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Adam Jaworski

TRANS-CANADA AIRLINES' PROGRESS, 1946-1950—A COMPARISON WITH U. S. TRUNK LINES

By ADAM JAWORSKI*

Research Engineer, Air Transport Board; M.Sc. (Eng.) 1931 Lwow; M. Law 1936 (Warsaw, Statistical Course, USAAF, Harvard, 1944-45; Dr. (Iur.) 1946 Oxford; *Formerly*, Lt. Col. Polish Air Force, England, 1946.

ON this continent Trans-Canada Air Lines is operating the largest unduplicated route mileage (8,362 miles in 1950); but in revenue ton-miles flown in domestic services, T.C.A. is in seventh place in the U. S. trunk lines' scale. Therefore, a comparative analysis of T.C.A. and U. S. trunk line operations is here presented to show how T.C.A.'s difficult economic task of serving a large network with a low traffic density affects its financial results.

As a basis for comparison, the U. S. trunk lines are probably the hardest test for any operator in the world because these trunk lines with their high standard of service and dynamic growth of operations are in the front line of civil aviation progress.

The most pertinent factors of traffic and income statistics will be presented by expressing T.C.A.'s data for the period 1946-1950 as a percentage of the U. S. trunk lines' total. In all graphs a semilogarithmic scale has been used because logarithms — as distinct from ordinary scales — show the rate of change and not the absolute values of changes. Progress is better evaluated by the rate of changes rather than by the absolute values of data, especially when two organizations with a different order of magnitude are compared.

TRAFFIC AND REVENUE COMPARISONS

Traffic (Revenue Ton-Miles). It is evident from Table 1 and Figure 1 that T.C.A. traffic in revenue ton-miles not only increased during the period 1946-1950, but increased faster than the corresponding figures for the trunk lines, however, the rate of progress diminished towards the end of the period.

Revenue Ton-Miles Related to Fuel Consumption (Fig. 1). Revenue Ton-Miles per gallon of gasoline consumed, is a more useful index than the commonly quoted weight load factor, because it reflects to some extent the fleet's characteristics. If the same revenue ton-miles are flown between two points by two fleets with equal load factor, it is obvious that when one fleet uses a larger aircraft its direct costs will be less.

* The views expressed in the paper are the author's and do not necessarily represent those of the Air Transport Board.

