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HIGHWAY NEEDS OF THE NATIONAL DEFENSE

MESSAGE

FROM

THE PRESIDENT OF THE UNITED STATES

TRANSMITTING

A LETTER FROM THE ADMINISTRATOR OF THE FEDERAL WORKS AGENCY, ENCLOSING A REPORT ON HIGHWAY NEEDS OF THE NATIONAL DEFENSE

JUNE 30, 1949.—Referred to the Committee on Public Works and ordered to be printed, with illustrations

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LETTER FROM THE PRESIDENT TO THE CONGRESS

To the Congress of the United States:

I transmit herewith a letter from the Administrator of the Federal Works Agency, enclosing a report on highway needs of the national defense.

The report was prepared at the request of the Congress by the Commissioner of Public Roads in cooperation with the several State highway departments. In compliance with the request, the Secretary of Defense and the National Security Reso·irces Board were invited to cooperate and have responded with suggestion of the indicated or potential needs for improved highways for the national defense. An expression of the views of the National Military Establishment, which has the concurrence of each of the military Departments and agencies, is appended.

The larger part of the report presents information in detail concerning the condition of the highways of the country and their fitness to meet defense and civil needs, with particular reference to the National System of Interstate Highways. There is indication also of certain measures intended to permit the taking of prompt highway improvement action in the event of a national emergency.

This report is a ıseful document. I recommend it to the consideration of the Congress in connection with such further provision as may be made for the continuance of Federal aid for highway construction.

HARRY S. TRUMAN.

THE WHITE HOUSE, *June 30, 1949.*

LETTER FROM THE FEDERAL WORKS ADMINISTRATOR TO THE PRESIDENT

FEDERAL WORKS AGENCY,
OFFICE OF THE ADMINISTRATOR,
Washington, May 27, 1949.

The PRESIDENT,
The White House.

MY DEAR MR. PRESIDENT: I transmit, with my approval, a report on highway needs of the national defense, prepared by the Commissioner of Public Roads in cooperation with the several State highway departments, and with the advice of the Secretary of Defense and the National Security Resources Board.

This report has been prepared in compliance with a direction of the Congress contained in section 2 of the Federal-aid Highway Act of 1948, approved June 29, 1948, quoted as follows:

"SEC. 2. The Commissioner of Public Roads is hereby directed to cooperate with the State highway departments in a study of the status of improvement of the National System of Interstate Highways, designated in accordance with the provisions of section 7 of the Federal-aid Highway Act of 1944; to invite the cooperation and suggestions of the Secretary of Defense and the National Security Resources Board as to their indicated or potential needs for improved highways for the national defense; and to supplement, not later than April 1, 1949, the report dated February 1, 1941, entitled 'Highways for the National Defense' (Seventy-seventh Congress, first session), to reflect current conditions and deficiencies."

The report is factual in the highest degree. It points to improvement needs on the country's most important highways that are of such moment as to warrant the most serious consideration.

I recommend the report and request that you transmit it, with your approval, to the Congress.

Sincerely yours,

PHILIP B. FLEMING,
Major General, United States Army,
Administrator.

LETTER FROM THE COMMISSIONER OF PUBLIC ROADS TO THE ADMINISTRATOR

PUBLIC ROADS ADMINISTRATION,
FEDERAL WORKS AGENCY,
Washington, May 27, 1949.

Maj. Gen. PHILIP B. FLEMING,
Administrator, Federal Works Agency.

DEAR GENERAL FLEMING: The accompanying report has been prepared at the direction of the Congress, to reflect the status of improvement of the interstate highway system, with indicated needs to serve the national defense, and to supplement the report of February 1, 1941, with current appraisal of conditions and deficiencies of the general highway system.

The State highway departments have all joined in a remarkably detailed examination of the mile-by-mile physical condition of the interstate highway system, thus affording for the first time an accurate evaluation of the roads upon which is concentrated the interstate flow of traffic on a Nation-wide scale.

In the preparation of the report, in accord with the direction of the Congress, we have requested and received full cooperation of the Secretary of National Defense. We have also had the suggestions of the National Security Resources Board.

In much the same manner as our great rivers gather to themselves the flow from innumerable other streams and their tributaries, the interstate highway system receives and must carry about 20 percent of the total vehicle-mileage generated by more than 41 million motor vehicles. The system of interstate highways comprises only 1-plus percent of the total of public roads and streets. The high percentage of total traffic reflects its peacetime use. This same limited system of major roads is clearly indicated to constitute the routes essential to defense needs.

Any complacency we may have as to the present adequacy of these major roads to serve in peace or in war is shattered by the evidence presented. The average age of all roadways is 12 years. The average age of the roadbeds on which these surfaces rest is 17 years. After 10 years of a 20-year program of rehabilitation and replacement, now begun, the surfaces on the unreconstructed portion of the system would average about 20 years of age, their roadbeds at least 25 years. These average ages point to the realistic size of the undertaking with which we are confronted.

The most serious deficiency of our highways today, not only the interstate system, but others of greater or less importance, is their lack of capacity to provide for the ever-increasing number of motor vehicles in service. This year the production of motor vehicles at present rates will range well above 5 million units. With a substantial allowance for vehicles taken out of service, the increase of vehicles in use, if it could be formed into a moving column, would stretch over 27,000 miles, or once around the world at the equator and 3,000 miles further on a second lap. The use of motor vehicles is the direct support of three of our major industries, without reference to the ancillary spread into numerous other elements of our economy. It seems unnecessary to argue that the annual addition of increments to overloaded and hence unsafe highways, cannot be continued at current rates without major enlargements and increases in the highway systems.

Because of the concentration of traffic on the interstate highway system the deficiencies are acute, particularly within the urban areas, but these inadequacies extend to the remaining mileage of the Federal-aid system, rural and urban, to many miles of the secondary Federal-aid system, and to other roads not included. If we are to have roads that are safe, and if we are to obtain the utility of the motor vehicle with economy, it is necessary to have a program of reconstruction, rehabilitation, and extension of highways consistent with the number and types of motor vehicles now in service, to which extraordinary additions are being constantly made.

The program substantially based on these requirements is clearly set forth in this report.

The report is the fourth in a series made at the direction of the Congress: Toll Roads and Free Roads, April 1939; Highways for the National Defense, February 1941; Interregional Highways, January 1944; and Highway Needs of the National Defense, the present report.

Together these reports provide a historical review of the growth and changing characteristics of our highways in relation to our whole national economy, during both peace and war, and a projection of future necessities based on solid facts whose authenticity cannot be called into question.

They demonstrate the ability of State governments and the Federal Government to cooperate in a study of national problems which have both local and national significance. The contributions of the State highway departments to this report in scope and content reflect a maturing of scientific precision in dealing with the problems. Their cooperation and aid are gratefully acknowledged.

I recommend that this report be placed before the President for transmission to the Congress for consideration of the factual evidence present as a basis for future highway programs.

Very respectfully,

THOS. H. MACDONALD,
Commissioner of Public Roads.

CONTENTS

HIGHWAY NEEDS OF THE NATIONAL DEFENSE

Section 2 of the Federal-aid Highway Act of 1948, approved June 29, 1948, provides that:

"The Commissioner of Public Roads is hereby directed to cooperate with the State highway departments in a study of the status of improvement of the National System of Interstate Highways, designated in accordance with the provisions of section 7 of the Federal-aid Highway Act of 1944; to invite the cooperation and suggestions of the Secretary of Defense and the National Security Resources Board as to their indicated or potential needs for improved highways for the national defense; and to supplement, not later than April 1, 1949, the report dated February 1, 1941, entitled 'Highways for the National Defense' (77th Cong., 1st sess.), to reflect current conditions and deficiencies."

This direction of the Congress has been complied with in every respect. A detailed study of the status of improvement of the National System of Interstate Highways has been made, with the complete cooperation of every State highway department. The Secretary of Defense and the National Security Resources Board have been invited to cooperate and have responded with suggestion of the indicated or potential needs for improved highways for the national defense; and the following report, supplementary to the report dated February 1, 1941, entitled "Highways for the National Defense," reflects the conditions and principal deficiencies of the highway system of the United States, existing December 31, 1948, as they are believed to affect the national defense.

SUMMARY AND RECOMMENDATIONS

THE NATIONAL SYSTEM OF INTERSTATE HIGHWAYS

The National System of Interstate Highways is the trunk-line highway system of the United States. It connects all the largest cities and most of the larger ones. On its rural sections it serves 20 percent of the traffic carried by all rural roads. Its urban sections thus far designated, to which further designation will add an almost equal mileage, now serves more than 10 percent of the traffic moving over all city streets.

This large measure of service is rendered by a network that includes only 1 percent of the country's total mileage of roads and streets. Without doubt, this system forms the most important connected network within the highway system of the country for service of the economy of peace.

Strategic importance of the interstate system

The National Military Establishment has determined that this same system includes in its rural sections substantially the roads of greatest strategic importance for service of the highway necessities of war. The urban sections designated are rated with the same authority as of prime importance for wartime duty, and the additional urban designation desirable for service of wartime movements is identical in character with the additional needs of normal usage in peace. This additional designation, consisting largely of circumferential routes in and around the larger cities, should be completed as promptly as possible.

A substantial part of the street network of our cities and much of the rural road mileage improved during a period of 40 years past, is seriously obsolescent. Traffic has grown faster than the responsive improvement of the street and highway facilities. Of the entire street and highway network, the interstate highway system, its most important segment, is by and large the most seriously obsolescent part. In the general lifting of arterial highway standards that is now needed and overlong delayed, the routes comprising the interstate system should be among the first considered for improvement.

Condition of the system

Recent research and development have provided definite guides which determine in detail the standards of design required for the adequate service of traffic of specific volumes and classes. The proper application of these standards will not only assure a safe and efficient accommodation of present traffic; it will also provide for the expected greater traffic of the future a facility of continuing usefulness, if the size and weight of vehicles are held within the limits recommended.

The determined conditions of the interstate system have been weighed against these standards, and the system has been found seriously deficient. It is most deficient in its sight distances and in the width of its pavements, shoulders, and bridges. The sight-distance deficiencies are the result of defects of alinement and vertical curvature. These are fundamental defects. Their correction involves the necessity of much relocation and the obtainment of new or enlarged rights-of-way, accounting in large measure for the high cost of essential improvements.

The relocation proposed would shorten the total length of rural sections of the system by 384 miles, urban sections by 257 miles, a total reduction of 641 miles from the present length of 37,800 miles. Other improvements proposed would substantially increase the traffic capacity of the system, and speed the flow of travel over it with further advantage in the convenience and safety of the movement.

If in 1948 rural sections of the system had been improved as proposed, 1,400 lives lost in traffic accidents might have been saved. If in the same year the proposed improvement of urban sections had been completed, the savings of travel time alone thereby made possible, valued at a cent a minute, would have amounted to approximately four-fifths of an annual installment of the capital cost estimated, amortized over a period of 20 years.

Cost of needed improvements

The estimated cost of improvements proposed is approximately $11,266,000,000, of which $5,293,000,000 is for sections of the system within the urban areas of cities of 5,000 or more population, and $5,973,000,000 is for rural sections. These costs are estimated on the basis of prices of construction work prevailing in 1948. They may be lowered by a decline of prices in the future.

They are, however, the costs of improvements required now to adapt the system to the needs of its present traffic. As improvements are undertaken, ample provision should be made for the increased traffic that may be anticipated in a period of 20 years. This will increase the costs as estimated, but not greatly.

Capital requirements of such magnitude obviously cannot be met from the revenue of a single year. The improvement is needed now. In part it can be deferred, but deferral means the acceptance of greater costs in lives lost, in inconvenience, and in the actual expense of vehicle operation. Correction of the existing deficiencies by measures at least as costly must be made in any case whenever in the future further improvement is undertaken on the roads and streets now forming the system. In a period no longer than 20 years, such improvement must be undertaken on every mile.

If the system is to be brought to a state of adequacy in this longest reasonable period, a capital investment averaging probably more than $500,000,000 per year will be required. No less provision can be economically justified.

Much greater economic and social benefit would result from a completion of the proposed improvement in a period far shorter than 20 years. Needs of the national defense further require a substantially more rapid improvement. The improvement can be so advanced with borrowed capital, and amortization over a period of 20 years will hold the annual revenue requirement, less interest, to the same amounts that would be required for a protracted improvement. The interest requirement would probably be more than equaled by benefits accruing to the increments of traffic the future will add to present volumes.

Federal aid for interstate system improvement

Federal-aid funds authorized for the primary and urban Federal-aid systems are currently being allotted to projects on the interstate system at the rate of approximately $75,000,000 annually. No other highway expenditure of the Federal Government is more clearly justified by the national interest involved.

To provide for improvement of the system at a rate not slower than the essential minimum, consideration should be given to the advisability of the authorization of additional Federal appropriations earmarked for expenditure only on the interstate system in urban and rural areas. Funds so authorized should be apportioned among the States in such proportions as to permit substantially equal progress in the correction of existing deficiencies in all States.

In view of the extraordinary interstate and national interest attaching to the system, Federal participation in the cost of improvements made in a ratio greater than the normal 50 percent would seem appropriate.

Some States may elect to accelerate the necessary improvement of the system by borrowing capital. In any such case it would seem desirable that the Federal law permit future allotment of Federal funds to be applied to the retirement of the indebtedness incurred for such improvements, exclusive of interest, in the same manner as presently provided for participation in current costs of improvement.

CONTINUANCE OF AID FOR OTHER HIGHWAYS RECOMMENDED

The recommended provision of additional Federal funds earmarked for the interstate system should not be subtracted from the provision for other parts of the Federal-aid primary and urban system, nor from the provision for secondary roads. There are deficiencies on other primary routes, of the same character as those shown by this report to exist on the interstate system, and they are more numerous in proportion to the larger mileage involved.

The National Military Establishment has pointed out that there may be additional routes, probably not exceeding a total of 2,500 miles, that are strategically as important as some now included in the interstate system. These are, doubtless, embraced in the Federal-aid primary system. Improvement of the principal secondary roads, long deferred, remains a present need whatever may be the provision for the primary roads, and these improvements also will contribute to a state of highway readiness for the national defense. The need for these other improvements is inferior only to needs on the interstate system.

The Federal Government should continue to authorize appropriations for the Federal-aid primary, urban, and secondary highway systems at rates not less than those established by the Federal-aid Highway Act of 1948.

DESIRABLE PROVISION FOR EMERGENCY CONSTRUCTION AND REPAIR OF ROADS AND BRIDGES

Before the outbreak of World War II there was recognized need for the construction or improvement of many sections of road required to give local access to new points of military and industrial concentration. After war began, these recognized needs quickly multiplied. Federal funds applicable to these access road purposes were not immediately available and, before they could be provided by special authorization of the Congress, the suddenly augmented traffic on many of the roads found them grossly inadequate. The resulting confusion and delays had a perceptible effect in retardation of the war effort.

Federal funds for emergency construction

It is impracticable to make definite plans long in advance of the event for avoidance of the repetition of a similar situation in the future. Assuming continuance of the Federal policy of appropriation for specific highway purposes, there will always be Federal funds authorized or appropriated for such specific purposes which could be diverted in emergency to other purposes. What is needed is permanent legislation authorizing the employment of such authorized funds for other purposes associated with the needs of national emergency declared by the President. The authority should be broad enough to cover national emergencies of war or peace, such as the necessity of access road construction incident to anticipated hostilities and necessities such as those experienced in consequence of the heavy snowfall of the past winter, and on other occasions as the result of major floods and other disasters. The legislation should authorize expenditures required for the making of essential surveys and the preparation of plans as well as for needed construction, and it should authorize Federal payment for war-necessitated construction up to 100 percent of the cost. Emergency repair and permanent rehabilitation of roads, including bridges, in disaster areas should be done under agreement with the State highway department and payment made therefor on the established pro rata for the regular Federal-aid highway program. The maximum sum to be available, without specific authorization, should be fixed by law, and provision should be made for subsequent replacement of amounts so used.

Stock piling of materials and equipment

The experience of World War II and recent major peacetime disasters indicate also the advisability of an amendment of the Federal Highway Act authorizing payment with Federal funds of a pro rata share of the cost of a continuous reserve or stock pile of certain highway and bridge materials. The freeze orders of World War II first stopped the flow of materials in commercial supply lines and then channelized them to consumers on a priority basis. Items in consumers' possession were not affected by the freeze orders, but considerable time was required to obtain the permits requisite for the acquisition of the most essential construction and maintenance materials after the controls were established. In anticipation of a similar future situation it is desirable that the supplies of certain materials in possession of the State highway departments at any moment be sufficient to provide for the needs of a period long enough to effect the resumption of essential supply under the conditions of wartime regulation.

Of certain materials that are regularly required, the reserve should provide for the normal consumption of not less than a 6-month period. Among the more essential materials are aggregates for portland cement concrete and bituminous concrete, bituminous materials, cement, chlorides for the treatment of ice-coated pavements, culvert pipe, nails, paints, steel and timber piling, structural steel and timber, steel products other than bridging, storage batteries, antifreeze for motor-vehicle radiators, tires and tire chains, and assorted equipment repair parts.

For use in the quick replacement of bridges destroyed by floods, and equally essential as a precaution against possible need in the event of war, it would be desirable to place in storage with the several State highway departments a substantial stock of portable bridge units capable of incorporation in permanent structures.

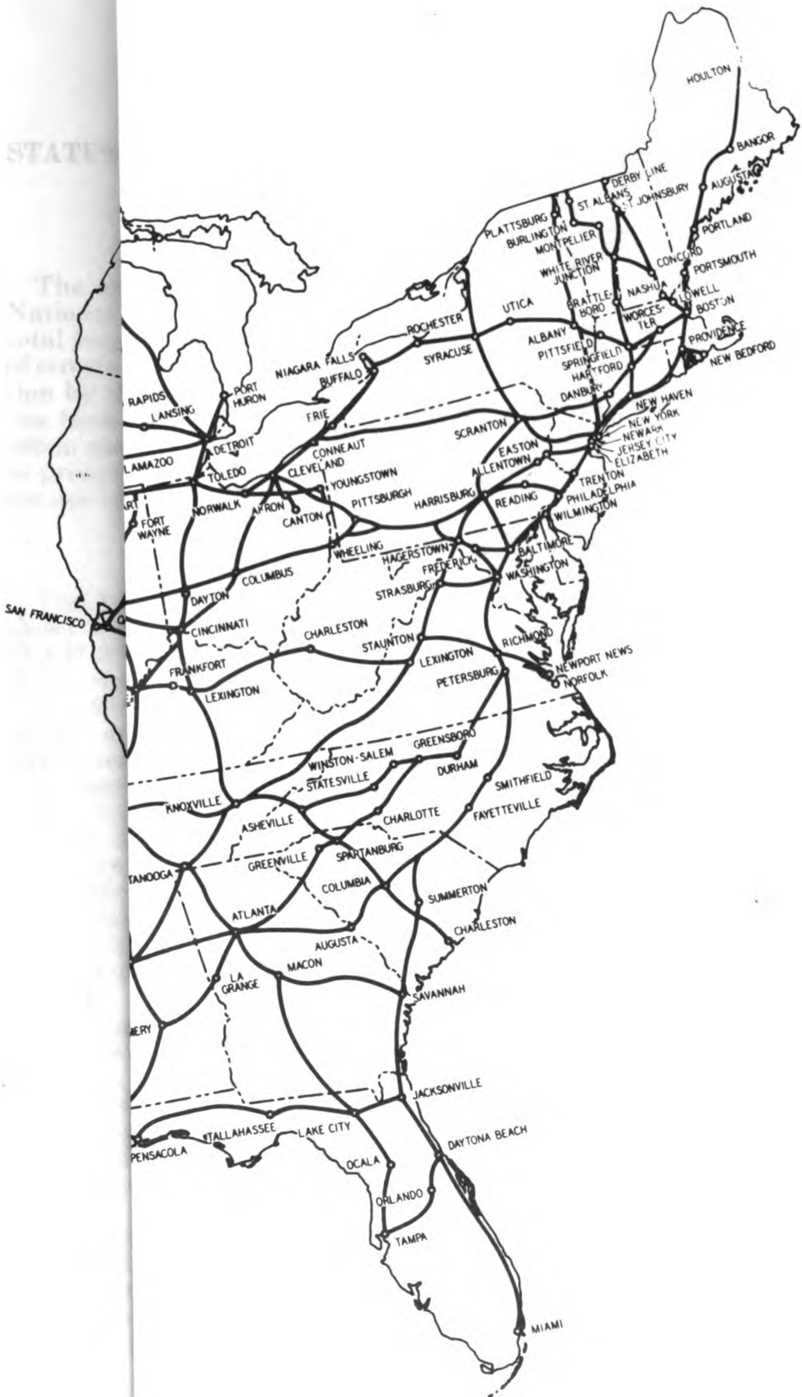
The foregoing recommendations of stand-by fiscal and stock-piling provisions have the endorsement of the maintenance and equipment committee of the American Association of State Highway Officials.

Repair of damage on local roads

To make these fiscal and stock-piling provisions the more effective for use in civil disaster relief, they should be made applicable to the restoration of damaged roads and bridges of the cities and counties in States which, by appropriate State legislation, establish requisite control of the undertakings by the State highway department. A further useful provision, designed to facilitate the interstate loan of materials, equipment, and equipment operators, would be a Federal guarantee of the repayment of such loans and liabilities incurred for injuries to workmen.

OTHER RECOMMENDATIONS

It is also suggested (1) that highway authorities should be represented through the Public Roads Administration and appropriate State highway departments on boards created to select sites for military and strategic industrial establishments to the extent necessary to assure efficient provision of highway connection, and (2) that adequate representation of highway and highway transport necessities should be provided for in any future establishment of agencies to apportion and ration war-essential materials in short supply.


HOULTON
BANGOR
AUGUSTA
PORTLAND
DERBY LINE
ST. ALBANS
ST. JOHNSBURY
PLATTSBURG
BURLINGTON
MONTPELIER
WHITE RIVER JUNCTION
CONCORD
PORTSMOUTH
NASHUA
LOWELL
BOSTON
BRATTLEBORO
WORCESTER
PROVIDENCE
NEW BEDFORD
UTICA
ALBANY
PITTSFIELD
SPRINGFIELD
HARTFORD
DANBURY
NEW HAVEN
NEW YORK
NEWARK
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SPARTANBURG
GREENVILLE
CHATTANOOGA
COLUMBIA
SUMMERTON
ATLANTA
CHARLESTON
AUGUSTA
MACON
LA GRANGE
SAVANNAH
MONTGOMERY
JACKSONVILLE
TALLAHASSEE
LAKE CITY
PENSACOLA
DAYTONA BEACH
OCALA
ORLANDO
TAMPA
MIAMI

STATUS OF IMPROVEMENT OF THE INTERSTATE HIGHWAY SYSTEM AND ITS SERVICE TO TRAFFIC

Extent of the System

The existing roads and streets presently serving as routes of the National System of Interstate Highways, shown in figure 1, have a total length of 37,800 miles. Of this total, 3,778 miles are composed of streets in "urban areas" including all cities of 5,000 or more population by the 1940 census, and 2,191 miles consist of streets in towns of less than 5,000 population. The total included mileage of streets in urban places is, therefore, 5,969 miles. The remainder of the system as presently designated consists of 31,831 miles of rural roads located outside of the limits of all towns and urban areas.

MILEAGE AND TRAFFIC

The 5,969 miles of urban streets included in the system represent about 2 percent of the 316,536-mile total length of all city streets. The 31,831 miles of the system's rural-road sections represent 1 percent of the country's total of 3,009,617 miles of rural roads.

In 1948, the 5,969 miles of urban streets included in the system served an estimated 20,740 million vehicle-miles of travel. This traffic, served by 2 percent of the total city-street mileage, was almost 11 percent of the traffic served by all city streets.

The 31,831 miles of rural roads included in the system served during 1948 an estimated 33,965 million vehicle-miles of travel. This traffic, served by 1 percent of the total rural-road mileage, was 17 percent of the traffic served by all rural roads.

The existing streets, constituting the urban sections of the system, carried in 1948 an average traffic of 9,500 vehicles daily. This compares with an average for all other city streets of about 1,600 vehicles per day.

Existing roads constituting the designated rural sections of the system carried in 1948 an average traffic of 2,915 vehicles daily. This compares with an average of about 1,295 for the entire Federal-aid primary highway system, 1,155 for the State highway systems (exclusive of local roads under State control), and 53 vehicles per day for all rural roads not included in any of these systems.

The 1 percent of the country's total rural-road mileage, which forms the rural portion of the designated interstate system, served in the several States an average of 27½ percent of the travel on all rural roads in each State by vehicles registered in other States. The designated rural system is thus shown to be outstandingly of service to that portion of the country's highway traffic that can be classed as interstate in character.

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POPULATION SERVED

Of the total urban population of 83,766,379 in the United States in all incorporated places, as shown by the 1940 census, 54,378,200, or 65 percent, was resident in cities and urban places connected by the designated interstate system. These included all of the cities of 250,000 or more in population, 49 of the 55 cities that had population between 100,000 and 250,000, 69 of the 107 cities that had population between 50,000 and 100,000, and 2,538 smaller cities, towns, and urban places.

Routes of the system traversed for some distance 1,160 of the 3,076 [1] counties in the United States. In these counties traversed, the 1940 population was 23,953,461, or 50 percent of the total rural population of the country.

The interstate highway system, when completed and improved, will include only about 1 percent of the Nation's roads and streets but will carry 20 percent of the total traffic. Many sections of the system now are as congested as U S Routes 3 and 20 in Boston, Mass., shown here.

