Effect of Highway Improvement on Travel Time of Commercial Vehicles

A Twenty-Five-Year Case Study

GERALD A. FLEISCHER, Assistant Professor of Industrial Engineering, Stanford University

The time saved by both private and commercial vehicles as the result of expenditures for highway construction, improvement, and maintenance is clearly of considerable importance to those engaged in evaluating prospective consequences of investment decisions. Studies of actual economic analyses indicate that decisions are frequently quite sensitive to the way in which analysts treat the value of time.

In essence, there are two aspects to the "time problem": (a) the numerical dollar value placed on units of time savings, and (b) the method of introducing the savings in the analysis. The subject of this paper applies principally to the latter; it is essentially a case study, examining in detail the interrelationships of two major sections of highway and a principal commercial user over a 25-yr period. Evidence developed clearly indicates that time is not economically significant simply when it is "released" by highway improvement; there is a considerable lag between the point at which time is saved and that at which it can be utilized in an economic sense. If conditions represented by the study are at all representative of conditions elsewhere in the country, then it follows that present methodology is incorrect in that it fails to give proper effect to the timing of this important consequence of highway improvement.

•FOR MANY YEARS in the United States, expenditure of public funds for highway construction, improvement, and maintenance has resulted largely from the subjective judgments of certain elected or appointed public officials. Choosing among possible investment alternatives has in general been guided by the principle of "the squeaky wheel gets the grease" or by so-called "sufficiency rating" techniques. Only isolated instances of application of sound objective methodology have been evident until the early 1950's.

Despite the type of criterion used to select among proposals (benefit-cost ratio, rate of return, excess of benefits over costs, etc.), all methods require measurement of the beneficial and adverse consequences of a particular investment alternative. Furthermore, all analysts agree that the time saved by vehicles, both private and commercial, is relevant to any highway economy study. This paper deals with the economic value of time saved by commercial vehicles as a result of highway investment in the context of quantitative history of a long section of highway over a large number of years in conjunction with the activities of a major user of that highway over the same period. It is the author's observation that such a "macro-view" has rarely been presented before—at least in available literature.

Paper sponsored by Committee on Highway Engineering Economy.

Two stretches of highway have been selected for study: US Interstate 5 between Portland and Grants Pass, Ore. (sometimes called the Pacific Highway or US 99), and US Interstate 5 between Portland and Seattle, Wash. In 1960, the route length of the former was 248 mi and that of the latter was 162 mi. The primary reasons for selection of these two sections of highway are (a) the common carrier of interest has used them over many years, and (b) cost and other data are comparatively readily available. Moreover, the operating schedules of the carrier are such that the cities of Grants Pass, Portland, and Seattle are of particular interest.

Consolidated Freightways, Inc., the largest trucking common carrier in the United States, was selected as the carrier of interest primarily because it has continuously used these routes for many years. Moreover, the company's activities over these highways were believed typical of over-the-road operation in other parts of the country.

The original plan was to examine the interrelationship between the highway and the commercial user for a period of 25 years, 1935-60. Although this objective was accomplished in most instances, data of interest are not complete for that entire period. Every effort has been made, however, to include all usable historical data covering as long a time span as possible between the years 1935 and 1960.

THE PROBLEM

Present Techniques of Treating Commercial Vehicle Time

Although there presently exists considerable controversy as to the appropriate numerical value to be assigned to time savings of commercial vehicles, there is general agreement as to the assumptions underlying the methodology involved in evaluating this time. The purpose of this section is to enumerate and discuss briefly certain common aspects of present techniques.

To consider a simplified but typical example, a project is being evaluated which is designed to save on completion of construction 10 sec per commercial vehicle; traffic studies indicate an average daily traffic (ADT) of 2,000 commercial vehicles in the first year. Then the total commercial vehicle-hours saved in the first year is ordinarily computed to be 10 sec per veh × 2,000 veh per day × 365 days per yr × 1 hr per 3,600 sec, or 2,028 hr. Assuming that this is a 30-year project and that year + 15 will be selected as the base year for purposes of analysis, then, if traffic estimates indicate that ADT in year + 15 will be 150 percent of year + 1, the commercial vehicle time saved in the base year is 1.50 × 2,028, or 3,042 hr. Finally, assuming that the present average hourly straight-time wage rate of commercial vehicle drivers in the geographic area of interest is estimated to be $3.00, then the total average annual value of commercial vehicle time saved is thus assumed to be $3.00 × 3,042, or $9,126. In most studies this sum is interpreted as the equivalent uniform annual benefit attributable to the project resulting from savings in commercial vehicle time.

There are, of course, a number of minor variations to the methodology illustrated by the example. For instance, a different "time cost" per hour may be applied to various classes of commercial vehicles, or the analyst may assume more than one occupant per vehicle. Nevertheless, the procedure just outlined is the one presently in vogue among analysts making highway economy studies in the United States, and occasional minor variations do not negate the general assumptions underlying the methodology.

The first of these assumptions is that time saved has economic value immediately on realization. That is, owners of the affected vehicles are able to make economic use of time saved as soon as it is "released" by highway improvement.

Second, additivity of increments of time is assumed. In the example, the 3,042 hr per yr saved resulted from the addition of many 10-sec increments. It is clear that, if the sum of increments has a given value, each of the individual increments has a proportional part of that value.

Third, it is frequently assumed that total hours of time saved are valued at the average straight-time wage rate of drivers in the geographic area of the highway improvement, although this may be changed due to the results of the Highway Cost Allocation Study (20).

Use of a "base year" concept rather than computations based on gradient growth is a fourth assumption underlying present methodology. That is, the value at the base year is selected as representative of all years, and is interpreted as equivalent to the uniform annual benefit.

Fifth, generally no provision is made for wage inflation. Because only the differences between alternatives are relevant, this omission may be unimportant if all cost elements vary at the same rate or exist in the same proportion in each alternative.

"Additivity of Increments" Argument

Inherent in current methodology is the assumption that small increments of time are additive. For instance, the example assumed that many 10-sec increments of realized time savings could be added together to produce a gross value for number of hours saved during the year.

Several arguments can be used to justify this assumption. First, it is clear that vehicles are not necessarily affected by improvement or construction of a single project but rather the sum of improvements over long sections of highway. That is, if a vehicle traverses 20 mi of highway, and if there are twenty such "10-sec improvements" over those 20 mi, then the time saved is a much larger figure—200 sec.

A second argument advanced in support of the additivity assumption is that these improvements not only affect large sections of highway but also take place over long periods of time. Even the most naive driver should be aware of substantial changes in the highway system in his area over a period of, say, the past five years. In view of these two preceding arguments, it is asserted that, though extremely short time increments may have little or no economic value in themselves, value does result from considering the accumulation of many such incremental improvements over long periods of time and long sections of highway.

A third facet of this assumption is the question of immediate economic usefulness of time saved by vehicles. If, as it has just been argued, the only reasonable way of apportioning savings resulting over the long run is to assign them to individual increments, then it follows that the highway user must be able to take immediate economic advantage of each increment. If this is not true, then some increments are relatively more valuable than others.

Despite general acceptance of the "additivity of increments" argument, there are a number of powerful objections. The first of these asserts that there is a time lapse (between the time at which an improvement is made and the point when drivers take advantage of the improvements) due to driving habits. That is, individual drivers may be used to a certain pattern of behavior on a given highway or highway system and will not readily abandon this pattern until some time after the improvement has been made. An example of such behavior is insistance on driving at a certain speed level below the maximum speed allowed by either law or road and traffic conditions.

A second objection is that operating characteristics of the carrier employing the commercial vehicle prevent full utilization of time saved. For example, a truck is transporting goods between cities A and B. If the truck has been arriving at its destination at 4:00 AM but, after improvement of the highway, is now able to arrive at 3:50 AM, then in this case it is unlikely that the ten minutes saved have any economic significance at all, particularly if the earlier arrival of the freight is of little benefit to the dock personnel at the destination terminal.

Finally, restrictions imposed by labor union contracts often mitigate or negate any savings in time accruing to the commercial vehicle as a result of highway improvement. A classic example of this situation is the eight-hour guaranteed wage which exists almost everywhere in the United States. Under these conditions a driver is guaranteed a full eight hours pay even though he may work only for some shorter period. A typical case is a driver who travels from A to B in, say, seven and one-half hours. Should the highway be improved to the point where he can make the trip in seven hours, or even six hours, the cost to his employer remains the same because a full eight hours of wages must be paid. (It should be noted that this simple example implies that the driver cannot be utilized at either the origin or destination terminals;

e. g., handling freight. This may not always be the case, although union contracts in the eleven Western States generally prohibit drivers from handling the freight at terminals or otherwise engaging in activities not directly related to the driving function.) On the other hand, of course, a reduction in trip time from, say, nine to eight hours results in a savings of one hour of overtime. Estimation of the economic consequences of highway improvements requires knowledge of the effects of the improvements on operations of the carriers.

Referring to the preceding discussion of the "additivity of increments" argument, it is clear that there are reasonable arguments opposing such assumptions. Unfortunately, however, these arguments remain in the realm of theory until researchers offer evidence either substantiating or refuting them. It is the purpose of this paper to report the results of an investigation designed to examine the validity of these assumptions which are currently so widely held and which are so important in the area of highway economics. Moreover, in exploring this topic a number of other questions of interest to highway analysts have been examined. These include (a) what changes the highway has undergone over a long period of time; (b) how the character of operations of the carrier has changed over this same period; (c) what the relationship, if any, is between expenditures in construction-improvement-maintenance of a highway and the travel time between points on the highway; (d) what changes have been made in wages, hours, and working conditions of drivers; and (e) whether the straight-time driver wage is a proper measure of the economic value to the carrier of time saved.

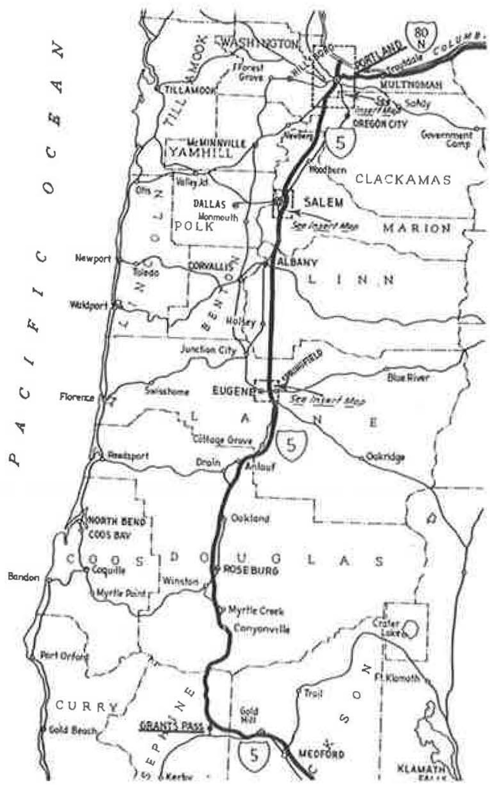

Figure 1. Truck route between Portland-Grants Pass.

THE HIGHWAY

During the data-gathering phase of the study, an attempt was made to get the same kind of information in similar form from both the Oregon and Washington State Highway Departments. The categories of data collected for the years 1935-60 are as follows:

1. Description of highway.
2. Annual construction, improvement, and maintenance costs.
3. Length of route.
4. Average daily traffic.
5. Traffic composition.
6. Traffic speed.

Although most of these data were provided by the Highway Departments of both States, the form in which it was received was dissimilar in some instances; hence, the minor variations between Oregon and Washington data.

