and width of the weaving area. The weaving section should have a width at least of one more lane than would be normally required by the total entering traffic that is to weave plus a sufficient number of lanes at each side to carry the through traffic without interference to the weaving vehicles.

Adequate sight distance ahead of the weaving area is also important in order that drivers may size up the situation in advance and make any necessary adjustments in order to arrive at the weaving area at the proper time and place.

More data are needed before determination can be made for the proper combination of length, width and angle of approach for various volumes and speeds of traffic. The data available seem to indicate that if the maximum length is more than 900 ft., traffic streams tend to travel side by side, resulting in a forced weaving near the end of the weaving section.

Accident records show that weaving areas are not necessarily places of hazard and traffic friction but can be constructed so that they are at least as safe as any other section of a modern highway.

APPRAISAL OF RURAL ROUTES

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SYNOPSIS

Straight line diagrams have provided a means of recording in one place the pertinent details and features of a non-uniform length of highway. Such diagrams have been developed by many States for each of the routes constituting their highway systems. The Public Roads Administration used similar record diagrams in development and portrayal of the features of the routes on the strategic system. Currently the states are preparing such diagrams for the routes on the Interstate System of highways.

The principal feature of these diagrams is the highway map, straightened out across the top of the sheet. Arranged on separate horizontal lines beneath and appropriately spaced along the length of the road were numerical, word, or symbol notations indicating type and width of roadbed and shoulders, traffic volumes, curves, grades, sight restrictions, accident locations and similar pertinent data. Because of the number of items to be recorded, the space allowed for each was limited vertically, and the information was often shown by abbreviated words to keep the length of the diagram within limits.

A major advantage of the straight line portrayal is the fact that all the data pertaining to a point on the road is shown directly beneath it on the other lines of the chart. However, many of the details were not easily recognized because they were expressed in numbers or words. It was thought that if these details could be graphed or plotted, their significance would be more apparent.

In developing a straight line diagram for a 38-mile route between Glastonbury and New London, Connecticut, various graphic methods were used. A map was used across the top of the sheet with all intersecting roads and villages shown in true position along the route being studied. Traffic was shown in profile. Desirable maximum operating speeds were established after consideration of topography and adjacent land use. They were shown alongside the actual average operating speeds. Widths of travelled path and shoulders were graphed to show their variations. Curves and grades were plotted to show length, degree or percent, and direction. Those in excess of the maximums desirable for each operating speed were accented. Sight distances insufficient for passing or stopping at the desirable speeds were plotted to show length of restriction in each direction. The accidents were located and classified by the direction the driver at fault was travelling.

With the diagram thus plotted, and the deficiencies in each feature accented, it was a comparatively simple matter to establish the limits of the sections most in need of reconstruction.

As an introduction to one of Connecticut's highway problems let us consider these facts. Connecticut is a small state with rolling topography. Its area is almost exactly 5,000 square miles. The Highway Department was organized over 50 years ago. In the course of that half century a vast network of State roads have been built to standards thought adequate at the time of construction. According to present standards a great proportion of the 3,000 miles on the system are now obsolete, because they do not possess the horizontal and vertical alignments necessary for safety at present day vehicle speeds.

Today Connecticut probably has the most dense network or spider web, of hard surfaced two-lane State highways in the nation and the world, 3,000 miles of State roads in 5,000 square miles. This network includes over 20 percent of all the public roads in Connecticut. As the system has grown, the maintenance responsibility has increased at an even faster rate because of the quality and intensity of maintenance being demanded. So now, while the Department is devoting more of its funds to maintenance than ever before, many obsolete portions of the system are in need of modern reconstruction although the pavement surfaces are as a rule better than when new.

TABLE 1
CONNECTICUT STATE HIGHWAY SYSTEM MILEAGE CLASSIFIED BY YEAR OF CONSTRUCTION

Year of Construction	Miles in Service	Percent of System	Cumulative Percent	Age in Years
Before 1909	98	3.3	3.3	over 40
1909–1913	121	4.1	7.4	over 35
1914–1918	203	6.9	14.3	over 30
1919–1923	403	13.7	28.0	over 25
1924–1928	720	24.4	52.4	over 20
1929–1933	615	20.9	73.3	over 15
1934–1938	415	14.1	87.4	over 10
1939–1943	276	9.4	96.8	over 5
1944–1948	93	3.2	100.0	
Total	2944	100.0		

A record of the present system mileage arranged by year of construction as in Table 1 indicates the great age of many miles.