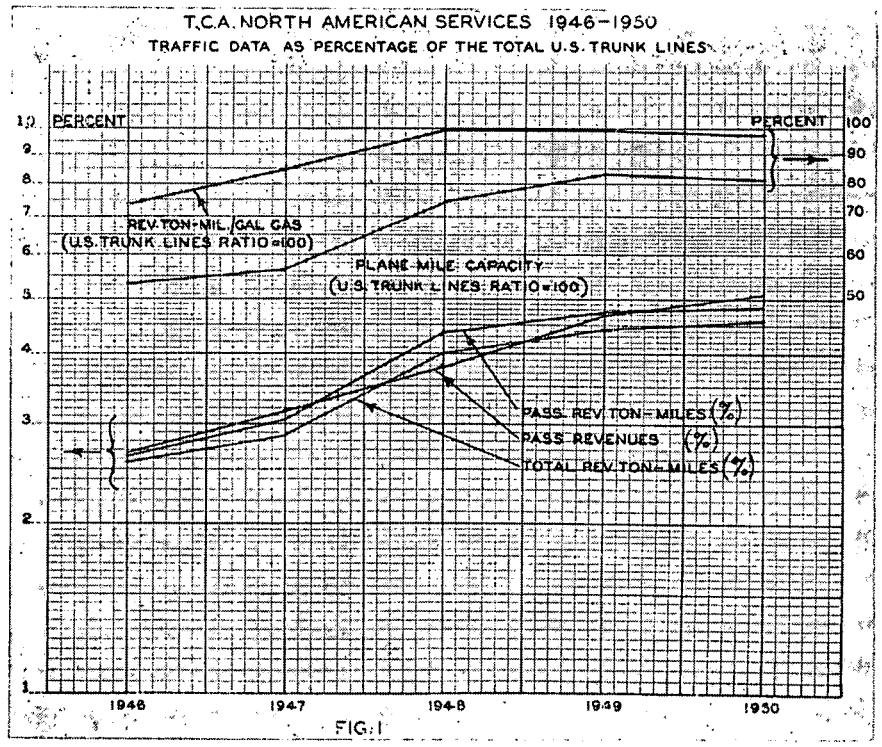

FIG. 1

For T.C.A., the relationship between the revenue ton-miles and gasoline consumed is of special importance, because the unit cost of gasoline in Canada is much higher than in the United States. Fortunately, T.C.A. almost caught up with the trunk lines in regard to this index in 1948 and 1949, but with fleet replacement in the United States with larger aircraft the discrepancy to T.C.A.'s disadvantage may occur again.

T.C.A.'s weight load factor for the period 1947-1950 fluctuated around 57.4 percent, and that of the trunk lines were rising to that level. Weight load factor should be considered together with Plane Mile Capacity and Revenue Ton-Miles per gallon of gasoline consumed. From Fig. 1 it may be seen that the rate of increase in the plane mile capacity is similar to that of revenue miles flown, but a slight decrease is noticeable in 1950.

Passenger and Cargo Traffic. Passenger-miles flown by T.C.A., in relation to the trunk lines are by a fraction of one percent higher than the revenue ton-miles, with a slightly smaller rate of increase in 1948-1949 (Fig. 1). The rate of increase of Passenger Revenues, when compared with passenger traffic was slightly less in 1948 but a bit higher in 1949.

The revenue ton-miles of T.C.A. cargo, composed of freight, express and excess baggage, represent less than one-half of the passenger

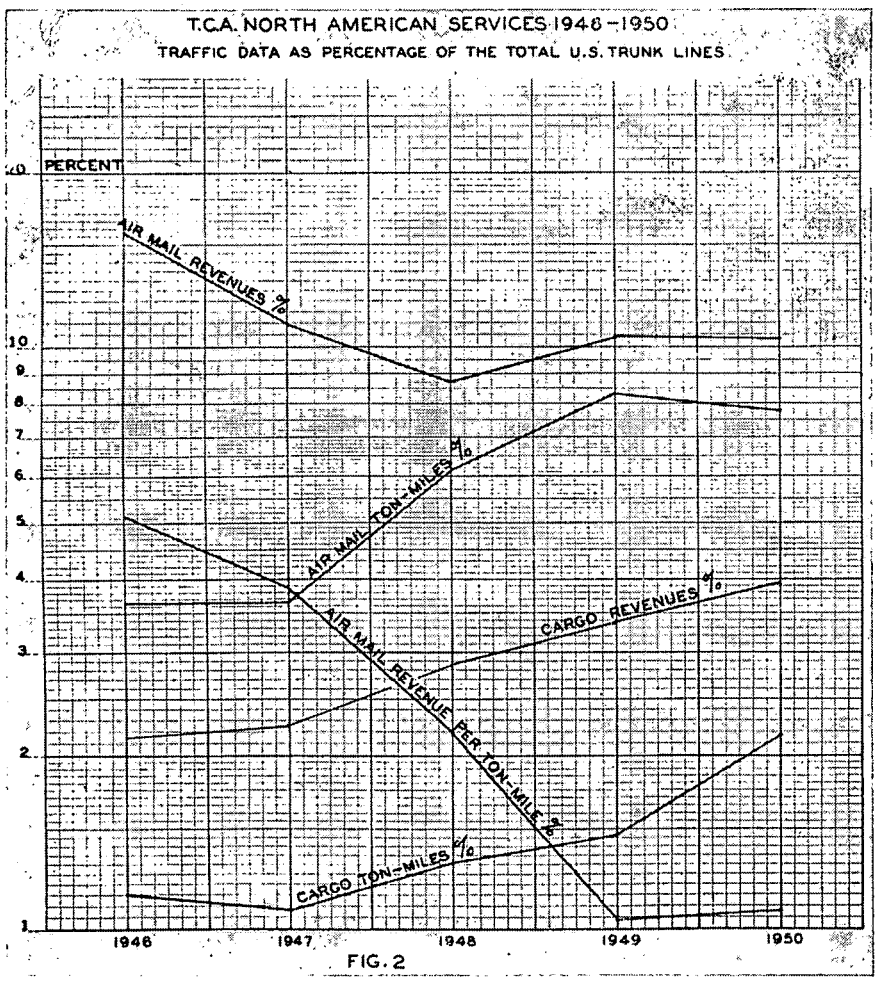

FIG. 2

traffic. Both these items are related on Figs. 1 and 2 to the corresponding figures of the trunk lines, and both have a relative upward trend.