Highway Between Portland and Grants Pass, Ore.

During the years 1935 through 1960, Consolidated Freightways' trucks operated over the highway between Portland, in the northwest corner of Ore., and Grants Pass, about 250 mi south of Portland. The subject highway is shown as Interstate Route 5 (Fig. 1).

TABLE 1

CONSTRUCTION, IMPROVEMENT AND MAINTENANCE COSTS[1], PORTLAND TO GRANTS PASS[2]

Year	Construction and Improvement Costs ($)		Maintenance Cost ($)
	Affecting Traffic	Aesthetic Value Only	
Before 1935	18,215,177	-	1,903,367
1935	757,359	-	156,470
1936	488,346	27,417	121,387
1937	1,441,770	-	162,792
1938	2,008,132	7,063	155,755
1939	371,447	7,529	153,204
1940	739,649	12,819	174,188
1941	1,117,492	2,243	192,504
1942	415,227	39,617	179,457
1943	1,157,546	-	234,639
1944	386,370	-	219,845
1945	340,436	-	259,143
1946	598,098	-	321,217
1947	1,614,419	1,316	458,066
1948	1,834,583	-	477,946
1949	2,475,727	-	628,986
1950	1,282,535	17,238	572,175
1951	1,364,410	28,756	643,784
1952	4,659,012	3,041	727,611
1953	2,479,429	11,534	697,036
1954	1,616 355	10,788	711,965
1955	11,808,501	44,262	632,400
1956	11,927,062	97,518	735,586
1957	6,544,464	139,766	801,640
1958	24,367,026	204,741	1,509,382
1959	18,396,291	87,531	831,949
1960	22,428,581	26,117	634,660

[1] Data provided by Oregon State Highway Department.
[2] Intersection of Union Avenue and Burnside Street in Portland to north end of Caveman Bridge in Grants Pass (1958 through 1960 begin on Harbor Drive at undercrossing of Burnside St.).

Construction, Improvement, and Maintenance Costs.—Because it is the partial purpose of this paper to indicate the relationship between highway expenditures and improved operations of the user, it was necessary to separate construction and improvement costs into two categories: those affecting traffic and those of aesthetic value only. The latter includes such items as planting of grass and shrubbery along the roadside and any other similar improvements which have no direct effect on vehicle speed. These appear with regard to construction and improvement costs, but are not relevant to maintenance expenditures.

Construction, improvement, and maintenance costs as reported by the Oregon State Highway Department are given in Table 1. Two observations can be made immediately from these raw data: (a) it is evident that total expenditures on the highway range widely from year to year; and (b) extremely large expenditures were experienced for the years 1955 through 1960. It was during this period that major construction was undertaken with the objective of bringing the highway into the Federal Interstate System.

Although the data in Table 1 are helpful, it is somewhat more illuminating to modify the statistics slightly. Due to variations in construction prices during the 26-year period, all annual construction, improvement, and maintenance costs were adjusted by appropriate values from the construction index as prepared by the Oregon State Highway Department. The adjusted data for construction and improvement were then added cumulatively, ignoring those expenditures that were of aesthetic value only. Results of this data modification are shown in Figure 2. The accelerated improvement program beginning in the early 1950's is clearly evident as is the attendant increase in maintenance costs.

Point-to-Point Mileage.—Detailed year-by-year route descriptions provided by the Oregon State Highway Department (not included in this paper) clearly indicate a number of alterations in highway alignment during the 1936-60 period. A major purpose of these changes, of course, was to bypass populated communities and otherwise shorten the travel time of vehicles passing through.

The reduction in highway distance traversed by Consolidated Freightways' trucks in traveling between Portland and Grants Pass is evident from Table 2 and Figure 3. Route distance was reduced by 30.55 mi during the 1935-60 period, an 11 percent overall improvement. The reduction is even more pronounced when one considers that the straight-line distance between Portland and Grants Pass is approximately 212 mi. Thus, in 1935 the route was about 67 mi above the theoretical minimum distance, and this "excess distance" was roughly 37 mi by 1960. The improvements, therefore, represent a reduction in the order of 45 percent of the greatest conceivable reduction. Referring to Figure 1, it is apparent that the locations of population and market centers between Portland and Grants Pass preclude the construction of a straight-line route between the two cities. Such a highway, at least in the foreseeable future, would be an improbable luxury. Hence, it is reasonable to assume that nearly all of the practicable reduction in distance has already taken place.

Average Daily Traffic.—Some indication of increase in use of the highway between 1935 and 1960 can be provided by statistics showing the ADT.

The Oregon State Highway Department conducts traffic counts at a number of points between Grants Pass and Portland. Of these, three have been chosen because of their strategic location:

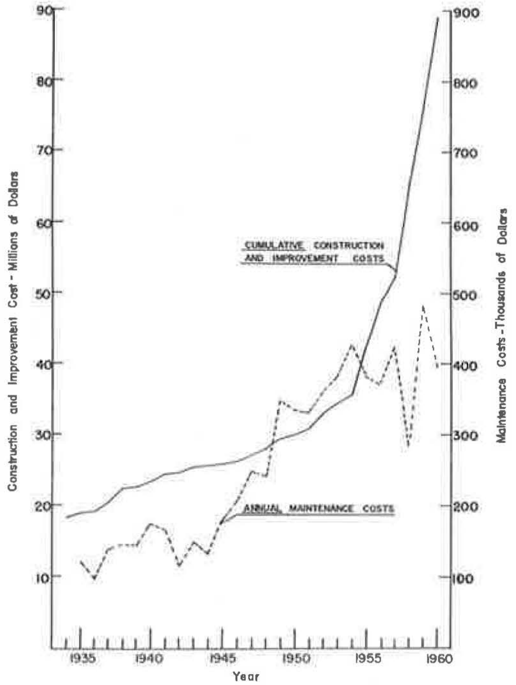

Figure 2. Construction, improvement and maintenance costs, Portland to Grants Pass adjusted by Oregon construction cost index (1940=100) except for years before 1935.

TABLE 2

LENGTH OF ROUTE[1], PORTLAND TO GRANTS PASS[2]

Year	Length of Route (mi)
1935	279.13
1936	279.13
1937	277.40
1938	276.70
1939	276.70
1940	275.92
1941	275.00
1942	275.08
1943	275.08
1944	272.26
1945	272.26
1946	272.26
1947	270.37
1948	269.02
1949	269.02
1950	269.02
1951	269.22
1952	268.75
1953	268.75
1954	268.75
1955	259.91
1956	260.02
1957	254.95
1958	253.52
1959	253.52
1960	248.58

[1] Data furnished by Oregon State Highway Department.

[2] Intersection of Union Avenue and Burnside Street in Portland to north end of Caveman Bridge in Grants Pass.

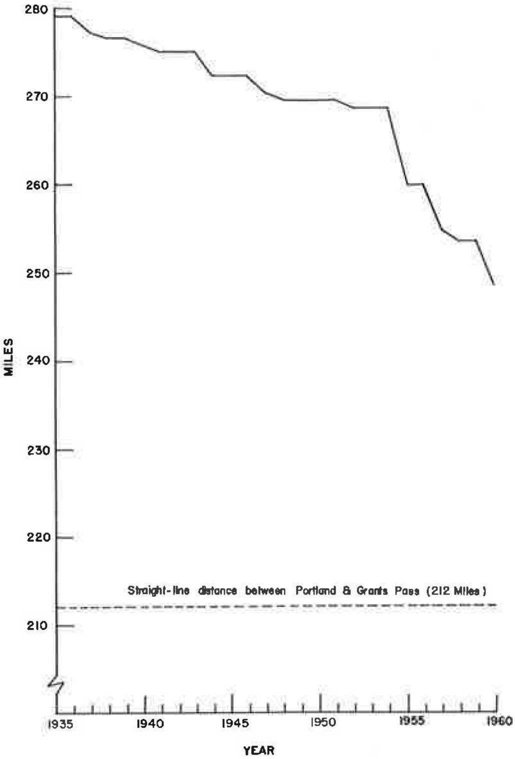

Figure 3. Length of route used by Consolidated Freightways' trucks, Portland to Grants Pass.

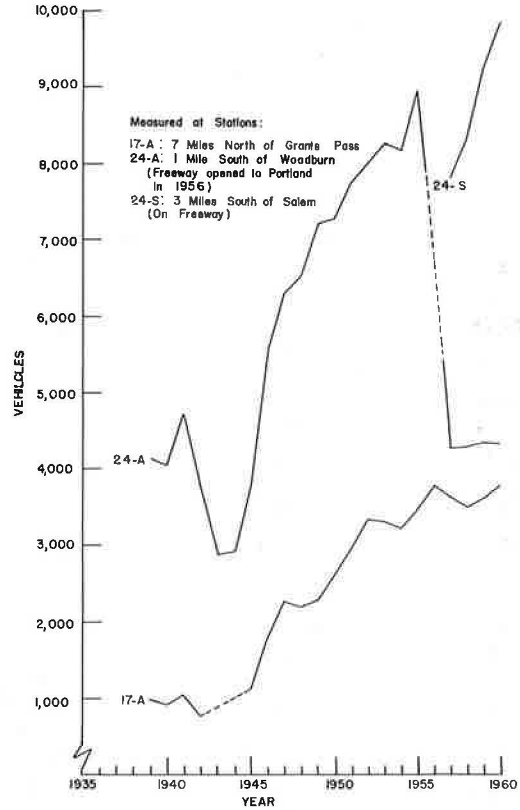

Figure 4. Average daily traffic, Portland to Grants Pass.

1. Station 17-A, 7 mi north of Grants Pass,
2. Station 24-A, 1 mi sourth of Woodburn, and
3. Station 24-S, 3 mi north of Salem.

Station 17-A was selected because the highway at that point has remained essentially unchanged during the past 25 years. That is, there have been no major highway system changes in that area which might have seriously altered the pattern of traffic flow.

Stations 24-A and 24-S should be considered together to appreciate changes in highway usage. The first of these is located on that portion of the highway which was the main route prior to opening of the Pacific Freeway in November 1956. Station 24-S is located on the new Pacific Freeway and hence measures traffic flow on the current principal through route.

ADT statistics are given in Table 3 and Figure 4. It is clear that, with the exception of the World War II period, traffic usage has been steadily increasing. In noting Station 17-A (just north of Grants Pass), it appears as though the rapid growth of the postwar era has begun to taper off. Stations 24-A and 24-S, on the other hand, indicate that rate of growth is continuing unabated. These differences may be explained in part by the urban character of the area between Salem and Portland; it is reasonable to expect that opening of a freeway in that area would attract a great deal of local traffic. Moreover, the reduction in through traffic on the old highway (measured at Station 24-A), with the resulting decrease in congestion, has probably caused the diversion of local traffic that previously had avoided the route. That is, Stations 24-A and 24-S doubtless measure traffic diverted from other local roads in addition to normal growth and transfers from the old highway (24-A) to the new one (24-S).

