal movement can then be captured from rated waybills provided by the RWRS of the baseline system. The revenue thus obtained reflects amounts very close to the actual settled revenue.

To determine revenue not included in repetitive, rated waybills, two methods are used: (a) estimation of the revenue based on historical performance and (b) provision for manual or automated entry of settled revenue--essentially, the revenue in the data base created from repetitive shipments would be updated as settled revenue is reported; thus 100 percent of revenue is provided on a historical basis.

In any case, it is expected that revenue at the level of an individual trailer or container supplied from RWRS will be the primary source of revenue input for profitability analysis.

Costs

The third data category--cost input--is not so easily derived as movement and revenue inputs. The proposed baseline system does not directly provide for the capture of all intermodal costs at the level of an individual trailer or container, since it is especially in the area of accounting for costs that divergent management practices prevail. It is here that profitability analysis must relate to existing railroad accounting procedures and be able to accept input at the level of accounting desired by each railroad.

To accomplish this task, a high-level structure that divides costs into commonly acceptable categories (e.g., line-haul versus facility costs, variable operating expense versus fixed operating expense) has been established as a framework for a chart of cost accounts. The identification of detailed components making up each category and the level of accounting at which the cost element is established are left to the discretion of the user. The method of determining the per-unit cost for appropriate costs must also be defined by the user, e.g., system average, manually calculated input, percentage allocations, standards. The intent is to measure cost in terms of individual van or container movement or at some level at which individual movements can be aggregated, so that a common base can be established for relating the movement and revenue data to costs incurred.

The data thus collected provide a pool of information variables that may be selected and related to each other in many ways. When dollars of revenue and costs are desired for a given terminal, the van or container movement records into and out of that terminal provide the key for pulling together and aggregating revenue and cost data associated with the terminal's traffic. Other variable and fixed expenses of the terminal's operation that are not directly associated with trailer or container movement are then determined based on the parameters defined by the railroad, e.g., some percentage of total agency overhead supplied by a responsibility accounting source. It can be seen that once the important profitability data elements are made available to levels that permit meaningful relationships to occur, any number of relationships (such as operating ratios or load factor) can be formed. The continuous maintenance of these data elements then forms the historical data base, which can be used in subsequent comparisons of current and previous activity. If the data are available, a railroad could establish its historical data base at one time. The historical data base could serve other uses, at the discretion of the railroad, e.g., modeling and forecasting.

For the proposed baseline system, forecasts and budgets are areas of optional input to be identified at the discretion of the user. Definition of any element as input does not preclude its automated generation from some railroad's existing system; the only limitation to such an automated input is the formatting of the value from the existing system so that it can be recognized as profitability-analysis input.

The Norfolk and Western Railway Company (N&W) (a subcontractor) recognizes profit and loss as important criteria for evaluating performance. To demonstrate the baseline system's capability for profitability analysis, a terminal profit-and-loss statement similar to the one in use at N&W has been generated for pilot demonstration testing.

The N&W shows revenue broken down into categories of inbound, outbound, other, and detention; segregation by still other categories (such as plan number) could be easily accomplished provided the revenue input data included the necessary identification of such controlling items.

The N&W expenses are identified by their responsibility accounting reports. Their pyramid of expense breakdown starts with the entire system's profit-and-loss report and breaks down to those of individual ramps. The baseline-system approach to capturing these cost elements is to allow the railroad to identify the cost accounts to be used and to input these cost items to the profitability-analysis system. In the case of N&W, an interface between the responsibility accounting system and some of each month's total cost elements is required. The profit/loss and revenue/cost ratios are then calculated.

The historical elements of revenue and cost (i.e., data from the same month last year, from the year to date, and from last year to date) are retrieved from the profitability-analysis data base. Accordingly, those elements entered into the system for each month become part of the historical data base, in which they can be modified and updated (if necessary) to provide subsequent historical comparative values. Forecasts or budgets could be entered and shown for the comparisons if the railroad so desired.