BRIDGES

On the entire system, as presently designated, there are 12,048 bridges. Of these structures 10,524 carry interstate routes over streams or natural water courses; 979 are over railroads; 384 span other highways. The remaining 161 are structures spanning two or more of the above kinds of crossings.

[1] For statistical purposes, parts of Yellowstone National Park in Idaho and Montana are counted as separate counties. For the same reason the District of Columbia is included as a county, and various independent cities, e. g., 24 in Virginia, are lumped in the respective counties of which they might logically be considered geographically a part.

8/48

(3) Year of initial preparation 1948
(Revisions are indicated in Date of data column)

(4) Route number 2 from E.JCT.U.S.31 IN BENT...

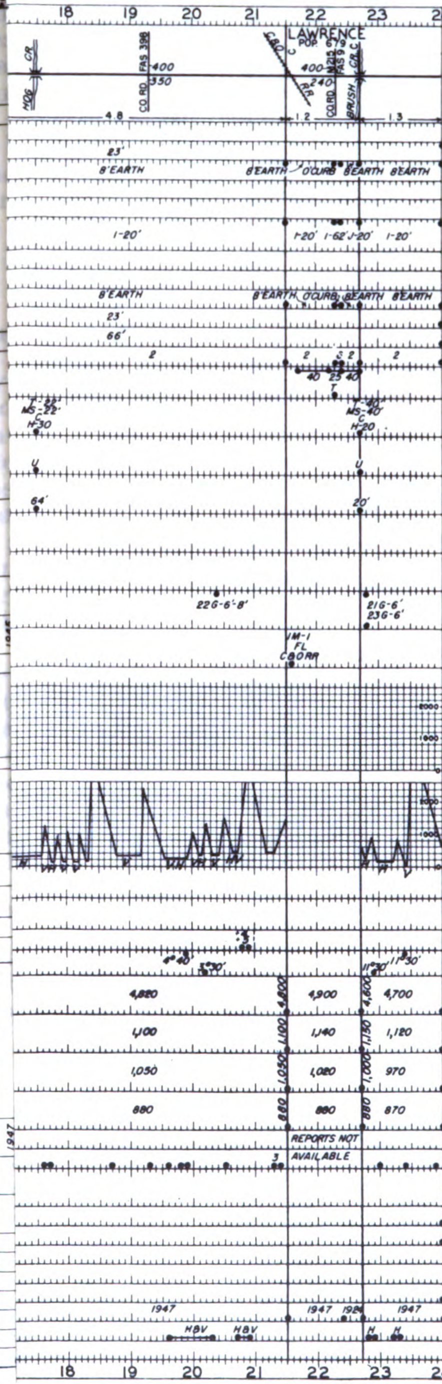
(1) State MICHIGAN

System INTERSTATE
STATE PRIMARY
FEDERAL-AID

Interstate Route 2
Federal-Aid Route 10
(2) U S Route 12
State Route —
Series —

Sheet 1 of 2 sheets

(5) SCALE OF MILES
(6) DIAGRAM OF ROUTE
(7) COINCIDING U.S. OR STATE ROUTE
PHYSICAL FEATURES OF HIGHWAY — LEFT
(8) R/W line measured from edge of pavement
(9) Shoulder width and type
(10) Pavement width and surface code
(11) Pavement width and surface code
(12) Main or center pavement width and surface code — OR — Traffic separation (TS) or parkway (P) width material and type
RIGHT
(13) Pavement width and surface code
(14) Pavement width and surface code
(15) Shoulder width and type
(16) R/W line measured from edge of pavement
(17) Total right-of-way width
(18) NUMBER OF TRAFFIC LANES
(19) TRAFFIC CONTROL DEVICES & SPEED ZONES
STRUCTURES CARRYING THE ROAD
(20) BRIDGES (over 20 feet) Length and rated capacity
(21) Vertical clearance above roadway
(22) Width between curbs or guard rails
STRUCTURES ABOVE THE ROAD
(23) Kind and vertical clearance above roadway
(24) Horizontal clearance
(25) OTHER RESTRICTED HORIZONTAL CLEARANCES (see code) — Left / Right
(26) RAILROAD GRADE CROSSINGS
(27) TRAVEL TIME THROUGH URBAN AREAS
(28) SIGHT DISTANCES — Direction of travel
(29) CONTROLLED ACCESS
(30) FRONTAGE ROADS
(31) GRADES OVER 3%
(32) CURVES OVER 3°
TRAFFIC — Annual average 24-hour volume
(33) Total
(34) Trucks and busses (local and foreign)
(35) Foreign (passenger cars)
(36) 30th highest hour
ACCIDENTS
(37) Fatal
(38) All others reported
(39) ILLUMINATION AND SIDEWALKS — Left / Right
(40) GROSS WEIGHT OF VEHICLE (Average daily maximum)
(41) AXLE LOAD (Average daily maximum)
(42) CONTROL SECTION NUMBER
(43) F A PROJECT NUMBER
(44) SPRING LOAD RESTRICTIONS
(45) YEAR BUILT (Existing surface)
(46) NO PASSING ZONES (One direction only)
(47)
(48) SCALE OF MILES



Of the bridges over streams 1,281 are on urban sections of the system, 9,243 on rural sections. Of the bridges over railroads 396 are on urban sections, 583 on rural sections of the system. Of those over highways 217 are on urban sections; 167 on rural portions. Of the 161 remaining structures, 104 are on urban portions and 57 are on rural sections. Of the total of 12,048 structures carrying the interstate routes, 1,998 are on urban sections and 10,050 on rural sections of the system.

Additional to the 12,048 bridges which carry the interstate routes over streams, railroads, and other highways, there are 943 bridges, 562 on urban and 381 on rural sections of the system, which carry railroads over the interstate routes; and 336 structures, 185 on urban and 151 on rural sections, which carry other highways over the interstate routes.

Status of Improvement of Interstate Highways

The system, as generally described above, consists of those existing roads and streets now commonly used for travel along the general lines of the designated interstate routes. All of these roads and streets were reviewed in detail by the State highway departments. Field surveys were made, as necessary, and these were supplemented by reliable records to prepare an inventory of the physical conditions existing on all parts of the system and an enumeration of the traffic which each section served in 1948. These data were uniformly compiled by all of the State highway departments and reported in detail to the Public Roads Administration, where they were summarized for the system as a whole.

Figure 2 shows a sample of the graphical highway data sheet on which the desired information was reported by the State highway departments. Supplementary to the report in this form, the States coded many of the items in preparation for mechanical tabulation, and this coding was verified, and the data tabulated and analyzed, by the Public Roads Administration.

The following pages summarize the more significant information revealed by the survey.

TYPES OF SURFACES

All but 24 miles of the system as it exists at present have been surfaced. Of the small unsurfaced mileage, 9 miles are urban and 15 miles are rural. Of this unsurfaced mileage, all but one-half mile had been graded and drained at the time of the survey.

Low-type surfaces

A small mileage—6 miles, of which 2 miles are urban and 4 miles rural—is surfaced with selected soil. These are the most primitive surfaces now existing on the system. With 138 miles of untreated gravel or stone surfaces, 3 miles in urban and 135 miles in rural areas, they constitute a total of 144 miles classed as of low-type surface. Of this total, 5 miles are urban and 139 miles rural.

Intermediate-type surfaces

Surfaces classed as of intermediate type, consisting of three low-cost types of bituminous surfaces, exist on 4,990 miles of the system, of which 417 miles are in urban and 4,573 miles are in rural areas.

High-type surfaces

By far the greater part of the system—32,642 miles—is paved with surfaces of high type. Of these surfaces 16,091 miles are high-type bituminous pavement, 2,390 miles in urban, and 13,701 miles in rural areas.

A mileage nearly as large—15,230 miles—is paved with portland cement concrete; 2,478 miles in urban, and 12,752 miles in rural areas. The remainder, 1,321 miles, is surfaced principally with brick or block pavements and different high-type surfaces in combination. Of this latter mileage, 670 miles are in urban, and 651 miles are in rural areas.

AGE OF SURFACES

While, as stated above, a very large part of the system is surfaced with pavements classed as of high type, and only an insignificant mileage remains unimproved, these facts of surface-type classification do not reflect the condition of the surfaces of the highways, and there is no convenient gage by which conditions so various as those of the surfaces existing on the system can be measured and intelligibly recorded and classified.

Average age

Perhaps the best indication of the condition of the surfaces may be found in their ages, which for all rural portions of the system are definitely known. The average age of all surfaces on rural sections of the system is 12 years. Many, of course, are much older. The roadways on which these surfaces are laid are nearly half again as old, averaging about 17 years of age. In other words, the average mile of rural highway on the interstate system consists of a surface that was last improved in 1937 and a roadway upon which the last major improvement of alinement and grade was made in 1932. These are most significant facts in view of the increases in traffic and the demands of safe operation that have occurred during these intervals.

Age by type of surface

Of the 27,104 miles of high-type pavement on rural sections of the system, 3,743 miles or 14 percent are more than 20 years old. Between 10 and 20 years of age there are 12,614 miles, or 46 percent of the total; and only 10,747 miles, or 40 percent, are less than 10 years old.

The surfaces of intermediate type average even older. Of the rural surfaced mileage of this class, totaling 4,573 miles, 614 miles, or 13 percent, are more than 20 years old; 2,698 miles, or 59 percent, are between 10 and 20 years of age; and only 1,261 miles, or 28 percent, are less than 10 years old.

The low-type surfaces on the system, being of less durable character, naturally are of lesser present age. Of the surfaces of this class, totaling 139 miles on rural sections of the system, only 3 miles, or 2 percent, are more than 20 years old; 50 miles, or 36 percent, are between 10 and 20 years old; and 86 miles, or 62 percent, are less than 10 years of age.

WIDTHS OF SURFACES AND SHOULDERS

Of the 5,969 route miles of the system in urban places, 695 miles are made up of pairs of one-way streets, the street mileage of which is twice the route mileage. The remainder, 5,274 miles, consists of two-way streets.

Urban surface widths

Of the street mileage of one-way streets, a total of 1,390 miles, only 168 miles are as much as 40 feet wide; 366 miles are between 30 and 40 feet wide; the largest fraction, 835 miles, are between 20 and 30 feet wide; and 21 miles are less than 20 feet in width.

Of the two-way streets, 2,069 miles are less than 30 feet wide, 1,011 miles are between 30 and 40 feet wide; 1,747 miles are between 40 and 60; and 447 miles are more than 60 feet wide.

Rural surface widths

Of the 31,831 miles of the system in rural areas, 31,816 miles are surfaced, and of this mileage 27,669 miles have two-lane surfaces.

This is one of a pair of one-way streets that carry U S Route 40 through Baltimore, Md. Note the different widths of pavement in the two blocks. A stopgap, relatively unsatisfactory means of handling heavy city traffic, there are 695 miles of such pairs of one-way streets on the interstate system.

There are 241 miles on which the two-lane surface is less than 18 feet wide, and an additional 5,868 miles on which it is between 18 and 20 feet wide. More than 40 percent of the existing two-lane surfaces, 11,637 miles, are between 20 and 22 feet wide; 4,694 miles are between 22 and 24 feet; and only 5,229 miles are as much as 24 feet in width.

Of the rural mileage surfaced with more than two lanes—a total of 4,147 miles—1,607 miles have three lanes; 1,056 miles have four or more lanes without central division; and 1,484 miles are improved with pavements centrally divided for separation of traffic of opposite direction. Nearly 11 miles of these divided pavements have six or more traffic lanes; 1,473 miles have four lanes, two for each direction of traffic.

Width of shoulders

Of the 31,831 miles of the system in rural areas, 421 miles are built without shoulders, curbs replacing this normal feature of rural road design. Of the 31,410 miles built with shoulders, 6,273 miles have shoulders less than 4 feet wide; 15,990 miles have shoulders between 4 and 8 feet in width, and on 9,147 miles the shoulders are 8 feet wide or more.

CURVATURE

Of the total length of the system in rural areas, 1,949 miles are located in areas classed as mountainous; 12,572 miles are located in areas of rolling topography; and 17,310 miles lie in generally flat or level areas.

This street is U S Route 422 in Reading, Pa. Its extreme width is negated by the lack of channelization or control, as evidenced by the haphazard, crowded vehicular movements.

Frequency and sharpness of curves

Both the number and the sharpness of curves, as would naturally be expected, are greatest on the sections of the system in mountainous areas. On the 1,949 miles in such areas there are 5,988 curves, or more than three for every mile, that are sharper than 3 degrees. On the sections in rolling topography, 12,572 miles in total length, there are 9,435 curves sharper than 3 degrees, a frequency of 1 to every 1⅓ miles; and on the 17,310 miles in flat topography the number of curves exceeding 3 degrees is only 6,473 or not much more than 1 in every 3 miles.

On the entire 31,831-mile extent of the system in rural areas curvature in excess of 3 degrees occurs at 21,896 points, an average of a little more than 1 in each 1½ miles of the system. All other curvature on the rural system is not greater than 3 degrees.

A 3-degree curve has a radius of about 1,900 feet. It is a curve that can be rounded with safety at 70 miles an hour; but any curvature of greater degree requires for safety a reduction of vehicle speed below 70 miles an hour. On a curve of 11 degrees (radius about 520 feet) it is unsafe to travel above 50 miles an hour. Curves sharper than 11 degrees occur on mountainous sections of the system with a frequency of more than once per mile. About once in each 1⅓ miles in

Photo by Tennessee Conservation Department

This 15-degree curve, on U S Route 31 in Tennessee, is a murderer. Three days after the picture was made to illustrate this report, a motorcyclist died because he failed to round the turn. A few weeks previously, two men were killed when their car hit a disabled truck which had to stop on the pavement because the shoulder was too narrow.

these sections in mountainous areas a curve is encountered which is sharper than 14 degrees, which is safe for a speed of only about 40 miles per hour.

Curvature and safe speed

If by reason of the frequency of occurrence of curves in excess of 11 and 14 degrees, the mountainous sections of the system in their present state were characterized, on the basis of curvature alone, as generally safe for speeds of 40 to 50 miles an hour, the same curve-frequency test applied to the sections in rolling topography would rate them as safe on the average for 60- to 70-mile speed. This, it should be added at once, is a rather broad generalization, because there are curves in some places on the system in rolling topography that are about as sharp as any in the mountainous areas. By similar broad generalization and like qualification, the greater part of the system in flat rural areas can be characterized, on the basis of curvature alone, as good for speeds approaching 70 miles an hour.

Since adequacy of design is determined by a number of conditions besides curvature, the general characterizations indicated in respect to curvature must be strictly so limited. All conditions considered, a very small part of the system as it now exists is satisfactory for travel at 70 miles an hour.

GRADES

The steeper grades on a highway become serious impediments to movements over the highway only when they are of substantial length. Vehicles climb short, steep grades on the momentum gathered on approaching down grades or stretches of level or light upgrade.

Classification of grades

For this reason, in the survey of the grades existing on the system, grades of various steepness were recorded as significant only where they exceeded certain lengths, varying with the rate of gradient. The determining lengths were 2,000 feet for grades between 3 and 4 percent, 1,000 feet for grades between 4 and 5 percent, and 500 feet for grades of over 5-percent steepness.

Grades of the several degrees of steepness were recorded when, either as continuous sections of single gradient or as an average of different grades within a continuous section, they extended to at least the determining lengths corresponding to the three grade classes. It follows that no grades of 3 percent or less were recorded except as, in combination with steeper grades, they averaged above 3, 4, or 5 percent for the required determining distances.

Grades steeper than 3 percent

As thus defined, there are 6,646 grades totaling 2,770 miles on the entire designated system that are steeper than 3 percent; 656 of these grades, totaling 226 miles, are on urban sections of the system; 5,990, totaling 2,544 miles, are on the rural portion of the system.

Steeper than 6 percent, there are on the entire system 668 grades, totaling 243 miles, of which 108, totaling 28 miles, are on urban sections, and 560, totaling 215 miles, are on rural sections.

The steepest grades

The two steepest grades on the entire system are both in urban areas. Both average more than 10 percent. One is on U S Route 40 in the town of Old Washington, Ohio (population, 297). The other is on U S Route 70 in Marion, N. C. (population, 2,889).

The grade on U S Route 40 averages just over 10 percent on a length of about one-third mile, but it includes a section of 14-percent grade one-fifth mile in length. An hourly traffic of 430 vehicles traveled this grade, up and down, in 1948. The road has an 18-foot two-lane bituminous pavement of high type.

The grade on U S Route 70 averages almost 11 percent for a distance of 0.15 mile. The up-and-down hourly traffic on this grade in 1948 was 555 vehicles. The street has a 55-foot concrete pavement.

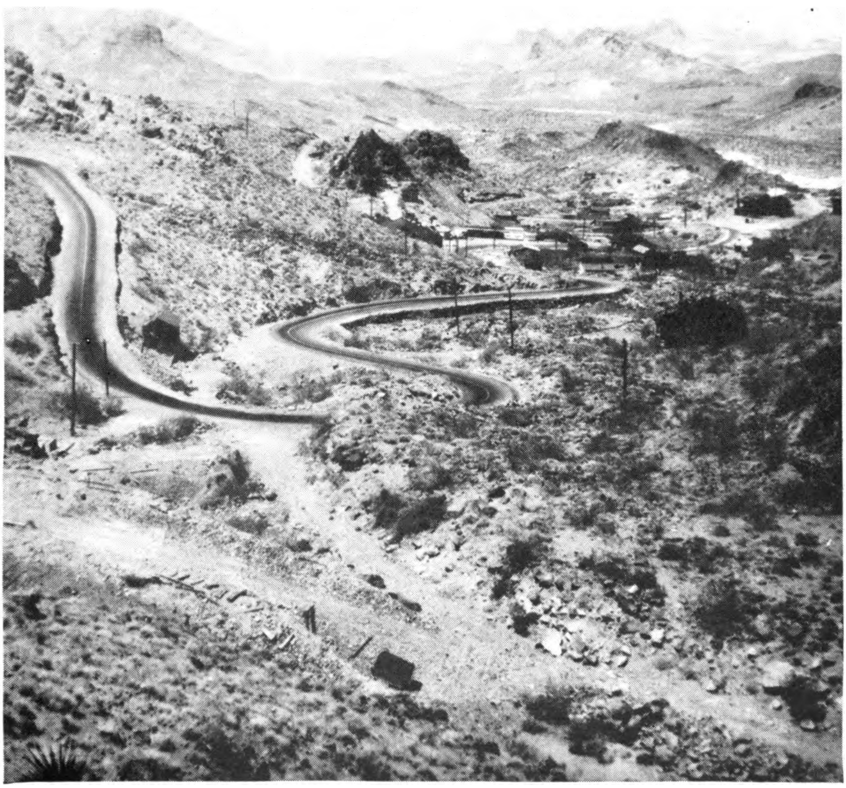


Photo by Norman G. Wallace

Such winding location, often pictured as evidence of good engineering, ignores the necessities of safe accommodation of modern traffic. This section of U S Route 66 in Arizona must be relocated to meet the interstate system standards. In total, 11,891 miles of the system require relocation.

The longest grade

The longest grade on the entire system is on U S Route 99, south of Bakersfield, Calif. It is 20 miles long and averages 4 percent over the entire length. Included, however, are two 6-percent grades, totaling more than 6 miles, and two 5-percent grades, totaling one-half mile.

On the grade there are 16 curves, 12 between 3 and 4 degrees and 4 between 4 and 5 degrees. Six miles of the grade are surfaced with an undivided pavement 30 feet wide; the remaining 14 miles have a divided four-lane pavement, varying between 20 and 25 feet wide on each side. The average daily traffic in 1948 was 8,650 vehicles, of which 18 percent were trucks and busses.

STOPPING SIGHT DISTANCE

In the 31,831 miles of the interstate system as it is presently improved, there are 21,028 sections of various length, totaling 2,087 miles, on which the road ahead is not visible for a distance sufficient to permit the stopping of vehicles moving at desirable speeds before striking low-lying objects and holes or other dangerous surface conditions. The mileage deficient in this respect is nearly 7 percent of the total rural mileage of the system. Safe operation on these sections can in some cases be provided for by the removal of sight-distance obstructions such as trees, cut slopes, and buildings. In the great majority of cases, however, correction can be made only by changes of the alinement or profile of the road, or both, to provide flatter horizontal and vertical curves.

PASSING SIGHT DISTANCE

Stopping sight distance is necessary for safety of operation on all roads. On two-way roadways of two and three lanes it is equally desirable that the road ahead be visible for a sufficient distance to permit drivers to move into the left or central lane long enough to pass other vehicles without danger of collision with oncoming vehicles. The lack of such safe passing sight distance is the principal reason for the formation of queues behind slow-moving vehicles and a major cause of the obsolescence of highways built in the past. Where passing sight distance is inadequate, safe drivers are restricted in their freedom of movement to almost the same degree as if the lane used for passing were filled with oncoming vehicles; and those who attempt to pass under these conditions are reckless drivers who all too often cause grief to others as well as themselves as a result of their action.

The sight distance required for safe passing varies with the speeds of the passed and passing vehicles and the speed of a possibly oncoming vehicle. For safe passing at the speeds that should be accommodated on the interstate system, a clear sight distance of 1,500 feet ahead is essential. It is not necessary that the road ahead be visible for this distance from every point on the highway. This is a condition that could be fulfilled only at a prohibitive cost. It is essential, however, for reasonable safety, that 1,500 feet of sight distance shall be available continuously over sections of the road sufficiently long to permit the completion of passing maneuvers, and that such sections shall recur at intervals sufficiently short to prevent the building up of queues of vehicles waiting to pass.

One of the more serious deficiencies of the interstate system as it exists today is found in the fact that there are 7,324 miles of the 29,276 miles in rural areas surfaced for two and three lanes—one-fourth of the entire mileage—on which this condition of safe travel is not present.

STOP SIGNS AND TRAFFIC LIGHTS

The free flow of traffic on the system at present is interfered with at numerous points, especially in urban areas, by stop signs, stop-and-go lights, and flashing beacons. On rural sections of the system there are 132 stop signs requiring the halting of vehicles moving on

Lines of crawling traffic on hills are not unexpected when the badly broken pavement is so closely hemmed in by guardrails and there is neither passing sight distance nor room to pass. This part of U S Route 40 in California is traveled daily by 4,000 vehicles. Passing sight distance is undesirably restricted on 7,324 miles of the interstate system.

the interstate highway. Besides these, on rural sections, there are 394 traffic lights of the stop-and-go variety and 302 cautionary flashing beacons. These stop signs and signals on rural sections of the system are encountered mainly in the more populous areas and in the vicinity of cities. Most of the 31,831 rural miles of the system is entirely free of such traffic control.

Conditions in cities

In cities the condition is very different. On the 5,969 miles in urban places there are 9,036 installations of such signs and signals, an average of 3 for every 2 miles. In the larger cities—those over 5,000 population—they average 2 to the mile. In the largest cities they are, of course, of still more frequent occurrence.

Stopping necessitated by these signals accounts in part for the very slow movement of traffic that is found to exist on urban sections of the system. In larger part, perhaps, the slow speed is occasioned by the many other obstacles to movement encountered. Among these are

Free flow of traffic and turning movements on urban portions of the interstate system are often hampered by traffic lights, narrow streets, parking, and entrances to gasoline stations and other business establishments, as shown here on U S Route 1 in Virginia. Improvement to interstate system standards would save 21 billion vehicle-minutes—almost 40,000 years—annually.

many unsignalized cross streets, jay-walking pedestrians, the midblock halting of vehicles to load or unload, the maneuvering of vehicles into and out of parking spaces, and the double parking of vehicles.

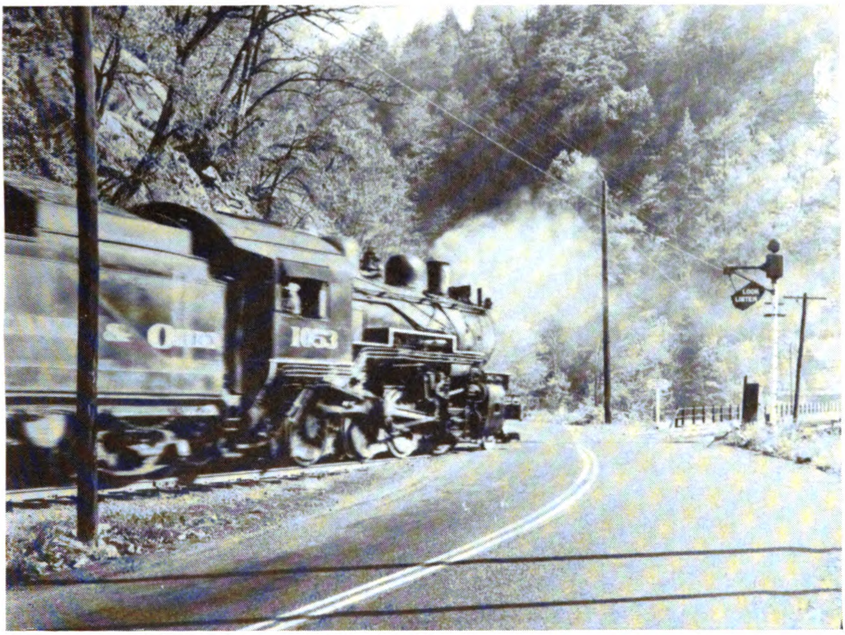
Speed of movement in cities

All of these causes together result, as shown by actual running tests made in all cities of 5,000 or more population, in an average speed of movement on sections of the system in cities of these sizes of only 18.1 miles per hour during the hours of peak traffic and 23.5 miles per hour during the off-peak hours. There is almost no variation from these averages in cities, from the smallest to the largest.