TABLE 3

AVERAGE DAILY TRAFFIC[1], PORTLAND TO GRANTS PASS

Year	Average Daily Traffic			
	Station 17-A	Station 24-A	Station 24-S	Stations 24-A and 24-S Combined
1939	991	4,135	-	-
1940	915	4,054	-	-
1941	1,053	4,729	-	-
1942	769	3,736	-	-
1943	No data	2,881	-	-
1944	No data	2,914	-	-
1945	1,111	3,760	-	-
1946	1,783	5,577	-	-
1947	2,257	6,314	-	-
1948	2,180	6,533	-	-
1949	2,272	7,219	-	-
1950	2,624	7,273	-	-
1951	2,977	7,759	-	-
1952	3,327	8,008	-	-
1953	3,307	8,301	-	-
1954	3,209	8,201	-	-
1955	3,462	8,974	-	-
1956[2]	3,784	6,716	-	-
1957	3,636	4,260	7,806	12,066
1958	3,491	4,277	8,318	12,595
1959	3,594	4,354	9,273	13,627
1960	3,779	4,329	9,856	14,185

[1] Data provided by Oregon State Highway Department.
[2] Pacific Freeway opened to Portland in November.

Traffic Composition.—Table 4 gives the distribution of traffic on the route used by Consolidated Freightways' trucks as measured at the three locations discussed in the preceding section. The data will not be analyzed other than to point out that (a) there has been no apparent trend or shift in traffic composition over the past 22 years, and (b) the percentage distributions noted north of Grants Pass are quite similar to those observed in the Salem-Woodburn area.

Traffic Speed.—The large and increasing expenditures made for construction, improvement, and maintenance of the highway during the 1935-60 period was demonstrated earlier. The rapid increase of highway usage during the same period has also been shown. Despite the greater number of vehicles on the highway, studies indicate that expenditures have generally resulted in an increase in overall traffic speed.

The magnitude of these increases is given in Table 5. Although vehicle speed data are collected at a number of measurement stations, the following three locations were selected for this discussion:

1. Station 24-1, Pacific Highway East, 5 mi south of Woodburn,
2. Station 24-2, Interstate 5, north of Salem, and
3. Station 24-3, Pacific Highway, 10 mi south of Salem.

Station 24-1, located just south of Woodburn, has remained essentially unchanged during the period 1949-60. The highway in the area is not built to freeway standards. Station 24-2, on the other hand, is located on the freeway section of Interstate 5 north of Salem, and data are available at this point for years 1956-60. The third data collection point, Station 24-3, is located south of Salem on a section of the highway which was improved to freeway standards in 1959.

The data of Station 24-1 are perhaps the most revealing because they supplement the freeway data recorded at Station 24-2. As noted earlier, traffic formerly moving on Pacific Highway East has been diverted to Interstate Route 5 in the area between Salem and Woodburn because of the construction of the latter to freeway standards. One would intuitively reason that such a diversion would occur, not only because of increased comfort and convenience on the new highway, but also because of opportunity for increased speed. However, not only were vehicles using the new highway able to travel at higher speeds than formerly, but those users remaining on the old route were able to do likewise. This phenomenon is probably caused by reduction in traffic congestion on the old road, allowing an increase in average speed. (Fig. 4 shows changes in traffic density on the opening of the new highway.)

Traffic speed is a function of vehicle capabilities and legal speed limits, in addition to highway characteristics. The truck speed limits in Oregon since 1935 are as follows:

Period	Speed (mph)	
	Minimum	Maximum
1935 - June 1941	None	35
June 1941 - July 1957	None	45
July 1957 to date	None	50

There was a wartime speed restriction on all vehicles of 35 mph between October 1948 and September 1945.

In view of the legal limits on truck speed, it is interesting that average commercial vehicle speeds as recorded at the measuring stations have frequently exceeded the legal maximums. For example, of the eleven statistics reported at Station 24-3, six of these are "violations." That is, the reported average speeds are in excess of maximum legal speeds for the respective years. Moreover, commercial vehicles operating on the two freeway routes, Stations 24-2 and 24-3, have apparently reached the maximum legal speed. Future readings of about 50 mph are therefore to be expected unless there is an increase in the speed limit.

Highway Between Portland, Ore., and Seattle, Wash.

Consolidated Freightways' trucks have operated between Portland and Seattle for over thirty years. Portland is in the northern part of Oregon, just a few miles south of the Oregon-Washington State Line, and data concerning this highway, therefore, had to be furnished by the Highway Departments of both States. The present truck route between Seattle and the Oregon State Line is shown as Interstate Route 5 in Figure 5.

Construction, Improvement, and Maintenance Costs.—As was the case for the section between Portland and Grants Pass, the 1935-60 period witnessed steady, ever-increasing costs of construction, improvement, and maintenance on the Portland-Seattle highway. Actual costs as provided by the Oregon and Washington Highway Departments are shown in Table 6.

Cost data for the Portland-Seattle highway have been adjusted by Construction Cost Indexes. The adjusted figures for construction and improvement were then added cumulatively, ignoring those expenditures that were of aesthetic value only, and are shown in Figure 6 along with annual maintenance costs. As was the case with the Portland-Grants Pass highway, Figure 6 clearly shows the impetus given the construction and improvement program beginning about 1950.

Although annual maintenance costs have increased since World War II, they have

TABLE 4

PERCENTAGE OF AVERAGE DAILY TRAFFIC[1], PORTLAND TO GRANTS PASS

Station	Year	Average Daily Traffic (%) Light Vehicles[2]	Light Trucks[3]	Heavy Trucks[4]	Truck & Semi-Trailer	Truck & Full Trailer	Total Trucks (except light trucks)	Buses
17-A	1939	83.5	5.2	9.4			9.4	1.9
	1940	84.0	4.9	9.1			9.1	2.0
	1941	84.5	6.0	3.0	2.4	2.6	8.0	1.5
	1942	81.7	5.3	3.6	2.9	4.3	10.8	2.2
	1943			No classification counts				
	1944			No classification counts				
	1945	80.0	5.4	3.3	3.0	6.1	12.4	2.2
	1946	84.5	4.9	3.8	2.1	2.8	8.7	1.9
	1947	83.0	5.2	4.7	2.9	2.5	10.1	1.7
	1948	80.7	7.3	4.0	3.4	3.1	10.5	1.5
	1949	80.3	7.4	3.6	3.7	3.4	10.7	1.6
	1950	79.1	8.4	3.3	3.4	4.3	11.0	1.5
	1951	87.5	1.0	3.2	2.6	4.8	10.6	0.9
	1952	88.1	1.0	4.0	4.6	1.5	10.1	0.8
	1953			No classification counts				
	1954			No classification counts				
	1955	83.9	1.1	5.6	5.0	3.4	14.0	1.0
	1956			No classification counts				
	1957			No classification counts				
	1958	80.2	1.2	5.6	5.4	6.8	18.7	0.8
	1959			No classification counts				
	1960			No classification counts				
24-A	1939	84.7	3.2	10.7			10.7	1.4
	1940	82.8	3.9	12.1			12.1	1.2
	1941	84.4	3.9	5.1	2.9	2.4	10.4	1.3
	1942	80.9	4.2	5.6	3.8	3.5	12.9	2.0
	1943	73.2	5.0	7.8	6.1	5.1	19.0	2.8
	1944	70.7	5.7	7.5	6.7	6.1	20.3	3.3
	1945	79.6	4.4	5.4	3.7	4.7	13.8	2.2
	1946	82.8	3.9	4.7	3.4	3.6	11.7	1.6
	1947	82.2	3.9	4.6	3.6	4.1	12.3	1.6
	1948	81.1	5.0	4.3	4.8	3.3	12.4	1.5
	1949	82.1	4.7	4.4	3.8	3.8	12.0	1.2
	1950	79.1	8.4	3.3	3.4	4.3	11.0	1.5
	1951	88.2	0.5	4.0	4.1	2.2	10.3	1.0
	1952	84.7	0.9	4.5	4.5	4.6	13.6	0.8
	1953			No classification counts				
	1954			No classification counts				
	1955	82.0	1.0	5.4	6.2	4.5	16.1	0.9
	1956[5]			No classification counts				
	1957	85.5	1.0	7.5	3.7	1.4	12.6	0.9
	1958	85.8	0.9	8.0	3.5	1.1	12.6	0.7
	1959			No classification counts				
	1960			No classification counts				
24-S	1957	83.3	0.3	3.7	6.0	6.2	15.9	0.5
	1958	81.8	0.4	4.0	6.7	6.6	17.3	0.5
	1959			No classification counts				
	1960			No classification counts				

[1] Data furnished by Oregon State Highway Department.
[2] 1951 to 1960—including passenger cars, panels, and pickups.
[3] 1939 to 1950—including panels and pickups.
[4] 1939 and 1940—including truck and trailer combinations.
[5] Pacific Freeway opened to Portland in November.

TABLE 5

TRAFFIC SPEED[1], PORTLAND TO GRANTS PASS

PASSENGER VEHICLES

Vehicle Type	Year	Traffic Speed (mph)		
		Station 24 - 1	Station 24 - 2[2]	Station 24 - 3[3]
Passenger	1949	52.6	-	52.2
	1950	53.0	-	53.6
	1951	53.2	-	55.3
	1952	49.5	-	52.4
	1953	52.1	-	50.0
	1954	51.0	-	Not available
	1955	49.9	-	53.6
	1956	50.1	63.1	54.1
	1957	50.4	63.2	52.0
	1958	51.3	63.1	54.4
	1959	52.2	63.8	61.1
	1960	52.4	64.7	63.5
Commercial	1949	42.5	-	45.6
	1950	45.9	-	46.9
	1951	46.1	-	48.7
	1952	43.6	-	45.5
	1953	44.5	-	44.2
	1954	43.5	-	Not available
	1955	43.2	-	44.7
	1956	44.5	46.7	45.8
	1957	43.6	48.4	44.4
	1958	44.9	48.4	47.0
	1959	45.7	48.9	48.1
	1960	46.7	50.3	50.1

[1] Data furnished by Oregon State Highway Department.
[2] Station established in November 1956, subsequent to opening of Interstate Route I-5.
[3] Highway at this location constructed to freeway standards in 1959.

TABLE 6

CONSTRUCTION, IMPROVEMENT AND MAINTENANCE COSTS, PORTLAND TO SEATTLE

Year	Construction and Improvement Costs ($)				Maintenance Costs ($)	
	East End, Broadway Br. to Ore.-Wash. State Line[1]		Ore.-Wash. State Line to Seattle[2]		East End, Broadway Br. to Ore.-Wash. State Line[1]	Ore.-Wash. State Line to Seattle[2]
	Affecting Traffic	Aesthetic Value Only	Affecting Traffic	Aesthetic Value Only		
Before 1935	1,473,279	-	18,167,394	-	13,903	Not available
1935	5,502	-	638,092	-	7,702	Not available
1936	7,520	-	888,540	-	8,441	Not available
1937	3,764	-	1,586,122	3,736	15,957	142,897
1938	26,072	-	445,621	-	17,432	134,504
1939	167,570	-	137,341	-	15,230	147,698
1940	40,012	-	14,822	12,686	16,371	172,164
1941	543,979	-	1,515,172	6,518	16,180	161,252
1942	140,298	-	887,237	-	15,909	175,142
1943	336,739	-	89,714	-	17,469	172,593
1944	63,926	-	391,602	613	20,883	175,181
1945	739	-	1,014,496	-	20,380	216,989
1946	39,024	-	986,533	-	28,291	262,555
1947	173,777	-	3,099,263	-	29,112	246,688
1948	52,757	-	1,982,858	47,442	42,775	287,673
1949	97.486	-	3,475,301	38,256	54,945	363,444
1950	69,320	-	2,895,167	34,113	55,472	343,555
1951	39,947	-	5,270,957	5,030	54,356	412,780
1952	22,960	19,874	9,365,338	21,007	57,918	413,158
1953	140,340	143,415	8,270,477	2,110	55,406	460,420
1954	47,694	-	13,985,559	3,478	68,005	493,427
1955	54,805	-	9,126,157	7,219	66,384	473,162
1956	11,722	-	11,415,333	5,027	83,055	580,016
1957	62,878	5,590	9,380,063	37,826	68,238	494,089
1958	7,341,847[3]	-	16,411,359	23,653	92,284	616,773
1959	55,359	20,742	12,512,346	-	87,588	567,198
1960	3,675,170[3]	21,303	6,542,536	11,974	38,813	Not available

[1] Data furnished by Oregon State Highway Department.
[2] Data furnished by Washington State Department of Highways.
[3] Building of new parallel structure and rebuilding of old structure to provide one-way flow of traffic across Columbia River between Portland and Vancouver.