To calculate the revenue or cost per unit and per load, movement data for traffic volume and loaded or empty status (provided by IMECS) are used. The movement data also provide the basis for the operating characteristics that management wants reported.

Reports to indicate load balances, to compare patron activity, and to portray empty line-haul costs compared with those for loaded mileage are other examples of operating statistics that could be derived from the profitability-analysis data base.

Profitability-Analysis System

In summary, the goals of the profitability-analysis component of the baseline system are to establish a data base of intermodal activity, revenue, and costs and to provide flexible, comparative reporting of the data at both detailed and summary levels. Movement data are supplied by the IMECS, revenue data are provided primarily from the RWRS, and most data will be obtained by interfacing with railroad financial and management systems to include intermodal service costs, directly related expenses (responsibility accounting), and transportation costs. The modular design will permit movement and revenue data either to be omitted or to be also input from sources external to the baseline IMIS should a railroad choose not to implement either or both of these baseline systems. Historical data will evolve from the collection of these inputs over time; forecasts and budgets will need to be entered from external sources if desired.

The design of the profitability-analysis component is of a generalized nature, so that the level of detail and control can be substantially determined by each railroad. Easy manipulation and retrieval of the data allow profitability reports to be formed to serve the varied needs of the management components within a railroad, and the concept can be adapted to suit the purpose of each railroad. A profit-and-loss statement for a terminal is one way in which profitability information may be portrayed. Traffic and operating statistics are still other ways.

The profitability-analysis concept allows for any number of future additions and enhancements, particularly data on those functions now designated as obtainable by interfacing with individual railroads. The importance of the baseline system is the establishment of a means for collecting intermodal profitability and performance information.

A major IMIS objective is to design and program the system to minimize dependence on one type of computer and to enhance the potential for widespread railroad industry adoption of the system. Therefore, the IMIS software is distinct from that of existing rail systems yet is able to interface with existing railroad central computer systems.

To avoid dependence on one computer, protocols have been developed to define standard transaction and data-element formats. IMIS has been written to communicate with existing central systems in terms of these established protocols. In addition, IMIS programming uses a widely available, high-level language to maximize its transferability.

Hardware Alternatives

There are two basic hardware alternatives for installing the IMIS: the same computer as the railroad's on-line operations control system or a separate computer.

There are several significant drawbacks to sharing the same computer as the on-line operations system:

1. From the state-of-the-art survey, it was learned that many of the railroads' computers are close to the saturation point. The addition of the IMIS, especially if written in a high-level language, may exceed the core-storage or disk-storage limitations of the host computer system. Hardware costs for computer sharing appear to be less than the second option because existing equipment is used. However, if additional core, disk or tape drives, communications lines, etc., must be purchased to include the IMIS, hardware costs may meet or even exceed those of the second alternative. This is true whether the computer saturation occurs as soon as IMIS is added or later. Accordingly, the hardware expense is dependent on the railroad's computer capacity.
2. Most on-line systems possess idiosyncrasies (such as specialized multithreading techniques, input-output overlap techniques, partition requirements, and other core-mapping techniques) that make independence of the installation, even with our interface modules, very difficult and costly in terms of software. This alternative is also the least transferable. Moreover, there is a possibility of greater impact on the host computer because some elements of the host system, such as the teleprocessing programs, may have to be modified to include the IMIS. Such modifications also increase the software cost.
3. Sharing the host computer is less acceptable to the industry than the other alternative because of potential compromise to the integrity of the host computer's on-line system. Those in charge of existing railroad computer systems will be extremely reluctant to allow direct access to their data bases and teleprocessing programs by new software because the process of error resolution (already difficult in an on-line system) is compounded by the presence of such software.