The cargo revenues on a percentage basis of U. S. trunk carriers were approximately twice as high as the cargo traffic, and the rate of increase is also higher, except in 1950. (Fig. 2.) This fact is due mainly to a faster decrease of revenues from ton-miles of cargo for the U. S. trunk lines as compared with the T.C.A. data.

Air Mail: Traffic and Revenue. Following the "all-up" mail policy in Canada, which benefits every user of post services in this country, the ton-miles of mail traffic show a relatively sharp percentage increase during 1947-1949, as indicated on Fig. 2 but this increase changes to a small decrease in 1950.

There is still controversy about the air mail revenue per ton-mile to U. S. carriers, because the payments for carrying mail have been used to rectify operating losses of some of the air carriers. However,

a separate investigation for each carrier is needed; first to establish the existence of subsidy in payment for carrying mail by him, and secondly, if mail subsidy is involved, what should be attributed to the communities with non-economic revenues and where the carrier is not permitted to abandon the services.

It must be remembered, however, that the present air mail rate of the largest trunk carriers that are carrying more than three-quarters of air mail traffic, is only $0.45 per ton-mile, which is roughly twice the amount paid by the U. S. Post Office to the railways for carrying mail, thus the ratio is the same as that between the air mail letter stamp and the ordinary letter stamp. Although present T.C.A. air mail revenues are still higher than the average of the trunk lines, the drastic downward trend of changes in relative payments for one ton-mile of air mail is evident from Fig. 2.

Total Expenses and Total Revenues. The T.C.A. average rate of increase (related to the progress of U. S. trunk lines) in total revenues, less air mail revenue, is much higher than the total expenses and total revenues of U. S. trunk carriers, as may be seen from Fig. 3. This is a very encouraging fact.

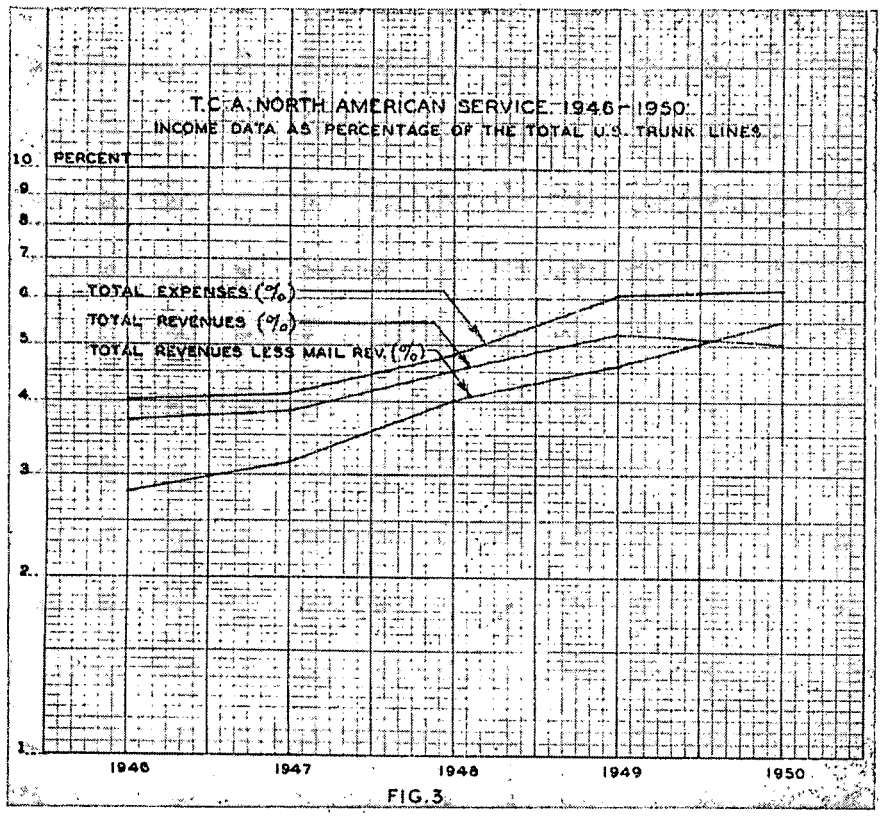

FIG. 3

The unpleasantly higher rate of relative increase in total expenses versus total revenues is obvious, but the real meaning of total revenues will be understood only if the mail payments are evaluated with the actual costs for carrying mail. Until this is done, total revenues less air mail revenue is a better criterion.