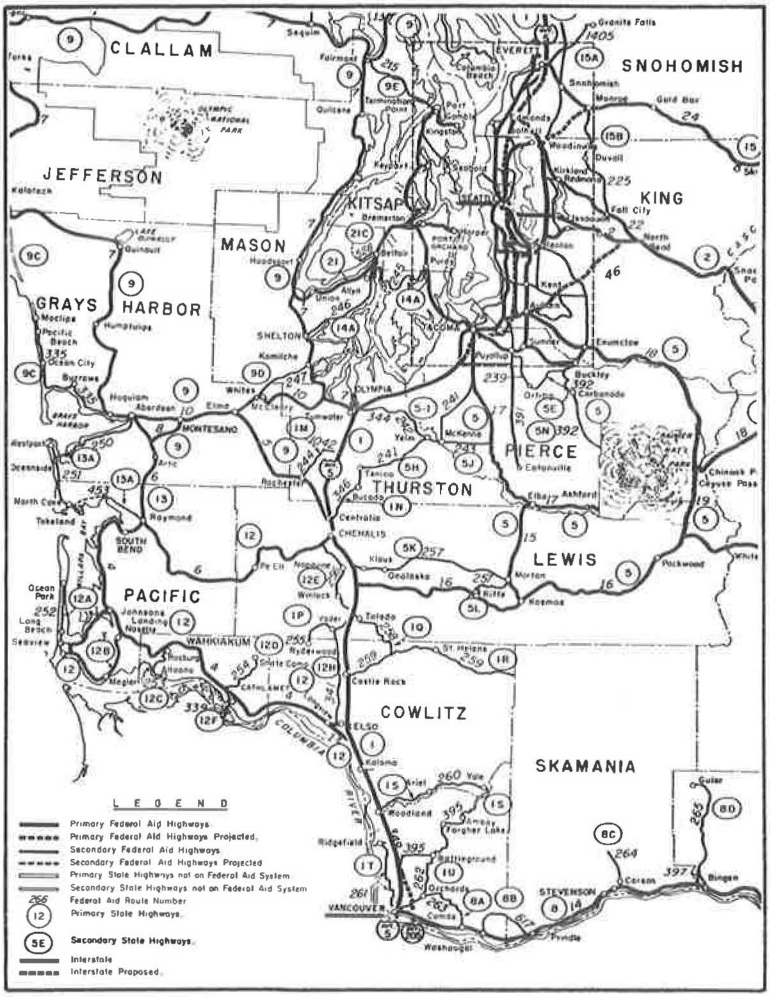

Figure 5. Truck route between Portland and Seattle (Interstate Highway Route 5).

not kept pace with expenditures for highway construction and improvement. This is indicated by the ratios of annual maintenance costs to cumulative construction and improvement costs, using the adjusted data on which Figure 6 is based. The overall average for the period 1935-60 may be computed as 0.0056, but the figures for 1952-60 are given in Table 7. Because maintenance costs are due to such factors as the age of highway, degree of use, and local weather conditions, as well as to the magnitude of the system as measured by expenditures for new construction and improvement, the observation indicated by the preceding statistics is not surprising.

Point-to-Point Mileage.—According to the Oregon State Highway Department, the distance between the east end of the Broadway Bridge in Portland and the Oregon-Washington State Line is 7.17 mi; the mileage has remained unchanged from 1935 through 1960. Route miles between the State Line and Seattle are given in Table 8, and the total route miles between Portland and Seattle are shown in Figure 7.

Overall reduction in distance during the 1936-60 period is, of course, quite evident. Decrease in mileage from 186.54 (in 1935) to 162.40 (in 1960) represents a reduction of 24.14 mi, or an improvement of approximately 13 percent. Moreover, because the straight-line distance from Portland to Seattle is about 133 mi, the reduction in mileage represents a 45 percent improvement when compared to the theoretical minimum.

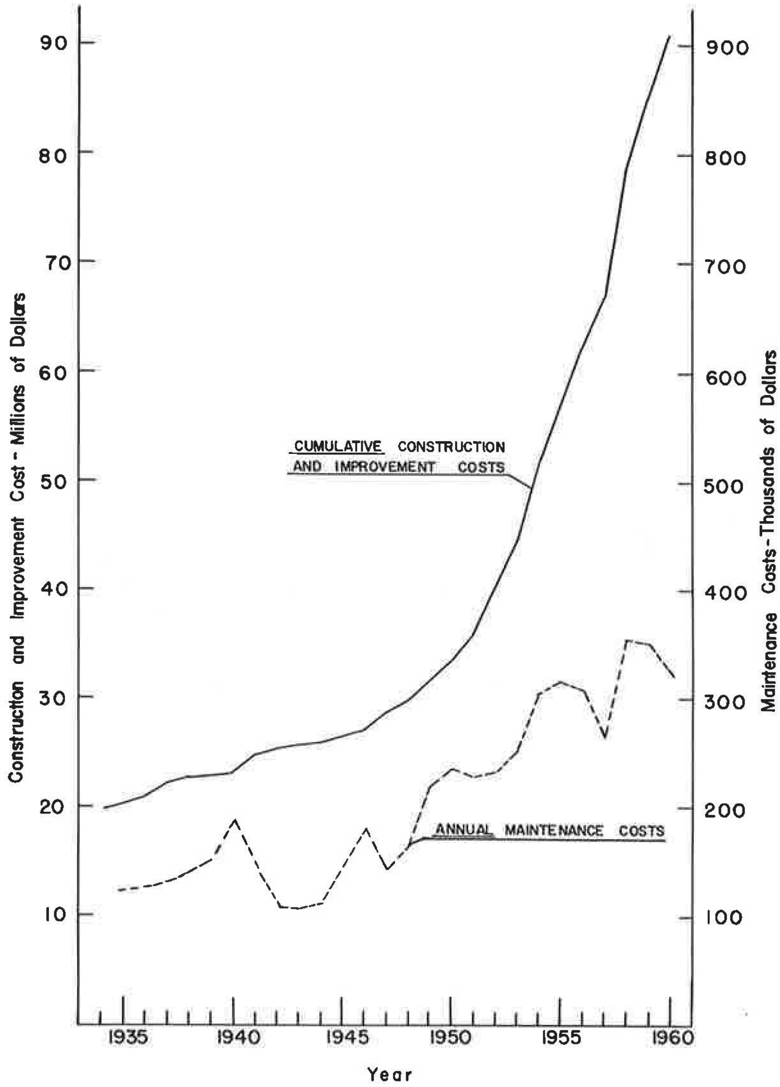

Figure 6. Construction, improvement and maintenance costs, Portland to Seattle, adjusted by Oregon and Washington construction cost indexes (1940 = 100) except for years before 1935.

This figure is derived as follows:

$$\frac{186.54 - 162.40}{186.54 - 133.00} = \frac{24.14}{53.54} = 45\%$$

The percentage improvement based on the theoretical minimum distance was also 45 percent for the Portland-Grants Pass highway.

Although not the major subject of this paper, such similarities are of interest in that they suggest development of standard data that may be useful to other researchers in the highway field.

TABLE 7

MAINTENANCE, CONSTRUCTION, AND IMPROVEMENT COSTS, 1935-60

Year	Annual Maintenance Cost ($)	Cumulative Construction and Improvement Cost ($)	Ratio[1]
1952	232	40,450	0.0057
1953	251	44,503	0.0056
1954	302	51,931	0.0058
1955	314	57,239	0.0055
1956	305	62,434	0.0049
1957	264	66,790	0.0040
1958	354	78,941	0.0045
1959	349	85,559	0.0041
1960	322	91,061	0.0035

[1]Of maintenance to construction and improvement costs.

Average Daily Traffic.—The Washington State Department of Highways has provided traffic density (and traffic distribution) data collected at some 37 points on the Portland-Seattle highway. Because the general pattern of traffic growth is roughly the same at all of these points, statistics from only three data-collection stations have been included (Table 9):

1. C.S. 0601, Interstate Bridge, Oregon-Washington State Line,

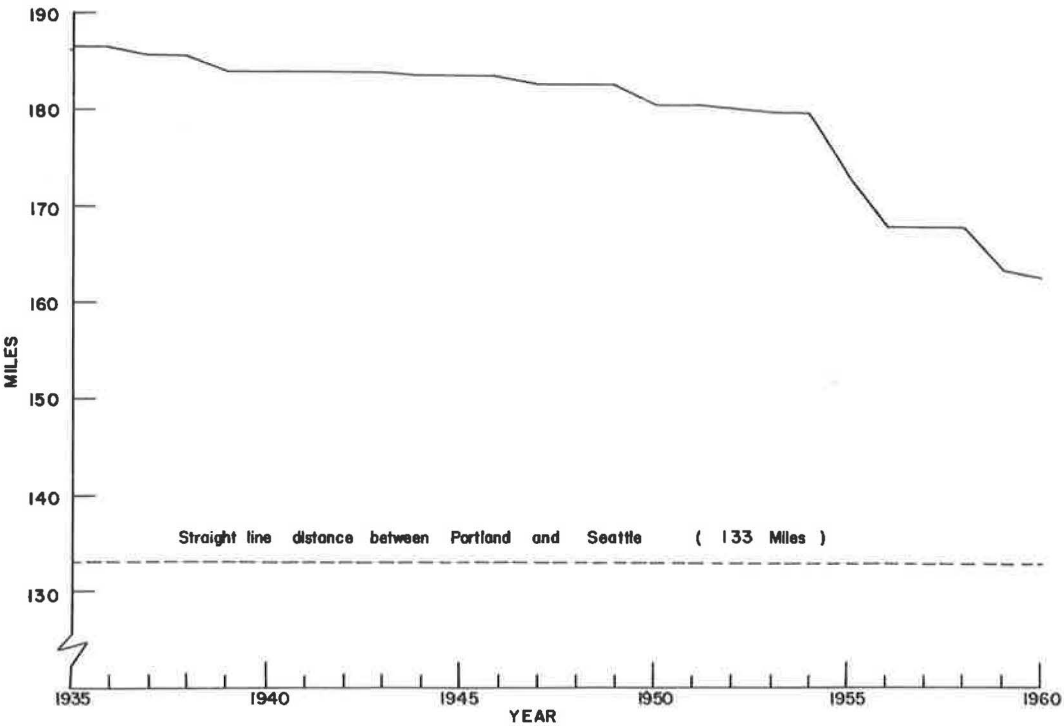

Figure 7. Length of route used by Consolidated Freightways' trucks, Portland and Seattle.

