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On A Rational Relationship For Certain Costs Of Handling Motor Freight

II. Stop-Time at Pickup and Delivery

W. EDWARDS DEMING

CONSULTANT IN STATISTICAL STUDIES

WASHINGTON 20016
4924 BUTTERWORTH PLACE

TEL. (202) EMERSON 3-8552

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Editor's Note: Part I of this article, "On a Rational Relationship for Certain Costs of Handling Motor Freight," appeared in the Summer 1978 issue.

INTRODUCTION

A previous paper (Part I of this title) dealt with man-minutes required on the platform to move freight from truck to platform, from truck to truck, and from platform to truck.[1] A rational relationship was developed to explain the time required to move shipments of various weights.

Stop-time at pickup and delivery will now be examined. The main purpose is to try to learn how stop-time varies with weight. Does it cost 10 times as much to pick up or deliver 5000 pounds as it does to pick up or deliver 500 pounds, or does it cost only four times as much, or six times as much?

Stop-time is interesting from the standpoint of the economics of transportation and the cost of living since it represents a prodigious expense. The total cost, nationwide, for stop-time at pickup and delivery of common general freight is about $1.5 billion. Of every dollar spent for transporting articles moved as common general freight by motor carrier, 13¢ is for stop-time at pickup and delivery.

STOP-TIME AT PICKUP AND DELIVERY

The driver of a pickup and delivery truck leaves the terminal with shipments to deliver to consignees. He stops at shippers to pick up freight. He may stop at the terminal of a connecting carrier to deliver shipments or to pick up shipments that will move onward in an interline haul. A shipment may consist of one piece or two or more pieces, cartons, boxes, barrels, and sacks. A shipment of 10,000 pounds could consist of two pieces each weighing 5000 pounds or 400 pieces each weighing 25 pounds.

Each delivery requires, besides the labor of unloading and loading, a count of pieces and a search for any piece missing or in excess, with a notation of any exception or visible damage. The driver must find, at the consignee, someone authorized to receive the goods and to sign the delivery receipt. He may have problems with illegible addresses. Each shipment picked up requires a shipping-order, properly written out and signed, to be signed also by the

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Dr. Deming is a consultant in statistical studies, Washington. The author acknowledges the assistance of Messrs. Benjamin J. Tepping, Dabney T. Waring, Robert G. Gawley, Edward P. Moritz, John P. Thompson.

driver, who certifies to the count of pieces. The driver must stow with care into his truck shipments that he picks up so that a piece, for example, will not crush another or leak oil on other freight. There is, thus, a certain amount of paper work and planning for the driver to take care of for any shipment regardless of its weight. This overhead time is the constant *a* in Eqs. 1 and 2.

DATA ON STOP-TIME

The cost-regions were circumscribed years ago by the Interstate Commerce Commission to permit use of costs for rate-making that would be appropriate to the region. It will be shown, however, that for any given weight, there is little variation between regions for the stop-time at pickup and delivery at shipper or consignee, and likewise for connecting carrier. The constant relationship between the active part of the stop-time for a heavy weight to the active stop-time for a light weight (manifest by the constant *c*) is especially striking.

The Interstate Commerce Commission collects every three or four years from the carriers allotted to a cost-region data on the man-minutes required for travel and for stop-time of pickup and delivery. The specific instrument is Form 4, on which a driver, on days selected by methods of probability-sampling, records the time he left the terminal; total pounds on board; time in and out at first stop; number of pounds removed; number still on board; same for his second stop; and onward over his route until he returns to the terminal with shipments he has picked up. Also shown are shipments he could not deliver for various reasons such as business closed on Wednesdays, could not find the consignee, shipment refused, shipment returned for visible damage.

The Interstate Commerce Commission transcribes, punches, and compiles the data
on Form 4 to show amongst other char
acteristics the stop-time for pickup an
delivery, by weight of shipment, in fin
weight-brackets. It compiles figures b
cost-region, separated for (a) pickup c
delivery at shipper and consignee and (b
at a connecting carrier.

Dabney T. Waring supplied copies of th
Commission's work-sheets which showe
the average weight of shipments in
weight-bracket versus the average stop-tin
in minutes per shipment.