Since about one-third of the day's traffic is known to pass over the streets during the two peak periods, totaling about 4 hours a day, the average speed of the all-day movement can be readily computed as 21.7 miles per hour, a speed at which it takes 2.77 minutes for a vehicle to travel a mile.

Time savings through improvement

The annual travel on sections of the system in cities of 5,000 population or more is 17,180 million vehicle-miles. The aggregate travel time for this movement at the prevailing speeds is 47,589 million vehicle-minutes. If the average speed of the movement were increased to 35 miles an hour, the minimum that would be required if the streets were adequately improved, this time would be reduced



Some 760 railroad grade crossings on the interstate system, such as this one on U S Route 60 in West Virginia, definitely should be eliminated. Another 1,287 grade crossings of branch lines and spur tracks require consideration. Only half of the total number of railroad crossings on the interstate system are separated from the highway by underpass or overpass.

by 20,919 million vehicle-minutes annually, taking into account the increased traffic that would have used these streets had they been so improved, and the shortened mileage resulting from the improvements At a cent a minute, this time saving would be worth more than $209 million annually, a sum about four-fifths as great as the annual cost of urban improvements hereafter proposed, spread over 20 years. In addition, the elimination of much stopping and starting would effect tangible and material savings of a larger order in reduced gasoline consumption and vehicle maintenance costs.

RAILROAD GRADE CROSSINGS

A total of 2,047 grade crossings of railroads remain on the roads and streets that presently form the designated system. This is only 17 less than the number of grade crossings that have been eliminated by the construction of grade-separating bridges.

Of the grade crossings remaining, 785 are crossings of railroad sidings or spur tracks only, but 1,262 are crossings of main-line tracks. Of these main-line crossings, 542 are crossings of single-track lines on which there are six or more train movements daily; 218 are crossings of two or more main tracks.

Capacity and Dimensions of Bridges

LOAD CAPACITY

With few exceptions the strongest of existing highway bridges are of the design designated as H20–S16. Such bridges are designed to support live loads equivalent in stress effect to those imposed by a 20-ton tractor truck of 14-foot wheel base coupled to a semitrailer with 16 tons on its single axle 14 feet to the rear of the rear axle of the tractor. The gross load of the combination, imposed over a length of 28 feet, is 72,000 pounds. Such bridges will carry, without increase of stress, longer vehicles of much greater gross weight and will support without failure the infrequent passage of heavy military vehicles, if the weight is properly distributed.

Bridges of other design strength are similarly designated as H15–S12, signifying an assumed design loading equivalent to that of a tractor-semitrailer combination of 27 tons gross weight, and as H20, H15, H10, etc., signifying the assumption of design loadings equivalent to those of single trucks of 20, 15, and 10 tons gross weight. In each case the wheel base of the combination assumed is 28 feet, and that of the single truck is 14 feet. All such bridges will safely carry vehicles of gross weight considerably in excess of the design vehicle if the weight is distributed over greater length.

Bridges of adequate capacity

Of the 12,048 bridges presently carrying the interstate routes over streams, railroads, and other highways, 1,607 are designed for or rated as of H20–S16 load capacity. Two hundred and nineteen of these are on urban sections of the system; 1,388 are on rural sections. Bridges rated as H20 number 2,207, of which 763 are on urban, and 1,444 on rural sections of the system. A total of 7,526 of the existing bridges, 887 on urban sections and 6,639 on rural sections of the system, are rated in classes from H15 to H19. These existing bridges on the system will all support with complete safety the frequent passage of vehicles conforming in weight to any of the State laws in current effect. None but the H20–S16 bridges is designed to carry some of the more extreme loads known to be moving over the system.

Bridges of inadequate capacity

A total of 677 of the existing bridges, 110 on urban, and 567 on rural sections of the system, are rated as of less than H15 capacity. All of these must be considered as of inadequate capacity; and 130 of them, 30 in urban, and 100 in rural areas, which are rated below H10 must be regarded as dangerously inadequate. Of all the bridges on the system it has been impossible to determine the load-capacity rating of only 31, of which 19 are on urban, and 12 are on rural sections of the system.

WIDTHS OF BRIDGES

From the foregoing it is apparent that, in respect to load capacity alone, most of the existing bridges on the system are reasonably ade-

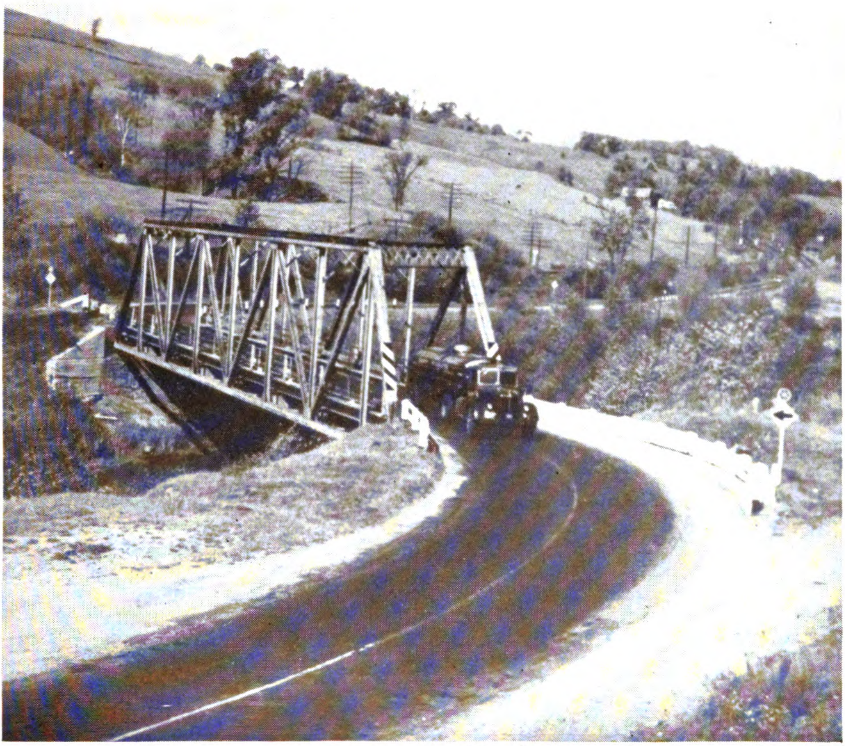


Photo by Vermont Department of Highways

Large vehicles are forced to straddle the pavement centerline in crossing this narrow bridge with its sharp-curved approaches, on U S Route 5 in Vermont On rural portions of the interstate system alone there are 8,187 bridges of inadequate width.

quate. Unfortunately, an equally favorable report cannot be made in respect to other features of their design and location.

The most serious deficiency of the existing bridges is their inadequate width. Many are narrower than the existing approach pavements, which themselves are often too narrow. Many more are not wider than the approach pavements, as they should be for equal safety and convenience, whether the pavements are sufficiently wide or not. And a very large number are grossly inadequate in their width for the volume of traffic they carry.

Width deficiencies

At the extreme of inadequacy are 52 two-way bridges which are less than 18 feet in horizontal clearance. Thirty-one of these bridges, each more than 80 feet long, are classed as long bridges. And, most unfortunately, 14, of which 9 are long bridges, are classed among the strongest of the existing bridges by ratings of H20. Two of these bridges less than 18 feet wide somehow managed to carry an hourly traffic in 1948 of more than 800 vehicles.

The widths of the existing bridges cover such a wide range, the relation of bridge width to the width of existing approach pavement is so various, and, moreover, the relation of the bridge width to the volume of traffic served is so complicated, that it is impossible to summarize in brief statement the many evidences of existing width inadequacy.

Here it may be sufficient to say that of the total of 10,050 bridges carrying the interstate routes in rural areas, only 1,863 conform fully to the standards of width regarded as reasonable for highways of such importance. With some tolerance, 1,517 additional structures may be accepted as substantially adequate; but 6,670 of the existing rural bridges, about two-thirds of the total number, are entirely too narrow.

Underpasses

A similar condition of width inadequacy affects the bridges which carry railroads and other highways, forming underpasses for the interstate highways. Of the 381 bridges which carry railroads over rural sections of the interstate system 316 do not provide sufficient horizontal clearance for the highway as it should be designed; and of 151 bridges carrying other highways over, 41 allow insufficient clearance for a proper width of the interstate highway.

VERTICAL CLEARANCE

In regard to vertical clearance, the situation is much better; in fact, extremely good. Most of the bridges carrying the interstate routes are of the deck type, with no overhead restriction whatever. The commonly accepted standard of vertical clearance for bridges, and the standard which is regarded as adequate for the interstate system, is 14 feet.

There are only 71 of the existing bridges carrying rural routes of the system that provide vertical clearance less than 14 feet. Eighteen of the bridges inadequate in this respect are structures of H20 capacity rating; 53 are of lesser capacity rating.

There are, however, on the rural system 2 highway overpasses, and 70 railway overpasses that provide vertical clearance less than 14 feet; and on the entire system, both urban and rural, there are 320 places where 14 feet of vertical clearance is not available. One hundred and seventy-five of these places are in urban areas and 145 in rural areas.

MATERIALS OF CONSTRUCTION

Of the 12,048 bridges on the system, 2,801, of an aggregate length of 189 miles, are built of steel. Three hundred and ninety-four of these steel bridges are 100 to 200 feet in length; 341 are 200 feet and longer. All but 189 are of H15 load capacity or stronger.

The 7,875 concrete bridges on the system are the most numerous of any single material, and their aggregate length, 191 miles, is slightly greater than that of the steel bridges. Only 149 of the concrete bridges are between 100 and 200 feet in length and only 93 are 200 feet and longer. Only 232 of the concrete bridges are of load capacity less than H15.

Twelve hundred and forty-five of the existing bridges are wooden structures, their aggregate length 29 miles. There are 47 of these bridges that are rated as of H20 capacity or more. Many are much weaker; in fact, the number of wooden bridges rated below H15 capacity, a total of 256, exceeds the number built of any other material.

Ten-foot vertical clearance and width narrower than the approach pavement, with the added hazard of a center pier, bottleneck the 13,000 vehicles a day, including 2,700 trucks and busses, that use this underpass on U S Routes 12, 14, and 151 in Wisconsin.

Of material other than steel, concrete, or wood there are 127 existing bridges, mostly of stone masonry. These have an aggregate length of only 7 miles. Nine are between 100 and 200 feet and 14 are 200 feet or more in length. Only two are rated at less than H15 capacity.

The aggregate length of all of the 12,048 bridges on the system is 2,194,592 feet, or about 416 miles.

Tunnels on the System

There are presently 21 tunnels on the interstate system as designated. Thirteen of these are on rural sections of the system; eight are on urban sections.

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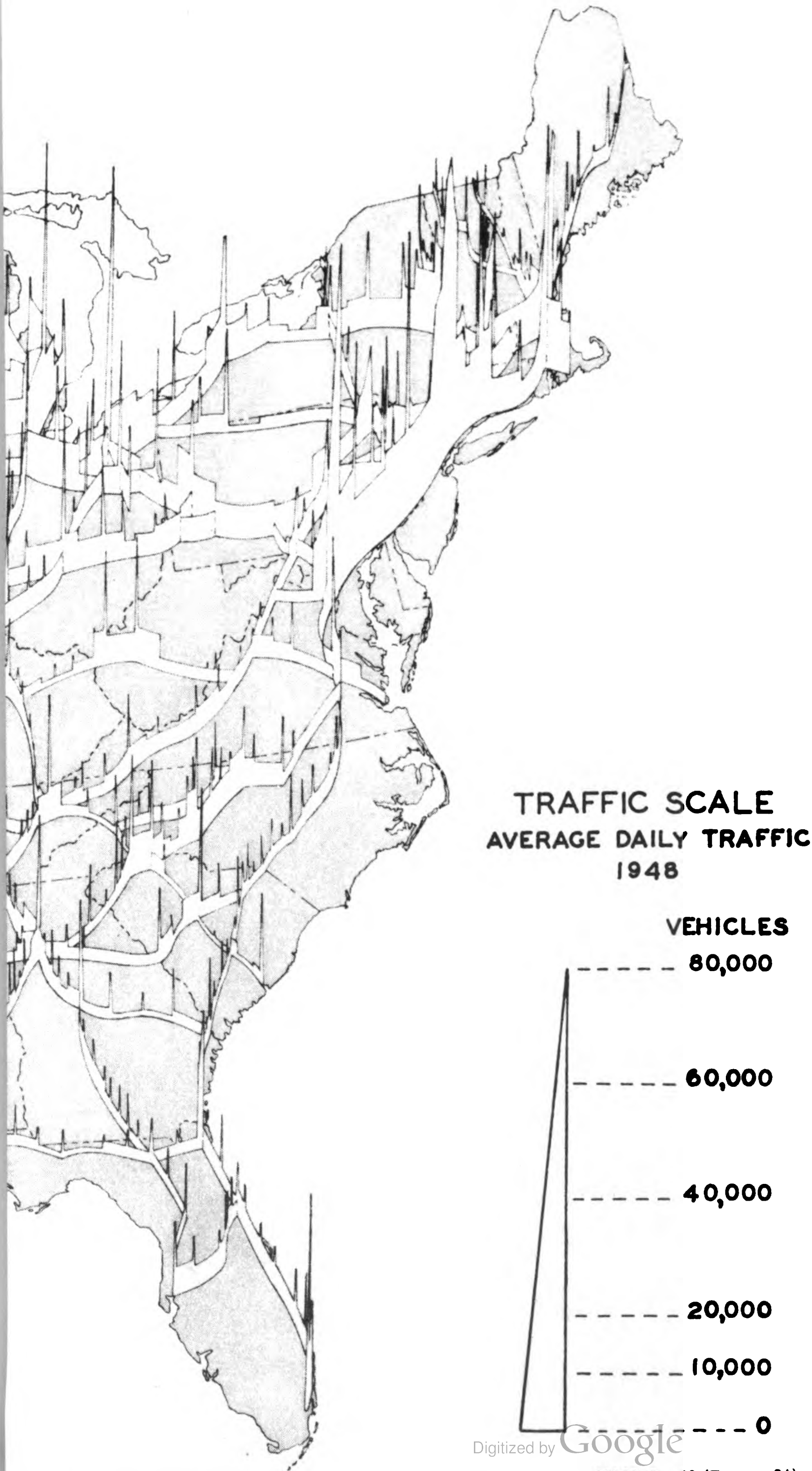
TUNNELS IN RURAL AREAS

Seven tunnels are in Pennsylvania. They range from 3,512 to 6,792 feet in length, and all provide 23 feet horizontal and 14.3 feet vertical clearance. All are approached by four-lane divided highways, and carried an hourly traffic of 800 to 1,000 vehicles in 1948.

The Mitchell Point tunnel on U S Route 30 in Oregon is so narrow, and its approaches so winding, that traffic-actuated signals were installed to operate the tunnel one way alternately in either direction. Every tunnel on the interstate system is in some degree inadequate in horizontal clearance.

There are four tunnels in Oregon. These vary in length from less than 400 feet to 827 feet, and in width from 16½ to 26 feet. Their 1948 hourly traffic was between 260 and 320 vehicles. Vertical clearance on all is 16 feet or more.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The remaining two tunnels in rural areas are the 531-foot Newcastle tunnel in California, and a 394-foot tunnel in Idaho. These have horizontal clearances of 30 and 20 feet, respectively. The vertical clearance of the Newcastle tunnel varies from 11½ to 20.7 feet; the minimum vertical clearance of the tunnel in Idaho is 15 feet. Hourly traffic in 1948 was 864 vehicles on the former and 171 on the latter.

TUNNELS IN URBAN AREAS

The Bankhead tunnel, a toll facility on U S Route 90 in Mobile, Ala., is 3,389 feet long and has a minimum vertical clearance of 12 feet. Although carrying an hourly traffic in 1948 of 1,030 vehicles, and approached at one end by a 50-foot pavement, the tunnel is only 21 feet wide.

The 540-foot Yerba Buena tunnel in California lies between the two sections of the San Francisco-Oakland Bay toll bridge. This tunnel, part of U S Route 40, carried 7,740 vehicles hourly in 1948. Average daily traffic for the year was 70,897 vehicles. The tunnel has two levels, the upper carrying six lanes of fast traffic in its 58-foot width. Vertical clearance on this level is 13 feet at the curb and 28.7 feet at the center. The lower level carries two interurban railway tracks and has a 31-foot, three-lane pavement for trucks. This section has a vertical clearance of 16 feet.

The Sumner tunnel in Massachusetts is a 5,635-foot toll facility under Boston Harbor. Approached by 63- and 83-foot pavements, it is only 21 feet wide and 12½ feet high. Its 1948 hourly traffic was 3,340 vehicles.

On New Jersey State Route 25 in Jersey City there is a depressed highway covered over for two-thirds of its 3,000-foot length. This semitunnel, with vertical clearance of 14½ feet and horizontal clearance of 49 feet, carried 4,550 vehicles hourly in 1948.

At the west approach to the Lake Washington floating bridge in Seattle, there is a 1,466-foot twin-bore tunnel that carried 1,250 vehicles an hour in 1948. Each of the two bores is 23½ feet wide and has a minimum vertical clearance of 14½ feet.

Other sizable urban tunnels are the 920-foot Beaucatcher tunnel in Asheville, N. C., and the 931-foot McCallie tunnel in Chattanooga, Tenn. These have horizontal clearances of 32 and 24 feet, and minimum vertical clearances of 14.4 and 20 feet, respectively; their hourly traffic in 1948 was 1,090 and 2,720 vehicles.

The smallest urban tunnel is in the town of St. George, Utah. Less than 500 feet long, it is 21 feet wide and 13½ feet high, with an hourly traffic of 585 vehicles in 1948.

Traffic Volumes on the System

Average daily traffic varied in 1948 from less than 200 to more than 70,000 vehicles on various parts of the system. The variation of traffic density throughout the system is shown in figure 3.

MILEAGE CLASSIFIED BY TRAFFIC VOLUME

There were 359 miles on which the traffic averaged less than 400 vehicles daily, all but 1 mile on rural sections of the system and the single urban mile in a town of less than 5,000 population.

On 3,518 miles, 36 in urban and 3,482 in rural areas, the traffic averaged between 400 and 1,000 vehicles daily. Carrying between 1,000 and 2,000 vehicles daily there were 9,496 miles, of which 229 were urban and 9,267 miles were rural.

Traffic between 2,000 and 3,000 vehicles daily was served by 8,098 miles of the system, 381 urban and 7,717 rural; and 7,945 miles, of which 834 were urban and 7,111 were rural, served traffic averaging between 3,000 and 5,000 vehicles daily.

Of the sections carrying heavier volumes of traffic, 4,636 miles carried between 5,000 and 10,000 vehicles, 1,874 miles between 10,000 and 20,000, 314 miles between 20,000 and 30,000, and 123 miles 30,000 or more vehicles daily. Of these several traffic volume classes, the mileage of urban and rural routes is as follows:

Average daily traffic	Urban mileage	Rural mileage
5,000 to 10,000	1,434	3,202
10,000 to 20,000	1,207	667
20,000 to 30,000	291	23
30,000 or more	119	4
Total, 5,000 or more	3,051	3,896

In the entire extent of the system there are 1,437 miles, all urban, on which the volume of traffic has not been determined.

SURFACE TYPES AND TRAFFIC VOLUME GENERALLY CONSISTENT

The types of surfaces existing on the system are generally consistent with the volume of traffic. Of the 144 miles of low-type surfaces, 73 miles are on roads traveled by less than 1,000 vehicles daily. Of the 4,990 miles of intermediate-type surfacing, 3,930 miles carry between 400 and 3,000 vehicles daily; and of the 32,642 miles of high-type surface, 29,155 miles are known to carry traffic greater than 1,000 vehicles daily.

Of the 6,947 miles known to carry traffic of 5,000 or more vehicles daily, 6,744 miles are improved with high-type surfaces, and only 200 miles have intermediate-type surfaces; most of the 3-mile remainder is temporarily unsurfaced.

But while there is this general consistency between surface type and traffic volume, inconsistencies are not lacking. For example, there are 33 miles of the system, carrying more than 3,000 vehicles daily, that have only a gravel surface; there are 29 miles that are surfaced with intermediate-type surfaces though their traffic exceeds 10,000 vehicles daily; and there are 119 miles improved with high-type pavements that serve traffic of less than 400 vehicles daily.

INCONSISTENCIES OF TRAFFIC VOLUME AND SURFACE WIDTH

It is in the relation of surface width and traffic volume, however, that the greater inconsistencies appear. On rural sections of the system there are 888 miles of 2-lane surfaces that carried 800 or more vehicles hourly in 1948. Of these, 72 miles are surfaced less than 20 feet wide. In contrast with the grossly inadequate widths of these sections, there are 50 miles of the rural system which, though they carried less than 300 vehicles an hour, are nevertheless improved as divided, multiple-lane highway; and besides these wide divided highways, there are 18 miles of undivided four-lane highway, 152 miles of three-lane, and 3,130 miles of two-lane highway 24 or more feet wide that also carried an hourly traffic of less than 300 vehicles.

The extreme of inadequate width on urban sections of the system is represented by 372 miles of streets less than 22 feet wide, in cities

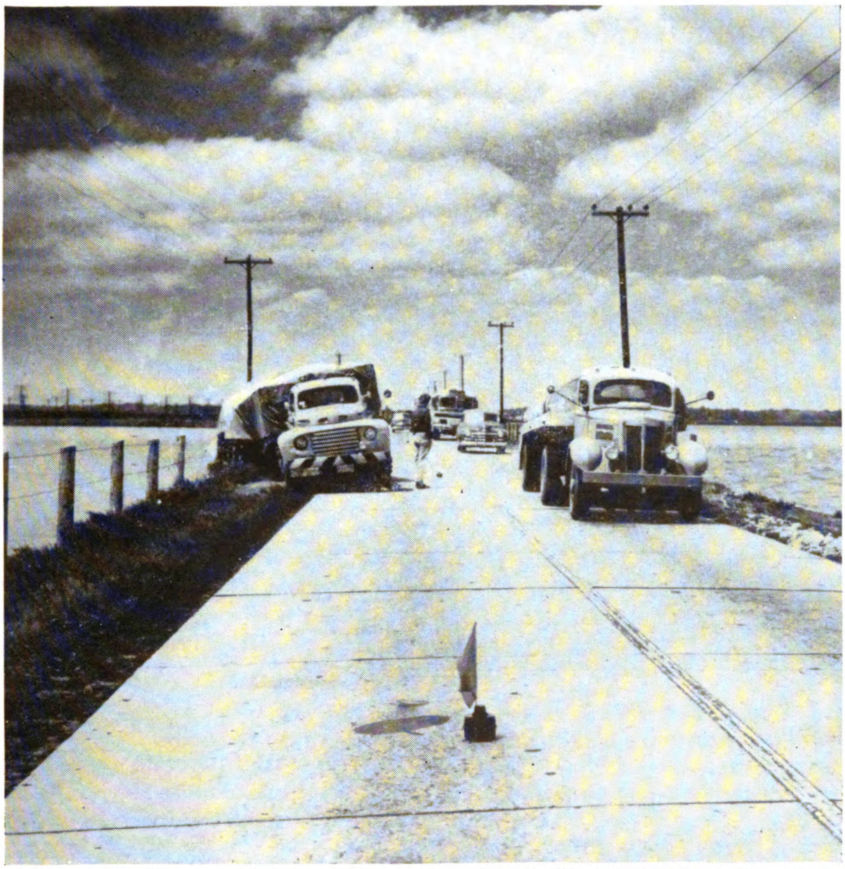


Photo by Mississippi Highway Department

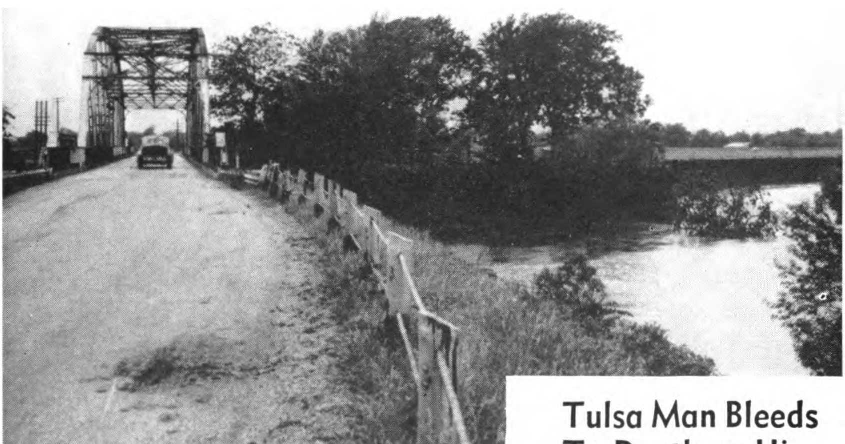
This is not a one-way road. Because the pavement on this causeway on U S Route 90 in Mississippi was inadequate in width and the shoulders too soft and narrow, the truck at the left sank deep into the ground when its wheels went off the pavement. Following traffic had to use the wrong lane to pass. Only 17 percent of the rural mileage of the interstate system is adequate in both surface and shoulder width.

of 5,000 population or more, of which 252 miles are known to have carried more than 300 vehicles an hour.

Fatal Accidents and Deaths

The State highway departments reported 3,603 fatal accidents known to have occurred on roads and streets constituting the designated interstate system in a 1-year period, generally the calendar year 1947. The actual occurrence of fatal accidents was probably somewhat greater, because there are substantial parts of the urban system for which accident data were unobtainable.