2. C.S. 0603, on US 99, Clark County, and
3. C.S. 1701, on US 99, King County.

Station C.S. 0603 is located in a rural area in the southern part of Washington. Station C.S. 1701, on the other hand, is located between Seattle and Tacoma, a heavily traveled area. Statistics representing traffic density as recorded at these two stations are shown in Figure 8. It is clear that the period since World War II has witnessed a steady increase in highway usage, although most highway analysts believe that it is reasonable to expect that the growth will not continue at the same rate. Parenthetically, it would be interesting to compare present-day traffic usage statistics with predictions made in, say, the 1930's. It is probable that one would find such predictions to have been remarkably conservative.

TABLE 8

LENGTH OF ROUTE, PORTLAND TO SEATTLE

Year	Route Length (mi) Between Ore.-Wash. State Line and Seattle[1]	Between Portland and Seattle[2]
1935	179.37	186.54
1936	179.37	186.54
1937	178,39	185.56
1938	178.39	185.56
1939	176.56	183.73
1940	176.56	183.73
1941	176.56	183.73
1942	176.56	183.73
1943	176.56	183.73
1944	176.09	183.26
1945	176.09	183.26
1946	176.09	183.26
1947	175.23	182.40
1948	175.23	182.40
1949	175.23	182.40
1950	173.19	180.36
1951	173.19	180.36
1952	172.86	180.03
1953	172.30	179.47
1954	172.30	179.47
1955	165.93	173.10
1956	160.48	167.65
1957	160.51	167.68
1958	160.51	167.68
1959	155.94	163.11
1960	155.23	162.40

[1]Data furnished by Washington State Department of Highways. [2]Includes 7.17 mi between Broadway Bridge in Portland and Oregon-Washington State Line.

Traffic Composition.—Table 10 summarizes the percentage of trucks, buses, and pickups observed at the three data-collection stations. On reviewing the data, the following observations were made. First, there is no apparent change in traffic composition over time. The percentage of commercial vehicles has risen slightly over the past fifteen years at C.S. 1701, but fallen slightly at C.S. 0603. Second, it is difficult to determine any difference in percentages between locations—during the ten-year period 1950-59, both C.S. 1701 and C.S. 0603 reported that the percentage of total traffic composed of commercial vehicles ranged between 15 and 17 percent. Finally, these statistics are quite similar to those reported by the Oregon State Highway Department (Table 4).

Traffic Speed.—No statistics describing actual vehicle speeds were furnished by the Washington State Department of Highways, although considerable data concerning vehicle legal speed limits were provided for the period 1949-60. The maximum speed for commercial vehicles was 40 mph between 1949 and 1954, and was 50 mph from 1955 through 1960. This compares to the Oregon truck speed limits of 45 mph for the 1949-57 period, and 50 mph between 1957 and 1960.

THE HIGHWAY USER

Routes

The largest freight terminal of Consolidated Freightways (at the time of preparation of this report) is located in Portland. This terminal not only trades freight with such major distribution areas as Seattle, Spokane, Los Angeles, and Chicago but also is a "break bulk" or "consolidation" point for freight originating or terminating in smaller communities in northwest Oregon. Portland is also a principal point for freight moving up and down the West Coast of the United States. It should be noted that this discussion

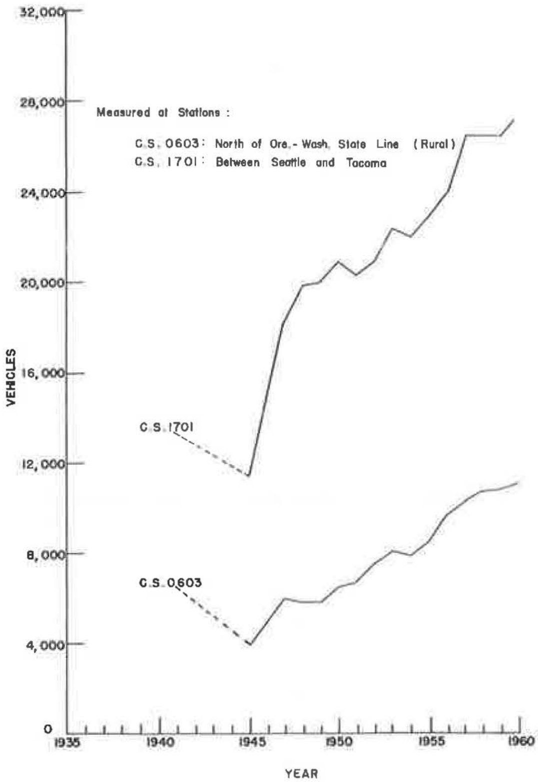

Figure 8. Average daily traffic, Portland to Seattle.

of Consolidated Freightways traffic moving on the two subject highways is not necessarily composed only of freight moving between Portland and Grants Pass or Portland and Seattle. For example, freight moving between points in California and Seattle will use both sections of highway. Other examples of traffic moving on trucks that use one or both of the subject highway are shipments moving between San Francisco-Spokane, Phoenix-Seattle, and Los Angeles-Vancouver, B. C.

Consolidated Freightways' vehicles moving between Portland and Grants Pass used US 99E before 1956. In that year, a large freeway section was completed between Salem and Portland, thus causing a change in routing. The Company's trucks currently use Interstate Highway Route 5 between Portland and Grants Pass, this is, in great part, what was formerly known as US 99E. Trucks moving between Portland and Seattle use Interstate Highway Route 5 shown in Figure 5.

TABLE 9
AVERAGE DAILY TRAFFIC[1], PORTLAND TO SEATTLE

Year	Average Daily Traffic		
	C.S. 0601	C.S. 0603	C.S. 1701
1941	19,100	6,500	13,300
1945	24,600	3,900	11,400
1946	26,500	4,900	14,800
1947	29,100	6,000	18,300
1948	31.900	5,800	19,800
1949	29,100	5,800	20,000
1950	31,600	6,500	20,900
1951	32,200	6,700	20,300
1952	34,500	7,600	20,900
1953	30,400	8,100	22,400
1954	29,800	7,900	22,000
1955	32,400	8,500	22,900
1956	34,400	9,700	24,000
1957	33,800	10,300	26,500
1958	35,200	10,800	26,500
1959	38,500[2]	10,900	26,500
1960	33,000	11,100	27,500

[1] Data provided by Washington State Department of Highways. [2] Second Interstate Bridge added.

TABLE 10
PERCENTAGE OF AVERAGE DAILY TRAFFIC THAT IS TRUCKS, BUSES AND PICKUPS, PORTLAND TO SEATTLE

Year	Percentage Trucks, Buses and Pickups		
	C.S. 0601	C.S. 0603	C.S. 1701
1941	8	-	14
1945	-	21	14
1946	-	19	13
1947	11	21	15
1948	11	21	13
1949	-	19	14
1950	-	15	16
1951	-	17	16
1952	-	16	15
1953	14	15	17
1954	-	15	16
1955	-	17	16
1956	-	17	16
1957	-	-	16
1958	-	-	16
1959	-	-	16
1960	-	-	19

Operations

Before about 1958, the general procedure required a driver to pick up freight in, say, Portland and move it to Seattle. He would then remain in Seattle until the next evening, whereupon he would return to Portland with another load. Typically, the driver would depart the origin terminal between 7:00 PM and midnight, and arrive at the destination terminal between 2:00 and 6:00 AM. The exact departure and arrival times vary, depending on such factors as freight-handling operations at the origin terminal, availability of trucks and drivers, and road conditions. Nevertheless, to provide overnight service between Portland and Seattle, it is necessary that freight picked up one day be processed and delivered at its destination by the morning of the next business day.

Beginning about 1958, it was found that the driving time between Portland and Seattle was reduced to the point where it was feasible to have the drivers make a round trip during one shift. During the period 1935 to the early 1950's it usually took from five to seven hours to travel between Portland and Seattle. And because drivers are paid overtime for all hours worked over eight, the additional overtime pay entailed in a one-shift round trip was deemed prohibitive. By 1958, however, driving conditions had improved to the point where a schedule could travel one-way in only four or five hours; thus, a driver could make a round trip in nine hours or so. Because of the reduced overtime required, the Company, with the concurrence of the Union, decided to begin round trip operations. The Company's operating personnel in Portland have indicated that approximately 40 percent of the drivers currently operating from Portland to Seattle return during the same shift. Driving time between cities has clearly not been sufficiently reduced to the point where all drivers can make a single round trip.

Consolidated Freightways' trucks moving between Portland and Grants Pass have experienced a similar drastic change in operating pattern beginning at a particular point in time. During the 1940's for example, the driving time between these two points was about eight or nine hours—just about the right number of hours to make up a driving shift with minimal overtime. Due to improvements in the highway, however, this on-the-road time was reduced to about seven hours by the late 1950's. Consequently, in 1960, the Company moved its driver layover point (sometimes called "division point") from Grants Pass to Medford, some 30 mi further south on the highway. Freight destined for Grants Pass is currently shipped to Medford where it is transshipped by local pickup and delivery trucks operating from the Medford terminal.

The Company was clearly able to eliminate its Grants Pass terminal and increase the number of miles per driver-hour paid for by this change in operations. Moreover, there were formerly three such division points between Portland and the San Francisco Bay Area. But with the reduction in driving time brought about by highway improvements, the Company was able to reduce these to two in 1960. The shift from Grants Pass to Medford was part of this change. Again, it is emphasized that the impact on trucking operations, in an economic sense, took place at a definite point in time rather than gradually over a long period.

(Large-scale trucking operations involving long distances and a great many points of origin and destination are necessarily quite complex. The preceding discussion attempts to simplify these complexities while retaining those elements essential to the development of this paper—a full and accurate description of all possible operating characteristics would be beyond the scope here. Nevertheless, it is believed that the generalizations that have been employed will in no way detract from the validity of the remaining discussion.)

Equipment Changes

Consolidated Freightways has operated a variety of types of equipment over routes in the Northwest during the last 25 years. Because of the legal restrictions of the States in which it operates, need for flexibility in assignment of equipment geographically, variations in terrain, etc., it is infeasible for the Company to maintain a homogeneous fleet at one point in time. Moreover, such factors as equipment design improvements and changes in legal restrictions are responsible for altering the general composition

TABLE 11

HISTORICAL TRAVEL TIMES FOR BUSES[1], PORTLAND-GRANTS PASS AND PORTLAND-SEATTLE

Year	Travel Time (hr: min)			
	Between Portland and Grants Pass		Between Portland and Seattle	
	Local	Express	Local	Express
1936	8:53	8:02	6:45	6:45
1937	8:56	8:08	6:45	5:15
1938	8:28	7:59	6:30	5:15
1939	8:28	7:59	6:15	5:15
1940	8:28	7:59	6:15	5:15
1941	8:21	7:49	6:15	5:15
1942[2]	9:38	9:12	6:40	6:40
1943[2]	9:48	9:46	7:45	7:45
1944[2]	9:12	8:59	7:45	7:45
1945[2]	9:12	8:59	7:45	7:45
1946	8:30	8:12	6:55	5:30
1947	8:13	8:08	6:40	5:35
1948	8:25	8:16	6:50	5:35
1949	8:40	6:44	6:50	5:20
1950	8:11	6:54	6:40	5:35
1951	8:11	6:54	6:40	5:35
1952	8:15	6:23	6:45	5:25
1953	8:15	6:51	6:45	5:20
1954	8:15	6:52	6:45	5:30
1955	8:15	6:27	6:40	5:05
1956	8:15	6:30	6:45	4:15
1957	8:15	6:30	6:25	4:15
1958	8:06	6:40	6:45	4:15
1959	8:06	6:40	6:35	4:15
1960	7:46	5:50	6:03	4:15

[1] Figures, representative times of actual schedules, provided by Western Greyhound Lines.
[2] A 35-mph speed limit imposed by U.S. Office of Defense Transportation from 1942 through 1945.

of the truck fleet over a period of years. The following remarks, then, apply to "typical" vehicles used by the Company between Portland-Seattle and Portland-Grants Pass.