On the other hand, in considering U. S. trunk lines total expenses, it should be mentioned that the operating losses in 1946-1948, especially in 1947, and the capital requirement for equipment, have increased considerably the amount of bank loans, thus imposing an appreciable burden for serving long term debts.

The downward relative trend of the total revenues in 1946-1948 in spite of almost unchanged percent of revenues excluding air mail payment was determined by the sharp drop in the relative revenue per ton-mile of air mail carried. (Fig. 2.)

The sharp increase in revenues in the United States in 1950 must be attributed in some degree to the impact of defense preparations. For example, the revenue from military operations represented 3.4 percent of United Airlines' total revenues and in absolute figures exceeds the revenues from carrying express traffic during 1950 ($3.6 million versus $3.1 million).

There is a downward trend in 1946-1948 in relative expense per revenue or available ton-mile, but the trend seems to level out in 1949-1950 with appproximately a 25 percent higher cost per revenue ton-mile.[1]

Traffic and Different Operation Indices

Traffic Density. In railway statistics, traffic density is reported in gross or net ton-miles per mile of operated road. It was found in the United States that for a very light density (approximately ⅓ below the average) railway operating costs increased considerably but after obtaining an average level of density, there was not a further decrease of costs[2]).

To some extent there is an analogy in air transportation, as indicated by the T.C.A.'s data in Table 1.

In 1949, T.C.A.'s traffic density was 39.1 percent of the trunk line average, although in available ton-mile T.C.A.'s figure is as high as 66.8 percent of trunk line average and 70.9 percent of the revenue ton miles. Therefore, T.C.A.'s low traffic density explains its higher cost than the trunk lines with the same order of available ton-miles flown.

The importance of traffic density was strongly underlined by Dr. D. W. Rentzel, Chairman of the C.A.B. (at that time) who stated during recent investigation of non-scheduled operations: "We have found

[1] An analysis of T.C.A.'s particular expenses for the period 1946-1950, has been submitted by the writer in the May issue of the Journal of the Royal Aeronautical Society, 1952.

[2] K. T. Healy: THE ECONOMICS OF TRANSPORTATION IN AMERICA, p. 168. Published—Ronald Press, New York, 1940.

TABLE 1

TCA'S AND U.S. TRUNK LINES[x] TRAFFIC FACTORS ON THE NORTH AMERICAN ROUTES (1946-1950)

Year (1)	1946 (2)	1947 (3)	1948 (4)	1949 (5)	1950 (6)
1. TRAFFIC (Rev. Ton-Mi. $000,000's)					
TCA	16.7	19.6	28.2	35.8	44.3
U.S. Trunk Lines	650.0	683.4	703.1	808.9	964.1
2. WEIGHT LOAD FACTOR (%)					
TCA	70.8	58.0	57.8	56.5	57.2
U.S. Trunk Lines	66.2	57.0	52.0	53.2	57.2
3. PLANE MILE CAPACITY (TONS)					
TCA	1.72	2.17	3.19	3.87	4.15
U.S. Trunk Lines	3.22	3.85	4.28	4.66	5.09
4. REVENUE TON-MILES PER (U.S.) GALLON GASOLINE CONSUMED					
TCA	2.04	2.03	2.20	2.27	2.37
U.S Trunk Lines	2.78	2.39	2.20	2.27	2.43
5. TRAFFIC COMPOSITION Rev. Ton-Mi. ($000,000's)					
TCA—Passenger	15.0	17.65	24.5	30.5	37.2
TCA—Cargo	0.51	0.76	1.4	1.9	3.3
TCA—Mail	1.2	1.2	2.3	3.4	3.6
U.S.—Passenger	573.0	579.9	558.7	638.0	767.3
U.S.—Cargo	44.2	70.6	106.9	130.0	150.5
U.S.—Mail	32.9	32.9	37.5	40.9	46.3
6. AVERAGE PASSENGER TRIP (MILES)					
TCA	510	420	469	479	480
U.S. Trunk Lines	497	490	473	468	460
7. AVERAGE SPEED MPH					
TCA	177	168	178	183	183
U.S. Trunk Lines	169	170	178	185	188
8. TRAFFIC DENSITY (Rev. Ton-Mi./Route Mi. Op.)					
TCA	2,658	2,522	3,591	4,467	5,293
U.S. Trunk Lines	13,500	13,360	12,860	14,520	17,180
9. REV. TON-MILES PER DOLLAR SPENT ON WAGES SALARIES					
TCA (R.T.M./Can. $)	1.95	2.25	3.25	3.24	3.90
U.S. Trunk Lines (R.T.M./U.S. $)	3.86	3.49	3.35	Not available	