For the 31,831-mile rural part of the system the report of accidents is believed to be substantially complete, and the reports indicate that



Tulsa Man Bleeds To Death as His Car Hits Bridge

STATE TRAFFIC DEATHS
1949 to date, 125; April, 3.
1948 to date, 104; April, 0.

MUSKOGEE, April 1—(AP)—James E. Wallace, 47, Tulsa, was killed Friday night when the car he was driving crashed into the Illinois river bridge on U. S. 64 between Gore and Vian, the highway patrols reported.

Two men with Wallace—Meryl Shanks and Paul Templeton, both of Webbers Falls—were not hurt, according to Patrolman R. T. Cramer who investigated the accident.

Cramer said Wallace's car failed to make a curve nearing the west end of the bridge and rammed it. The Tulsan's shoulder artery was cut and he bled to death shortly before reaching a Muskogee hospital.

Photo by Oklahoma Highway Commission

The news story only tells how James Wallace was killed, not why. The approach road runs along the bank of the river on the far side, and swings sharply onto the narrow bridge. Improvement of the interstate system might prevent almost 1,200 accidents and save more than 1,400 lives each year, on the rural sections alone.

there were 2,859 fatal accidents on this rural mileage. These accidents took 3,460 lives.

ACCIDENT RATES

The average rate of fatal accident occurrence on rural sections of the designated interstate highway system was 9.04 per hundred million vehicle-miles. This may be compared with an approximate rate of 9.11 fatal accidents reported for all rural highways in the United States in 1947. However, the accidents on the rural interstate system resulted in fatalities at the rate of 10.94 per hundred million vehicle-miles, whereas the corresponding rate for all rural roads, at 10.66, was slightly lower.

It is apparent that the rural interstate system, in its present state of improvement, is about as safe as, but certainly no safer than, the average of all rural roads, and since its traffic is far above the average in volume, it accounts for an exceptionally large proportion of the annual highway death toll.

RELATION OF ACCIDENT RATES TO LANE WIDTH

On the system as it is presently improved, the fatal accident rate for all two-lane sections was 9.19 per hundred million vehicle-miles. On all three-lane sections, the corresponding rate was 9.08; on undivided four-lane sections, it was 9.41; and on all divided multiple-lane sections, it was 7.65. The superiority of the divided sections from the standpoint of safety is rather marked; the apparently anomalous rate for the three-lane sections possibly results from the fact that these sections carry traffic which in relation to their width is somewhat lower than the similar relation on the existing two-lane roads.

Even the more gratifying rate shown for the existing divided highways is not as low as it might have been had many of these sections been more adequately designed in respect to elements other than their width.

REDUCTION OF ACCIDENTS THROUGH IMPROVEMENT

What a really adequate improvement of the entire system would do to reduce the fatality toll as it stands at present is, of course, a matter of speculation. Some measure of the possibility may be gained from the lower accident rate recorded for portions of the system deemed adequate in their present condition. Of 1,900 miles of the rural system on which this report indicates that no improvement is required, the rate of fatal accidents, known for 1,689 miles, was only 5.65 per hundred million vehicle-miles. Had all parts of the system—its two-, three-, and four-lane sections, divided and undivided—had an accident experience as low in rate as these 1,689 miles requiring no improvement, the fatal accident rate for the whole rural system would have been 5.35 per hundred million vehicle-miles, a reduction of 40.8 percent from the actual rate of 9.04.

At the lower rate there would have been 1,167 fewer accidents and more than 1,400 lives would have been saved in 1 year on the rural sections of the system only.

Appraisal of Current Conditions and Deficiencies

The condition of the existing roads constituting the system having been determined in detail by the several State highway departments, the deficiencies existing were appraised by applying to the determined conditions uniform standards relating to each significant element of design.

ESTABLISHMENT OF STANDARDS

The standards to be applied were previously agreed upon by the Public Roads Administration and a committee of State highway officials appointed by the American Association of State Highway Officials. In general, the standards agreed upon are identical with those adopted by the association August 1, 1945, to govern the design of highways included in the interstate system. In certain respects, however, it was necessary to define more exactly the previously agreed standards in order to facilitate their uniform application for the purposes of this report.

The standards adopted by the association in 1945 contemplate the provision of design adequate for the service of traffic as it may be expected to develop in a period of 20 years subsequent to the construction of each section of the system as it is improved. This necessitates an estimate of future traffic growth which can be undertaken with reasonable assurance only in the light of specific consideration of the potentialities of each section of the system.

For the purposes of this report such specific consideration has been impracticable. The standards have therefore been applied to all sections of the system in relation to their traffic in 1948. Appraisal of the deficiencies of the existing roads and bridges has been based upon the actual 1948 traffic as reported. The improvements contemplated to eliminate the determined deficiencies, which improvements form the basis of the cost estimates reported, have been planned to serve with adequacy the traffic which it is judged would have used each section of the system, had it been so improved in 1948.

THE STANDARDS APPLIED

The principal standards so applied, both for the determination of deficiencies and the estimation of costs of required improvements, are briefly described here.

Traffic basis

The design shall be such as to accommodate traffic density of the thirtieth highest hour of 1948.

Design speed

Design speed shall be in accordance with the following:

	Miles per hour	
	Minimum	Desirable
For rural sections of the system:		
Flat topography	60	70
Rolling topography	50	60
Mountainous topography	40	50
For urban sections of the system	40	50

Curvature

Curvature shall be related to design speed as follows:

Design speed	Degree of curvature	
	Maximum	Desirable
70 miles per hour	4	3
60 miles per hour	6	5
50 miles per hour	9	7
40 miles per hour	14	11

Stopping sight distance

Applicable to all sections, the road surface ahead shall be visible for distances varying with the design speed as follows:

Design speed	Stopping sight distance in feet
70 miles per hour	600
60 miles per hour	475
50 miles per hour	350

Passing sight distance

Applicable to two-lane sections only, the following criteria are to be observed:

1. In any 6,000 feet of roadway length, the road surface shall be visible for at least 1,500 feet ahead on a roadway length of at least 1,000 feet.

2. The minimum percentage of the length of roadway on which the road surface is visible 1,500 feet ahead shall vary with the density of two-direction traffic in the thirtieth highest hour, as follows:

Thirtieth highest hour, two-direction traffic	Percentage of roadway length with 1,500-foot visibility of surface ahead
Less than 500 vehicles	16⅔
500–600 vehicles	30
600–700 vehicles	60
700–800 vehicles	90

Gradient

Maximum gradient preferably shall not exceed 5 percent, and in no case shall exceed 6 percent.

Supporting strength

The strength of the road surfaces and foundations shall be adequate for the support of 18,000-pound axle loads in the frequency to be expected.

Right-of-way

Right-of-way width for two-lane rural highways shall preferably be 200 feet, with a minimum of 120 feet. For four-lane rural highways, 250 feet is desirable and 150 feet minimum.

For urban highways, right-of-way width will be determined by economic feasibility.

Control of access

Control of access shall be provided where State laws permit and where traffic conditions warrant. Where required, in the absence of permissive State laws, additional right-of-way should be provided sufficient for the construction of frontage roads with controlled access to the through highway.

Lane width

For two-lane rural highways on which traffic density in the thirtieth highest hour is less than 200 vehicles in one direction or 300 in both directions, a minimum lane width of 11 feet is required. For two-lane rural highways of thirtieth-highest-hour traffic density greater than the above, lane width shall be 12 feet.

For rural highways of four or more lanes, lane width shall be 12 feet.

For all urban highways lane width shall be 12 feet.

Divided highways

Divided roadways are required on all highways on which the two-direction traffic volume was 800 or more vehicles in the thirtieth highest hour of 1948. Division may be provided on highways of lesser traffic volume where such provision is less costly than the provision of the required passing sight distance for single two-lane roadways.

The width of median strip on divided highways shall be as follows:

	Width in feet	
	Minimum	Desirable
Rural highways	15	40
Urban highways	4	12

Three-lane highways

Three-lane highways are not permissible.

Shoulder width

In mountainous areas shoulder width shall be a minimum of 4 feet, and elsewhere a minimum of 10 feet, measured to the intersection of shoulder and side-slope planes.

Railroad grade separations

Separation of grades shall be provided at all railroad crossings of two or more main-line tracks, and at all crossings of single main-line tracks on which there are six or more regular train movements daily.

Although by the agreed standards separations are required to be provided at crossings of single main-line tracks of five or less train movements daily only where justified by economic analysis, they were, for purposes of the cost estimate prepared for this report, provided at all such crossings.

Highway grade separations

Separation of grades is to be provided at all highway intersections where the sum of the two-direction traffic volumes on the intersecting roads in the thirtieth highest hour of 1948 was 2,000 vehicles or more, and the lowest volume on any of the roads intersecting was at least 500 vehicles in the same hour.

Bridges

All bridges shall be of steel, reinforced concrete, or masonry construction, and designed for H20–S16 design loading. Bridges include all structures of a length between abutments greater than 20 feet.

Clear height shall be at least 14 feet over the entire width of traffic lanes and at least 12½ feet over the effective shoulder width.

The four-lane undivided pavement on this bypass of U S Route 101 in California was an attempt to cope with mounting traffic volume. The present 20,000 vehicles a day are far beyond the road's practical capacity, and lack of access control prevents free-flowing movement. About 1,350 miles of the interstate system now surfaced with three or more lanes undivided should be rebuilt as multilane divided highways.

Clear width of bridges of a length of 80 feet or less between abutments shall be equal to the full width of the approach roadway including shoulders.

On bridges of a length greater than 80 feet between abutments, the width between the edge of the pavement and face of curb shall be at least 2 feet and preferably 3 feet. The face of the rail shall be in all cases at least 3½ feet and preferably 4½ feet outside the edge of the pavement.

Sidewalks shall be provided on bridges wherever the volume of pedestrian traffic justifies.

At underpasses, the lateral clearance between the right edge of the pavement of through-traffic lanes and abutments, walls, or piers shall be at least 6 feet. The lateral clearance between the left edge of the pavement and center piers shall be at least 4½ feet.

Deficiencies of Existing Roads and Bridges

When the various conditions existing on the roads, streets, and bridges which presently constitute the designated interstate system are compared with the foregoing defined standards, it is found that a very large mileage of the roads and streets and most of the existing bridges are in some respects inadequate.

MUCH IMPROVEMENT NEEDED

Of the 31,831 miles of roads in rural areas some improvement is required on all but 1,900 miles. Of the 5,969 miles of roads and streets in urban areas all but 398 miles require some improvement. Of the 10,050 bridges carrying rural sections of the system only 483 are completely adequate by the defined standards. The degree of the deficiency of roads and structures in some measure inadequate varies widely, from slight to serious.

SURFACE TYPE DEFICIENCIES

The choice of surface types on the system is reasonably consistent with the volume of traffic carried by the various sections.

Low-type surfaces

The 24 miles unsurfaced and 144 miles surfaced with low-type surfaces are, of course, clearly deficient. A substantial part of these mileages carries traffic in excess of 2,000 vehicles a day. But even on the sections of somewhat lighter traffic, considering that they are part of the country's major network, low-type surfaces are out of place.

Intermediate-type surfaces

The existing surfaces of intermediate type, found on 4,990 miles of the system, are mostly on sections of relatively low traffic volume.

Only about 91 miles, or about 2 percent, of the total of 4,573 miles of rural roads surfaced with pavement of intermediate type carry as many as 5,000 vehicles per day. Only 568 rural miles, about 12 percent of the total, carry 3,000 or more vehicles a day. The choice of surface for the 91 miles may be seriously questioned; the additional 477 miles carrying traffic between 3,000 and 5,000 vehicles per day may be said to border upon inadequacy.

The situation in the urban areas is less favorable. Of the total of 417 miles of urban sections paved with intermediate types of surface, 26 percent carry traffic of 5,000 vehicles or more daily; 48 percent carry 3,000 or more vehicles a day.

Of the 93 miles with traffic between 3,000 and 5,000 vehicles daily, 27 miles are in towns of more than 5,000 population. At least this mileage and the 109 miles carrying upward of 5,000 vehicles daily are of doubtful adequacy.

High-type surfaces

The bulk of the system, 5,538 miles in urban areas and 27,104 miles in rural areas, is paved with high-type surfaces. On the whole, the choice of pavement type as represented in the existing improvements on the system is appropriate.

Other factors

But a mere classification of surface types does not clearly establish the structural sufficiency of the existing surfaces. Many miles of the surfacing of appropriate type are doubtless of insufficient depth,

Overtaxed capacity and inadequate width result in many accidents annually on bridges in urban areas, such as this one on U S Route 1 in Washington, D. C.

and the foundation support of a large mileage is probably untrustworthy. The survey that has been made could not, in the limited time available, definitely establish the facts in this regard.

Age of surfaces

The age of the surfaces, previously mentioned, is the best available indication of the probability of a considerable measure of surface inadequacy. The average age of the rural surfaces of all types is 12 years; the average age of roadways on which they are laid is 17 years. Much of the mileage is, of course, of greater age than these averages.

The age of the rural mileage by 10-year groups is shown graphically in figure 4. As this graph also indicates, about 57 percent of the existing surfaces will probably wear out and require replacement in the next 10 years. This projection is based upon a knowledge of the life span of surfaces of all types, gained from a wide study of past surface replacement, and takes into account all of the conditions that contribute to retirement, of which physical deterioration is only one.

The same basis underlies the prediction that about 52 percent of the high-type pavements on the system will require replacement by 1959, and that 85 percent of the intermediate-type surfaces and 93 percent of the low-type surfaces will be retired in the same 10-year period.

RATE OF FUTURE IMPROVEMENT

If surfaces of the system are retired in the future at a rate no greater than that of the past, all but the newest and most durable of the now existing surfaces will be replaced in the next 20 years. In view of the more pressing demand for correction of obsolescence already felt and likely to increase in urgency in future years, this is a conservative prediction; but it may serve to set a maximum limit upon the time in which all of the presently recognized deficiencies of the interstate system should be corrected. As the present surfaces are replaced, at least, if at no faster rate, the widths, alinements, sight distances, grades, and all other features of the routes of the system should be brought to the standards recommended in this report as desirable. The building of new surfaces on these routes at any time hereafter without at the same time correcting the serious geometric defects that exist, will be an indefensible prolongation of obsolescence.

DEFICIENCY OF SURFACE AND SHOULDER WIDTH

The present inadequacy of surface width is a much more serious deficiency of the system than the inadequacy of surface type. More than two-thirds of the rural mileage has surfaces that are too narrow.

Substandard widths on rural roads

The minimum surface width complying with the defined standards under any conditions is 22 feet, and this applies only where the hourly traffic is less than 300 vehicles. The existing surface width is less than 22 feet on 17,746 miles of the system in rural areas, which is more than 55 percent of the total rural mileage. These are not all lightly traveled roads. The hourly traffic volume is less than 300 on only about 9,868 miles of these narrow roads, and is 300 or more vehicles on the remaining 7,878 miles. In fact, about 600 miles of these rural roads with surfaces less than 22 feet wide have hourly traffic volumes of 800 or more vehicles and should be improved as four-lane divided highways.

Surface width of 24 feet is required by the standards for traffic volumes of 300 to 800 vehicles an hour; and multiple-lane divided roads are required for volumes of 800 vehicles or more—four 12-foot lanes for traffic from 800 to 3,000 vehicles, and six lanes for traffic of 3,000 vehicles or more. Three-lane roads and undivided highways of four lanes or more are not desirable and have no place in the standards; however, for hourly traffic volumes of less than 800 vehicles, where two lanes would suffice, they are considered adequate.

Multiple-lane roads needed

On the basis of these standards and the already experienced traffic of 1948, there is a total of about 9,250 miles of the two-lane rural

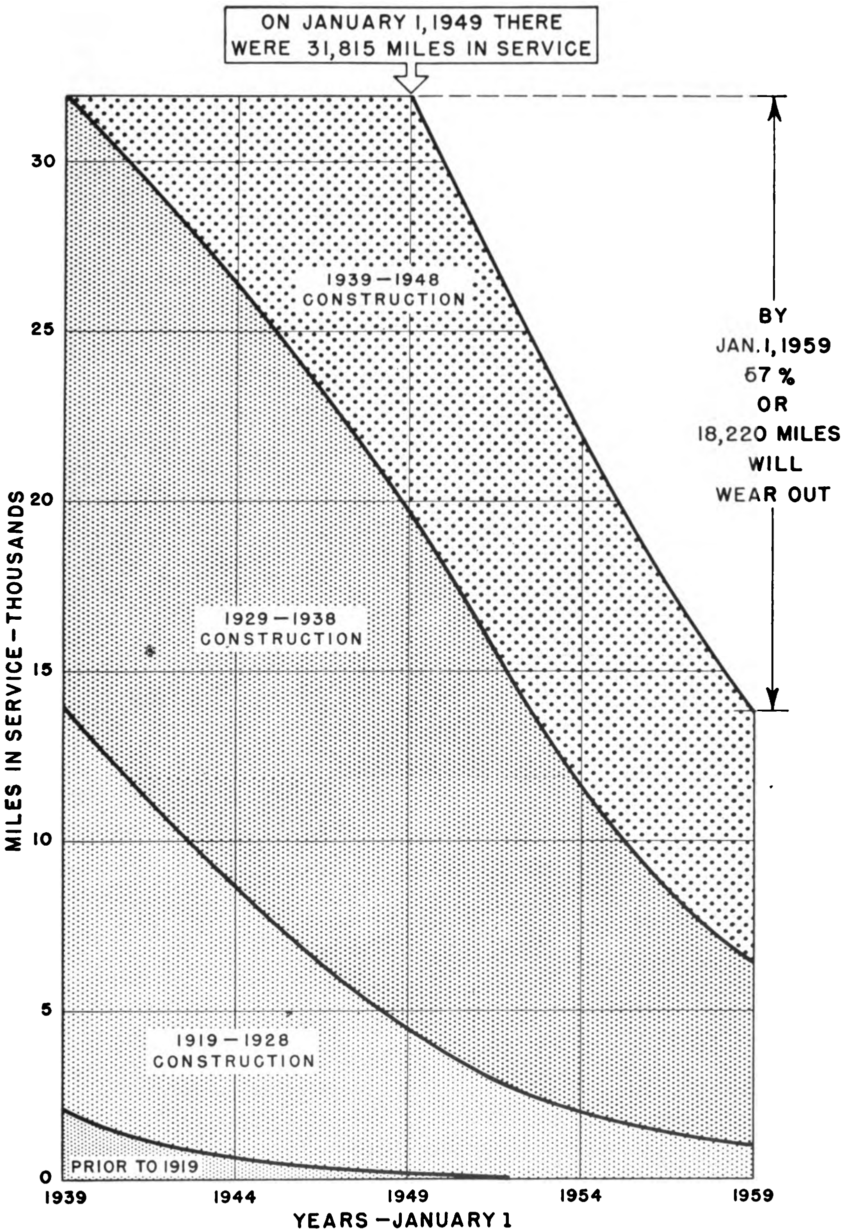
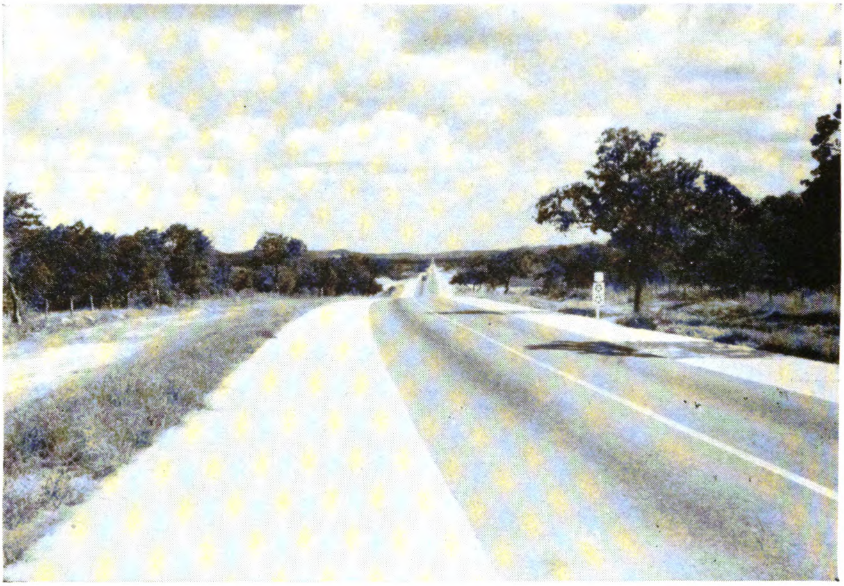


FIGURE 4.—Age of rural road mileage on the interstate highway system.

roads that should be widened to 24 feet to serve their traffic properly. There are also about 875 miles of two-lane roads that should be converted to four-lane divided highways; about 1,350 miles now surfaced with three or more lanes undivided which should be rebuilt as multiple-lane divided roads; and there are more than 450 miles of divided highways on which the traffic lanes are presently of inadequate width.

Shoulder width

Except in mountainous areas, the defined standards call for shoulder width of 10 feet, measured to the intersection of shoulder and side-slope planes. This is equivalent to an effective shoulder width of about 8 feet. In mountainous areas the standards call for an effective



More than 71 percent of the rural mileage of the interstate system—22,684 miles—is without 8-foot minimum width shoulders, such as these on U S Route 87 in Texas.

shoulder not less than 4 feet wide. Shoulders effectively 8 feet wide are needed to provide an extra emergency lane into which to turn to avoid a collision. They are needed also as an area in which to stop for the changing of tires or the making of other emergency repairs, and for other similar purposes related to highway safety and the avoidance of obstruction of free traffic flow. More than 71 percent of the rural mileage of the system, 22,684 miles, is without shoulders as wide as 8 feet. On this mileage, parked vehicles must necessarily encroach to a greater or less extent on a traffic lane.

Nearly 6,700 miles have no shoulder as wide as 4 feet, the minimum allowed by the standards in mountainous areas. Since only 1,949 miles of the rural system are in areas classed as mountainous, it is apparent that much of this gross shoulder inadequacy has no such justification of exceptional terrain.

Deficiencies of both pavement and shoulder width

Approximately half of the rural mileage of the system is deficient in both shoulder and surface width. On this mileage, surfaces already too narrow are further constricted whenever a vehicle has to stop for any reason along the way.

Of the entire rural mileage, 5,500 miles at most are adequate in both surface and shoulder width.

Urban width deficiencies

Streets in urban areas should have greater paved widths than rural roads because of the general absence of shoulders and greater frequency of parking. It is, therefore, a startling commentary upon the width

About 875 miles of two-lane rural roads on the interstate system should be converted to four-lane divided highways like this one in Maryland.

of the urban interstate system mileage to find that 2,391 of the 4,141 urban miles for which complete data are available are inadequate in paved width even by the rural road standard.

DEFICIENCY OF CURVATURE

On rural sections of the system there are 3,199 curves of more than 14 degrees, the maximum recognized by the standards as permissible in mountainous areas, and more than half of them are in areas classed as flat or rolling.

There are 15,115 curves, or approximately one every 2 miles on the average, that are sharper than the standard specified as desirable for the type of terrain in which they are located. Of those, 11,182 are sharper than the maximum prescribed by the standards for the desirable design speed; and 6,473 are sharper than the maximum permissible for the minimum design speed suggested for such class of terrain.

DEFICIENCY OF GRADIENT

The standards prescribe an absolute maximum of 6 percent for grades on the system. •There are 668 grades that exceed this limit, 560 on rural, and 108 on urban sections of the system. The aggregate length of these excessive grades is 243 miles, of which about 28 miles are in urban areas.

Grades of 3 to 6 percent

While grades up to 6 percent are permitted by the standards, any grade over 3 percent, if it is long enough, will slow heavy trucks to a speed at which they become annoyingly obstructive of the free flow of lighter traffic. If, under these conditions, the pavement is of two lanes, and especially if passing sight distance is unduly restricted, the obstruction of the heavier vehicles may become dangerous as well as annoying.

Under these conditions a remedy is desirable, and it may be applied by reduction of the grade to a maximum of 3 percent, or by the construction of additional lanes on both sides of the highway, or by the construction of an added lane for slow-moving trucks on the uphill side for at least the distance in which they will be undesirably reduced in speed.

On rural sections of the system there are 5,430 grades of 6 percent or less but more than 3 percent. They aggregate about 2,350 miles in length. Of these, 5,018 grades, totaling about 2,180 miles, are on two-lane or three-lane highways; the remainder are on multilane highways of adequate and inadequate width.

Widening needed on grades

Most of these grades between 3 and 6 percent in steepness are short enough, or exist on roadways wide enough, or for other reasons are acceptable, so that no improvement is required for the correction of a grade deficiency. But 916 of them, totaling more than 400 miles in length, should be widened in some way to abate the nuisance of slow-moving trucks. Of these instances, 592 are on two-lane roads that should be widened on the uphill side for an aggregate distance of about 300 miles by the addition of a truck lane; 284 are on two- and three-lane highways for a total length of 114 miles that require widening to four lanes; and 40 are on multilane highways that require widening. There are only 21 miles in the last category.

Steeper grades

In addition to the above widening necessitated on grades of less than 6 percent, a similar treatment is required on 65 of the grades of 6 percent or more, involving the desirable widening of 26 miles, most of which is now two or three lanes wide.