Prior to 1938[1], the Company operated 90-hp gasoline engine, four-wheel tractors with full trailers on the subject highways. The horsepower rating of these tractors was increased to 120 hp in 1939. The Company converted to diesel-powered tractors in 1942, rated at 150 hp; and six-wheel tractor, six-wheel full trailer combinations were introduced in 1944.

The next major equipment change occurred in 1948 when 220-hp diesel tractors began to be used. The rating of these engines was increased to 280 hp in 1951 and increased again to 285 hp in 1953. Two semitrailers hauled in tandem were substituted for the single full trailer beginning in 1955 in order to increase cargo-carrying capacity. No additional significant equipment changes took place between 1955 and 1960.

It is believed that these changes are similar to those experienced by truck operators in other parts of the United States. Inasmuch as technological improvement and the continuing search for increased productivity are well established in fact, it is reasonable to expect analogous advancement in the future.

[1] All dates pertaining to equipment usage are approximate.

Travel Time Between Points

Two methods have been used in an attempt to reconstruct the historical driving times between Portland-Grants Pass and Portland-Seattle. The first of these is based on the records of a scheduled carrier of passengers, Western Greyhound Lines. Through the generous cooperation of the Company, passenger time schedules were provided showing departure and arrival times for both express and local buses using the subject highways during the period 1936-60.

Table 11 shows the historical running times between points, and includes only actual road times between origin and destination cities. The data pertaining to local buses include delay times at local stops and are therefore poor indicators of truck travel times. On the other hand, express bus data reflect only time spent on the road between origin and destination, and are thus considered to be good approximations of time spent by trucks traveling over the same routes. Express bus travel time is shown in Figure 9.

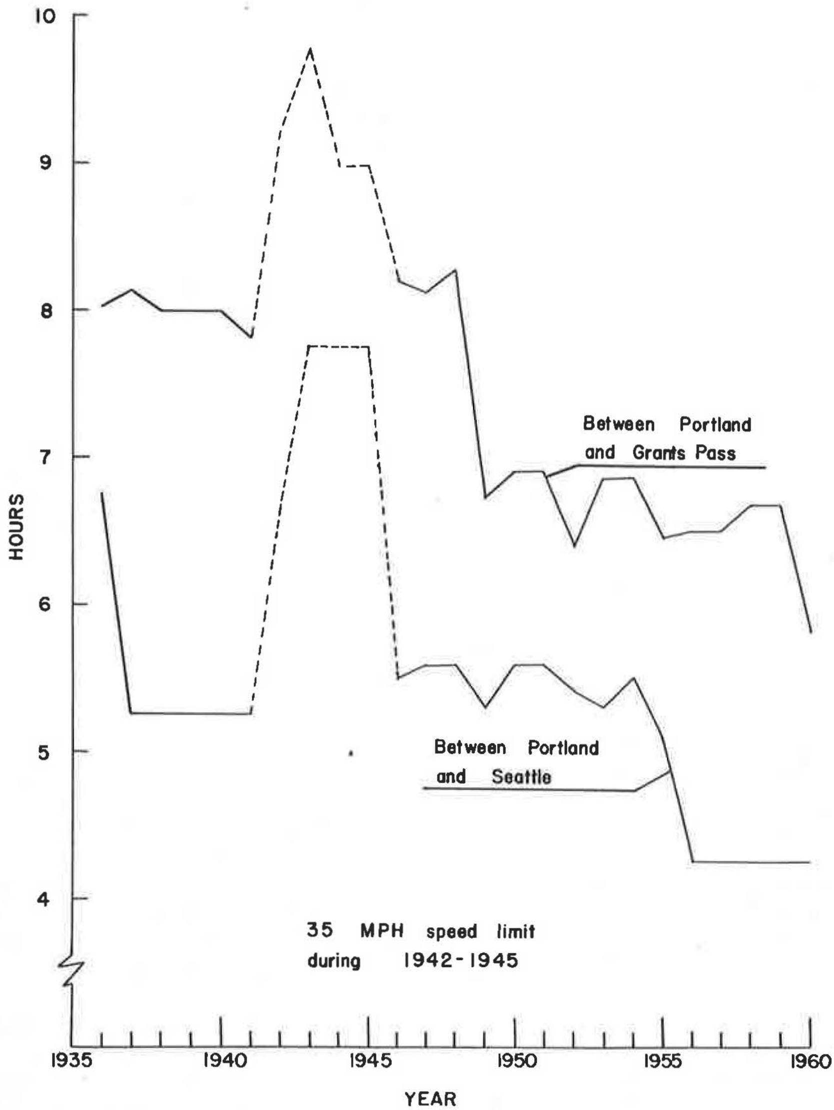

Figure 9. Express bus travel times (data from Western Greyhound Lines).

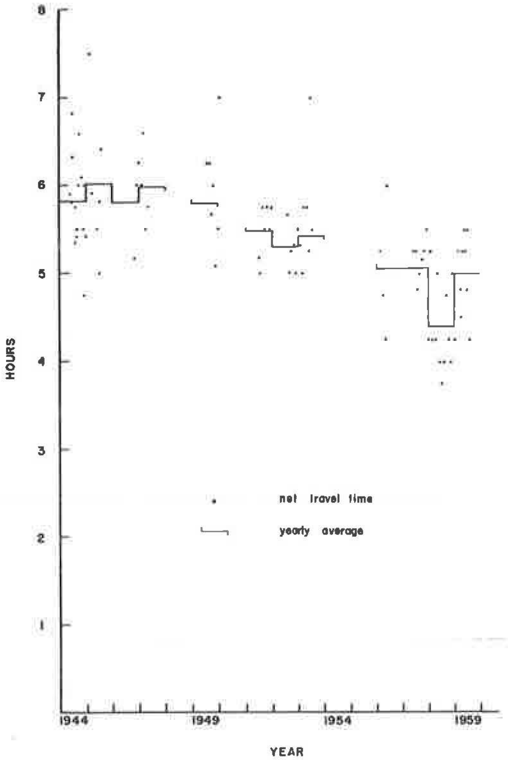

Figure 10. Truck travel times between Portland and Seattle.

TABLE 12

HISTORICAL TRAVEL TIMES FOR TRUCKS BETWEEN PORTLAND AND SEATTLE

Year	Travel Time (hr: min)	
	Sample Size	Average Driving Time
1944	15	5:49
1945	7	6:02
1946	3	5:48
1947	4	5:59
1948	-	-
1949	6	5:48
1950	-	-
1951	7	5:29
1952	6	5:18
1953	6	5:26
1954	-	-
1955	-	-
1956	4	5:04
1957	8	5:04
1958	12	4:24
1959	12	5:00

The second method used for determining historical travel times for Consolidated Freightways' trucks proved considerably more difficult. It was hoped that records of departure and arrival times would have been retained by the Company, but such was not the case. At any rate, some of the older drivers were consulted, and they estimated driving times between Portland and Grants Pass as follows:

1938	10 hr
1943	9 hr
1947	8 hr
1960	7 hr

Fortunately, greater success was achieved with regard to trips between Portland and Seattle. Through a series of inquiries in the Portland area, a valuable, though incomplete, set of driver log books was uncovered. A sample of trip information was taken from each of the available log books, the sample being selected in such a way as to insure adequate seasonal representation. Actual driving times between Portland and Seattle were determined by considering time of departure from one city and time of arrival at the next, subtracting all time in stops (for whatever reason) along the road. The results are shown in the form of a scatter diagram in Figure 10. Next, yearly average driving times were determined by taking the mean of the sample points for each year (Table 12).

The data in Figure 10 show a wide range of driving times, even within a single year. This variability is primarily explained by trip-to-trip differences in such factors as traffic and weather conditions. Nevertheless, a clear pattern of decreasing driving time is indicated—a reduction from about six to five hours seems to have been effected during the fifteen years after World War II. (The Greyhound Lines' express bus statistics were approximately 5.5 and 4.5 hr, respectively, during this same period.)

A comparison of travel times between cities for Consolidated Freightways' trucks and Greyhound express buses indicates (a) bus times have always been less than truck times, and (b) the gap has been narrowing in recent years. The first phenomenon is largely explained by the superior operating characteristics of buses, particularly with regard to maneuverability in traffic and ability to traverse highways with extreme grades. Because continued improvements in highways tend to mitigate these advantages, narrowing of the gap between bus and truck travel times is to be expected.

All trip times discussed in this section are "pure" in the sense that they exclude all routine and nonroutine stops made by the vehicle while traveling from origin to destination. Dinner stops, equipment breakdown, etc., have been omitted in order to generate unbiased statistics. The preceding discussion of operations, on the other hand, included total elapsed time between points. Data from the driver log books indicate that an additional 30 to 45 min of delay time per one-way trip should be added to driving time in order to compute total elapsed time between Portland and Seattle. The Portland-Grants Pass times discussed earlier represent total elapsed time.

TABLE 13

DRIVER STRAIGHT-TIME DAILY WAGE RATES[1,2]

Oregon Contracts		Washington Contracts	
Period	Wages per 8-Hr Day ($)	Period	Wages per 8-Hr Day ($)
		11/34 - 11/35	7.75
		12/35 - 7/36	-
		8/36 - 1937	8.00
		1937 - 1938	8.75
3/41 - 3/43	8.75	1938 - 1941	-
3/43 - 3/44	9.80	4/41 - 11/41	9.00
3/44 - 3/45	9.80	5/42 - 4/43	10.00
3/45 - 3/46	10.05	4/43 - 1944	10.00
3/46 - 10/46	11.00	1944 - 1945	10.00
10/46 - 1/47	11.50	1945 - 1946	10.50
1/47 - 3/47	11.75	1946 - 1947	11.25
3/47 - 5/48	12.00	1947 - 5/48	13.00
5/48 - 5/49	13.50	5/48 - 5/49	13.80
5/49 - 5/50	13.60	5/49 - 5/50	14.36
5/50 - 5/52	14.00	5/50 - 5/51	14.76
5/52 - 8/52	15.50	5/51 - 5/52	15.26
8/52 - 3/54	16.16	5/52 - 5/54	16.16
3/54 - 5/55	17.12	5/54 - 5/55	17.12
5/55 - 5/56	17.76	5/55 - 5/56	17.76
5/56 - 5/57	18.40	5/56 - 5/57	18.40
5/57 - 5/58	18.96	5/57 - 9/58	18.89
5/58 - 5/59[3]	19.76	9/58 - 5/59	19.76
5/59 - 5/60[3]	20.56	5/59 - 5/60	20.56
5/60 - 5/61[3]	21.36	5/60 - 5/61	21.36

[1]Data source: Teamster's Union contracts.
[2]Line haul drivers only, truck and trailer or tractor and semitrailer over 125 mi.
[3]Based on hourly rather than mileage pay.

Payments to Drivers

Hourly Wages.—Determination of wage data is complicated by the various factors on which wages are computed. For example, different contracts apply in different geographical areas[2], wages depend on the type of equipment being operated, and, particularly in recent years, wages may be computed on an hourly or mileage basis.