One mile out of every 30 in the present system is over 40 years of age. One mile in seven has been maintained for over 30 years. More than one quarter of our system was built over a quarter century ago. Fifty-two and four-tenths percent of Connecticut's state highways still remain on alignments unchanged in 20 years.

The need to maintain hard all-weather road surfaces has been the first responsibility.

Secondly, it is the responsibility of the Department to reconstruct the main routes whenever the traffic volumes increase beyond the safe capacity of the existing rural arteries and to extend them into the cities where congestion and accidents levy their greatest tolls.

A third problem confronting the Department is what to do about the obsolete highways in the system and particularly those whose two-lane capacity is not taxed at all or only on a few summer weekends. Frankly, Connecticut does not have the resources to reconstruct these roads when they reach a certain age. The pavements on these roads have been excellently maintained; it is usually in other characteristics that they exhibit their inadequacies. The curvature, gradients and sight distance restrictions are not proper for the vehicle speeds common today. Hence the appalling accident experiences. It is the high accident frequency locations which often focus attention on such a highway.

The answer to this problem of "what to do?" has been the subject of numerous reports by the Connecticut Bureau of Highway Planning. Many of these have been in the form of memoranda for use within the Department. Occasionally, public interest and demand for action have indicated the desirability of publishing a planning report on a certain highway. The means of describing the studies and reaching the conclusions has often seemed unsatisfactory. Maybe there was too much opinion and not enough fact. The difficulties of translating engineering terms into words understandable to the layman are great. Sometimes pictures can be used to assist the presentation. The report on Connecticut Route 58 contained many. It too contained maps and diagrams but each of these was devoted to only one or two subjects. The need for interrelating the great variety of pertinent facts has long been recognized. The device known as the straight line diagram provides a means of showing that inter-relationship.

The first experience Connecticut had with the straight line diagram method was back in

1939 in the compilation of data requested by the Public Roads Administration in developing the report on "Toll Roads and Free Roads."

The straight line diagram basically consists of a road map straightened out across the top of the sheet so that the horizontal scale indicates distances along the road. Other features, such as side roads, watercourses, railroads, political boundaries, and urban or corporate limits are shown wherever they meet or cross the road. The rest of the sheet is divided horizontally to provide a series of spaces in which other data may be recorded and referenced to the correct location along the road by vertical lines at regular or special intervals. Separate horizontal lines are used for each of the characteristics to be shown. The recordings are usually made in numbers, words or symbols because of space limitations.

In the diagrams prepared for "Toll Roads and Free Roads" the diagram scale was 1 in. equals 20 miles and data on 20 subjects were recorded on separate lines. Word or numerical records were used on 7 lines while chart, profile or graphical recordings were used on 13 lines. The straight line diagrams in the published report followed the form on which the data had been recorded in the states although some data were deleted.

In the diagrams currently being developed for the roads constituting the interstate system the States are recording data on 42 items. Because of the great number of items only eight of these can be shown graphically.

Straight line diagrams of the mileage included in the Connecticut State Highway System were produced in 1942 by the Planning Survey. On them only such data were recorded as was thought useful for that record. The drafted scale was 10 in. to the mile. In addition to the usual cross road and boundary information, roadside culture was shown on the map section where space was also left for showing poles, billboards, and other data useful for spotting accident locations. Arranged on separate lines and indicated by words, abbreviations or numbers were the details of type, width, traffic, curvature, vertical and horizontal sight distances, cause of restriction, and grades as they were available from the inventory, traffic survey or critical features studies of the planning survey.

It is recognized that the straight line diagrams discussed above were primarily designed for use in engineering offices. Only infrequently was the device used to portray details in a report which might reach the public. However, as it developed in Connecticut, there appeared to be merit in presenting the more striking or pertinent roadway details in our planning reports. In so doing it was necessary to graph or simplify the data pictorially. Our attempt was always to present the data in a form understandable to the interested layman. Graphical presentation was used instead of words or numbers wherever possible.