DEFICIENCY OF SIGHT DISTANCE

Safe stopping distance

Within the 31,831 miles of the rural system there are 21,028 sections, totaling 2,087 miles in length—nearly 7 percent of the total mileage—on which sight distance sufficient to permit safe stopping is not available. All but 1,625 of these sections are on either two- or three-lane roads. The 1,625 sections on multilane highways total 161 miles in length; the two- and three-lane mileage involved is 1,926.

Safe and satisfactory operation on these sections can, in some cases, be provided by the removal of view obstructions such as trees, cut-slopes, and nearby buildings; but in the great majority the alinement or profile of the road, or both, must be changed to flatten horizontal or vertical curves.

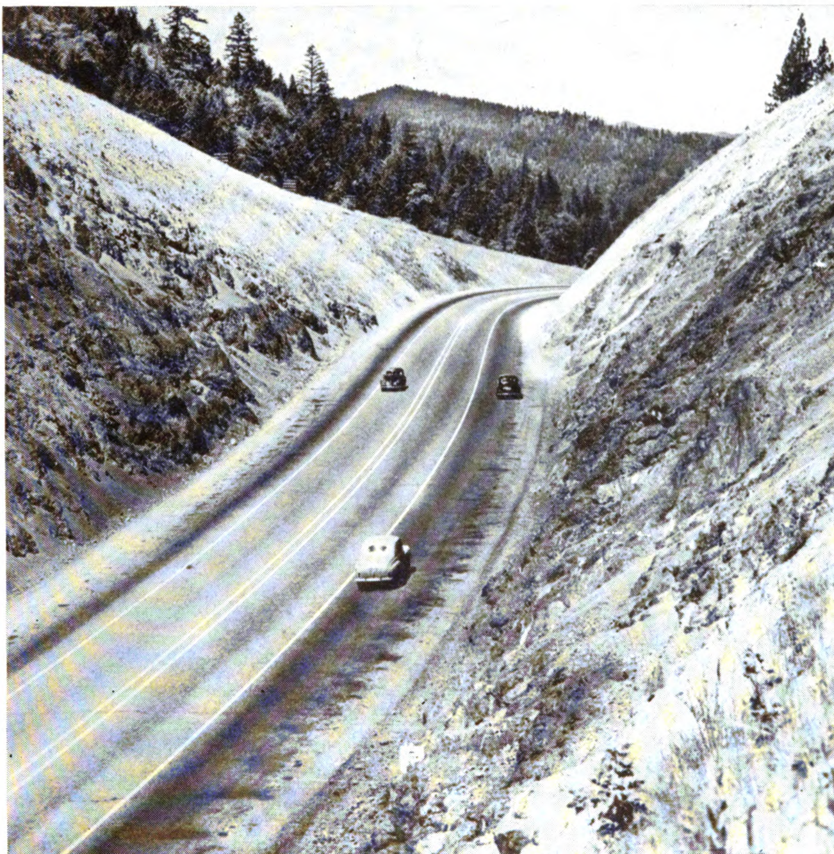


Photo by Oregon State Highway Commission

The two-lane U S Route 99 in Oregon, carrying 2,150 vehicles a day, crossed this mountain pass with grades of 6 percent on each side of the summit. Tremendous excavation would have been required to provide adequate passing sight distance, so the State widened the section over the summit to four lanes instead.

Safe passing distance and essential capacity

Passing sight distance is required only on two-way roadways of two and three lanes. Of these categories, on the rural system, there are 29,287 miles, including about 11 miles that are unsurfaced; and of this total, passing sight distance is undesirably restricted on 7,324 miles or about 25 percent.

Of the 7,324 miles, 3,968 miles carried an hourly traffic of less than 500 vehicles in 1948. Roads that carried traffic in excess of 800 vehicles hourly aggregate 1,456 miles. The remainder, 1,900 miles, is on roads that carried traffic of between 500 and 800 vehicles an hour.

Correction of deficiencies

Correction of these passing-sight-distance deficiencies can be accomplished in three ways, as follows:

1. By improving the alinement and profile of the existing highway. This may involve the relocation of short sections where horizontal curves cause the restriction; or it may necessitate additional excavation at the summit of grades where the restriction is caused by short vertical curvature.
2. By constructing another highway that will meet the required standards on a new location.
3. By constructing an additional two-lane highway, which with the existing highway will form a divided four-lane highway, on which sight distance of the extent required for safe passing on two- and three-lane roads is not needed.

Of these three means the choice of the most feasible depends on such conditions as the relative adequacy of the surface and other features of the existing road and the present and estimated future traffic.

Conversion to four-lane divided highways

The expenditure of any substantial sum for the lengthening of sight distance on the 1,456 miles that carried hourly traffic of 800 vehicles or more will be wasteful. These roads should be promptly transformed into four-lane divided highways.

Correction of sight-distance deficiencies on the 1,900 miles carrying 500 to 800 vehicles hourly will generally require extensive relocation to develop the alinement needed to provide the sight distance necessary for these roads as two- and three-lane highways. The traffic on these roads is increasing, and in the not distant future may be expected to reach volumes requiring the capacity of divided four-lane highways. When this is done the extended sight distance will not be required. For this reason, the more feasible and perhaps less costly correction in the case of a high percentage of the roads carrying between 500 and 800 vehicles hourly would appear to be early replacement of the existing two- and three-lane roads with four lanes, divided.

Likewise, it may be more feasible to reconstruct to four lanes some of the 3,968 miles now carrying less than 500 vehicles per hour, especially those sections in rough terrain where extensive work would be required to lengthen the sight distance to the required standards.

DEFICIENCY OF INTERSECTION WITH RAILROADS

The defined standards require elimination of all grade crossings of railroads consisting of two or more main-line tracks, and of all crossings of single-track lines on which there are six or more train movements daily.

The 218 remaining crossings of the first category and 542 of the second, a total of 760 crossings, are definitely of sufficient hazard to warrant their elimination.

The need for elimination of the remaining 502 grade crossings of single main-line tracks carrying less than six daily train movements and of the 785 crossings of sidings and spur tracks can be determined only by a careful analysis in each case, giving proper weight to traffic hazard and delay and inconvenience.

Of the 760 grade crossings that definitely should be eliminated, 574 are on urban sections of the system. Only 186 are on rural sections. When these figures are compared with the 1,051 urban and 1,013 rural

Elimination of main-line railroad grade crossings in urban areas often requires extensive construction, as is evident in this sketch of a proposed treatment on U S Route 40 in Ohio.

crossings that already have been separated by the construction of underpass or overpass structures, it is apparent that the work of grade-crossing elimination to date has been much more thorough on the rural than on the urban sections of the system.

DEFICIENCY OF INTERSECTIONS WITH OTHER HIGHWAYS

There are 118 intersections of rural routes of the designated system with other highways at which the combined hourly traffic on the intersecting roads exceeded 2,000 vehicles in 1948, with at least 500 vehicles on the intersecting road of least traffic density. Under these conditions the standards require separation of the grades of the intersecting roads by the construction of overpass or underpass bridges.

In rural areas

It is apparent that the need for this type of improvement on rural sections of the system is not great, and it is encouraging to compare the remaining need of only 118 structures with the 341 similar grade separations already existing.

In urban areas

It is in the urban areas, however, where the greatest need for separation of grade intersection with other streets or highways will exist. This will usually be accomplished by the elevation or depression of the interstate highway for considerable distances. Application of the traffic-volume criterion to the heavy volumes normally present at city intersections would require this in any case, but even where, at particular street intersections, the cross movement may be less than 500 vehicles per hour, the need for greater freedom of flow on the heavy-traffic interstate route is such as to require elimination of the grade intersections anyhow, and in this case the desired end will usually be attained by closure of the unimportant cross streets and diversion of their traffic to nearby separated intersections.

Improvement other than separation

It should be added here, that while on rural sections of the system no great need is found for further separation of highway grade intersections, there is widespread need for the improvement of intersections by other means, such as the lengthening of sight distance, the construction of deceleration and acceleration lanes on the interstate highway, and the construction of channelizing islands to regularize intersecting traffic movements.

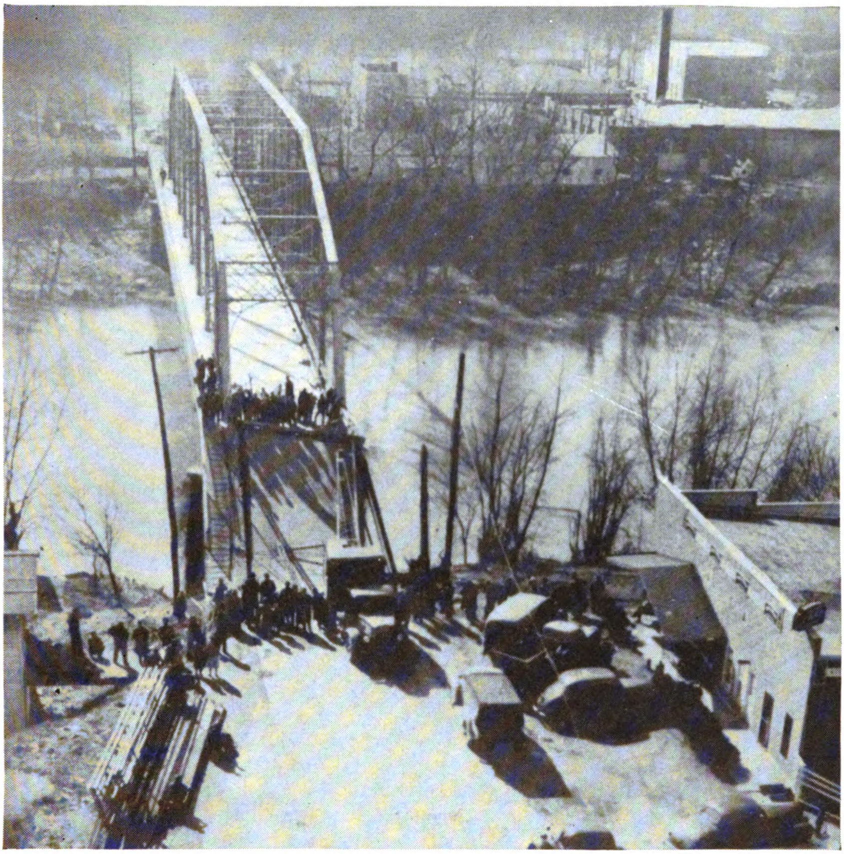
DEFICIENCY OF BRIDGES AND TUNNELS

Deficiency of bridge load capacity

The extent of bridge insufficiency has already been generally indicated in the foregoing description of the existing bridges. The defined standards call for load capacity equivalent to that provided by H20–S16 design. The weighing of vehicles now using routes of the system has shown definitely that this standard is none too high for normal civil usage, and it is definitely required in anticipation of possible military needs.

When, at all weighing points, the average weight of all maximum loads occurring with a frequency of at least once daily is found to be 30 tons, and at frequent points throughout the system once-daily-loads reach maxima averaging nearly 62 tons, it is apparent that bridges safely designed for the 36-ton gross vehicle weight on a 28-foot wheel base that is accommodated by the H20–S16 design are a necessity on the system.

On the entire system there are at present only 1,607 bridges of H20–S16 design or rating, of which 1,388 are in rural areas and 219 in urban areas. All other bridges on the system, 8,662 in rural areas and 1,779 in urban areas, are deficient in some degree in load-carrying capacity by the standard adopted. The deficiency is slight in respect to 2,207 bridges, 1,444 on rural sections of the system and 763 on urban sections, which are rated as of H20 design. All other existing bridges are of definitely inferior strength for the interstate system. The numbers thus deficient are 7,218 in rural areas and 1,016 on urban sections of the system.



Seriously inadequate in load-carrying capacity are 677 bridges on the interstate system. This one on U S Route 25 in Kentucky, old and too narrow, had one span completely wrecked when an Army truck hit the end post. Some 8,234 bridges on the system fail to meet the interstate standards for load capacity.

Deficiency of bridge clearance

But it is not alone in carrying capacity that the existing bridges are deficient. They are more seriously deficient in horizontal clearance and to some degree in the vertical clearance they provide.

None of the H20–S16 bridges, in either rural or urban areas, is deficient in vertical clearance. However, there are 905 of the bridges of this standard capacity in rural areas that are in some degree inadequate in horizontal clearance. Of these, 627 are substantially inadequate; the remainder are only moderately inadequate.

Of the H20 bridges, 18 in rural areas and 4 in urban areas are deficient in vertical clearance; and 1,084 of the bridges of this capacity in rural areas are inadequate in horizontal clearance, 222 of them only moderately so.

It is impossible to rate the adequacy of horizontal clearance for many bridges in urban areas because of uncertainty as to the hourly traffic volume they carried. It is believed that nearly all existing H20–S16 bridges in urban areas are of substantially adequate horizontal clearance. However, more than half of the urban bridges of H20 capacity are seriously inadequate in width.

Of the bridges of capacity inferior to H20, only 53 in rural areas and 10 in urban areas are deficient in vertical clearance. But these bridges, deficient in load-carrying capacity, are also generally deficient in horizontal clearance. Of 7,218 such bridges in rural areas 6,198 are thus deficient, 5,181 of them substantially so.

Deficiency of tunnel clearance

Of the 13 rural tunnels all but one are substantially adequate in vertical clearance, but all are in some degree inadequate in horizontal clearance.

Of the eight tunnels in urban areas, three are deficient in vertical clearance and all are inadequate in horizontal clearance.

Character and Cost of Required Improvements of the System

In the light of the conditions found by the survey to exist on the roads and bridges now constituting the designated interstate highway system, and in consideration of the standards agreed upon as necessary for adequate service of the 1948 traffic on the system, the several State highway departments were asked to determine the kind of improvement that would be required to bring the entire system up to a desirable degree of adequacy, as of the present time, and to estimate the cost of so doing.

As a result of this analysis only 1,900 miles of the system in rural areas and 398 miles in urban areas, as they presently exist, are found to require no improvement. The mileage here classified as urban includes 98 miles in towns of less than 5,000 population. For purposes of the estimate of costs of required improvements, only those sections of the system included within the limits of the urban areas of cities of 5,000 population and more, as defined by the Federal-aid Highway Act of 1944, have been classified as urban. On this basis, the mileage requiring no improvement is 1,998 miles rural and 300 miles urban, a total of 2,298 miles, or about 6 percent of the system as it now exists.

CHARACTER OF ROAD IMPROVEMENT REQUIRED

All other parts of the system are found to require some measure of improvement. The essential improvement of 8,687 miles, about 23 percent of the system as it now exists, consists of widening only. Of this total, 8,306 miles are rural, 381 urban.

Improvements classified as reconstruction, which can be effected with no more than minor relocation of the existing roads, are required on 14,283 miles, nearly 38 percent of the existing total mileage. Of these roads 13,467 miles are in rural areas and 816 miles in urban areas.

The most extensive change, improvement which requires complete departure from existing alinement and relocation, is required on the remaining one-third of the system as it now exists. The estimated mileage of the relocated roads is 11,891, which is less than the length

Photo by Texas State Highway Department

More than 2,000 miles of the urban portions of the interstate system will have to be relocated, in many cases as controlled-access freeway with frontage roads such as the Central Boulevard in Dallas, Tex.

of the existing roads by 641 miles; and the total length of the system, 37,800 miles at present, is shortened by this amount to 37,159 miles. Of the 11,891 miles of relocated highways, 9,867 are in rural areas and 2,024 in urban areas.

BRIDGE CONSTRUCTION REQUIRED

On the 11,891 miles of highway relocation proposed, there are 4,893 bridges that would have to be constructed. Of these, 2,693 are on the relocated rural sections and 2,200 are on the urban relocations.

On the sections of the system to be improved on approximately the present locations, totaling 22,970 miles, and on the 2,298 miles otherwise adequate, there are 5,925 bridges which require improvement in some degree, some by outright reconstruction. Of these 5,187 are on rural sections and 738 on urban sections of the system.

TUNNEL CONSTRUCTION

Of the 13 existing rural tunnels, 6 of the least adequate will be avoided in the proposed improvement of the system by relocation of the existing approach roads. The remaining seven, all adequate in vertical clearance, will be supplemented in the proposed improvement by parallel bores. The twin bores, then of adequate width, will each carry one direction of traffic.

Improvement of urban tunnels

Of the eight existing urban tunnels, all but one are proposed for enlargement by the State highway departments. These are the Yerba Buena tunnel in California; the Sumner tunnel in Boston, Mass.; the semitunnel in Jersey City, N. J.; the Beaucatcher tunnel at Asheville, N. C.; the McCallie tunnel in Chattanooga, Tenn.; the tunnel in St. George, Utah; and the Lake Washington tunnel in Seattle, Wash.

The one existing urban tunnel for which no improvement was proposed by the State highway department is the Bankhead tunnel at Mobile, Ala. This tunnel, with its slightly restricted vertical clearance and 21-foot clear width, for an hourly traffic of over 1,000 vehicles in 1948, is regarded by the Public Roads Administration as definitely inadequate. The existing tunnel was built in 1940 at a cost of about $4,000,000. Its inadequacy of width, at least, should be corrected by the construction of a parallel tube, which should provide a minimum vertical clearance of 14 feet. For this purpose an estimate of $5,500,000 has been added to the State highway department's estimate of costs.

New tunnels proposed

In addition to the required work of enlargement of existing tunnels, construction of five new tunnels is proposed, of which one is on a rural section of the system and four are in urban areas.

The one new rural tunnel proposed is on U S Route 40 in California at the approach to the Carquinez Strait Bridge.

The four proposed new tunnels in urban areas are a 900-foot tunnel in Louisville, Ky.; a 700-foot expressway tunnel in Boston, Mass.; a 2,400-foot freeway tunnel in Kansas City, Mo.; and a new Palisades tunnel in New Jersey.

TRAFFIC SERVICE OF THE IMPROVED SYSTEM

The 2,298 miles of the system on which no road improvement is required, served in 1948, on the 1,998 rural miles included, an average daily traffic of 4,190 vehicles, and on the 300 urban miles an average of 17,350 vehicles daily. The State highway departments estimate that the 34,861 miles proposed for improvement, if they had been improved as proposed in 1948, would have served on the 31,640 miles of rural sections included an average of 3,450 vehicles, and on the urban sections totaling 3,221 miles an average of 15,360 vehicles daily.

On the basis of these traffic volumes, it is estimated that the system, if it had existed in 1948 in the proposed state of improvement, would have served in that year, on its shortened improved length of 37,159 miles, approximately 62,115 million vehicle-miles of travel. Of this total, 42,380 million vehicle-miles would have been served by the 33,638 miles of rural routes, and 19,735 million vehicle-miles would have been served by the 3,521 miles of urban routes.

These estimates indicate that the system, if it had been improved as proposed in 1948, would have accommodated on its rural sections, constituting approximately 1 percent of the total rural road mileage, more than 21 percent of the total vehicle-mileage on rural roads. On its sections included within the urban areas of cities of 5,000 population or more, constituting approximately 1 percent of the total city street mileage, it would have served more than 10 percent of the total mileage of urban travel.

COST ESTIMATE OF PROPOSED IMPROVEMENTS

The cost of improvements found to be required has been estimated by the State highway departments on the basis of prices prevailing in 1948. The Federal-aid highway price index for 1948, referred to average prices for the years 1925–29 as 100, was 158.2. Compared with 1940 prices, the average for 1948 was nearly 114 percent higher. Costs of the improvements are, therefore, estimated at high prices; in fact, at the highest prices obtaining for any year in the history of the Federal-aid highway program.

If, in the future, as appears probable, there is some decline from the 1948 price level, the cost of the proposed improvements is likely to be less than the estimate; but no attempt has been made to anticipate the probability in this regard.

Total costs

On the basis of 1948 prices, as stated, the estimated cost of all work proposed on the interstate highway system, as thus far designated, is $11,266,400,000. Of this total, $5,973,000,000 is for improvement of rural sections of the system and $5,293,400,000 is for work proposed on urban sections. The cost of urban improvements is 47 percent of the total.

Widening

Of the $11,266,400,000 total cost, $957,800,000 is for the widening of 8,687 miles of the system as it exists at present, an average of $110,300 per mile. For all rural sections to be widened, a total of 8,306 miles, the cost is $729,300,000, averaging $87,800 per mile. For the 381 miles of urban sections to be widened, the cost is $228,500,000, averaging $599,800 per mile.

Reconstruction

The cost of reconstructing 14,283 miles of the system, involving more than widening but no extended relocation, is estimated at

$3,022,700,000, an average of $211,600 per mile. For all rural sections to be reconstructed, a total of 13,467 miles, the cost is $2,117,100,000, averaging $157,200 per mile. For the 816 miles of urban sections to be reconstructed, the cost is $905,600,000, averaging $1,109,800 per mile.

Relocation

The cost of relocated sections of the system, aggregating 11,891 miles, is $7,236,700,000, an average of $608,600 per mile. For all

"They shall not pass" at this point on U S Route 78 in Alabama, where sight distance is practically zero. The 20-foot pavement is badly damaged and the shoulders worn and narrow, yet this road must handle 3,350 vehicles daily. Reconstruction to remedy such conditions is required on 14,283 miles of the interstate system.

rural relocated sections, totaling 9,867 miles, the cost is $3,077,400,000, averaging $311,900 per mile. For all urban relocated sections, totaling 2,024 miles, the cost is $4,159,300,000, averaging $2,055,000 per mile.

Right-of-way, bridges, and tunnels

All foregoing cost estimates include costs of right-of-way, and of the bridges and tunnels included in the road sections.

The estimated cost of right-of-way is $735,000,000 for all rural sections to be improved, an average of $23,200 per mile, and about 12 percent of the cost of the rural sections. For all urban sections the estimated cost totaling $1,667,000,000 averages $517,600 per mile and is more than 31 percent of the cost of the urban sections.

The estimated cost of all bridges to be built or altered on the system is $2,888,900,000. This amounts to about one-fourth of the estimated cost of all work required. Of the total bridge cost, $1,687,200,000, or 58 percent, is for structures in urban areas. New structures to be built on relocated sections of the system represent 72 percent of the total bridge cost.

The estimated cost of all tunnel work proposed is $106,200,000. Of this amount, $82,400,000 is for the enlargement of existing tunnels, of inadequate width. The cost of the five new tunnels to be constructed is estimated at $23,800,000. Of the total cost of tunnels, $46,600,000 is for tunnels in rural areas and $59,600,000 for tunnels in urban areas.

Combined, the estimated costs of right-of-way, bridges, and tunnels amount to $5,397,100,000, which is 48 percent of the estimated total costs. In rural areas, the cost of these elements of the proposed improvements is $1,983,300,000, about one-third of the total rural cost; in urban areas it is $3,413,800,000, which is nearly two-thirds of the total urban cost.

Costs of road construction

After deduction of the costs of right-of-way, bridges, and tunnels, the remainder of the estimated cost, which is the net cost of all road construction, is $5,869,300,000, which represents an average cost of $168,400 per mile for the mileage to be improved. The corresponding cost of road construction work to be executed on rural sections of the system is $3,989,700,000, an average of $126,100 per mile; and for road work only in urban areas the cost is $1,879,600,000, an average of $583.600 per mile.

COST PER MILE

Including all costs, the $11,266,400,000 cost of the work proposed represents an average of $323,180 per mile for the mileage to be improved, and $303,190 per mile for the entire mileage.

Rural and urban costs per mile

The similar total cost for rural sections of the system, $5,973,000,000, represents an average of $188,800 per mile for the mileage to be improved, and $177,600 per mile for the entire mileage, including the 1,998 miles that are adequate in their present condition.

On the same basis, the total cost for urban sections, $5,293,400,000, represents an average of $1,643,400 per mile for the mileage to be improved and $1,503,400 per mile for the entire mileage, including the 300 miles already adequate.

Ratio of rural and urban costs

The cost of the actual work required, on a per-mile basis, appears from the above figures to be about 8.7 times as great for the urban as for the rural sections of the system. On the basis of the total mileage of the system, including the mileage on which no work is required, the per-mile costs of urban and rural work are in the ratio of about 8.5 to 1.

COST PER VEHICLE-MILE

If, in 1948, it had been possible to invest in the system the $11,266,400,000 of capital estimated as required for the improvements proposed, that sum could have been raised by a payment of only 18.1 cents for each mile of vehicle travel on the system in that one year. This figure represents the vehicle-mile cost for 1 year's usage only. Vehicle registration and vehicle usage are increasing. In future years

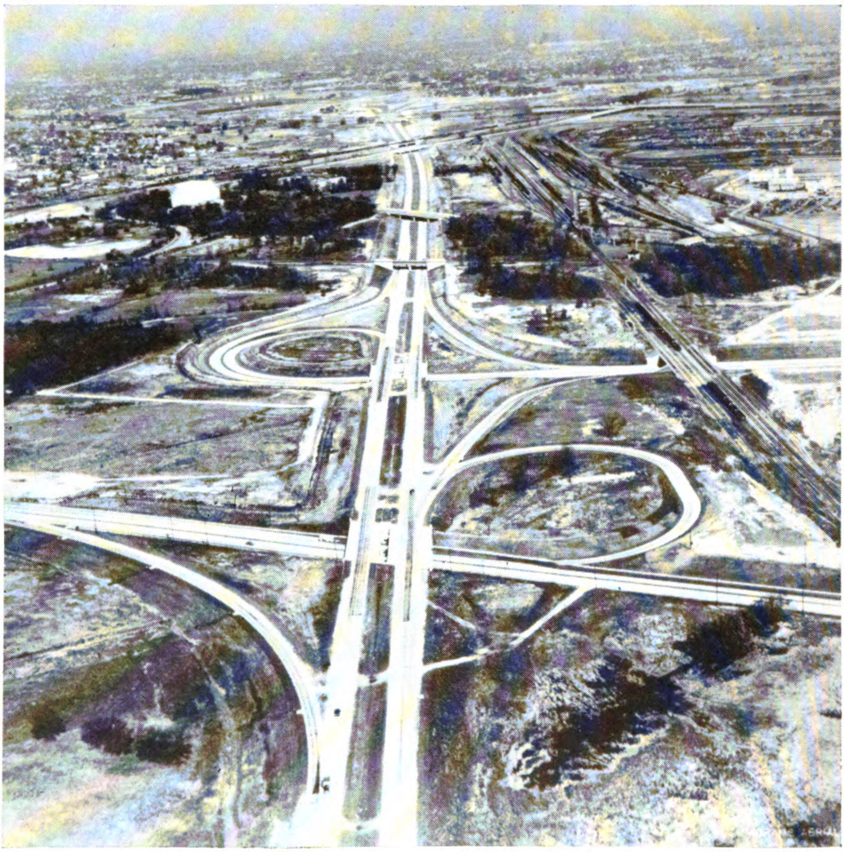


Photo by Abrams Aerial Survey Corp.