The daily straight-time wages given in Table 13 and (Fig. 11) are believed to be typical of those paid to operators of commercial vehicles on the Portland-Grants Pass and Portland-Seattle highways. Specifically, the wages as shown are based on (a) an eight-hour day, (b) payments made to line haul drivers rather than local pickup and delivery drivers, (c) operators of truck and trailer or tractor and semitrailer vehicles, and (d) for trips of more than 125 mi in length in any one day. Only one increase in wages is noted during the World War II period due to government restrictions. Another period of relatively stable wage levels occurs around 1950. This is probably explained by the Union emphasis on winning increased fringe benefits; e.g., six paid holidays were initiated in May 1950.

An important though often overlooked aspect of wage payments to drivers is the contractual obligation to provide a minimum number of hours of pay. That is, if a driver is called to work on a specific day, the company is obliged to pay him for at least a certain number of hours, regardless of the time actually worked. Washington contracts required a four-hour minimum pay period until 1943, at which time the minimum was increased to eight hours. Minimum periods were the same under Oregon contracts, except that the increase from four to eight hours occurred in 1948. It will be recalled that the Portland-Grants Pass and Portland-Seattle trips have always involved at least

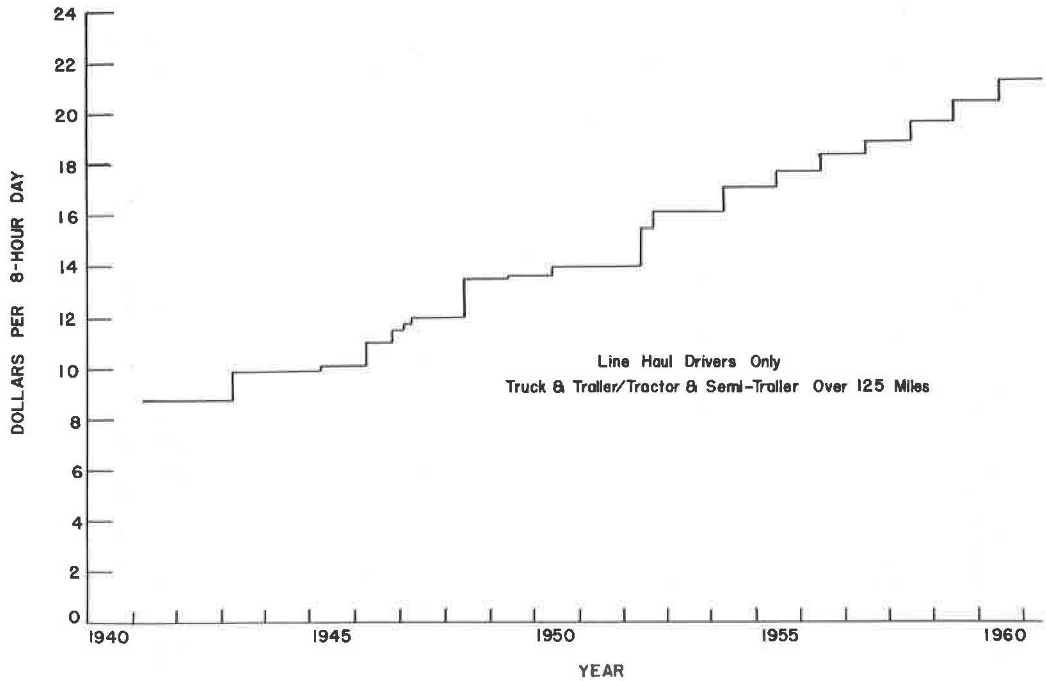

Figure 11. Straight-time daily wage rates, Oregon-based drivers.

---

[2]This was the case before the late 1950's, but the trend in recent years has been towards uniformity throughout the West.

TABLE 14

DRIVER WAGE PAYMENT SCHEDULE

Period	Wage Payment ($/mi)	
	For Less than 250 Mi Driven	For over 250 mi Driven[1]
5/58 - 5/59	0.08⅛	0.08⅝
5/59 - 5/60	0.08⅜	0.08⅞
5/60 - 5/61	0.08⅝	0.09⅛

[1] By one driver without intervening rest period.

four hours of driving time. Therefore, for all practical purposes, an eight-hour minimum wage should be considered.

Although both Washington and Oregon wage data are presented, it is probably most reasonable to consider only wages paid under Oregon contracts within the context of this paper. This is so because drivers operating on the Portland-Grants Pass and Portland-Seattle routes are primarily based in Portland. Moreover, all of the extra (nonscheduled) trips operating between Portland and Seattle originate in Portland.

Two observations can be made at this point concerning the contractual restrictions discussed in the preceding paragraphs. First, proper economic analysis should recognize that only increments in wages paid are relevant. For example, a reduction in trip time from seven to six hours clearly results in no incremental decrease in driver pay. Furthermore, a reduction in trip time from nine to eight hours not only results in a savings of one full hour of wages, but this should be incrementally valued at the overtime wage rate. A second observation is that drivers are paid for total trip time rather than simply time actually spent driving the vehicle. Thus it is necessary to consider the effect of decreased driving time on nondriving activities (such as rest stops) in order to evaluate the economic consequences of highway improvement properly.

Mileage Pay.—In May 1958, a major contractual change occurred which should be of considerable interest to highway economic analysts. At that time, the contracts were revised to provide for wage payments to drivers on either an hourly or mileage basis, whichever is greater, according to the schedule in Table 14. The point at which the mileage rate exceeds the hourly rate occurs at 239 mi.

An interesting aspect of this "new" type of wage payment is the effect it might have in evaluating the beneficial consequences of highway improvement, for now the analyst must consider mileage rather than hourly wage rates in some instances. It is misleading, however, to believe that a reduction of one mile in route length means a corresponding reduction of one mile of driver pay. This is so because the most recent contracts specify that, in the event of such a reduction, the company may reduce the driver's wage only over a period of six years from the date of the reduction at the rate of one-sixth per year. For example, suppose a driver has been driving a 300-mi route and the highway has been improved to the point where the route is now only 294 mi. The driver's pay will then be reduced by $0.09⅛ per trip each year over a period of six years, until it has finally been reduced by $ 0.54¾. Thus, even under the mileage payment plan, there is a time lag between the date of the improvement and the date at which the improvement is fully economically meaningful to the company. During the six-year postimprovement period, both the drivers and the company share in the benefits in varying proportions.

Incremental Fringe Benefits.—There are, of course, costs associated with so-called fringe benefits which add to the variable cost of driver labor. Consolidated Freightways reports the following categories of fringe benefits, most or all of which are paid under the various contracts:

1. State workmen's compensation.

2. State unemployment.
3. Federal unemployment.
4. Federal Insurance Contributions Act (FICA).
5. Health and welfare.
6. Pension.
7. Holidays.
8. Vacations.
9. Cost of living increases.

Although most of these are fixed in the sense that their cost is independent of the driver's direct wages, some of them are meaningful when considered incrementally. That is, State compensation, vacations, and cost of living increases vary directly with gross pay and thus should be considered by the highway economic analyst. That is, a reduction in $1.00 of driver wages also results in a decrease in the corresponding appropriate fringe benefits. The incremental fringe benefits recently paid by Consolidated Freightways are summarized in Table 15.

There are other fringe benefits, such as State unemployment and FICA, which are also based on wages; e.g., FICA is presently 3⅛ percent of the first $4,800 of annual earnings. But inasmuch as drivers usually earn far in excess of these base amounts,

TABLE 15

INCREMENTAL FRINGE BENEFITS[1]

Type of Benefit	Date	Minimum Employment (yr)	Rate of Benefit
Washington Workmen's Compensation	1958	-	3.79% of gross wages
	1959	-	4.28% of gross wages
	1960	-	4.24% of gross wages
	1961	-	4.57% of gross wages
	1962	-	5.06% of gross wages
Oregon Workmen's Compensation[2]	1958	-	0.790% of gross wages
	1959	-	0.605% of gross wages
	1960	-	0.682% of gross wages
	1961	-	0.737% of gross wages
	1962	-	0.825% of gross wages
Cost of living increases	8/1/59	-	$0.01 above regular contract increases
	2/1/60	-	$0.02 above regular contract increases
	8/1/60	-	$0.01 above regular contract increases
	2/1/61	-	$0.02 above regular contract increases
Vacations	1961	1[3]	1/52 of gross pay
		3	2/52 of gross pay
		11	3/52 of gross pay
		18	4/52 of gross pay

[1] Data provided by Keith Anderson, Cost Accountant, Consolidated Freightways, Inc.
[2] Workmen's Compensation rates in Washington are compulsory and Oregon is self-insured. This is reason for large variations in percentages.
[3] Vacation benefit for drivers having less than one year's service, but hired prior to July 1, 1961, was 1/35 of gross pay.

TABLE 16

SUBSISTENCE PAY AT DIVISION POINTS[1]

Contracts	Period	Subsistence Pay per Day ($)
Oregon	Before 1946	0.00
	5/1/46 - 5/1/48	1.00
	5/1/48 - 5/1/51	1.50
	5/1/51 - 5/1/52	2.00
	5/1/52 - 5/1/53	3.00
	5/1/53 - present	4.50
Washington	Before 1947	0.00
	1947 - 1949	1.00
	1949 - 11/1/50	2.00
	11/1/50 - 5/1/53	3.00
	5/1/53 - present	4.50

[1]Data source: Teamster's Union contracts.

they have no relevance in an incremental sense. That is, a small incremental reduction in driver wages will not affect costs due to these fringe benefits.

Subsistence Allowance.—Beginning in 1946 (Oregon) and 1947 (Washington), contracts have provided for daily subsistence payments to drivers away from their home terminal. For example, Portland-based drivers hauling a load to Seattle one night and returning the following evening are to be paid a subsistence allowance for the day spent in Seattle. (In this example, only one subsistence payment is allowed.) These allowances, as specified by the Oregon and Washington contracts, are given in Table 16.

These subsistence payments are of interest to the highway economic analyst because they may be affected by highway improvement. For example, consider the recent changes in operational scheduling for trucks traveling between Portland and Seattle. As soon as the highway improved to the point where a driver could make a roundtrip in one shift, subsistence payments were no longer necessary. Furthermore, when the number of division points for trucks moving from Portland to the San Francisco Bay Area was reduced from three to two, an additional subsistence payment was thereby eliminated. The economic value to the company of highway improvement, therefore, may consist of reduction in subsistence allowance costs in addition to savings in driver wages. Although Consolidated Freightways has no readily available data indicating the magnitude of these savings, they are believed to be substantial. This clearly appears to be a fruitful area for further research.

SUMMARY AND CONCLUSIONS

Highway Expenditures and Operating Benefits

The two preceding sections, taken together, indicate the effect of highway expenditures on the operations of Consolidated Freightways' trucks using the subject highways during the period 1935-60. Clearly, the States of Oregon and Washington have expended large sums of money in constructing, improving, and maintaining their highway systems during this period (Table 17). Moreover, the largest portion of these expenditures has taken place during the most recent decade. Through 1953, the cumulative (adjusted) construction and improvement expenditures totaled $34,422,000 for the highway between Portland and Grants Pass; at the same time, the total was $44,503,000 for the highway between Portland and Seattle. In both instances, more dollars were expended during the last seven years of record (1954-60) than throughout all the preceding years.

It is equally evident that these expenditures have resulted in marked improvement

TABLE 17

CUMULATIVE CONSTRUCTION AND IMPROVEMENT EXPENDITURES ON SUBJECT HIGHWAYS

Highway	Expenditure[1] ($)	
	Before 1935	Through 1960
Portland-Grants Pass	18,215,000	89,081,000
Portland-Seattle	19,641,000	91,061,000

[1]Cost data after 1935 adjusted by State construction cost indexes.

in operations for vehicles using the highways. For example, Consolidated Freightways' trucks traveling between Portland and Seattle in 1947 required approximately six hours for the one-way trip. By 1959, this had been reduced to less than five hours, allowing the Company to make considerable changes in its operations. Western Greyhound Lines experienced similar benefits; their express buses traveling between Portland and Grants Pass improved their travel time from approximately eight hours in 1936 to less than six hours in 1960.