In pursuit of this goal many changes were made. Traffic was shown as in profile; the height of the traffic band was proportional to the volume and through traffic was shown differently from local traffic by shading. Roadway and shoulder widths were shown with a varying width band exaggerated enough to show the difference. Curves were graphed by indicating the degree of curvature vertically and length of curve horizontally. Percents of grades were similarly indicated by vertical bands.

Since the unobstructed sight distance is so important to the behavior of the vehicle operator it was thought essential to indicate that item on the diagram. Here however, the data from the critical feature study was inadequate. The sight distance survey obtained the location and minimum lengths of the restriction. No data on the clear sight distances were available and it is the clear distance which provides the passing opportunity. Moreover the passing distance varies with the speeds of the vehicles. Therefore, before plotting either clear or restricted sight distances it was necessary to know vehicle speeds.

Probably the discussions concerning the proper speeds to use for sight distances, led to a basic change in Connecticut's use of the straight line diagram in route reports. In all of the studies where alternative improvements were being appraised, it had been necessary to determine the average operating speeds on the various sections of the existing roads. They could easily be obtained on routes being diagrammed, but were those the speeds to be used in design of any improvement? Would new designs be based on existing operating speeds? Of course not. If safe operating speeds were adequate, there wouldn't be much need for improved design.

As stated in one of the planning reports, "The critical element in the evaluation of an existing highway and in establishing standards of construction for a new one, is the maximum operating speed for which the road should be expected to serve. We have, therefore, established desirable maximum operating speeds for various sections of the routes, depending upon the character of the development, which the routes traverse."

In all recent straight line diagrams, therefore, the type of development has taken an important position, and operating speeds, both the actual and the desirable, are shown. The desirable operating speed, moreover, is used not only in the determination of the sight distance restrictions but also to differentiate between satisfactory and deficient curves in the existing alignment of the route.

From this discussion of the evolutionary development of straight line diagrams, let us now turn to the diagram developed in one of our recent route studies. It is believed that this development of graphical means of pointing up deficiencies did much to crystallize the modernization problem on the New London Turnpike. The route was 38 miles long, built between 1922 and 1926. The report recommended nine first stage improvements totalling 8 miles, to be followed by three improvements of 7-mile length at a later time. The only illustration used was the 34-in. sheet folded as an appendix to that report. It was originally drafted at 2 in. equal 1 mile because that was the scale of the topographic maps of the area. Figure 1 shows a portion of the diagram.

Approximately one-third of that diagram entitled "Roadway and Traffic Characteristics" was devoted to a map which shows the existing road as an open band stretching from Glastonbury Center to New London. The map arrangement was used instead of a straight line for the road because it is more easily understood by the laymen. The alignment, road network and town boundaries assist in orientation. Fifty-foot contours were shown in color to give an indication of the rugged or level character of the terrain. The topographic map provided a place for showing the proposed alignment changes, and colored shading was available for calling attention to the proposed improvements without obliterating other detail. Because the curved road of the map did not register with the lineal scale of the other diagrams, it was necessary to mark the mile points on both the map and the traffic profile.

Below the map and above the diagrams, the type of development and the names of the localities were noted. Daily traffic was shown in shaded profile thoughout the length of the diagram. The sharp breaks were referenced to the intersecting roads by road or street names, and the humps in the profile confirm the urban nature of the development. The quantity of traffic on normal summer Sundays was so far in excess of that on the average day, that its levels were indicated between important route junctions.

Operating speeds were shown by numerical volumes on two lines. Actual average speeds obtained by the floating car method were shown like dimensions on a drawing. The desirable maximum operating speeds were established at 50 miles per hour for rural sections and at 30 miles per hour for urban areas with 40 miles per hour transitional speed zones in between. The differences between actual and desirable speeds at any point can be readily obtained by subtraction. The cause of the reduction may often be traced to specific roadway elements, noticeable above or below the "speed" lines on the sheet.