The alternative that has been recommended to handle intermodal operations is a dedicated computer. The most appropriate type would be a minicomputer. This option has the following advantages:

1. This alternative offers a well-defined interface with the host computer via a communication link, which virtually eliminates all need for the IMIS to accommodate and compensate for installation-dependent idiosyncrasies. Only that logic directly involved in simulating the host computer's terminals and transactions needs to be

isolated in an interface module, and thus this option provides greater transferability.

2. The initial hardware cost is a variable that depends on the size of the individual railroad's intermodal operations. There will be a higher initial hardware cost if an additional computer is used; however, if the IMIS causes the host computer to become saturated, later hardware costs could exceed the cost of a dedicated minicomputer. Also, development of the IMIS on a minicomputer that is upwardly compatible allows the system to operate on more than one size of computer. This enables railroads with a small volume of intermodal data to use a small, less-expensive minicomputer and provides a system that railroads with large intermodal operations can implement on a larger machine.

3. By providing an independent IMIS, the potential compromise of the host system's integrity is eliminated. This makes it more acceptable to the industry and lessens the software costs. At the same time, the computer used for intermodal data does not perform most of its processing synchronously with the host computer, which causes little adverse impact on host-computer performance standards and core- and disk-storage requirements.

TERMINAL COMMUNICATIONS DEVICES

Devices that communicate with the IMIS system also require discussion. There are three basic types: a cathode-ray tube (CRT), an intelligent terminal, and a minicomputer.

A CRT, often called a dumb terminal, is a simple mechanical device for transmitting and receiving data images. It provides no processing of data at the local level. Of the three types, it is the least expensive. It can be used best at locations in which the volume of intermodal data is low.

An intelligent terminal is a more-sophisticated device. Typically, it consists of a CRT with a small amount of core, auxiliary storage, and a printer. It can provide processing of the input data prior to its transmission to the IMIS system. This processing can take the form of preliminary or low-level editing of the input data, which would reduce the load on the communication line and the central minicomputer by eliminating unproductive transmissions. Input or output images can be retained for subsequent communication or printing. Additional functions for use only at the local level can be programmed for the local terminal. Such functions can be run in an off-line mode to fit the needs of the individual location. Simple functions that require little storage are the most feasible for the intelligent terminals. Because intelligent terminals provide more capabilities, they cost more. They would best be employed at facilities with substantial volumes of intermodal input data.

A minicomputer provides the maximum capability for local processing. Greater amounts of core and auxiliary storage allow availability of numerous, more-complex functions. Any of the functions listed for consideration in future phases of IMECS could be implemented as a part of the central IMIS. However, since these are essentially local functions, they could be distributed to the local minicomputer; this would decrease communications costs and provide greater capabilities. In addition, one minicomputer could be used to support the needs of both its resident location and those locations in the same geographic area too small to justify having their own computer. Minicomputers have the greatest potential for future development; they also represent the greatest hardware costs. Thus, they are best suited for facilities with the largest intermodal operations or for support of several operations from one point.

These three types of devices provide great flexibility in the implementation of the IMIS. Any one can be selected, or all three can be used simultaneously. Each railroad can tailor the configuration of its terminal communications devices to fit its resources and information requirements. This flexibility also allows for future upgrading of a railroad's hardware capabilities to reflect the changing conditions of the intermodal services provided by the railroad.

As mentioned earlier, the FRA-developed system has undergone a pilot demonstration on the Norfolk and Western railroad. The demonstration traffic lane was between Detroit and St. Louis with communications links to the railroad headquarters in Roanoke, Virginia, and to the contractor's computer in McLean, Virginia. All three modules were in operation and profitability reports were prepared by traffic lane for the two terminals involved and system intermodal profitability.

On completion of the pilot program, a review was concluded, and corrections were made to the baseline specifications and detailed specifications. These were delivered to FRA along with training manuals and programming instructions. This material is available to any railroad from the Federal Railroad Administration in Washington, D.C.