Still another benefit resulting from highway expenditures is indicated by the traffic density data of Table 9. Here, measurements of ADT were taken before and after improvement of the highway to freeway standards. The demonstrated increase in ADT suggests that it is appropriate to consider that congestion would have increased travel times unless highway facilities had been improved. That is, expenditures for construction, improvement, and maintenance not only reduce highway distance but also are necessary to mitigate the effects of increased traffic density. In a sense, it is necessary to run in order to stand still.

It is dangerous to present historical statistics in a study such as this one, because there is frequently a tendency to extrapolate the data without justification. This comment has particular relevance to the data concerning reductions in route length during the 25-year period. Although the "excess" distances (number of miles in excess of the straight-line distance between points) for both the Portland-Grants Pass and Portland-Seattle highways were almost halved between 1935 and 1960, it is not reasonable to assume that reductions will take place in the future on a similar scale. As noted earlier, such factors as population centers and topography define a traffic lane fairly rigorously. Thus, it is more reasonable to expect that future improvements will be designed not so much to decrease highway distance as to result in such benefits as improved traffic flow and accident reduction. Where distances will not be decreased, operating costs will be increased as speeds increase; hence, considerations of the "trade-off" between decreased time and increased vehicle-operating costs will become a subject of even greater interest to highway economic analysts.

Time Lag

Examination of the operating characteristics of Consolidated Freightways' trucks on the Portland-Grants Pass and Portland-Seattle highways clearly indicates a considerable lag between the point at which time is saved and that at which it can be utilized in an economic sense. The large sums of money spent for highway construction, improvement, and maintenance have resulted in decreased travel times between origin and destination cities. (The inverse relationship between highway expenditures and vehicle speed is evident, despite the increase in traffic density during the 25-year period.) Nevertheless, it has been demonstrated that the Company was unable to take advantage of speed increases until trip time was reduced to the point where operations could be drastically revised.

The lag between physical realization and economic utilization has essentially two interdependent aspects. The first of these, of course, is the lag as measured in number of years. For example, it has been shown that time saved by Consolidated Freightways' trucks between Portland and Seattle in, say, 1948, was worthless until about 1958 when a one-shift turnaround became feasible. An economic analysis attributing dollar benefits to the Company in 1948 would therefore have been in error. That is, the assumption by analysts, so widely held currently, that time savings necessarily have immediate economic value, is fallacious in principle.

The second aspect of this phenomenon is the dollar value of time savings. If time cannot be economically utilized when it is saved, it obviously has no value whatsoever—at least as far as the Company is concerned. But what is its value when utilization finally takes place? The importance of this question is evident when one considers that present methodology normally bases the dollar value of time on current wages. For example, an analyst evaluating the benefits of a highway improvement in, say, the fall of 1948, would probably have credited the project with $1,687 ($13.50 ÷ 8) for each hour of commercial vehicle time saved (using the average straight-time hourly rate). However, if the hour saved does not become economically meaningful until 1958, then a value of $2.47 ($19.76 ÷ 8) may be more appropriate. (This simple example does not imply that the author favors basing the value of time on straight-time hourly wages. It is only used here to indicate roughly the magnitude of changes in the parameter which take place over the span of time between physical realization and economic utilization. Nevertheless, because all present schemes for deriving time value are primarily based on driver wages, these remarks are appropriate[3].)

The primary reason for the lag between the point at which time is "released" by highway improvement and the point at which it becomes economically useful to the carrier is the operational characteristics of the individual company. In the case of Consolidated Freightways' operations between Portland and Seattle, for example, time saved could not be used until a turnaround during a single shift was made possible. An additional reason for this lag may be restrictions imposed by the particular Union contract governing the drivers. It has been noted that drivers are not allowed to handle freight at the origin or destination terminals. If they were, then "released" driving time could be utilized by the Company. Moreover, the employer does not have complete freedom to alter existing work practices, at least not from a practical point of view. Both the new turnaround scheduling at Seattle and the change in "division point" locations from Grants Pass to Medford were effected with the concurrence of the Union.

Economic Value of Time Saved

From the point of view of the company, wages cannot be saved until the driver is allowed to perform the same amount of work in less time, where "time" refers to that which is paid for and not the length of time taken to perform a given task. Because the value of time savings is largely dependent on the operating characteristics of the carrier, it follows that evaluating savings at the straight-time driver wage rate is inappropriate. For example, a highway improvement that reduces trip time from eight to seven hours has no value to the company. If an improvement reduces trip time from, say, five to four hours, and if this reduction allows the drivers to make a turnaround in one shift, then the last added improvement effectively results in a four-hour saving in driver wages. And if an improvement results in a driving time reduction from nine to eight hours, then the hour saved should be evaluated at overtime rather than straight-time wage rates. Moreover, because it is the total of all consequences of a project which is relevant, proper economic evaluation must include incremental fringe benefits such as those discussed earlier under "The Highway User."

Of course, certain economic benefits may accrue to the carrier as the result of highway improvement, even if driver wages may not be immediately reduced. In some cases, for example, drivers are allowed to perform nondriving activities at the origin or destination terminals. (These instances are rare among unionized drivers in the West.) Other opportunities for economically using savings in driver time occurs with

[3] Wage inflation presents no problem under certain conditions (2, p. 6).

regard to scheduling terminal activities and elimination of subsistence payments at "layover points." Still another benefit to the carrier occurs if a time saving permits the same amount of freight to be carried with fewer units of road equipment thereby reducing the carrier's capital costs.

It is clear from the preceding remarks that there are a number of economically meaningful consequences of reduction in driving time. But it is equally apparent that neither has time economic value (to the carrier) as soon as it is released, nor is its value measured by straight-time driver wages. Such assumptions, presently in vogue among highway economic analysts, are conceptually invalid and their continued unquestioned acceptance will in some instances lead to the selection of economically inferior alternatives. (There have been some recent attempts to establish the value of time in a more reasonable manner, but all present methodology persists in the assumption about timing of these benefits.)

The Future

In addition to verifying or disproving a given thesis, historical evidence of the type presented in this paper can also be used to indicate what may be expected in the future.

Additional reduction in vehicle travel time between Portland and Seattle will allow a greater percentage of single shift round trips because present one-way travel time of four and one-half to five hours has resulted in only about 40 percent of the schedules taking advantage of the round trip. Variability in (a) road time and (b) departure time from the origin terminal still causes a large percentage of the schedules to arrive at the destination terminal too late for return during the same shift. It is reasonable to expect that continued reductions in trip time will increase the number of schedules that are beneficially affected although, due to certain other operating characteristics, it is doubtful that 100 percent utilization will ever be accomplished. Future vehicle speed increases between Portland and Grants Pass are not as likely to yield significant economic benefits as those that are in prospect between Portland and Seattle.

Contractual provisions for sharing time savings between management and labor were discussed in the section on "The Highway User." This occurs, it will be recalled, when drivers are paid on a mileage, rather than time basis. Under this payment schedule, wages saved as the result of a reduction in trip length revert to the company at the rate of one-sixth a year for six years. Because contracts are subject to renegotiation, it is possible that future contracts will be written so as to "freeze" the route length for wage payment purposes, to allow the company to take full advantage of the savings, or to share the benefit on some other basis. In any event, this is an obvious example of the effect of labor-management contractual provisions on the value, as well as the timing, of benefits accrued as the result of highway improvement.

Future contract changes that will also be of interest to highway analysts are those relating to wages and fringe benefits. The steady increase in wages over the years since 1935 has been indicated and it seems reasonable to assume that the trend will continue. If all cost factors (other than capital costs) increase at the same rate, then this presents no problem. But, if this is not the case, analysts will have to take note of these changes and make appropriate adjustments to input data used in highway economy studies. Statistics presented earlier in this paper indicate that the problems of prospective rate of increase in wages and its proper treatment in economy studies are worthy of further research.

REFERENCES

1. "Road-User Benefit Analyses for Highway Improvement." American Association of State Highway Officials (1960).
2. Fleischer, G.A., "The Economic Utilization of Commercial Vehicle Time Saved as the Result of Highway Improvement." Doctoral dissertation, Stanford University, Project on Engineering-Economic Planning (Aug. 1962).
3. Giffin, H.W., "Some Observations on the Value of Time Saved to Motorists." HRB Proc., 28:53-56 (1948).
4. Grant, E.L., and Ireson, W.G., "Principles of Engineering Economy." 4th ed., Ronald Press (1960).

5. Grant, E. L. and Oglesby, C.H., "Economy Studies for Highways." HRB Bull. 306, 23-39 (1961).
6. Green, F.H., "Value of Time Saved by Commercial Vehicles as a Result of Highway Improvements." Unpublished U.S. Bureau of Public Roads report (1960).
7. "Economic Analysis in Highway Programming, Location and Design." HRB Special Report 56 (1960).
8. "Line-Haul Trucking Costs in Relation to Vehicle Gross Weights." HRB Bull. 301 (1961).
9. "Time and Gasoline Consumption Motor Truck Operations as Affected by the Weight and Power of Vehicles and the Rise and Fall in Highways." HRB Research Report 9-A (1950).
10. Johnston, W.W., "Travel Time and Planning." Traffic Quart., Vol. 10 (Jan. 1956).
11. Kent, M.F., "Fuel and Time Consumption Rates for Trucks in Freight Service." Public Roads, Vol. 31 (April 1960).
12. Lawton, L., "Evaluating Highway Improvements on Mileage and Time-Cost Basis." Traffic Quart., Vol. 4 (Jan. 1950).
13. McCullough, C.B., and Beakey, J., "Time Element Benefits." Economics of Highway Planning, Oregon State Highway Department, Technical Bull. 7 (1938).
14. McKie, C.A., "Analysis of Benefits Accruing to the Motorist Through Shortened Distance and Surface Improvement." Mississippi Highways (Nov. 1946).
15. Mohring, H., "The Nature and Measurement of Highway Benefits: An Analytical Framework." Northwestern University (June 1960).
16. Moyer, R.A. "An Analysis of Highway-User Benefits on California Inter-State System Resulting from Completion of a 10-Year Full Freeway Program." University of California, Institute of Transportation and Traffic Engineering, Special Report 30 (1955).
17. "Substantial Operating and Maintenance Savings and Other Benefits that Accrue to Trucking Firms Using the New York State Thruway." New York State Thruway Authority (1958).
18. Ritter, L.J., and Paquette, R.J., "Value of Time Savings Effected by Highway Improvements." Highway Engineering, 2nd ed., Ronald Press (1960).
19. U.S. Bureau of Public Roads, "Selective Bibliography on Value of Time, Comfort and Convenience." U.S. Government Printing Office (1958).
20. U.S. Congress, House, "Final Report of the Highway Cost Allocation Study." House Documents 54 and 72, U.S. Government Printing Office (1961).
21. Vaswani, R., "Value of Automobile Transit Time in Highway Planning." HRB Proc., 37:58-71 (1958).
22. Lee, R.R., Fleischer, G.A., and Roggeveen, V.J., "Engineering-Economic Planning of Transportation Facilities—A Selected Bibliography." Stanford University, Project on Engineering-Economic Planning (Sept. 1961).