Lacking a better method, surface type and year built have been written out on the next line.

The width of travel path and shoulders were both drawn to scale and dimensioned. The travel path diagram was shaded so that the width changes could be readily noticed.

In earlier diagrams, the degree of curvature was indicated by the height of a bar rising from a base line. Length of curve was indicated by the width of the bar. That method was abandoned because reverse curves failed to appear as such. The present diagram indicates the direction of the curve by placing those deflections to the left above and the lineal deflections to the right below the line, just as a driver travelling to the right across the drawing would observe them. This method differentiates the simple, compound and reverses types of curvature. It calls particular attention to the reverse curves by the extreme height of the diagram. The dashed

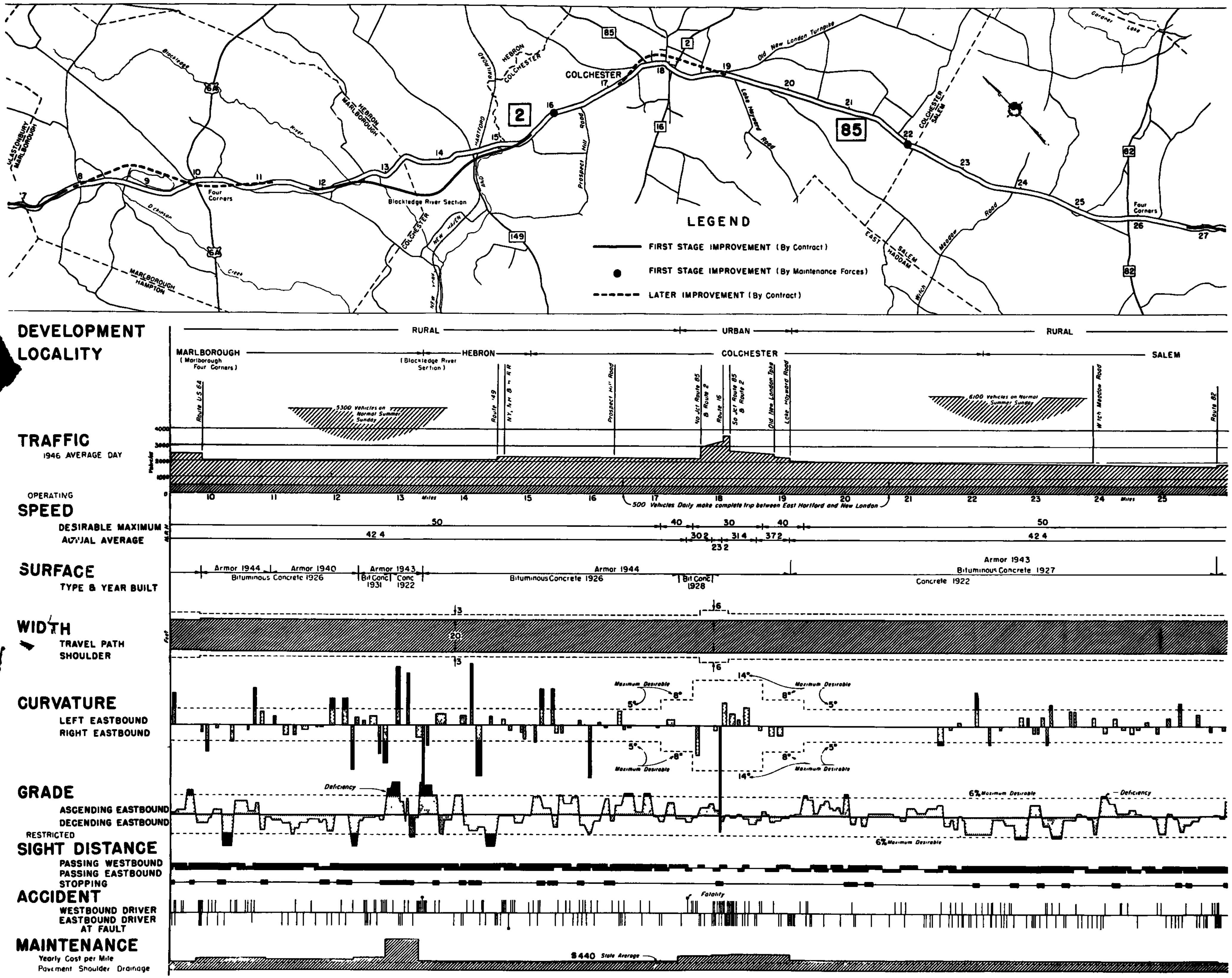
LEGEND
FIRST STAGE IMPROVEMENT (By Contract)
FIRST STAGE IMPROVEMENT (By Maintenance Forces)
LATER IMPROVEMENT (By Contract)
COLCHESTER
Four Corners
Blackledge River Section
Old New London Turnpike
Lake Hayward Road
Prospect Hill Road
Witch Meadow Road
DEVELOPMENT
RURAL
URBAN
LOCALITY
MARLBOROUGH (Marlborough Four Corners)
HEBRON
(Blackledge River Section)
SALEM
TRAFFIC
1946 AVERAGE DAY
5300 Vehicles on Normal Summer Sunday
6100 Vehicles on Normal Summer Sunday
500 Vehicles Daily make complete trip between East Hartford and New London
OPERATING
SPEED
DESIRABLE MAXIMUM
ACTUAL AVERAGE
SURFACE
TYPE & YEAR BUILT
Armor 1944
Bituminous Concrete 1926
Armor 1940
Armor 1943
Bit Conc 1931
Conc 1922
Bit Conc 1928
Bituminous Concrete 1927
Concrete 1922
WIDTH
TRAVEL PATH
SHOULDER
CURVATURE
LEFT EASTBOUND
RIGHT EASTBOUND
Maximum Desirable
GRADE
ASCENDING EASTBOUND
DECENDING EASTBOUND
Deficiency
6% Maximum Desirable
RESTRICTED
SIGHT DISTANCE
PASSING WESTBOUND
PASSING EASTBOUND
STOPPING
ACCIDENT
WESTBOUND DRIVER
EASTBOUND DRIVER
AT FAULT
Fatality
MAINTENANCE
Yearly Cost per Mile
Pavement Shoulder Drainage
$440 State Average