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The Energy Crisis and Intermodal Competition

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This paper analyzes the effects of recent changes in the supply and price of energy on freight transport modes. This is accomplished by studies of the relative energy efficiency of the modes, the relative energy cost intensity of the modes, and the effects of government intervention. Relative modal energy efficiency is analyzed by comparing similar types of service. This approach goes beyond simple comparison of aggregate fuel efficiency data. The conclusion reached is that the relative efficiencies change for different types of service. Energy cost intensity is an important component of the effect of fuel price increases on relative modal competitiveness. Fuel costs are now approximately 55 percent of total waterway operating costs, 24 percent of total truck costs, and 12 percent of total rail costs. Therefore, as energy costs increase, barge costs increase the most, and rail costs increase the least. Government control of the price and supply of energy can prevent railroads from realizing cost and efficiency advantages. Also, the regulatory system creates a lag in railroad recovery of rising fuel costs. The main implication here is that increasing energy costs will improve the competitive position of the rail industry. However, such an improvement may be circumvented by government intervention in the energy market.

This paper evaluates the effect of changes in the supply and cost of energy on intermodal competition. First, there is a review of the relative energy efficiency of the freight modes in which the emphasis is on comparing similar types of service. Second, the effects of energy price increases on the relative cost competitiveness of the freight modes are determined. Finally, the effect of government action on the energy market will be discussed.

MODAL ENERGY EFFICIENCY

The issue of relative modal fuel efficiency arises together with the focus on energy problems. Although numerous studies and reports have focused on fuel efficiency, most simply compare aggregate rail shipments with aggregate truck and barge shipments. These comparisons may result in misleading conclusions because they do not attempt to compare the fuel efficiency of similar types of service.

Truck Energy Efficiency

Truck fuel economy varies; it may depend on type and size of engine, cargo weight, vehicle speed, and the presence of various fuel-saving devices such as gear governors and wind deflectors. Actual truck fuel efficiency is usually in the range of 4-8 miles/gal.

A field survey of rail-competitive intercity truck movements by the National Motor Transport Data Base (NMTDB) of the Transportation Research and Marketing Company in Salt Lake City provided data on truck fuel economy for this analysis. The survey consisted of 28 000 interviews with tractor-trailer drivers taken at 20 locations around the country from 1977 to July 1979. Survey data were used in two ways. First, the driver's actual reported fuel efficiency was tabulated. Second, empty mileage for various types of truck operations was calculated. The amount of empty mileage that a particular freight haul causes is vital in computing the energy cost of that particular move or class of movement.

Table 1 presents a detailed breakdown of the effect of empty mileage and tonnage on fuel efficiency. The table shows that fuel efficiency increases as average tonnage increases and as empty mileage decreases. Fuel efficiency was determined from statements by drivers in the NMTDB interviews. [In the table, the following assumptions were made: (a) an empty truck averages 6 miles/gal; (b) a 15-ton truck averages 5 miles/gal; (c) a 20-ton truck averages 4.75 miles/gal; (d) a 25-ton truck averages 4.5 miles/gal; and (e) the price of fuel is 90¢/gal (1).]

Rail Energy Efficiency

Rail fuel economies are often presented as an aggregate all-rail figure. However, as shown in Table 2, fuel economies for rail differ widely among types of service (2-5). For instance, Table 2 shows that unit trains can be up to nine times as fuel efficient as can local trains. The figure of 207 ton-miles/gal for all types of service is an average of the extremes of high-efficiency unit-train service and low-efficiency local service.

Barge Fuel Efficiency

Only one type of barge service is appropriate for comparison with rail. Most barge hauls are bulk movements that essentially compete with unit-train service. The barge fuel-efficiency figure is approximately 280 net ton-miles/gal (4). This figure accounts for empty mileage but not for barge circuity.

Energy Efficiency Comparison

A comparison of energy efficiency for similar services by the different modes can be made by using

Table 1. Truck energy efficiency.