x)—Caribbean and Hawaiian Airlines not included.

it true in air transportation that the two most important factors in costs are density of traffic and length of haul."[3]

According to the BEA experience with Viking aircraft, on the London-Paris route, (215 miles) the doubling of traffic density will bring down the total operating cost per available ton-mile by 20 percent. Similar increase in utilization or stage length will decrease total cost by 19 or 19.8 percent respectively. (The last figure indicates that the 215 mile stage length for the Viking is too short, as it probably is for any existing aircraft of the 27 passenger class). But it is underlined by P. G. Masefield who presented these figures, that the greatest saving in total costs per available ton-mile (approximately 23

[3] American Aviation Daily, April 25, 1951, page 350.

percent) will be obtained by substituting for the Viking the more modern "Ambassador"[4].

Traffic density, in turn is determined by several factors, from which the route characteristics is the most important (see C.A.A. traffic study quoted below). Professor H. K. Koontz in an excellent analysis of the trunk lines, stated that the poor route characteristics, e.g. between small towns, and not the size of the company or the over-competition on particular routes, have been chiefly responsible for the deficit of the not-successful trunk lines.[5]

However, the proposed remedy; consolidation of the present 16 trunk lines into four larger groups will not improve the poor routes' characteristics if the present flight frequencies are unchanged. It will only rob Peter to pay Paul. The saving in overhead by merging into larger units will be negligible because according to Professor Koontz's analysis the size of the company is not significant in the unit costs.

Surely, the elimination of duplicating services of some of the air-lines will represent a considerable saving, but this was already in the study by F. W. Gill and G. L. Bates who pointed out the appreciable losses inflicted by the over-competition.

Average Passenger Trip and Average Speed. A slight downward trend in average length of passenger trip between 1946-1950 is shown both by the trunk lines and T.C.A., so that the relative position of T.C.A. was practically unchanged with its passenger trip approximately 2.5 percent longer as compared with the trunk lines average (Tables 1 and 2). The C.A.A.'s basic formula for the traffic between two cities shows that it is roughly proportionate to the product of the populations of these two communities divided by the distance between them, assuming economic character and area density held constant.[6] Therefore, T.C.A.'s relative increase of traffic may indicate that for the T.C.A. Domestic system the ratio of population of connected places and corresponding distances may grow faster than for the trunk lines.

The trend of T.C.A.'s relative average speed between 1946-1950 is slightly downward (Table 1), although there is a significant upward trend in absolute figures.

Revenues to Gross Property. The ratio of total revenue to the combined value of fleet and ground equipment, could be defined as the index of capital utilization. As the same property is used by T.C.A. and some of the trunk line carriers for overseas operations, by

[4] P. G. Masefield: SOME ECONOMIC FACTORS IN AIR TRANSPORT OPERATION, Brancker Memorial Lecture, The Journal of the Institute of Transport, London, March, 1951, page 98, Figs. 12 & 17.

[5] Koontz, H. D., Economical Managerial Factors Underlying Subsidy Needs of Domestic Trunk Line Carriers, 18 Journal of Air Law and Commerce (1951).