The number of weight-brackets was 20
more, depending on how many points
high weights (about 20,000 pounds) o
viously represented deliveries and picku
at trailer-drops, or truck-loads on palle
for the forklift, which have been exclude

Shipments of light weight, about
pounds, give problems. They are likely
be abnormal in some way, possibly of o
shape or hazardous, some refused by
United Parcel Service and the Post Off
Department. A more usual difficulty is th
practically all shipments of light wei
move under minimum charge, for wh
two-thirds of the freight bills fail to sh
the weight. It is doubtful that the dri
weighs every shipment of minimum cha
for his record on Form 4. Average wei
of 29 or 30 pounds in the weight-brac
under 50 pounds could be undefinable.
would accordingly expect to find now
then a point at the lower end of the ch
as in Fig. 1, where the stop-time was
above the expected time calculated f
the curve. The point at the low en
excluded from the data for four regions
failure to conform to the equation (Ir
South connecting carrier, Fig. 1, Mid
west shipper and consignee, Rocky M
tain connecting carrier, New Englan
connecting carrier). All data for the
tral Region at connecting carrier appe
be faulty, so were not included in the
ages at the foot of Table I, for us
Table II.

Figure 1

The points come from Form 4 for Intra South 1973, for pickup and delivery at connecting carrier. The line is Eq. 2 with the least squares values of the constants for this cost-region,

$$\log (y-3.04)=\log 1.91 +.780 \log (x/100).$$

This set of data shows the worst fit of all 25 sets.

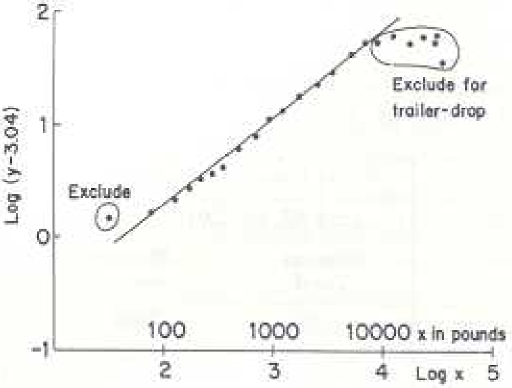
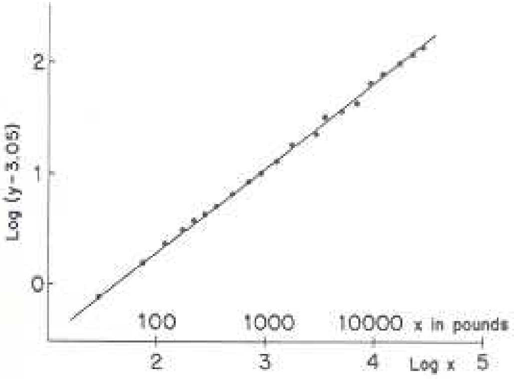


Figure 2

The points come from Form 4 for Rocky Mountain 1972, for pickup and delivery at shipper and consignee. The line is Eq. 2 with the least squares values of the constants for this cost-region,

$$\log (y-3.05)=\log 2.00 +.762 \log (x/100).$$

Most of the 25 sets of data (except for Figure 1) fit equally well.



CONCLUSIONS

The conclusions stated here are based on the least-squares values of the constants *a*, *b*, *c* in Eqs. 1 and 2; also on scores of preliminary charts, two examples of which appear as Figs. 1 and 2. The values of the constants *a*, *b*, *c* appear in Table I. The standard errors give some indication of how

Table I

Values of a, b, c for Stop-Time Derived from Form 4 of the Interstate Commerce Commission, for Various Cost-regions, with Standard Errors