Complete separation of both highway and railroad crossings, as exemplified by the Detroit Industrial Expressway, permits fast, uninterrupted flow of traffic and unhampered turning movements.

the usage of the system, in terms of vehicle-miles of travel on it, will increase. The amount of the probable increase is a matter of speculation.

Future traffic

If traffic using the system in future years is assumed to remain at the level estimated for 1948, the capital cost of the proposed improvement would represent about nine-tenths of a cent per vehicle-mile of the traffic that would be served in a period of 20 years. Since this traffic assumption is very conservative, the computed cost per vehicle-mile is correspondingly conservative. A cost little more than seven-tenths of a cent per vehicle-mile over a 20-year period would probably be a more reasonable measure of the capital burden of the proposed improvements spread over a 20-year period.

Rural and urban vehicle-mile costs

These figures are based on the improvement cost estimated for the system as a whole. For the rural sections only the capital investment would have been repaid by a payment of about 14.1 cents per vehicle-mile of the 1948 traffic, or a maximum of about 7 mills per vehicle-mile in 20 years, a figure that may be reduced in view of the probable traffic increase to less than 6 mills per vehicle-mile.

For the urban system the corresponding vehicle-mile payments and costs are 26.7 cents for 1 year's traffic; 1.33 cents for the traffic of 20 years continued in the 1948 volume, and probably little more than 1 cent as traffic is likely to develop in a 20-year period.

Comparison of the costs given for the urban and rural sections indicates that the improvement of the urban sections as proposed, in terms of the traffic served, is slightly less than twice as expensive as the proposed improvement of the rural sections.

DATA BY STATES

Table 1 shows the mileage of the system as it is proposed for improvement in the rural and urban areas of each State and the corresponding total mileage; and the estimated costs of improving sections of the system in urban and rural areas of each State and the corresponding percentage of such costs in relation to the respective national total costs.

TABLE 1.—*Mileage of the interstate highway system and estimated costs of improvements proposed, by States*

State	Mileage of the system, when improved						Estimated total cost of improvements proposed					
	Rural	Percent of total	Urban	Percent of total	Total	Percent of total	Rural	Percent of total	Urban	Percent of total	Total	Percent of total
Alabama	826.2	2.46	64.6	1.83	890.8	2.40	$73,306,050	1.23	$14,670,200	0.28	$87,976,250	0.78
Arizona	1,123.3	3.34	13.6	.39	1,136.9	3.06	80,579,000	1.35	11,529,000	.22	92,108,000	.82
Arkansas	476.5	1.42	41.3	1.17	517.8	1.39	58,752,400	.98	19,536,800	.37	78,289,200	.69
California	1,714.2	5.10	186.3	5.29	1,900.5	5.11	552,672,000	9.25	616,755,000	11.65	1,169,427,000	10.38
Colorado	627.1	1.86	34.6	.98	661.7	1.78	39,175,883	.66	33,117,640	.62	72,293,523	.64
Connecticut	163.3	.49	99.1	2.82	262.4	.71	63,596,000	1.06	155,706,000	2.94	219,302,000	1.95
Delaware	22.9	.07	2.6	.07	25.5	.07	25,019,500	.42	24,409,000	.46	49,428,500	.44
Florida	1,012.6	3.01	128.6	3.65	1,141.2	3.07	63,137,100	1.06	52,125,400	.98	115,262,500	1.02
Georgia	1,027.3	3.05	83.3	2.37	1,110.6	2.99	103,148,750	1.73	72,578,835	1.37	175,727,585	1.56
Idaho	608.2	1.81	8.7	.25	616.9	1.66	46,773,000	.78	3,470,000	.07	50,243,000	.45
Illinois	1,314.1	3.91	226.8	6.44	1,540.9	4.15	321,168,042	5.38	535,209,461	10.11	856,377,503	7.60
Indiana	906.0	2.69	159.4	4.53	1,065.4	2.87	139,233,570	2.33	250,203,840	4.73	389,437,410	3.46
Iowa	640.5	1.90	29.7	.84	670.2	1.80	68,935,700	1.15	9,413,000	.18	78,348,700	.70
Kansas	672.8	2.00	28.7	.82	701.5	1.89	71,698,390	1.20	18,085,000	.34	89,783,390	.80
Kentucky	578.8	1.72	69.6	1.98	648.4	1.74	100,534,698	1.68	81,398,001	1.54	181,932,699	1.61
Louisiana	470.7	1.40	126.4	3.59	597.1	1.61	89,065,900	1.49	131,944,000	2.49	221,009,900	1.96
Maine	277.8	.83	22.6	.64	300.4	.81	43,740,000	.73	30,431,000	.58	74,171,000	.66
Maryland	219.8	.65	45.7	1.30	265.5	.71	140,493,484	2.35	101,784,296	1.92	242,277,780	2.15
Massachusetts	176.8	.53	159.0	4.52	335.8	.90	112,783,600	1.89	339,112,500	6.41	451,896,100	4.01
Michigan	894.1	2.66	68.4	1.94	962.5	2.59	181,335,450	3.04	235,063,700	4.44	416,399,150	3.70
Minnesota	766.9	2.28	83.6	2.37	850.5	2.29	58,395,501	.98	103,115,543	1.95	161,511,044	1.43
Mississippi	569.3	1.69	121.7	3.46	691.0	1.86	62,017,800	1.04	26,122,000	.49	88,139,800	.78
Missouri	1,032.8	3.07	38.0	1.08	1,070.8	2.88	133,579,990	2.24	101,704,000	1.92	235,283,990	2.09
Montana	1,217.4	3.62	26.3	.75	1,243.7	3.35	108,507,450	1.82	8,097,000	.15	116,604,450	1.03
Nebraska	453.9	1.35	6.7	.19	460.6	1.24	40,869,000	.68	7,370,000	.14	48,239,000	.43
Nevada	526.3	1.56	11.0	.31	537.3	1.45	17,940,300	.30	1,628,000	.03	19,568,300	.17
New Hampshire	169.0	.50	32.0	.91	201.0	.55	26,910,000	.45	13,419,000	.25	40,329,000	.36
New Jersey	90.3	.27	102.1	2.90	192.4	.52	59,703,300	1.00	344,350,100	6.51	404,053,400	3.59
New Mexico	989.7	2.94	22.8	.65	1,012.5	2.72	52,257,000	.87	5,852,700	.11	58,109,700	.52
New York	962.3	2.86	72.0	2.04	1,034.3	2.78	643,146,000	10.77	219,135,000	4.14	862,281,000	7.65
North Carolina	637.0	1.89	75.7	2.15	712.7	1.92	42,993,000	.72	29,864,000	.56	72,857,000	.65
North Dakota	478.8	1.42	19.5	.55	498.3	1.34	29,365,120	.49	15,785,600	.30	45,150,720	.40

Ohio	999.8	2.97	216.6	6.15	1,216.4	3.27	396,185,000	6.63	362,406,000	6.85	758,591,000	6.73
Oklahoma	734.4	2.18	45.7	1.30	780.1	2.10	136,767,500	2.29	29,650,000	.56	166,417,500	1.48
Oregon	675.2	2.01	27.8	.79	703.0	1.89	94,450,000	1.58	23,465,000	.44	117,915,000	1.05
Pennsylvania	1,025.9	3.05	331.0	9.40	1,356.9	3.65	528,013,000	8.84	398,566,000	7.53	926,579,000	8.22
Rhode Island	23.4	.07	25.2	.72	48.6	.13	6,082,000	.10	79,925,976	1.51	86,007,976	.76
South Carolina	604.5	1.80	92.5	2.63	697.0	1.88	39,425,750	.66	80,143,000	1.51	119,568,750	1.06
South Dakota	499.5	1.48	15.2	.43	514.7	1.39	40,196,800	.67	4,638,000	.09	44,834,800	.40
Tennessee	967.2	2.88	77.7	2.21	1,044.9	2.81	172,634,734	2.89	69,022,782	1.30	241,657,516	2.15
Texas	2,573.0	7.65	191.8	5.45	2,764.8	7.44	286,883,400	4.80	149,104,200	2.82	435,987,600	3.87
Utah	672.3	2.00	31.8	.90	704.1	1.89	61,208,300	1.03	23,045,000	.44	84,253,300	.75
Vermont	311.4	.93	28.4	.81	339.8	.91	47,508,220	.80	6,910,300	.13	54,418,520	.48
Virginia	844.6	2.51	57.1	1.62	901.7	2.43	170,536,000	2.86	36,773,000	.69	207,309,000	1.84
Washington	521.0	1.55	58.5	1.66	579.5	1.56	118,363,500	1.98	66,096,600	1.25	184,460,100	1.64
West Virginia	165.7	.49	46.2	1.31	211.9	.57	94,514,500	1.58	112,095,000	2.12	206,609,500	1.83
Wisconsin	424.4	1.26	24.7	.70	449.1	1.21	75,025,050	1.26	52,178,950	.99	127,204,000	1.13
Wyoming	949.0	2.82	23.7	.67	972.7	2.62	54,309,750	.91	5,759,910	.11	60,069,660	.53
District of Columbia			16.6	.47	16.6	.04			180,670,000	3.41	180,670,000	1.60
National total	33,638.0	100.00	3,520.9	100.00	37,158.9	100.00	5,972,936,482	100.00	5,293,435,334	100.00	11,266,371,816	100.00

SUBSTANCE OF THE 1941 REPORT

The section of the Federal-aid Highway Act of 1948, to which this report is responsive, directs first that a study be made of the status of improvement of the National System of Interstate Highways, and further requests that the report to be submitted shall supplement the report dated February 1, 1941, entitled "Highways for the National Defense," to reflect current conditions and deficiencies.

GENESIS OF 1941 REPORT

The results of the study that has been made of the status of improvement and deficiencies of the interstate highway system are presented in the foregoing pages. Fully to supplement the 1941 report, a good deal more is required, and in order that the purposes of what follows may be clearly understood it is desirable at this point to refer to the inception of the earlier report and briefly summarize its principal findings and recommendations.

The 1941 report was requested by President Franklin D. Roosevelt in a letter to John M. Carmody, Administrator, Federal Works Agency, under date of June 21, 1940, in which the President wrote as follows:

> In order that we may be assured of the adequacy of our highway system to meet the needs of our national defense, I would like you, in cooperation with the Advisory Commission to the Council of National Defense and the War and Navy Departments, to have the Public Roads Administration of your Agency make a survey of our highway facilities from the viewpoint of national defense and advise me as to any steps that appear necessary.
>
> I suggest that particular attention be paid to the strength of bridges, the width of strategic roads, adequacy of ingress to and egress from urban centers, and the servicing of existing and proposed Army, Navy, and Air bases. * * *

The report, Highways for the National Defense, prepared by the Public Roads Administration in response to this request of the President, was submitted to the Federal Works Administrator by the Commissioner of Public Roads under date of February 1, 1941. On the same day it was transmitted to the President.

RECOMMENDATIONS FOR SPECIFIC DEFENSE OPERATIONS

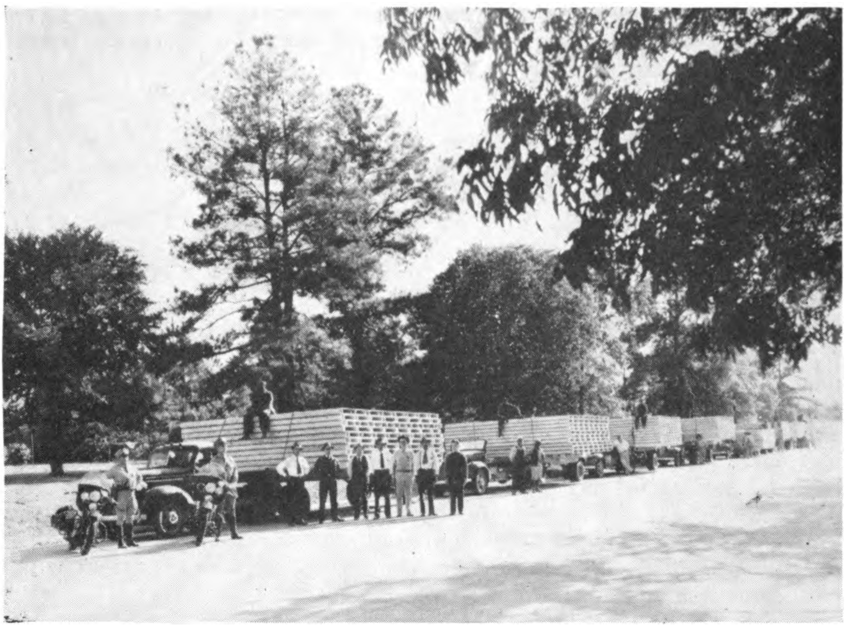
The report recommended two general programs of highway improvement as necessary to correct deficiencies then current. The first, and more urgent of the two, was a program intended to supply needed highway facilities for specific defense operations then developing. The needed facilities were classified as (1) reservation roads, (2) access roads, and (3) tactical roads.

Reservation roads consisted of company streets and other roads within the Federal reservation areas of Army cantonments, depots, and bases, and the various shore establishments of the Navy.

Access roads included numerous roads, each of relatively short mileage, required to give local access from main highways, railroads, and waterways to Army and Navy reservations, and industrial plants engaged in the defense production program. Roads to civil airports and landing fields were also included in this category.

Tactical roads included certain small mileages of roads giving access to isolated points of strategic importance, generally in coastal or border regions, and larger mileages near military reservations and in other areas that might become theaters of tactical maneuvers.

On roads of these classes, previously of little or no importance from the viewpoint of civil traffic needs, the report anticipated the development of a considerable defense usage which would necessitate substantial improvements attributable primarily to the defense needs.



Access roads are an important adjunct to military establishments. This truck fleet of tent platforms was on the way to Camp Shelby, Miss., where a tent city was built to quarter 50,000 soldiers in training.

RECOMMENDATIONS FOR THE STRATEGIC NETWORK

The second general program recommended was to consist of essential improvements of the strategic network, a connected system of highways which had been previously designated by the War and Navy Departments as the routes of principal importance from the standpoint of national defense. At the date of the report this network consisted of a system of main trunk routes totaling approximately 74,600 miles, and auxiliary roads approximately paralleling the main lines on each side, with cross-connections at frequent intervals.

The network included routes joining all important centers of defense industry and all military and naval concentration points. Its main lines, with few exceptions embraced within the Federal-aid highway system, included all routes of the interregional highway system previously recommended by the Public Roads Administration in its report, Toll Roads and Free Roads.[1] The auxiliary lines consisted in considerable part of State and local roads not included in the Federal-aid system.

The report recognized that the strategic network, in its main lines at least, was heavily used by civil traffic. Its service of purely military traffic would necessitate few if any improvements not required for the accommodation of civil needs. Its development to complete adequacy for the service of both classes of traffic was viewed as a long-time operation and practically continuous undertaking. Improvements of certain sections, partaking of the character of access and tactical roads, and elimination of a number of the more serious weaknesses, particularly substandard bridges, were recommended as urgent necessities. Otherwise the improvement of the strategic network was reported as of less urgency than the provision of reservation, access, and tactical roads.

SURVEY OF NEEDS

Surveys and studies made antecedent to the report, by the Public Roads Administration in cooperation with military and naval authorities and the State highway departments, indicated improvement needs in respect to each of the classes of roads described, as follows:

Reservation roads.—Improvement or outright construction of 1,500 miles entirely within Federal reservations. Since roads of this class were subject to the jurisdiction of the War and Navy Departments, the cost of their improvement was not estimated and no recommendation was offered concerning the authorization or appropriation of essential funds.

Access roads.—Determined need of the improvement of 2,830 miles, to serve 192 military reservations, at an estimated cost of $220,000,000; and additional needs, of indeterminate but substantial extent and cost, to serve vital defense industries.

Tactical roads.—Damage of local roads by military training maneuvers, reported as already occurring, was cited as indicative of an eventual need of construction or reconstruction, the extent of which could not be estimated.

Strategic network.—Determined needs consisted of the strengthening or reconstruction of 2,436 bridges of load capacity inferior to the H15 design standard, a minimum for both civil and defense traffic; the widening of 5,090 miles of roads surfaced less than 18 feet wide; and the strengthening of approximately 14,000 miles of surfaces incapable of supporting in all weather 9,000-pound wheel loads. It was estimated that these deficiencies could be eliminated by an expenditure of approximately $458,000,000.

APPROPRIATIONS RECOMMENDED

To permit a reasonably satisfactory accomplishment of the most urgent improvements of the several classes of roads, the report recommended immediate appropriations by the Federal Government in the following amounts:

1. For access roads, including new sections of highway to replace existing highway connections broken by necessary closures at military reservations and industrial sites, $150,000,000.

[1] H. Doc. No. 272, 76th Cong., 1st sess., Apr. 27, 1939.

2. For tactical roads, including the repair of damage caused by tactical maneuvers, $25,000,000.

3. For the strategic network, including the replacement of substandard bridges and the correction of other critical deficiencies, not less than $100,000,000, to be apportioned among the States in accordance with the existing Federal-aid formula, and made available to

Photo by Vermont Department of Highways

Commercial and passenger vehicles and an Army convoy mutually impede each other on this winding mountain highway, U S Route 2 in Vermont. The road is inadequate in almost every detail—width, shoulders, curvature, grade, and sight distance. The broken culvert guardrail in the foreground is evidence of the inadequate width.

pay costs of projects on a basis of Federal participation somewhat higher than the existing 50-percent limitation.

4. For the making of engineering surveys and plans for development of the strategic network, including extensions into and through municipalities, $12,000,000 to be apportioned among the States and matched by them on the existing Federal-aid basis.

REVISION OF FEDERAL HIGHWAY ACT PROPOSED

Finally, to facilitate the accomplishment of necessary improvements, the report recommended amendment of the Federal Highway Act (1) to authorize addition to the Federal-aid system of any roads conforming to the main lines of the strategic network, as designated by the War and Navy Departments; (2) to make roads and bridges on auxiliary lines of the network eligible for improvement with Federal-aid secondary road funds; and (3) to permit the use of Federal-aid funds in payment of part of the cost of acquiring necessary rights-of-way and attendant property damage.

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FEDERAL HIGHWAY LEGISLATION OF THE WAR PERIOD

There was no action responsive to the recommendations of the report of February 1, 1941, for several months. In the meantime, additional routes were designated by the War Department for inclusion in the strategic network. These, with the larger mileage previously designated by the War and Navy Departments, were indicated on a map, revised to May 15, 1941, which, as approved by the Secretary of War, is herewith presented as figure 5.

Surveys of needed reservation and access roads were continued by military authorities and the Public Roads Administration in cooperation with the State highway departments, and existing authority and means were employed to undertake some of the improvements found necessary. The Work Projects Administration undertook the construction of a considerable mileage of reservation roads. Improvements to eliminate deficiencies of the strategic network were undertaken as Federal-aid projects; and funds available for improvement of the Federal-aid system and for Federal-aid secondary roads were allotted to the improvement of access roads, as existing law and the initiative vested in the State highway departments permitted.

On June 2, 1941, the President sent a message to the Congress requesting provision of funds for the construction of defense highway projects. After extended hearings in both Houses, the Congress on July 21, 1941, passed a bill considerably at variance with the President's recommendations. The President vetoed this bill.

THE DEFENSE HIGHWAY ACT

Finally, on November 19, the President signed a revised bill, prepared after further extended congressional hearings. In little more than 2 weeks the Nation was at war.

The measure approved on November 19 was the Defense Highway Act of 1941. It authorized the $150,000,000 appropriation for access-road construction and 10 of the 12 million dollars for planning strategic network improvements recommended by the Public Roads Administration 10 months earlier. The funds authorized for access roads were made available for payment of the entire construction cost of such roads.

The States were required to match the planning funds in the usual 50–50 ratio. For strategic network improvements the law authorized an appropriation of $25,000,000 to be apportioned in accordance with the Federal Highway Act formula and $25,000,000 to be allocated by the Federal Works Administrator without regard to the formula. The Federal share of the cost of projects undertaken under both of these authorizations was increased to 75 percent.

To meet the need of tactical road repair forecast in the Public Roads Administration report, the act authorized the Commissioner of Public Roads to reimburse States for the necessary rehabilitation and repair of roads of the States or their subdivisions and to certify the cost to Congress for repayment out of appropriations to be made for the purpose. It also made the provisions recommended for (1) incorporation of main lines of the strategic network in the Federal-aid system, (2) use of available Federal-aid secondary road funds on lines not included in the Federal-aid system, and (3) Federal payment of part of the cost of strategic network right-of-way acquisition.

Finally, the act also included an authorization of $10,000,000 for the construction of flight strips adjacent to public highways to facilitate the landing and take-off of aircraft.

SUBSEQUENT AMENDMENTS

During the course of the war this first of the wartime highway measures was thrice amended to increase financial provisions initially made, and all provisions were finally repealed by a joint resolution, approved July 25, 1947. The totals of funds authorized for each of the purposes originally recommended and the amounts of each authorization expended are shown in table 2, where they are compared with the appropriations recommended for each purpose by the report of February 1, 1941, Highways for the National Defense.

TABLE 2.—*Appropriations recommended by the report of Feb. 1, 1941, appropriations subsequently authorized, and amounts of such appropriations allotted to projects*

Purpose	Appropriation recommended by report of Feb. 1, 1941	Appropriation authorized	Net amount allotted to projects
Strategic network:			
Construction	$100,000,000	$50,000,000	$46,761,974
Surveys and plans	[1] 12,000,000	10,000,000	9,641,828
Access roads	150,000,000	[2] 150,000,000 [3] 110,000,000 [4] 25,000,000 [5] 285,000,000	268,977,283
Tactical roads	[1] 25,000,000	[6] 5,000,000	[7] 13,959,835

[1] These sums recommended for appropriation; requirements not estimated in detail.
[2] Act of Nov. 19, 1941.
[3] Act of July 2, 1942.
[4] Act of Apr. 4, 1944.
[5] Total amount authorized for access roads was $290,000,000. This included authority to use $5,000,000 for road construction in maneuver areas, which has been deducted (see footnote 6).
[6] Included in $290,000,000 authorized for access roads.
[7] Includes amount allotted to the construction of roads in maneuver areas and approved claims for reimbursement of road-repair costs incurred by local governments.

THE WAR'S EFFECT ON THE HIGHWAY PROGRAM

There was close agreement between the sums estimated as required in the 1941 report and the amounts subsequently authorized and expended. The amount estimated for access roads was specified as a minimum, not including some needs which at the time could not be estimated. The sum subsequently appropriated substantially exceeded this minimum estimate. As suggested by the report, the construction of access roads was the work of greatest urgency. It was work that simply had to be done to provide access of the barest adequacy to military reservations, war production plants, and sources of strategic war materials. It was, therefore, the class of road-building activity that encountered the least impediment in the various restrictive measures applied during the war. But this does not mean that the effort to carry out even this most necessary road-construction work was wholly unobstructed. On the contrary, it was beset constantly with indecision, delay, and restrictions often arbitrarily and unintelligently applied, that began with the approval of projects, continued through the endorsement of plans, and persisted to the completion of projects.

THE LESSONS LEARNED

The fact that the strategic network improvement as provided for and as accomplished differed in widest measure from the estimated need does not mean that needs did not exist in the magnitude of the estimate. The estimate was extremely conservative. The existing needs, some of them of most serious character, simply were not met. For the most part, we went through the war with the highways we had at its beginning. Even the gravest deficiencies went unrectified. Not only construction, but also maintenance activity was radically curtailed by arbitrary controls imposed. Road surfaces deteriorated. On high military authority, roads were pronounced expendable.

In this experience of World War II, all concerned with responsibility for the condition of the country's highways and with the efficiency of highway transportation for peace or war may find a valuable lesson. The lesson is that when war starts, major road building stops. The major facilities required for the service of peacetime traffic are the arterial highway facilities required for service in a future war and they must be built in time of peace. There is no reason to expect that the demands of combatant forces during a future war will be more tolerant of highway construction activity than they were in World War II.

WORK IN ADVANCE OF THE DEFENSE HIGHWAY ACT

The whole story of the work that was done to meet the more urgent highway needs of the last war is not told in the figures of table 2. Much had been done in advance of the passage of the Defense Highway Act of 1941—and even before the February 1 report was rendered—to prepare for the construction of needed roads, and actually to build some of them.