[6] In addition to these two qualitive factors, there are some others not susceptible to mathematical measurement like; direct verus indirect connections, number of schedules, time of schedules, service standards, etc. Some very interesting statistical data on these points are given by the C.A.A. publication— EFFECTIVE COMMUNITY AIR TRAFFIC POTENTIAL — Washington, D. C., July, 1950.

TABLE 2

TCA's AND U.S. TRUNK LINES[x] OPERATING REVENUES AND EXPENSES FACTORS ON THE NORTH AMERICAN ROUTES (1946-1950)

*(TCA Revenues and Expenses are in Can. $=.909 U.S. $)

Year (1)	1946 (2)	1947 (3)	1948 (4)	1949 (5)	1950 (6)
1. REVENUE COMPOSITION ($000,000)					
TCA—Passenger	8.0	10.5	14.9	19.5	24.2
TCA—Cargo	0.38	0.53	0.89	1.2	1.7
TCA—Mail	3.8	3.8	4.6	5.4	5.4
U.S. Passenger	273.	303.	335.	378.	431.
U.S. Cargo	16.	22.	28.	32.	39.
U.S.—Mail	21.	29.	48.	45.	46.
2. TOTAL EXPENSES PER REV. TON MILE ($R.T.M.)					
TCA	0.827	0.872	0.782	0.780	0.714
U.S. Trunk Lines	0.488	0.542	0.582	0.538	0.480
3. TOTAL REVENUES PER REV. TON-MILE ($/R.T.M.)					
TCA	0.752	0.782	0.740	0.740	0.719
U.S. Trunk Lines	0.482	0.520	0.586	0.568	0.542
4. MAIL REVENUE					
[a] Percent of Total Rev.					
TCA	29.5	24.9	22.3	20.4	17.0
U.S. Trunk Lines	6.8	8.1	11.7	9.8	8.8
[b] Per Mail Ton-Mile $					
TCA	3.12	2.98	2.03	1.59	1.48
U.S. Trunk Lines	0.55	0.70	0.84	1.35	1.17
5. REVENUES EXCL. MAIL PER REV. TON MILE (Mail Traffic Excluded)					
TCA	0.571	0.628	0.626	0.652	0.597
U.S. Trunk Lines	0.472	0.549	0.549	0.540	0.522
6. REVENUES TO GROSS PROPERTY[a]					
TCA—Domestic and Overseas	0.987	0.565[b]	1.042	1.740[a]	2.407[a]
U.S. Scheduled— Domestic and Overseas	1.41	1.22	1.24	1.945[a]	2.154[a]
7. TOTAL REVENUES TO NATIONAL INCOME Per Mile (0/000)					
TCA	1.31	1.40	1.67	2.01	2.25
U.S. Trunk Lines	1.74	1.80	1.85	2.12	2.23

[x] Caribbean and Hawaiian Airlines not included.

[a] Property and Equipment without deductions for depreciation for the period 1946-1948 and Net Property & Equipment for the period 1948-1950, therefore the periods are not comparable.

[b] Purchase of the North Star Equipment for $12.9 mill.

NOTE: There may be a difference between Total Revenue and the sum of revenues from passenger, cargo and mail, because the total revenues include also non-scheduled revenues and these figures are rounded.

SOURCE: As in Table 1 and for the national income in Canada and the United States:

National Accounts, Income and Expenditure, Preliminary 1950, Dominion Bureau of Statistics, Ottawa.

Survey of Current Business, July, 1950 and February, 1951. U.S. Dept. of Commerce, Washington, D. C.

considering this index, it is necessary to include the whole system (domestic and overseas).

For T.C.A. this index is increasing in absolute values and relatively to the U. S. trunk lines as may be seen from Table 2, disregarding the low level in 1947 owing to the purchase of North Stars for $12.9 millions.

Only the net book-value of the property and equipment was available for the trunk lines for 1949 and 1950.

Revenue Ton-Mile related to Wages and Salary. In 1948 T.C.A. reached 106.7 i.e., $3.25 \times 100 \div 3.35 \times 0.909$, percent of trunk lines output in revenue ton-mile per U. S. dollar spent on salaries and wages, (for the period 1946-1950, it was assumed Canada $ = 0.909 U. S. $). This index is probably a better indication of organization efficiency than the relation to number of employees which disregards the expense for that purpose.