	15-Ton Truck			20-Ton Truck			25-Ton Truck		
Loaded Miles (%)	Fuel Cost per Revenue Mile (cents)	Fuel Cost per Net Ton-Mile (cents)	Net Ton-Miles per Gallon	Fuel Cost per Revenue Mile (cents)	Fuel Cost per Net Ton-Mile (cents)	Net Ton-Miles per Gallon	Fuel Cost per Revenue Mile (cents)	Fuel Cost per Net Ton-Mile (cents)	Net Ton-Miles per Gallon
50	33.0	2.2	41	34.6	1.7	52	35.3	1.4	64
60	28.2	1.9	48	29.0	1.5	62	30.0	1.2	75
70	24.6	1.6	55	25.4	1.3	71	26.5	1.1	85
80	21.8	1.5	62	22.8	1.1	79	23.8	0.9	95
83[a]	21.2	1.4	64	22.0	1.1	82	23.0	0.9	98
90	19.5	1.3	69	20.6	1.0	87	21.5	0.8	105
100	18.0	1.2	75	19.0	0.9	95	19.8	0.8	114

[a] Base case.

Table 2. Rail energy efficiency.

Service Type	Average Tons per Car	Loaded Miles (%)	Net Ton-Miles per Gallon
Unit train	100	50	350
Carload	45	60	198
Long-haul TOFC	30	75	172
Short-haul TOFC	40	65	97
Local	45	55	40
All types	53	57	207

Note: Data on net ton-miles per gallon were obtained from the following sources: unit-train, carload, and short-haul TOFC from U.S. Department of Commerce study (4); long-haul TOFC from DOT report (5, p. 60), although the Atchison, Topeka, and Santa Fe Railway Company Ten-Pack equipment increases this by 15 percent; local from DOT report (5); and all types from AAR yearbook (2).

Table 3. Relative energy efficiency: rail versus truck.

Type of Service	Net Tons per Vehicle	Loaded Miles[a] (%)	Net Ton-Miles per Gallon	Energy Efficiency: Rail to Truck[b]
Unit train				4.4:1
Train	100	50	350	
Truck	25	50	69	
Rail carload				2.2:1
Train	45	60	198	
Truck	20	80	77	
Long-haul TOFC				2.3:1
Train	30	75	172	
Truck	15	85	64	
Short-haul TOFC				1.6:1
Train	40	65	97	
Truck	15	70	54	
Local				0.6:1
Train	45	55	40	
Truck	20	60	61	

[a] These are typical for the service types mentioned.
[b] Adjusted for rail circuity, 1.17 percent of truck (4, 6).

Table 4. Fuel costs as a percentage of total truck, rail, and barge revenue.

Item	July 1978	January 1979	July 1979	July 1980 (estimate)
Truck				
Price of diesel fuel per gallon ($)	0.55	0.65	0.90	1.50
Fuel cost per revenue mile ($)	0.13	0.15	0.21	0.35
Revenue per running mile ($)	1.01	1.08	1.16	1.38
Fuel cost to total revenue (%)	13	14	18	25
Rail[a]				
Price of diesel fuel per gallon ($)	0.36	0.40	0.64	1.20
Fuel cost to total revenue (%)	7.5	7.9	10.2	16.2
Barge[b]				
Price of diesel fuel per gallon ($)	0.38	0.43	0.80	1.25
Fuel cost to total revenue (%)	32	34	48	57

Note: These are percentages of revenue; the fuel costs as a percentage of costs would be higher.

[a] Figures for July 1978-July 1979 calculated from AAR data (2); they are averages for all types of service for all U.S. class 1 railroads.
[b] Figures obtained from various barge companies.

the data supplied in Tables 1-3. Five energy efficiency ratios for different types of rail and truck service are presented in Table 3. The rail statistics were obtained from the same sources used in Table 2 (2-5), and the truck statistics were obtained by using the NMTDB field survey to get typical loaded/empty ratios for the different types of truck service. [Inland waterway barge statistics, determined from a 1974 U.S. Department of Commerce study (4), showed 277 net ton-miles/gal and an energy efficiency ratio for rail to barge of 1.5:1. This figure was adjusted for barge circuity, which was 1.60 percent of rail (6,7).] The tons per vehicle and the percentage of loaded miles assumed for each case were used to calculate the net ton-miles per gallon achieved by each of the modes in the various types of service. The efficiency ratios are based on net ton-miles per gallon adjusted for the circuity factors involved when modal comparisons are made. The ratios show the efficiency relationships between modes when average tonnage, loaded-mileage percentage, actual engineering efficiency, and circuity are taken into account.