Early in 1940 the War Department, and somewhat later the Navy Department, had begun to request the assistance of the Public Roads

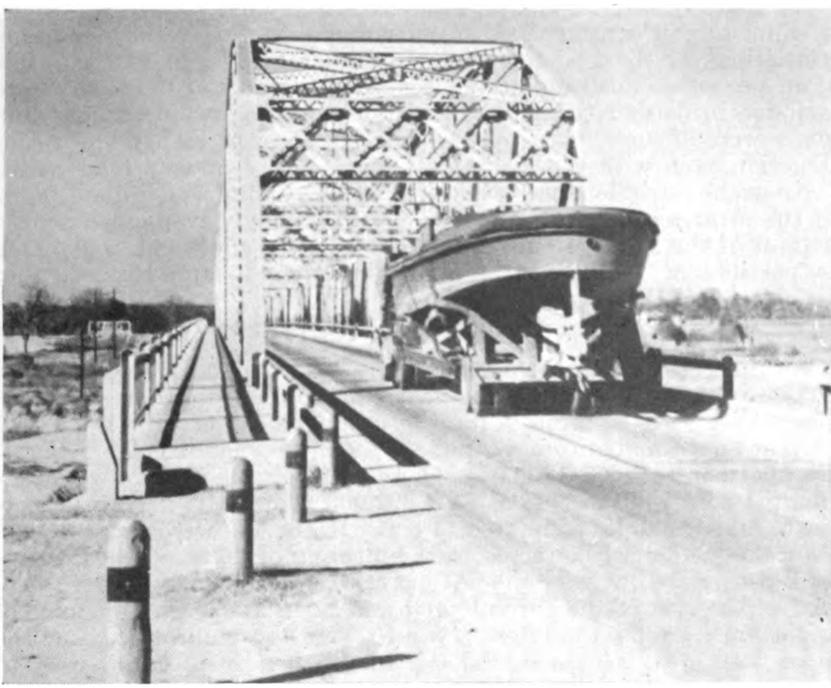
Before a $100,000,000 ordnance plant suddenly sprang up in a little village in Indiana, this was a two-lane road carrying 700 vehicles a day. After plant operations began, traffic swelled to 14,000 vehicles daily, necessitating the widening of 11½ miles of the route to a four-lane divided highway.

Administration in studies of the condition and desirable improvement of roads leading to military and naval posts and establishments. Up to the date of the 1941 report 140 such studies had been completed and many more were subsequently undertaken and completed.

Provisions of the Federal Highway Act of 1940

The Federal Highway Act of 1940, approved September 5, 1940, had contained several permissive provisions designed to authorize acts deemed necessary in preparation for the national defense. One of these authorized the Public Roads Administration to employ for the construction of projects desirable from the standpoint of the national defense, Federal-aid funds which it was expected would remain unexpended at the close of their period of normal availability. Another authorized the use of administrative funds of the Public Roads Administration—

to pay the entire engineering costs of the surveys, plans, specifications, estimates, and supervision of construction of projects for such urgent improvements of



Because of highway transport, war production could be undertaken anywhere that factories and workmen were available. This PT boat is being hauled from an inland "shipyard" to the sea.

highways strategically important from the standpoint of the national defense * * * undertaken on the order of the Federal Works Administrator and as the result of request of the Secretary of War, the Secretary of the Navy, or other authorized national defense agency.

A third empowered the Commissioner of Public Roads, in approving Federal-aid highway projects to be carried out with the then unobligated funds apportioned to any State, to give priority of approval to, and expedite the construction of, projects recommended by an appropriate Federal defense agency as important to the national defense.

Provisions of the Emergency Relief Act

Similar provisions were carried in the Emergency Relief Appropriation Act, fiscal year 1941, relating to the use of relief funds by the Work Projects Administration for planning and building roads important for defense purposes. While relief rolls remained, a total of $85,150,000 of relief funds matched by sponsors' contributions totaling $28,750,000 was expended, largely for the construction of roads in Army and Navy reservations but also, in part, for access roads to military reservations and defense plants.

Response of the States

Generally, the State highway departments complied readily with requests for the use of their apportioned Federal-aid funds for purposes of study and the planning of access-road improvements. When it came to the construction of such roads, however, the remaining restrictions of the Federal law and similar provisions of State law often presented insurmountable obstacles. Many of the roads were included in neither the Federal-aid nor State highway systems, and many were of such character and location as to be ineligible for construction even with the available Federal-aid secondary road funds.

No such restrictions prevented the application of Federal-aid funds to the strategic network and the States willingly responded to the request of the Public Roads Administration for allotment of as much as possible of the currently available funds to the correction of deficiencies of that system.

Federal-aid programs in 1941

At the end of October 1941, shortly prior to the passage of the Defense Highway Act of that year, the combined Federal-aid programs consisted of projects for the improvement of 11,271 miles of road at an estimated total cost of $397,812,700 including the Federal-aid allotment of $224,135,000. Of these totals, 2,884 miles at an estimated construction cost of $144,392,900 were on the strategic network, and 197 miles estimated to cost $16,584,400 were access roads. Projects particularly directed to the meeting of defense needs, therefore, constituted at that time 27 percent of the mileage and 40 percent of the cost of the current program. An unobligated balance of apportioned funds, the latest of which were those authorized for the fiscal year 1942, remained available for further high-priority uses, to be augmented shortly by apportionment of the fiscal year 1943 funds, last of the prewar authorizations.

TOTAL AMOUNT OF WORK DONE

To the extent that use of these regular Federal-aid funds for access roads and strategic network projects was permitted they were applied for the most part to the needs contemplated in the 1941 report. In final event, these funds, together with the special defense highway appropriations, provided for the improvement of 1,678 bridges and 7,763 miles of road in the strategic network at total cost of $418,662,500, and for the construction of 1,254 bridges and 12,914 miles of access roads at total cost of $356,104,200.

In terms of total cost the actual improvements of the two classes compare with needs estimated in the 1941 report as follows:

Strategic network improvements:	
Estimated in the 1941 report, total cost	$458, 000, 000
Actually constructed, total cost	418, 662, 500
Access roads:	
Estimated in the 1941 report, minimum total cost	220, 000, 000
Actually constructed, total cost	356, 104, 200

The rates at which these two classes of work were undertaken, in terms of total cost, are shown in figures 6 and 7. The rates of undertaking several classes of access-road projects, varying in the character of the objective area, are shown in figure 8.

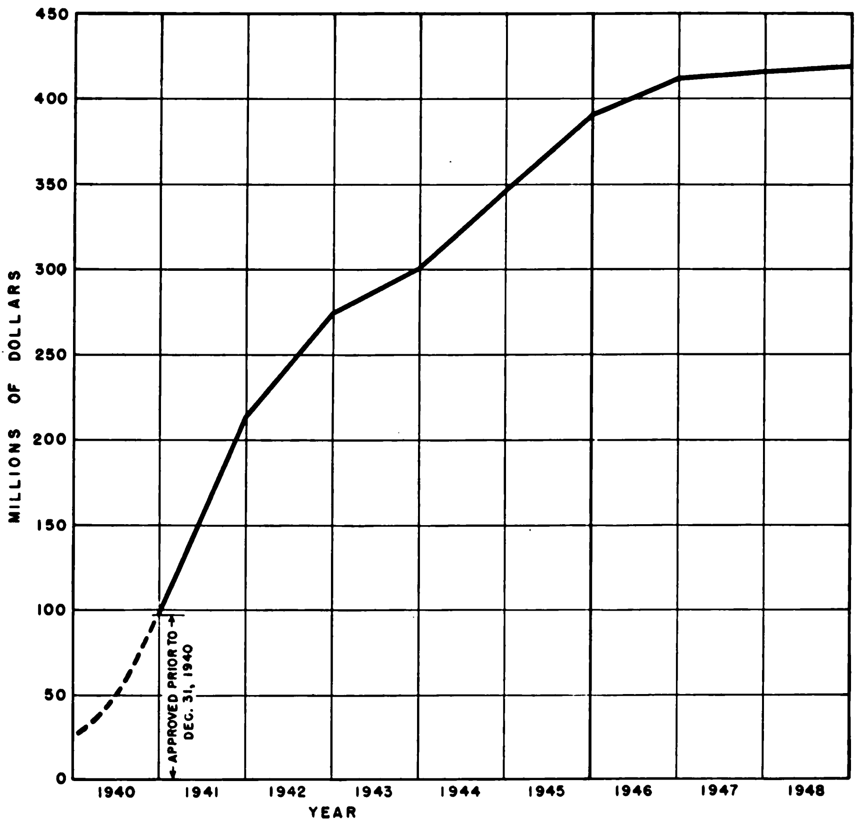


FIGURE 6.—Cumulative total cost of projects on the strategic network approved for construction.

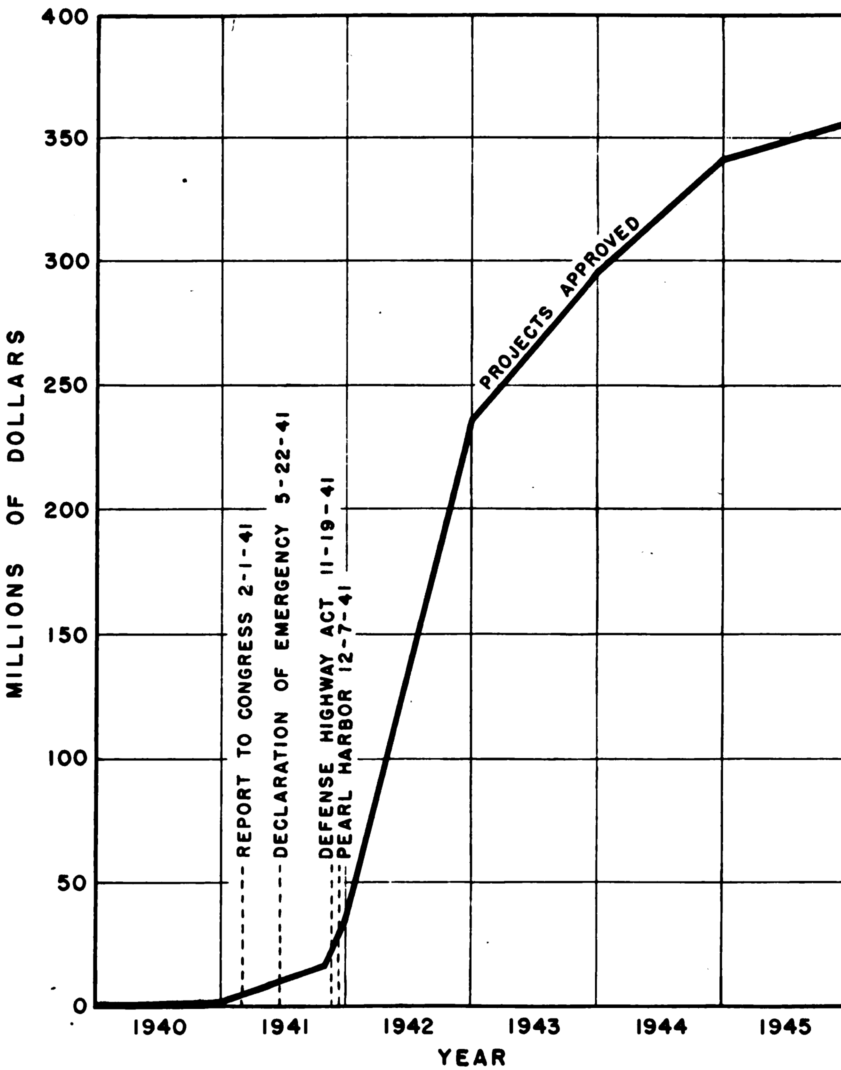


FIGURE 7.—Cumulative total cost of access-road projects approved for construction.

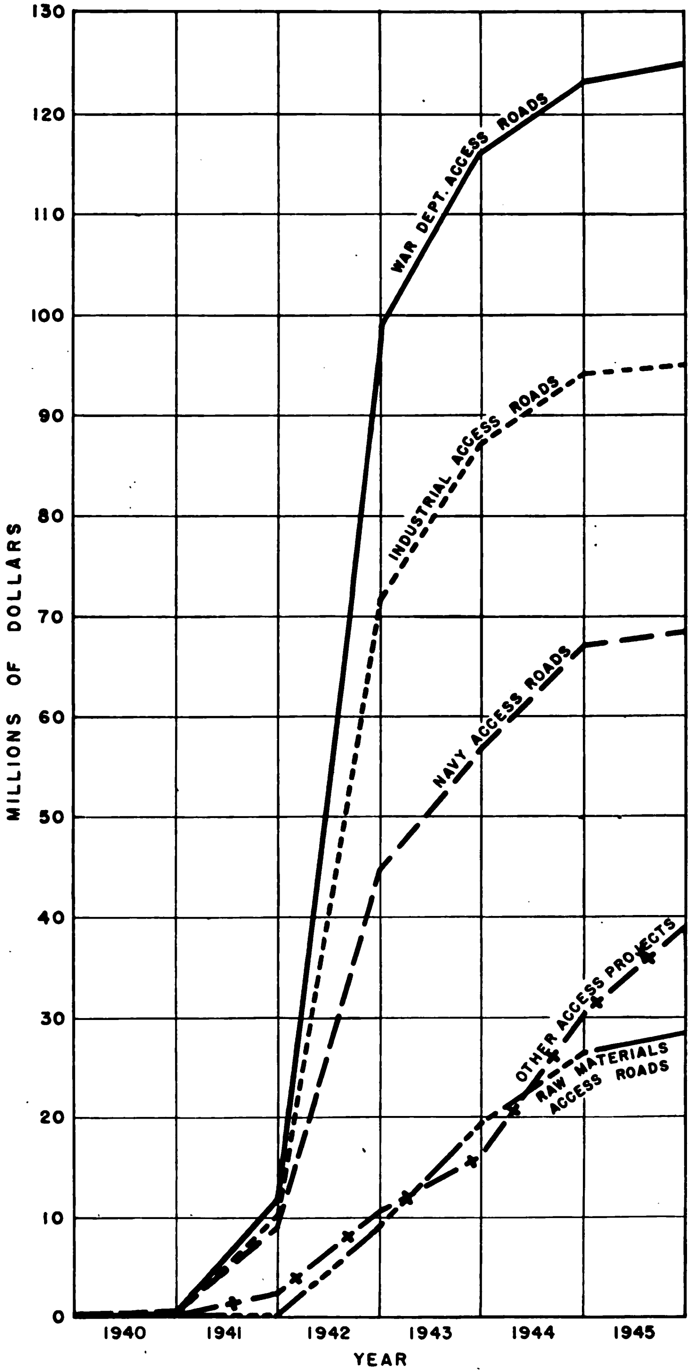


FIGURE 8.—Cumulative total cost of the various classes of access-road projects approved for construction.

THE INTERSTATE HIGHWAY SYSTEM AND ITS RELATION TO NATIONAL DEFENSE

In the period between the First and Second World Wars the Public Roads Administration had at various times sought the advice of the War Department as to which of the many highways composing our total 3,000,000-mile system might be considered to be of principal strategic importance in the event of war.

The first of these inquiries was made in 1922. At that time the State highway departments and the Bureau of Public Roads were engaged in the selection of routes to comprise the Federal-aid highway system, designation of which had been required by the Federal Highway Act, then recently enacted. That act had made it clear that the contributions of the Federal Government to highway improvement would thereafter be confined to a system of principal highways, mainly interstate in character, and limited initially in each State to a mileage not exceeding 7 percent of the State's total road mileage.

THE PERSHING MAP

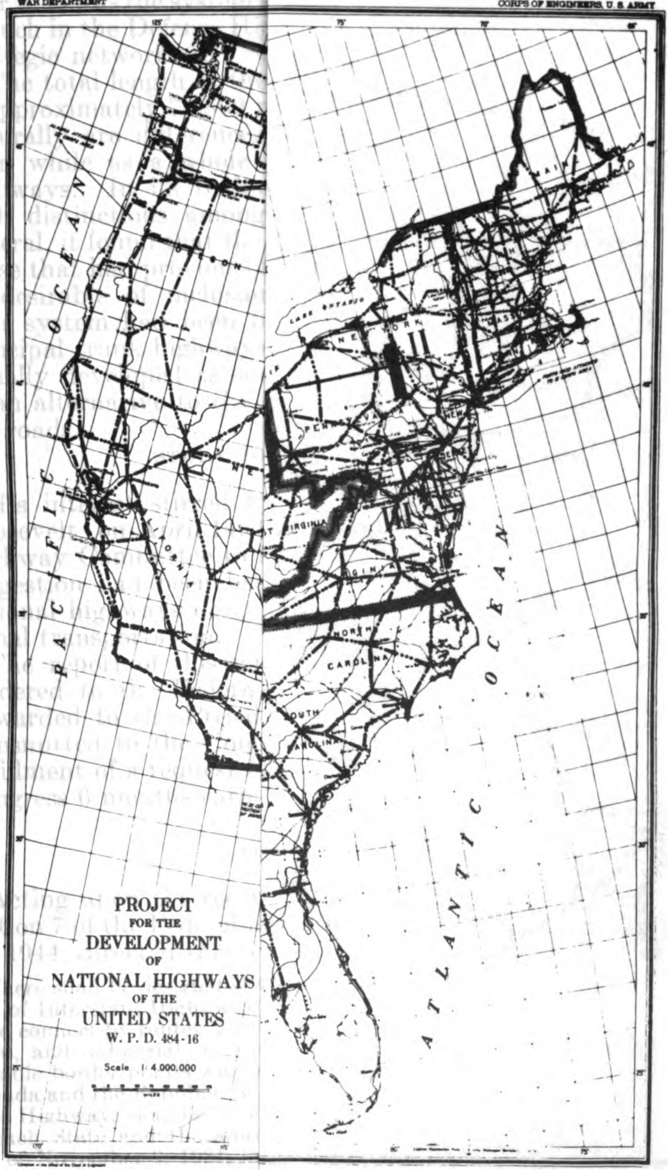
The rural roads of the United States were then in large part unimproved. It was evident that the selection of certain roads for improvement with Federal aid would result in the earlier improvement of those roads. If there were some roads which were, in greater degree than others, important from the viewpoint of national defense, it was obvious that they should be included in the system then in process of designation, because such inclusion would assure their earlier improvement. Moreover, a basic reason for any concern of the Federal Government with the improvement of highways was the desirability of the improvement for the better discharge of particular Federal responsibilities, including the responsibility of national defense.

To the request of the Bureau of Public Roads for its indication of the most important strategic highways, for inclusion in the system to be improved, the War Department responded by supplying a map of the United States on which were shown the highways so regarded. This map, approved by General Pershing, has since been known as the Pershing map (fig. 9). The highways on it were included in the Federal-aid system as it was designated, and all of them have since been substantially improved.

THE STRATEGIC NETWORK

From time to time, after its first consultation with the military authorities, the Bureau of Public Roads renewed its inquiries concerning the defense importance of highways, and especially as another war loomed as a possibility these inquiries were carefully considered by the War Department. In the main, the indications following

WAR DEPARTMENT CORPS OF ENGINEERS, U. S. ARMY



these further reviews coincided with those of the Pershing map, but there were some additions, and the latest of these were shown on a map, revised to May 15, 1941, and approved by the Secretary of War. It was the system shown on this map and referred to specifically as such in the Defense Highway Act of 1941 that became known as the strategic network (fig. 5).

The total length of the highways included in the strategic network is approximately 78,800 miles. Within a system of this extent, there naturally are differences of importance among the roads included, even while as a whole the system comprises the most important highways. In its review in 1941, the War Department indicated such distinctions among the routes included in the network. In general, it found that the routes of greatest importance coincided with those that had previously been chosen by the Bureau of Public Roads as desirable of inclusion in a system of interregional highways.[1] This system had been proposed by the Bureau as constituting the principal trunk highways of the United States that should be preferentially developed as such with road-user revenues and Federal aid as an alternative to the construction of a smaller system of national toll roads.

STUDY OF INTERREGIONAL HIGHWAYS

His interest stirred by the suggestion of the Bureau, President Roosevelt, on April 14, 1941, had appointed a National Interregional Highway Committee to review the surveys and data upon which the suggestion had been based and to recommend a limited system of national highways designed to provide a basis for improved interregional transportation.

The report of this committee, entitled "Interregional Highways",[2] rendered to the Federal Works Administrator January 1, 1944, was forwarded to the President and by him, on January 12, 1944, was transmitted to the Congress with his favorable recommendation, in fulfillment of a request for such a report which had been made by the Congress 6 months earlier.[3]

CONGRESSIONAL ACTION

Acting upon the recommendations of this report, the Congress, in section 7 of the Federal-aid Highway Act of 1944, approved December 20, 1944, directed that—

> There shall be designated within the continental United States a National System of Interstate Highways not exceeding 40,000 miles in total extent so located as to connect by routes, as direct as practicable, the principal metropolitan areas, cities, and industrial centers, to serve the national defense, and to connect at suitable border points with routes of continental importance in the Dominion of Canada and the Republic of Mexico. The routes of the National System of Interstate Highways shall be selected by joint action of the State highway departments of each State and the adjoining States, as provided by the Federal Highway Act of November 9, 1921, for the selection of the Federal-aid system. All highways or routes included in the National System of Interstate Highways as finally approved, if not already included in the Federal-aid highway system, shall be added to said system without regard to any mileage limitation.

[1] Toll Roads and Free Roads, H. Doc. No. 272, 76th Cong., 1st sess.
[2] Interregional Highways, H. Doc. No. 379, 78th Cong., 2d sess.
[3] Amendment of the Federal Highway Act, July 13, 1943 (57 Stat. 560).

SELECTION OF THE INTERSTATE SYSTEM

Complying with this congressional direction, routes for inclusion in the authorized National System of Interstate Highways were selected by the several State highway departments, and a system composed of the routes selected, with minor modifications required to effect interstate continuity, was approved by the Federal Works Administrator, August 2, 1947.

The system then approved was composed of 37,681 miles. There remained at that time, within the 40,000-mile limitation fixed by the law, the authority to designate an additional 2,319 miles, which it was expected would be largely composed of desirable circumferential and distributing routes in urban areas.

Since the original approval of the system, a few changes have been made; and the system as presently designated, totaling 37,800 miles, is that shown in figure 1. The condition of the system so constituted was the subject of the study reported in the first part of this report. The balance of 2,200 miles within the 40,000-mile limitation is still reserved mainly to be comprised, after further detailed study, of essential circumferential and distributing routes in urban areas.

STRATEGIC IMPORTANCE OF THE INTERSTATE HIGHWAY SYSTEM

As previously mentioned, the War Department, in its designation of routes comprising the strategic network recommended in 1941, had indicated the superior importance of certain routes within the network generally coinciding with routes that had been chosen as an inter-regional system by the Bureau of Public Roads. The remainder of the network consisted in large part of routes which had been originally indicated on the Pershing Map of 1922.

Military convoys would not unduly interfere with passenger and commercial traffic if the highways were adequate in pavement and shoulder width. This Army truck train in Texas completely occupied the lane in its direction of travel, and forced opposing vehicles part way off the road.

CHANGE IN NEEDS, 1922–41

Indication of the larger mileage was of greater necessity in 1922 than in 1941. At the earlier date the improvement of rural roads was at its beginning. A Federal-aid system, which legally could embrace upward of 200,000 miles, was in process of designation. It was desirable that the system should include all routes of substantial military importance in order that they would receive the preferential consideration for improvement which was to be accorded routes of the system. The comparatively large mileage indicated was included in the Federal-aid system and since has been substantially improved.

In view of the progress that had been made in improvement of the larger network, the situation in 1941 called for an indication of the part of the included mileage, relatively of primary importance, which then should be treated preferentially in the programing of further improvement. It was for this reason that the War Department specified its particular interest in a part of the network.

Following the direction of the Federal-aid Highway Act of 1948, the Secretary of Defense and the National Security Resources Board have been invited to cooperate in the preparation of this report. Each has been requested to indicate again, and as of the present time, the potential needs for improved highways for the national defense.

Outstanding in the advice received from the National Military Establishment is the comment that the National System of Interstate Highways comprises the principal routes of strategic importance.

RECOMMENDATIONS OF THE SECRETARY OF DEFENSE

The report[1] of a special committee directed by the Secretary of Defense to consider the matter on behalf of the entire National Military Establishment comments as follows:

1. The National Military Establishment considers a relatively small "connected system of highways interstate in character," constructed to the highest practical uniform design standards, essential to the national defense. Because of the time required, and cost, such a system must be planned for and constructed during peacetime.

2. The transportation utilization experience of the military forces during World War II was the basis for recommendation as to routes that should become a part of the National System of Interstate Highways. It is believed that this system will, in large part, provide the principal system of connecting highways to serve the national defense.

3. However, as weapons and methods of warfare change there will be a significant change in the strategic importance of a relatively small mileage of connecting highways not a part of the National System of Interstate Highways. These other highways should be identified and given equal priority in design and construction within practical economic limits. The total mileage of "other highways of strategic importance" as foreseen at this time will not exceed 2,500 miles. It will be an exception if any of the "other highways of strategic importance" are selected which are not now a part of the Federal-aid system of highways. However, it is believed provision should be made for adding such sections of highways which are not on the Federal-aid system without regard to any mileage limitation.

[1] See appendix III.

CHANGES IN THE VOLUME AND CHARACTER OF HIGHWAY TRAFFIC DURING WORLD WAR II

The impact of World War II upon the motor-vehicle industry and the use of the highways was sudden and dramatic. Within a few weeks after Pearl Harbor, Japanese conquests had shut off the supply of crude rubber. Even before that time it had become apparent that the productive capacity of the industry was insufficient to supply the military with mobile equipment and at the same time maintain a high level of production for civilian use. Furthermore, it was imperative that a segment of the industry's manufacturing capacity, skills, and manpower be converted to the task of supplying the needs of wartime aviation.