The rate of progress of this factor is the most striking of all factors of traffic and income previously discussed. However, no data are available for the trunk lines for the 1949-1950 period.

Total Revenue related to the National Income. No single index or series of numerical factors can define adequately the position of any of the transportation modes in the national economy, especially if such means have been in operation only during the last thirty years. It may be said that transport in the economy has more imponderabilia than any other industry. The total transportation revenues do not show how the pattern of many industries was decided by transportation activities.

With these reservations, a single index was chosen to make possible at least a very general appraisal of the relative position in the national economy of T.C.A. and the trunk lines. The index of total revenues of the carriers to the national income, seems to be suitable for this purpose. The upward trend of this index during the period 1946-1950 is evident for T.C.A. and the trunk lines. (Fig. 3.) In 1950 T.C.A. had improved its relative position in the national economy by 72 percent as compared with 1946. The corresponding figure for the trunk lines is 28 percent. T.C.A. Domestic Services in 1950 had a better relative position in the national economy than the trunk lines. In 1946 the reverse was true.

Trend in Relation of Revenues from Different Traffic and Cost Consideration

When the revenues from passengers, cargo (express, freight, excess baggage) and air mail, are taken on a weight and distance basis, i.e., per ton-mile, a relationship is obtained which is far removed from a cost ratio, even when this latter ratio could be only roughly estimated.

Taking in each case the revenues from a ton-mile of cargo as 100, we see the following trend:

REVENUE PER TON MILE FROM CARGO COMPARED WITH THAT FROM PASSENGER AND MAIL[7]

Cargo Revenue per Ton-Mile = 100

	Year	1946	1947	1948	1949	1950
T. C. A.	Passenger	71	85	96	101	126
	Mail	419	428	319	252	287
Trunk Lines	Passenger	131	167	229	241	217
	Mail	152	224	321	549	452
United Air Lines	Passenger	151	179	262	282	260
	Mail	145	161	412	296	269

The upward trend of T.C.A.'s ratio of passenger revenue versus cargo revenue on weight basis, in 1950, is nearly in the same place as the corresponding ratio of the trunk lines was in 1946, but the mail-cargo ratio is nearly equal to that of United Air Lines, which may be considered as the forerunner in trends for the trunk lines. (But with the new mail rate of $0.45/ton-mile for the Big Four, the mail-cargo ratio for the United Air Lines will decrease probably up to 175).

Equal revenue for one ton of passenger and mail seems to be a goal for T.C.A. and for U. S. trunk lines. For T.C.A. the trends indicate that this may be reached in 1952, close to a ratio of 140, which seems to be rather low. This could be improved by slowing the rate of decrease of the mail-cargo ratio and speeding up the passenger-cargo revenue per ton-mile relationship. If the railway revenue ratio on ton-mile basis for passenger-mail-cargo-revenue is as 5:3:1, the airlines, after reaching in a few years, the United Air Lines position of 1950, i.e., the ratio 3:3:1, will drive to the next step, probably 3.5:3:1. (It may be recalled that the Ernst & Ernst report on mail-pay-subsidy, based compensatory mail rate on the first class passenger fare structure and treated cargo as a fill-in service).

However, it must be remembered that space requirement (cubic feet) for unit weight is 5.3 higher for passengers than for cargo or mail[8]). Besides the value per pound and loading density, there are

[7] Cargo revenue of the United Air Lines was compiled from the United Air Lines Annual Report—1950, as a weighted average from express and freight revenue. In 1950, revenue per ton-mile was $0.58 for passenger, $0.60 for mail, $0.34 for express, $0.19 for freight, with a weighted average of $0.22 for cargo (express and freight).