Figure 1

lines placed along each side of the curvature diagram indicate the maximum curvature which can be safely negotiated at the maximum desirable operating speed (assuming proper superelevation on the curves). A 14-deg. curve is as safe for vehicles operating at 30 m.p.h. as the 5-deg. curve at a location where the desirable speed is 50 m.p.h.

Inasmuch as the character of land development was the prime consideration in establishing maximum speeds it is paramount in establishment of maximum desirable curvature also.

Because one purpose of this diagram was to direct attention to deficiences, the portions of the curve bars outside of the dashed lines were made solid black, in contrast to the shaded portion of the bars which are safely negotiable.

Grades were indicated in a similar manner. Ascending grades for eastbound vehicles are above the base line. Descending grades for that direction were shown below the line. Vertical curves at changes of grade account for the sloping edges of this bar chart. The maximum grade desired, 6 percent on this type of route, was indicated and excessive grades were shown in solid black as deficiencies.

Both passing and stopping sight distance deficiences were shown in wide black lines parallel to the baselines. Because sight restrictions from a point on a highway depend on the direction of travel, the westbound passing restrictions were indicated above the line and the eastbound below it. Each of the maximum desirable speeds has its own requirement for safe passing and safe stopping. Using these "yardsticks", the construction plans were studied to determine the locations where the safe sight distances were not available.

The accident reports covered a 7-year period and almost 700 reports were the source of the accident data. The direction of the driver at fault as well as the precise location were determined and shown on the chart. The grouping of accidents directly beneath the diagram showing roadway elements often indicates the contributing factors. The coincidence of the deficiencies indicated on the several lines of the chart called attention to a number of spots as in great need of improvement.

It was a relatively simple matter to prove the interrelationship of the deficiencies in horizontal curvatures and vertical gradient when these are accompanied by a cluster of accidents and a fatality where they coincide near mile 34, on Douglas Hill in Waterford and at mile 13, near the Blackledge River. There is no doubt that improvements are warranted at such locations.