Cost-region	At Shipper and Consignee						At Connecting Carrier					
	a	σ_a	b	σ_b	c	σ_c	a	σ_a	b	σ_b	c	σ_c
Middle Atlantic, 1973	4.92	.29	2.35	.21	.758	.024	2.62	.20	2.49	.35	.719	.048
East South, 1973	4.71	.23	2.54	.17	.728	.018	2.75	.07	1.77	.10	.817	.024
Intra South, 1973	4.66	.07	1.84	.08	.773	.013	3.04	.39	1.91	.30	.780	.048
South Central, 1973	4.60	.52	2.46	.34	.714	.028	3.22	.33	2.23	.31	.740	.047
Southwest, 1972	4.07	.05	1.67	.07	.805	.014	2.43	.40	1.99	.34	.755	.043
Middlewest, 1972	4.02	.11	2.36	.10	.716	.010	3.16	.50	2.31	.37	.735	.037
Rocky Mountain, 1972	3.05	.05	2.00	.06	.762	.008	2.08	.24	1.52	.19	.871	.039
Pacific, 1972	3.81	.22	1.90	.20	.758	.035	2.88	.55	1.86	.43	.784	.054
Transcontinental, 1972	4.33	.28	2.42	.21	.727	.023	2.45	.15	2.27	.31	.717	.047
New England I, 1971	3.79	.28	2.10	.19	.749	.021	2.00	.44	2.50	.43	.637	.080
New England II, 1971	4.24	.43	2.17	.25	.783	.026	2.50	.37	1.43	.37	.889	.077
East Central, 1971	4.59	.21	2.58	.15	.719	.013	2.62	.42	1.85	.45	.819	.089
Central, 1971	4.29	.10	2.60	.13	.663	.015	.50*	.48*	5.71*	1.02*	.471*	.045*
Average of the above numbers	4.24	xxx	2.23	xxx	.743	xxx	2.65	xxx	2.01	xxx	.772	xxx

* Excluded from the averages.

the equation fits the data. Better indications are given in Figs. 1 and 2. Fig. 1 shows the worst fit of Eq. 2. Fig. 2 shows another set of data, between which there was little choice: they all fit about equally well.

Table II shows the average stop-time for selected weights for pickup and delivery at shipper and consignee on the left, and at connecting carrier on the right, based on national averages as shown at the foot of Table I.

The constant *a* represents that portion of stop-time that is independent of the weight of the shipment picked up or delivered (cf. the text that follows Eq. 1). This constant varies from region to region for shipper and consignee over a range that is allowable in view of the standard errors of *a*; likewise for connecting carrier. There appears to

Table II

Average Total Man-Minutes at Stop for Pickup and Delivery, Calculated by Use of Eq. 1

Weight of Shipment in Pounds	At Shipper and Consignee		At Connecting Carrier	
	$a=4.24$, $b=2.23$, $c=.758$		$a=2.65$, $b=2.01$, $c=.758$	
	Minutes Total	Minutes per cwt	Minutes Total	Minutes per cwt
50	5.56	11.12	3.84	7.68
75	6.03	8.04	4.27	5.69
100	6.47	6.47	4.66	4.66
150	7.27	4.85	5.38	3.59
200	8.01	4.01	6.05	3.02
250	8.71	3.48	6.68	2.67
300	9.37	3.12	7.27	2.42
350	10.00	2.86	7.85	2.24
400	10.62	2.65	8.40	2.10
450	11.21	2.49	8.94	1.99
500	11.79	2.36	9.46	1.89
600	12.91	2.15	10.47	1.74
700	13.99	2.00	11.44	1.63
800	15.03	1.88	12.37	1.55
900	16.03	1.78	13.28	1.48
1000	17.01	1.70	14.16	1.42
1500	21.61	1.44	18.31	1.22
2000	25.84	1.29	22.12	1.11
4000	40.77	1.02	35.58	.889
6000	53.92	.899	47.42	.790
8000	66.02	.825	58.33	.729
10000	77.40	.774	68.60	.686
12000	88.25	.735	78.37	.653
14000	98.66	.705	87.76	.627
16000	108.72	.679	96.82	.605

be no correlation between (a) the constant *a* for shipper and consignee and (b) the constant *a* for connecting carrier. In other words, there appears to be a national figure for the constant *a* for shipper and consignee, and another national figure for connecting carrier, with only statistical fluctuations from one region to another.

It is noteworthy that the constant *a* is on the average 1.6 minutes less for connecting carrier than for shipper and consignee (2.65 vs. 4.24). This inequality seems reasonable since connecting carriers are ready at appointed times to receive freight from another carrier or to hand it over.