[8] Passenger space requirement of the B.O.A.C. "Argonaut" (built in Canada) is 0.42 cu. ft./lb. of passenger weight, and space requirement (i.e., reciprocal of the loading density) for cargo according to the S.B.A.C. formula is) .079 cu. ft./lb. of cargo. In the A.T.A. recommendation this is increased to 1.1 cu. ft./lb. of cargo or baggage. On freighter aircraft like Bristol Freighter of Fairchild Packet, the cargo space requirement is much higher than S.A.B.C. or A.T.A. standards, owing to the galley allowances.

other factors which have a decisive influence on transportation of a particular commodity by air.[9]

No wonder that on the railways, where more experience has been accumulated in accounting and where passengers have more room, "figuratively speaking — the average railroad express rate makes it five times as cheap to ship one-self rail express as to buy a Pullman ticket."[10]

Passenger transportation on the railways is only a small fraction of goods carried, (the opposite is true for the air carriers), and mostly passenger fares are below fully allocated expenses, but in many instances passenger revenues are above the out-of-pocket cost, thus contributing to the overheads. However, cost allocation to passenger trains — likened to the air mail — is a very arbitrary procedure, because most costs are common to all services.

The aircraft power requirements for a given speed and gross-weight are, broadly speaking, directly proportional to the frontal area. One pound of passenger weight requires $5.3^{2/3} = 3.04$ times more engine power than one pound of air cargo. If so, by dividing by 3.04 all power expenses (fuel, oil, engine labor, material and depreciation) and deducting the Passenger Service Account, the reduction in total expense of the T.C.A. Domestic system in 1949 would be as high as 22 percent, if instead of passengers an equal amount of ton-mile of cargo had been flown, this figure may be considered as a minimum because no saving is accounted for in respect of sales expenses, upkeeping of cabin equipment, and flight insurance, which expenses are certainly higher for passenger transportation than for cargo. (Only air-express includes pick-up and delivery cost, which is not borne by the airlines in the case of passenger movement.)

This theoretical estimate of at least 22 percent lower cargo transportation cost than passenger is supported by British European Airways' experience, which shows that the total operating cost per capacity ton-mile for the "Passenger" Dakota (42.8d/C.T.M.) is 26.2 percent higher than for the "Freighter" Dakota (33.6d/C.T.M.) on the same stage lengths. (Average stage length 166 miles and yearly utilization 1,750 hours.) The variable costs (cruising plus landing cost) for the "Passenger" Dakota are 33.6 percent greater than for the Freighter. By increasing the utilization to 3000 hr. per year, the difference in total cost per available ton-mile between "Passenger" and "Freighter" version of the Dakota is increased to 28 percent.[11] For a

[9] C.A.A. Report: DOMESTIC AIR CARGO, Washington, D. C. 1948, analyses for such factors as: 1) Concentration of source of supply, 2) Distance to market, 3) Ability to absorb transportation charges (measured by the difference between wholesale price of the product and the cost of wages or materials for producing it), 4) Perishability or seasonability. A fifth factor may be added: susceptibility to pilferage (see Air Transportation, April, 1951, p. 10).

[10] T. Wolfe: AIR TRANSPORTATION, p. 478, McGraw-Hill, New York, 1950.

[11] The information regarding Dakota Passenger and Freighter was kindly given by P. G. Masefield, Chief Executive of B.E.A., in a letter of April 16, 1951.

larger aircraft this difference will be still higher,[12] especially if the aircraft was originally built for cargo transportation. Present ground-costs of cargo handling are undoubtedly high, but passenger handling in the impressive offices maintained by some of the airlines is unlikely to be less expensive.

Conclusion

All things considered, it is a reasonable deduction that T.C.A.'s rate of progress as related to the trunk lines' operations has had an upward trend during the period of 1946-1950; such an achievement speaks for itself. But speeding up the replacement of fleets by the trunk lines with an aircraft of a higher working capacity that may double the present total available seat-miles, will make the relative progress for T.C.A. more difficult in the future than it has been in the past.

The impact of defense preparations on the 1951 air traffic increase cannot be assessed at present, but it seems probable that it will slow down in 1952, thus the rate of progress will be closer to the 1946-1950 trend lines than to the spectacular results of 1951.

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[12] The total cost per mile in 1949 of the C-54 (cargo) operated by Flying Tiger was $1.16 against $1.56 (average from 13 trunk lines) for the DC-4 (passenger). Thus DC-4 passenger is approximately (as the depreciation methods may differ) ⅓ higher in total operating cost per mile than its cargo version. It is obvious that per ton-mile the difference will be still higher. (Compiled from the data in K. E. Kast's paper: "The Air Carrier's Problem" Air Transportation, May, 1951.