When the apparent coincident deficiencies had been spotted for the entire route by coloring a stripe vertically through them, consideration was given to the extent of the improvement to be recommended. The improvement of individual deficiencies was recommended when that would result in improving the adequacy of a considerable length of the highway. That was done in six locations whose total length was only about a mile. Where the vertical stripes were closely spaced a continuous improvement, often on new location, was indicated. Three such improvements were recommended after study of the topography adjacent to the existing route.

On the map the recommended improvements were indicated by heavy dots or lines overlaid with the colored shading. On the lower portions of the diagram the location of the recommendations was shown by colored vertical bands.

Most of the material used in the preparation of such a diagram can be taken from the road life and map files maintained by the highway departments, supplemented by additional field reconnaissance where necessary. To be sure, it requires a considerable number of man-hours of labor to compile all the data from the various sources and to accurately plot them to scale on the diagram. The work involved in preparing the diagram used in our New London Turnpike report provided us with a most satisfactory means of appraising this route and was well worth the time and effort involved.

A route that is entirely inadequate with regard to capacity, where congestion exists during the peak hourly periods of the day, and where reconstruction on new alignment seems indicated, is not the type of route where a roadway characteristics diagram should be employed.

As pointed out earlier in the discussion, its most advantageous use is on those routes which possess satisfactory roadway capacity but are deficient in the roadway elements affecting the safe and efficient movement of vehicles. These deficiencies are usually found to exist under the headings of alignment, gradient and sight distance.

A study of a diagram, depicting graphically the roadway elements, clearly indicates the deficient sections most in need of reconstruction. Such a diagram based on sound factual information is a powerful weapon for highway administrators to use in backing up the need for highway improvements. However, the search for improved methods of appraisal is continuing.

FUNCTIONAL DESIGN FOR GROUND TRANSPORTATION FACILITIES AT AIRPORTS

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SYNOPSIS

Based on recognized principles of traffic operation, the author herein brings out the design of airport ground transportation facilities from a functional standpoint. Roadway and terminal facilities at the LaGuardia and Newark Airports have been fitted within existing physical limitations to operating demands and the more efficient and economical use of land. Experience gained at these facilities and through surveys of probable future demands have been utilized in the planning for the New York International Airport (the largest in the world) in its initial stage as well as the ultimate development.

Facilities for handling the ground transportation vehicles, such as cargo trucks, airport buses, urban buses, taxis and private passenger cars, are discussed and illustrations presented showing the importance in their location and design for greatest utilization of the terminal facilities at the airport. In the rearrangement and future design of these ground transportation facilities, an effort has been made to provide roadways free of parked vehicles, reserving the roadway exclusively for movement, loading and unloading. It is also pointed out that since a great portion of the revenue from an airport must be derived from nonflight sources, the design must be considered economically as well as functionally, thereby eliminating unnecessary overhead.

Construction of New York International Airport was begun by the City of New York in 1942. The Port of New York Authority became responsible for the operation, maintenance and development of this airport, as well as LaGuardia and Newark, under a 50 year lease arrangement in 1947 and 1948. After 18 months operation of LaGuardia Airport, and 9 months operation of Newark Airport, we have gained valuable data and experience in the location, design and arrangement of ground transportation facilities at airports.

One of the first steps in the development of this airport system, was to obtain data on the magnitude of the ground transportation problem. How do people travel to and from the airport? How many use regular buses, taxis, airport buses and limousines, and private passenger cars? What percentage of the people coming to the airport are passengers, sightseers, or people bidding others good-bye, or are meeting an air passenger? How may trucks, taxis, buses, and passenger cars enter and leave the airport during the day? What is the peak hour and peak day loads in relation to average hours and average days? What are the volumes of traffic entering the various roadways and when do they occur? What facilities do the patrons of an airport desire? How large should these desired facilities be and where should they be placed? These are questions which must be answered before designing an airport. They are, of course, the same questions which generally must be answered in the design of any other transportation facility.

There is one problem which The Port of New York Authority must contend with, not always present in other transportation organizations; that is, its facilities must be so designed that they will pay their way, as the Port Authority is a self-sustaining organization,