Several points can be made about the ratios shown in Table 3. First, the data show that barge movements are sometimes not as energy efficient as the unit-train rail movements with which they compete. Also, it can be seen that long-haul unit-train service has the greatest energy advantage over truck service, whereas some local rail service is not as energy efficient as trucks that perform the same type of service.

The main point of the analysis is that service type is extremely important when energy efficiency is evaluated. Simple statements that rail service is more energy efficient than truck service or that barges are more energy efficient than railroads are misleading. Relative modal energy efficiencies can vary widely depending on what kind of transportation service is being analyzed.

The implications of the efficiency comparison are these:

1. Loss of energy efficiency due to modal shift is an invalid argument against branch-line abandonment.
2. When used for the same type of service, barge movements are sometimes not as fuel efficient as are rail movements.
3. Rail movements could become even more relatively efficient if rail empty mileage were reduced. Usually, rail movements have more empty miles than do truck movements for comparable services.

ENERGY COSTS

In considering intermodal competition, the important factor about relative energy efficiency is how these efficiencies affect the relative energy costs for the different modes. As energy costs rise, total costs are affected differently depending on the energy cost intensity of each mode. Fuel efficiency alone is only one element of a carrier's total cost structure. The mode with the highest percentage of energy costs out of total costs will be that most affected by energy cost increases, regardless of relative fuel efficiency. A comparison of fuel costs as a percentage of total revenue for truck, rail, and barge operations from July 1978 to July 1980 is shown in Table 4.

Truck Fuel Costs

For the purpose of this analysis, only intercity rail-competitive trucks will be examined. This is an important distinction because the structures of fuel costs are somewhat different for the various types of trucking operations. Specifically, the fuel costs of the shorter-haul less-than-truckload (LTL) trucking operations make up a lower percentage of the total costs than do those of the truckload operations.

In 1978, fuel costs were 5-7 percent of revenue for some of the major regular-route common-carriage

Table 5. Effects of fuel price increases.

	July 1979		July 1980 (estimate)	
Mode	Fuel Cost as Percentage of Total Costs (%)	Increase in Total Costs as Result of 50% Increase in Fuel Price (%)	Fuel Cost as Percentage of Total Costs (%)	Increase in Total Costs as Result of 50% Increase in Fuel Price (%)
Rail	12	6	18	9
Truck	24	12	32	16
Barge	54	27	66	33

Note: The analysis holds nonfuel costs constant; percentage figures are calculated from revenue percentages in Table 4.

trucking companies involved primarily in LTL terminal-to-terminal operations. By comparison, fuel costs were approximately 13 percent (see Table 4) of revenue for owner-operators involved in long-haul intercity trucking. The difference is primarily due to the fact that the LTL operations have other, substantially higher nonfuel costs, for example, labor, terminals, and local pickup and delivery. The fuel cost per revenue mile and revenue per running mile (calculated from actual NMTDB data) are given in Table 4 for truckload trucking operations (the price for July 1980 assumes that a 10 percent increase in nonfuel costs is passed on in rate increases).

This analysis concentrates on truckload trucking operations because this is the type of trucking service that competes most with other modes. The analysis assumes that the average fuel economy is 5 miles/gal when the truck is loaded and 6 miles/gal when it is empty. In Table 4, fuel cost as a percentage of truck revenue is given for the standard case of an owner-operator involved in truckload service for July 1978 to July 1980. Between July 1978 and July 1979, the percentage of fuel cost to total revenue increased from 13 to 18.