The constant *b* reflects the speed of motion, once the freight starts to move. A low value of *b* indicates speed better than average. Differences in *b* between regions, if differences existed, would indicate differences in efficiency. As with the constant *a*, the constant *b* for shipper and consignee varies from region to region within a range that is allowable in view of the standard errors. Likewise for connecting carrier. Again, as with the constant *a*, there is no correlation between the constant *b* for shipper and consignee and for connecting carrier. The author, therefore, adopts for Table II for shipper and consignee average values of *a* and *b* under shipper and consignee and likewise for connecting carrier.

The constant *c* (the slope of the logarithmic lines, as in Figs. 1 and 2) is the most important constant of the three (*a*, *b*, *c*). It tells how the cost of loading and unloading freight varies with the weight. The slope *c* is the prime purpose of this investigation. It dominates the ratio of stop-time for a heavy weight to stop-time for a light weight.

The constant *c* exhibits near uniformity over all regions. The average value of *c* for shipper and consignee and also for connecting carrier is .758, which is recommended for all regions.

The recommended value for *c* means that the man-minutes at stop-time for delivering a shipment of 5000 pounds is not 10 times the man-minutes required for 500 pounds, but is only 5.7 times as much ($10^{.758}=5.7$).

One of the main uses of Table II would be for rate-making. Another use would be an aid for the reduction of costs. The management of any carrier may measure its own costs against the average if it wishes to look into the matter of possible causes of a significant difference. Comparison of costs is facilitated by use of the constants *a*, *b*, *c*. Individual costs would require, for comparison, individual constants *a*, *b*, *c*, derived from an appropriate series of measurements, possibly patterned after Form 4.

It would be a mistake for the management of a carrier to proceed on the thought that if a driver or a group of drivers seem to show a time longer than average, it is because these drivers are poor in performance and could do better under the existing system. Interpretation of data requires careful application of the statistical method. Reduction of costs should be approached in two ways: (1) alterations of the system, the responsibility of management, to facilitate better efficiency without additional effort on the part of the driver; (2) help to drivers by discovering, by statistical methods, which drivers are out of line. Both moves are important, though experience shows the first needs greater attention.[2]

As will appear later, it is questionable whether there are any meaningful differences in the constant *a* in Table II from one cost-region to another. The same remark holds for the constant *b*. The observed differences from region to region may reflect differences in the administration of Form 4 from region to region,[3] rather than (as is commonly supposed) different ways to handle freight in the various regions or different types of freight. It is also possible that the differences from region to region for shipper and consignee may arise from different degrees of urbanization. This possibility leads to the suggestion that new principles by which to understand stop-time might emerge from tabulation of the original data from Form 4 in terms of a new set of cost-regions defined, not as geographic areas, but in four or five strata formed by degree of urbanization.

Differences in the constants *a* and *b* from region to region for connecting carrier may reflect different systems for the interchange of freight and different relative amounts of freight interchanged. This suggestion may indicate the direction for further research on the data from Form 4.

The data used here are for pickup and delivery taken together. One could, of course, separate pickup from delivery and could furthermore separate pickup into two or more density-groups; likewise for delivery. One would find that the constants derived from pickup differ slightly from the constants for delivery. One would expect also some slight variation by density. The conclusions presented here are basic to further research.

THE MATHEMATICAL RELATIONSHIP

The mathematical relationship fitted here is the same as it was in Part I, namely,

$$(1) \qquad y=a+b(x/100)^c$$

where

x is the weight, in pounds, of a shipment, x/100 its cwt.

y is the average man-minutes required to handle shipment of weight x.

a is a constant number of man-minutes, independent of weight. This time is allowance for paper work, sorting, studying illegible addresses, plus counting pieces, finding the consignee or someone authorized to sign the delivery-receipt, finding the man authorized to sign the shipping-order.

b is a constant.

c is a constant, the slope in Fig. 1 and 2.

y−a is the variable cost (measured in man-minutes) of handling weight x.

In logarithmic form, Eq. 1 appears as

$$(2) \quad \log(y-a)=\log b+c\log(x/100)$$

A plot of log (y−a) on one axis and of log (x/100) on the other will give a line, provided (a) the appropriate constant *a* is inserted and (b) *c* is a constant independent of weight, as the data in fact do indicate (see Figs. 1 and 2).