Rail Fuel Costs

Between July 1978 and July 1979, the average price paid by U.S. railroads for a gallon of diesel fuel increased from 36¢/gal to 64¢/gal (a 78 percent increase). In July 1978, fuel cost was 7.5 percent (on an industrywide basis) of total rail revenue. (Some railroad fuel costs were as low as 6 percent and others as high as 8.5 percent of revenue.) The 78 percent increase in the price of fuel in one year resulted in an increase in rail fuel costs to 10.2 percent of total rail revenue. This new percentage accounts for the changes in nonfuel costs (which the analysis assumes increased 10 percent from July 1978 to July 1979). Rail fuel costs are shown to be as high as 16 percent of rail revenue by July 1980.

Barge Fuel Costs

Historically, barge companies have paid a few cents more per gallon for fuel than have the railroads, although fuel prices for barges vary greatly. Long-term fuel contracts are relatively uncommon in the barge industry, and railroads get a slightly better price due to volume buying and longer contracts.

During the summer of 1978, when railroads were paying 36¢/gal for fuel, barges were paying an average of 38¢/gal. At that time, fuel costs were approximately 32 percent of barge revenue. One year later, in July 1979, barges were paying approximately 80¢/gal.

By July 1979, the difference between the average price paid for fuel by barges and railroads had increased from 2¢ to approximately 16¢. This was because barge operators purchased a larger percentage of their fuel in small quantities at one time (spot market) than did the railroads during this period. Recently, spot-market prices have been very much above the standard contract prices.

At 80¢/gal (the July 1979 price), fuel costs paid by the barges made up 48 percent of their revenue. (This calculation assumes that nonfuel costs rise at a rate of 10 percent per annum.) If one assumes that fuel prices will continue to rise at this rate, by July 1980, fuel costs will be almost 57 percent of barge revenue. It is apparent that energy cost increases affect barge costs more than they do those of the other modes. This is due to the fact that barges are so much more fuel cost intensive than the other modes.

Energy Cost Comparisons

By using the calculations made so far, a comparison of the fuel costs of the different freight modes can be made. Table 5 shows how fuel price increases affect transport costs. The first case shows how transport costs will increase if fuel costs increase 50 percent above July 1979 levels. The second case shows the effect to be expected if fuel costs increase in 1980 to the levels forecast in this paper.

The analysis shows that the changing energy situation may significantly affect the cost competition between modes, especially between rail and barge movements. The era of inexpensive energy is over, and any mode that is energy intensive will become less competitive if energy costs continue to increase at a vastly greater rate than the costs of other sectors of the economy.

Supply of Energy

All three freight modes use middle-distillate fuel for most of their intercity freight movements. Middle distillates have been in especially short supply (when compared with other petroleum products) during the recent fuel shortage. Almost all users of middle distillates could be considered essential users to some extent. Because of the relatively inelastic demand (compared with other petroleum products) and because retail prices are not controlled, the recent shortage of middle distillates caused large increases in the price of this type of fuel.

As of January 1980, middle-distillate stocks were low for that time of year. Shortages are forecast for the winter of 1980. The severity of the shortages will depend on the weather, conservation efforts, and the true level of secondary and tertiary storage of home-heating oil (which is not now known). It is not unreasonable to expect conditions to occur that will result in severe shortages of middle distillates throughout 1981 and, with these shortages, still higher prices.

EFFECTS OF GOVERNMENT INTERVENTION

Since middle distillates are used primarily by essential users, any severe shortages in the middle-distillate market might result in government intervention. Such action might affect the relationship between energy price increases and competition between the modes. Some existing government actions and regulations are affecting this competition.