The method of fitting the curve to the data was the method of least squares, with equal weights for log (y−a), and with log x free of error. This is very close to the correct weighting, as explained in the earlier paper.[4]

COMPARISON WITH THE COMMISSION'S PROCEDURE

As the author understands, the Commission, for the computation of minutes per shipment (the basis for the calculations presented here) allocates a number of minutes for overhead time to each shipment picked up or delivered at one stop. The active time on a multiple pickup or delivery is then apportioned amongst the shipments in proportion to weight. The total time, overhead plus active, for all the shipments picked up or delivered at one stop, is equal to the total time that elapsed from stop to start. The simple illustration in Table III for delivery of three shipments shows the difference between the Commission's treatment and the relationship derived here (Eq. 1 or its equivalent, Eq. 2). In Table III for illustration of application of the Commission's rule, 2.5 minutes for the overhead time was used.

The three shipments weigh 200 pounds, 400 pounds, and 2000 pounds. The total time to deliver the three shipments to a consignee would be 44.47 minutes by Eq. 1

Table III

Illustrative Example of Multiple Delivery to Show the Difference Between Eq. 1 and the Commission's Procedure. Three Shipments Delivered to Consignee at One Stop. The Total Time at the Stop for the Commission Is Set Equal to the Total Time Calculated by Eq. 1.

		Equation 1 a=4.24, b=2.23, c=.758				Commission			
Shipment Number	Weight (pounds)	Overhead	Active	Total	Mins per cwt	Overhead	Active	Total	Mins per cwt
1	200	4.24	3.77	8.01	4.00	2.5	2.84	5.34	2.67
2	400	4.24	6.38	10.62	2.66	2.5	5.69	8.19	2.05
3	2000	4.24	21.60	25.84	1.30	2.5	28.44	30.94	1.55
All three	2600	12.72	31.75	44.47	xxx	7.5	36.97	44.47	xxx

This equation and the Commission's rules would differ in allocation of this total time to the three separate shipments. The difference shows up clearly in Table III. The ratio of active times for weights 2000 pounds and 200 pounds is 21.60/3.77=5.7 by Eq. 1, but is exactly 10 by the Commission's rule. The Commision's rule, by comparison with Eq. 1, charges too much time to the heavy weight, and not enough time to the light weight.

Most deliveries are for single shipments. Most pick-ups are for more than one shipment, the average number being now around 2.4. The Commission's rule for pickup or delivery leads to no distortion in the original data on man-minutes per shipment for pickup or delivery of single shipments, and to very little distortion for shipments all within the same weight-bracket. It leads to substantial distortion, however, for pickup or delivery of shipments of widely different weights at a single stop. This distortion in the original data is in the direction of an over-estimate of the man-minutes for heavy shipments and a corresponding under-estimate for light shipments.

This distortion for pickup or delivery of more than one shipment of widely different weights at a stop is built into the basic data that went into the calculations. For this reason, the slope $c=.758$ obtained here is conservatively high. Re-work of Form 4 at the Commission by use of Eq. 1, followed by repetition of all the author's calculations, would lead to a slope slightly lower than the figure $c=.758$ obtained here, and to a slightly higher ratio of stop-time for light weights to the stop-time for heavy weights.

FOOTNOTES

[1] W. Edwards Deming, "On a Rational Relationship for Certain Costs of Handling Motor Freight," *Transportation Journal*, vol. 17, No. 4, 1978, pp. 5–13.

[2] W. Edwards Deming, "On Some Statistical Aids Toward Economic Production," *Interfaces*, vol. 5, 1975.

[3] Max Bershad, Margaret Gurney, Leon Pritzker, Benjamin J. Tepping, Technical Note No. 2, Bureau of the Census, Washington 1969. W. Edwards Deming and Morris H. Hansen, "Some Theory on the Influence of the Inspector and Environmental Conditions," *Statistica Neerlandica*, vol. 26, No. 3, 1972: pp. 101–112.

[4] W. Edwards Deming, *Statistical Adjustment of Data* (Wiley 1943; Dover 1964), Ch. 7.