Government Economic Regulations

The government now interacts in the petroleum market by controlling the price of domestic crude oil, controlling the retail price of gasoline, and forcing reallocation of crude and retail supplies. There now exists the legislative mandate for many more avenues of intervention by the government. Among these are (a) government allocation of all petroleum products in times of shortage (e.g., U.S. Department of Energy Special Rule 9), (b) government mandate on refinery yields, and (c) import quotas on petroleum products. The legislature is now working on other plans for government intervention. Such plans include schemes to set aside allocations to heating-oil users of all the middle distillate that they claim they need.

The basic thrust behind all present and proposed government regulations of the middle-distillate market is the control of price and supply. These regulatory controls are essentially subject to political rather than economic considerations. Under these conditions, the relative competitiveness between modes will not reflect the true costs of the economic inputs of the modes. Diversion to a more fuel-efficient mode will not occur if prices and supplies are artificially controlled. It is clear that government energy policies have a strong impact on intermodal competition.

Interstate Commerce Commission Regulations

The regulatory actions of the Interstate Commerce Commission (ICC) have an impact on how the energy crisis affects the different freight modes. All regulated carriers experience regulatory lag in recovering fuel cost increases. Specifically, the railroads have experienced up to 150 days' lag over the past year. (In this case, "lag" is defined as the period between the time at which the cost increase occurs and the time at which the rate increase goes into efffect.) Although efforts are being made by the ICC to reduce the problems of regulatory lag, the shortest possible lag period may still be from 50 to 60 days. Overall, the U.S. railroads lost an estimated $250 million in unrecovered fuel cost increases during the past 10 months.

Trucking companies also have their problems with regulatory lag. Barge operations are only 8 percent regulated; thus the majority of barge rates are not subject to regulatory lag. The important point is that the lag times affect the freight modes to different degrees and, because of this, rapid fuel price increases will cause a greater short-term problem for the railroads than they will for trucks and barges. Rail rate increases are subject to lag, whereas most barge rate increases are not. The effect of lag on railroads is greater than it is on trucks. Specifically, trucks face less regulatory lag than do the railroads, for the following reasons:

1. ICC procedures measure spot prices for trucks but contract prices for railroads.
2. Truck rate increases are effective on 1 day's notice; the railroad increases require 10 days' notice.
3. Truck rate calculations are allowed to be more retroactive than are those for rail rate increases.
4. The ICC covers the expense of surveying and reporting trucking cost information, whereas the railroads must cover the expense of surveying and reporting rail cost information. These costs for paperwork and administration can be substantial.

The main point is that the uneven treatment by the ICC results in a substantial financial disadvantage for the railroads in the short run because they cannot recover their fuel costs as fast as can the truckers. This disadvantage results in financial loss to the railroads and somewhat negates any advantages that the railroads have from their fuel efficiency and from their not being as energy cost intensive as other modes.

SUMMARY

The important points of this analysis with respect to relative modal energy efficiency are as follows:

1. It is important to compare similar types of service when looking at relative modal energy efficiency.
2. Rail is often the most fuel-efficient mode when similar services are compared.

With respect to the impact of energy costs, the important points are as follows:

1. Cost structure is important in assessing the impacts of energy price increases on relative transport costs.
2. Energy price increases affect barge costs the most because barges are so energy cost intensive. Rail costs are affected the least because rail is the mode that is the least energy cost intensive.

The main points with respect to energy, competition, and public policy are as follows:

1. Market reaction to increasing energy prices can be distorted by government interaction (e.g., price and supply controls).
2. Preferential treatment of truckers by the ICC results in short-term financial disadvantages for the railroads in times of rapidly increasing fuel prices.

If economic forces are allowed to work, cost considerations will naturally result in the appropriate switch to the more-efficient mode. The extent of the switch will reflect the true economic costs of energy and the other inputs on transportation costs. Appropriate modal choice is an important goal because, while energy conservation is important, it should not be maximized at the expense of all other economic considerations.

If energy cost goals are suboptimized (e.g., by the imposition of price controls), the cost advantage that railroads have with respect to energy will be negated. Under these conditions, it will be difficult for relative rail rates to decrease.

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