WARTIME CONTROLS

To meet these critical conditions a series of decisive steps was taken in swift sequence—but none too soon—by the Federal Government. Tire sale and deliveries were curtailed on December 11, 1941, and tire rationing began on December 30. Production and sales of automobiles for civilian use was terminated in January 1942, and new cars not yet marketed were pooled for rationing. The production of commercial vehicles was subjected to the surveillance of the War Production Board. The Office of Defense Transportation was given the task of supervising wartime transportation. Under these restrictions the allocation of new trucks and busses to civilian use was reduced to a trickle, with the military receiving the lion's share of production in the form of all types of mobile equipment.

Gasoline rationing, under the supervision of the Office of Price Administration, was instituted in the Eastern States in May 1942. Under the impetus given by the Baruch report [1] the Office of Rubber Director was created, and the synthetic rubber industry grew, slowly but surely, from an infant to a giant. The Baruch report also helped to crystallize a systematic plan for mileage rationing to conserve vehicles, gasoline, and rubber. Under this plan Nation-wide gasoline rationing was put into effect in December 1942, almost simultaneously with an acute gasoline shortage in the East, which forced reductions in the values of the A, B, and C ration coupons issued for passenger cars.

SHORTAGES DURING THE WAR

The year 1943 was one of acute shortages. In gasoline supply these shortages were most severe in the Eastern States; and twice during that year it was necessary to institute a ban on pleasure driving. The campaign of German submarines against tankers and other vessels plying the east coast had virtually cut off this source of supply. The Big and Little Inch pipe lines were not yet completed; railway tank cars were in short supply; and military demands, both domestic and

[1] Report of the Rubber Survey Committee, September 1942.

offshore, were mounting. The shortages of tires remained acute; and the general situation forced the reduction of ration coupon values throughout the Nation during the latter part of the year. In 1944 the situation was only a little eased; but there were adjustments of allocations and restrictions, in recognition of the essential role of transportation in the wartime economy. Replacement of worn-out equipment

The highways can serve in unusual wartime emergencies. This damaged transport plane, after an emergency landing, was stripped of its wings and towed to the nearest airport.

in freight and mass passenger transport became less difficult in the later months of the war; and there was an effort to provide replacement parts for all types of motor vehicles.

The story of wartime motor-vehicle transportation is one of adjustment to unprecedented conditions. Motorists and commercial users, in the face of shortages of equipment, tires, and gasoline, were forced to adapt their activities to burdensome governmental restrictions.

The regulating agencies, in their turn, had to improvise, to try one scheme and then another, to back-track—in short, had to learn how to do a job that had never been done before. The success of this joint effort is evident in the statistics of wartime travel.

MOTOR-VEHICLE REGISTRATIONS AND TRAVEL DURING THE WAR PERIOD

During the 20-year period just preceding World War II motor-vehicle registrations and traffic increased steadily, except for a slight,

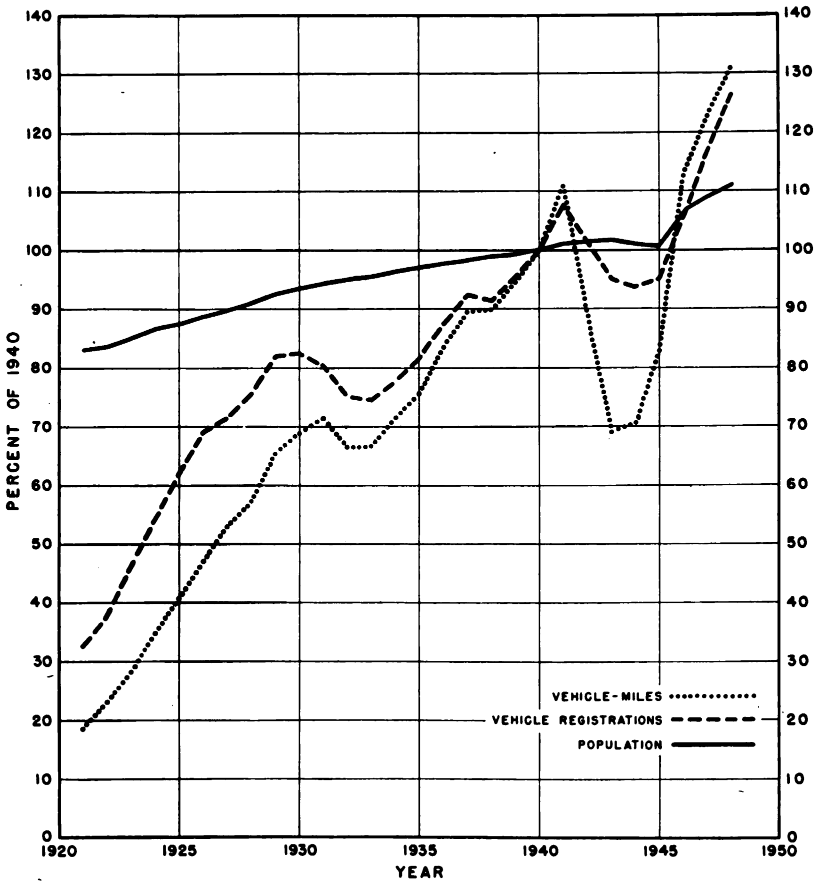


FIGURE 10.—Trends in growth of population, vehicle registrations, and vehicle-miles of travel (base year 1940=100).

temporary dip during the depression years. The increase from 1921 to 1941 was more than threefold for registrations and approximately sixfold for vehicle-miles of traffic. In figure 10 the trends in population, registrations, and vehicle-mileage from 1921 to 1948 are shown, with 1940 as the base year.

Decline of traffic

In 1941 highway traffic increased at an accelerated rate, because of the abnormal activity preceding our entry into the war. Almost immediately after war was declared, however, traffic began to decline, at first in anticipation of shortages and later in response to actual shortages and governmental restrictions on the purchase of automobiles, tires, and gasoline. Figure 11 shows for the eastern, central, and western sections of the country a comparison of highway traffic on rural roads in each month of 1942 and 1943 with that in the corresponding month of 1941. The effective dates of important restrictions affecting traffic are indicated on the chart Throughout the 2 years, relative traffic declines were greatest in the East and least in the West. Nation-wide rationing, which became effective about the 1st of December 1942, brought the curves almost together, temporarily, but the curve for the western section soon rose and continued well above that for the eastern section.

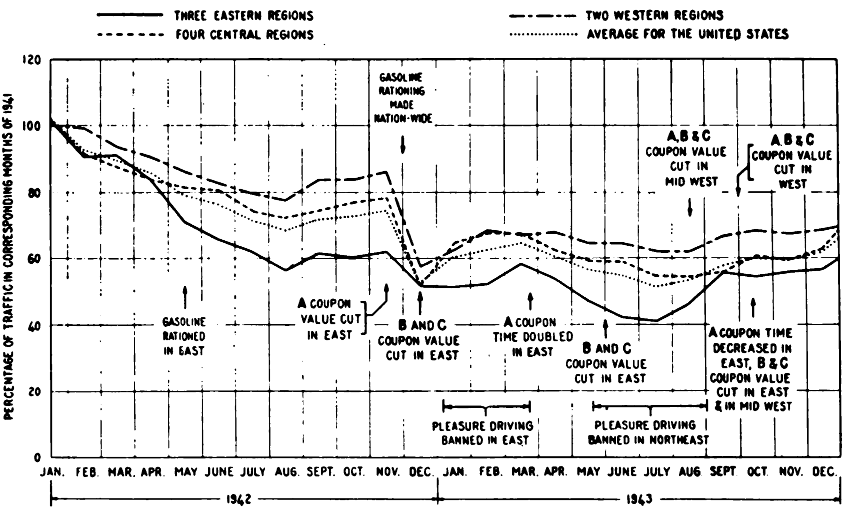


FIGURE 11.—Comparison of traffic on rural roads in each month of 1942 and 1943 with that in the corresponding month of 1941, by regions, and the dates of gasoline rationing.

As can be seen in figure 10, traffic started rising in 1944, even though the war was not yet over; and upon the cessation of hostilities rose very rapidly until, in 1948, it was back to the level it would have attained if the upward prewar trend had continued without interruption.

Table 3 gives the vehicle-miles of travel on all rural roads and city streets in each year from 1941 to 1948, inclusive, and the relation to 1941 travel of that of each subsequent year. The decline of traffic from 1941 to 1943 was 42 percent on rural roads and 33 percent on city streets. The reason for the greater decline on rural roads is undoubtedly that a higher proportion of the traffic on them was recreational and nonessential, while a larger proportion of the urban traffic was to and from work and for other essential purposes.

Drop in recreational travel

Figure 12, which shows vehicle-miles of travel on rural roads by months for 1941, 1943, and 1948, brings this out more clearly. Most of the recreational travel on rural roads occurs in the summer months, and the high summer travel peaks in 1941 and 1948 are apparent.

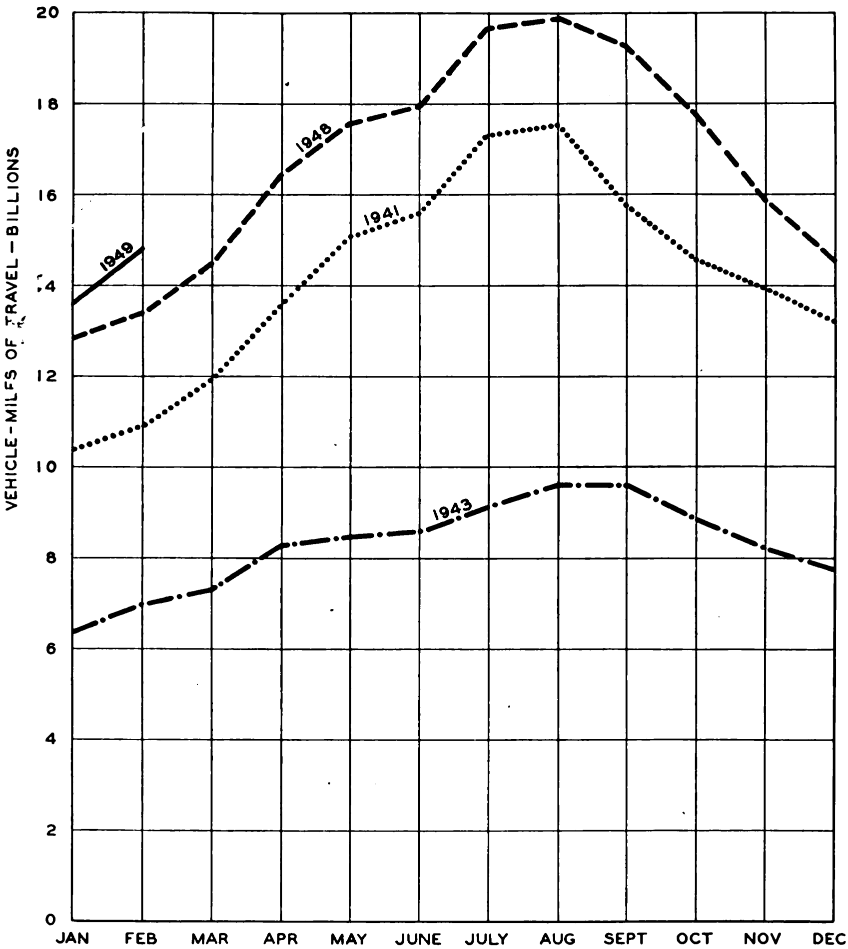


FIGURE 12.—Vehicle-miles of travel on rural roads, by months, in 1941, 1943, and 1948.

In 1943, however, the summer peak was materially flattened, and much of the seasonal difference which remained could be accounted for by the difficulties of winter travel in some sections of the country. This would indicate that wartime efforts to eliminate pleasure driving were fairly successful.

TABLE 3.—*Motor-vehicle travel on all rural roads and city streets, 1941–48, and ratio to 1941 travel*

Year	Travel on all rural roads		Travel on city streets		Total travel	
	Amount of travel (million vehicle-miles)	Ratio to 1941	Amount of travel (million vehicle-miles)	Ratio to 1941	Amount of travel (million vehicle-miles)	Ratio to 1941
1941	169,805	1.00	163,591	1.00	333,396	1.00
1942	129,876	.76	138,235	.85	268,111	.80
1943	99,127	.58	108,990	.67	20[illegible],117	.62
1944	101,879	.60	110,750	.68	212,629	.64
1945	119,883	.71	129,743	.79	249,626	.75
1946	170,606	1.00	170,049	1.04	340,655	1.02
1947	186,534	1.10	184,088	1.13	370,622	1.11
1948 [1]	199,396	1.17	194,259	1.19	393,655	1.18

[1] Preliminary estimates, based on incomplete data.

TABLE 4.—*Travel by passenger vehicles and trucks on main and local rural roads, 1941–48*

Year	Travel on main rural roads (million vehicle-miles)			Travel on local rural roads (million vehicle-miles)		
	Passenger vehicles	Trucks	Total	Passenger vehicles	Trucks	Total
1941	98,320	24,185	122,505	37,084	10,216	47,[illegible]
1942	74,117	19,218	93,335	28,614	7,927	36,[illegible]
1943	53,665	17,359	71,024	20,916	7,187	28,1[illegible]
1944	55,420	17,235	72,655	21,829	7,395	29,224
1945	66,885	18,907	85,792	25,849	8,242	34,091
1946	99,803	24,346	124,149	36,210	10,247	46,457
1947	108,880	28,632	137,512	36,883	12,139	49,022
1948 [1]	117,272	30,840	148,112	38,584	12,700	51,284

[1] Preliminary estimates, based on incomplete data.

Another striking illustration of the elimination of recreational travel during the war is given in figure 13, which shows daily traffic volumes on the Merritt Parkway in Connecticut during corresponding periods of the spring and summer in 1941, 1942, and 1943. In 1941 there were very high traffic peaks on week ends and holidays, whereas in June and July 1943 there was less traffic on such days than during the business days of the week.

TRUCK TRANSPORTATION IN WARTIME

In table 4, the vehicle-mileages of passenger vehicles and trucks are given separately for main and local rural roads, for each year from 1941 to 1948, inclusive. Main roads are generally State highways, or primary State highways in cases where all or nearly all of the rural road mileage is under State jurisdiction. In 1948, nearly three-quarters of all travel on rural roads was on these main roads, as can be seen from the table, and 21 percent of this travel was by trucks. The discussion of truck traffic is confined to main rural roads because weight surveys have been made principally on this class of road since the 1936–38 prewar period.

Limited decline of truck traffic

Truck traffic, as well as passenger-car traffic, declined during the war, but to a much less extent. Further, the decline was confined largely to the lighter types of vehicles. Table 5 shows the vehicle-miles of travel by trucks and truck combinations on main rural roads from 1941 to 1948, and ratios to 1941 travel of the traffic of subsequent years.

TABLE 5.—*Travel by single-unit trucks and truck combinations on main rural roads, 1941-47, and ratios to 1941 travel*

Year	Single-unit trucks		Truck combinations		Total	
	Amount of travel (million vehicle-miles)	Ratio to 1941	Amount of travel (million vehicle-miles)	Ratio to 1941	Amount of travel (million vehicle-miles)	Ratio to 1941
1941	19,056	1.00	5,129	1.00	24,185	1.00
1942	14,308	.75	4,910	.96	19,218	.79
1943	12,672	.66	4,687	.91	17,359	.72
1944	12,459	.65	4,775	.93	17,234	.71
1945	13,602	.71	5,305	1.03	18,907	.78
1946	17,838	.94	6,508	1.27	24,346	1.01
1947	20,746	1.09	7,886	1.54	28,632	1.18

TABLE 6.—*Travel by empty single-unit trucks and truck combinations as a percentage of total truck travel on main rural roads, 1941–47*

Year	Percentage of total truck travel by—		
	Empty single-unit trucks	Empty truck combinations	All empty trucks and combinations
1941	34.6	28.4	33.3
1942	46.0	31.8	42.3
1943	46.6	30.9	42.3
1944	49.1	30.6	43.9
1945	50.4	30.8	44.9
1946	53.6	33.8	48.3
1947	51.7	32.9	46.5

The decline in truck vehicle-mileage on main rural roads from 1941 to 1943 was 28 percent, compared to the 42-percent decline for motor vehicles of all kinds shown in table 3. For single-unit trucks the decline was 34 percent but for truck combinations, which are the heavier vehicles, the decline in vehicle-mileage was only 9 percent.

"Empty" trucks used to carry passengers

In view of the efforts made during the war to haul over the highways the maximum possible tonnage in relation to gasoline usage, it is somewhat surprising to find that a higher percentage of the vehicle-mileage was by empty vehicles in the war years than in the prewar years. Table 6 shows the travel by empty vehicles as a percentage of total truck travel, in each year from 1941 to 1947, inclusive. The percentage of empty-vehicle travel increased from 1941 on through the war, and it was not until 1947 that there was a reversal in this trend. Vehicles carrying passengers only were classed as empty, and

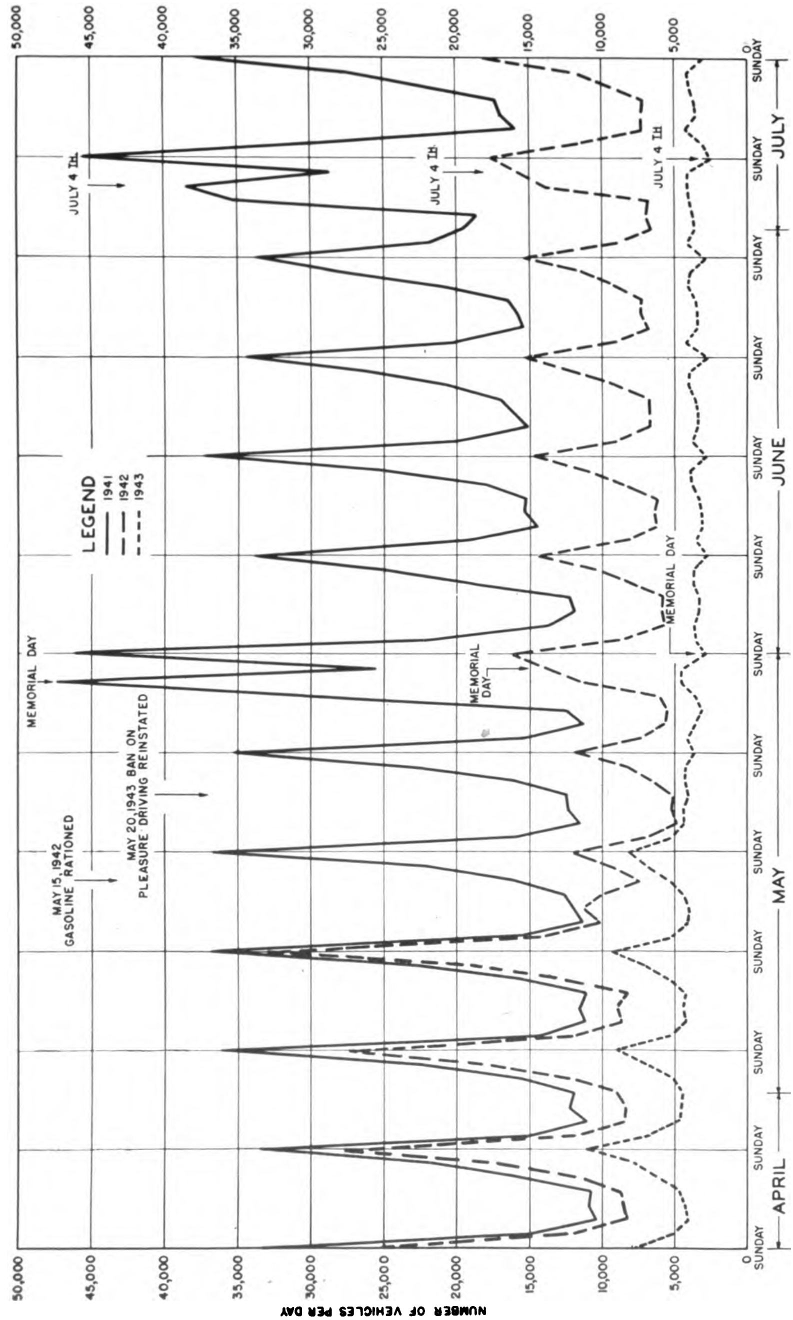


FIGURE 13.—Daily traffic volumes on the Merritt Parkway in Connecticut during corresponding periods of 1941, 1942, and 1943 showing the effect of gasoline rationing and restriction on pleasure driving.

the explanation is undoubtedly that the difficulties of obtaining passenger automobiles, and their high cost, caused many owners of trucks to use these vehicles in lieu of passenger cars. This explanation is borne out by the fact that it was the lighter vehicles that accounted for most of the increase in the percentage of total travel by empty vehicles. The percentage for empty truck combinations did not vary much from 30 percent throughout the period from 1941 to 1947, whereas that for single-unit trucks increased from 34.6 percent in 1941 to 53.6 percent in 1946. Since the beginning of the war, approximately half of the travel by single-unit trucks on the highways has been by empty vehicles compared to about one-third in the prewar period.

For the year 1946, when the greatest proportion of the vehicle-mileage was by empty vehicles, the percentages for single-unit trucks in each region were as follows:

Region:	*Percent empty*	Region—Continued	*Percent empty*
New England	51. 8	West North Central	47. 8
Middle Atlantic	44. 2	West South Central	68. 7
South Atlantic	51. 6	Mountain	61. 9
East North Central	49. 5	Pacific	46. 7
East South Central	61. 4		

It was in the South Central regions, and the Mountain region, therefore, where the greatest use of trucks for passenger-car purposes was made.

Vehicle-mileage of trucks

Because of the increased proportion of empty vehicles, the vehicle-miles traveled by loaded vehicles, of course, declined somewhat more than the total vehicle-mileage of trucks and combinations. Offsetting this, however, was the increase in the proportion of combinations and the heavier loading of that type of vehicle so that the ton-mileage hauled decreased less than the vehicle-mileage. Table 7 gives the average carried load of loaded trucks and combinations by years from 1936 to 1947, inclusive. There was little change in the average loading of single-unit trucks during that period, but a continued upward trend in that of truck combinations from 1941 to 1946. The average load carried by all types of vehicles increased somewhat faster, because of the increasing proportion of combinations.

TABLE 7.—*Average load carried by loaded trucks and truck combinations on main rural roads, 1941–47*

[Tons]

Year	Single-unit trucks	Truck combinations	All trucks and combinations	Year	Single-unit trucks	Truck combinations	All trucks and combinations
1941	2. 29	8. 23	3. 64	1945	2. 40	9. 31	4. 84
1942	2. 24	8. 47	4. 12	1946	2. 31	9. 70	4. 84
1943	2. 30	8. 74	4. 38	1947	2. 26	9. 63	4. 81
1944	2. 36	8. 96	4. 63				

TABLE 8.—*Ton-mileage hauled on main rural roads by single-unit trucks and truck combinations, 1936–47*

[Millions of ton-miles]

Year	Single-unit trucks	Truck combinations	All trucks and combinations	Year	Single-unit trucks	Truck combinations	All trucks and combinations
1936	14,257	13,747	28,004	1942	17,346	28,358	45,704
1937	16,426	16,018	32,444	1943	15,570	28,306	43,876
1938	17,940	17,756	35,696	1944	14,987	29,709	44,696
1939	20,262	20,350	40,612	1945	16,186	34,178	50,364
1940	22,899	23,348	46,247	1946	19,101	41,791	60,892
1941	28,487	30,250	58,737	1947	22,610	51,000	73,610

Ton-mileage hauled

Table 8 gives the ton-mileage hauled by single-unit trucks and truck combinations from 1936 to 1947, inclusive. From 1941 to 1943 the total ton-mileage declined about 25 percent, but the ton-mileage moved by combinations declined only about 7 percent. Prior to the war the ton-mileage was divided almost equally between single-unit trucks and truck combinations, whereas, beginning during the war and continuing subsequently combinations have carried about twice as much as single-unit trucks.

Heavy loads

The heavier wartime loads were due in part to the lifting or relaxing of restrictions on sizes and weights by the States, in order to permit the maximum possible utilization of our trucking capacity during the emergency. The result was greatly to increase the frequency of heavy gross loads and heavy axle loads, thus increasing the strain on pavements and bridges.

Figure 14 shows the number of heavy gross weights per 1,000 trucks and combinations in a prewar period (1936–38) and each year from 1942 to 1947, inclusive. Of each thousand vehicles using the highways, the number weighing 30,000 pounds or more was almost three times as great in 1943 as in the prewar period, and the number weighing 50,000 pounds or more increased fivefold, from 3 to 15 per thousand.

Figure 15 shows that the increases in heavy axle load frequencies were of similar proportion, and that this trend has persisted into the postwar period. Thus the upward swing in heavy axle load frequencies, which was started by the relaxation of weight limitations during the war, has not yet been arrested.

BUS TRANSPORTATION IN WARTIME

The sharp reduction in the use of passenger automobiles during World War II imposed unprecedented loads on public transit facilities. The numbers of busses in city and suburban service increased from 37,855 in 1941, to 45,610 in 1943, and 48,525 in 1944. Intercity busses increased in number from 18,420 in 1941 to more than 28,000 in 1943 and 1944.[2] The Office of Defense Transportation [3] reported that intercity motor carriers of passengers transported 209 percent more persons in 1944 than in 1941; and that local transit operations

[2] Bus Facts, seventeenth edition, 1945: quoted from the magazine Bus Transportation.
[3] A Review of Highway Transport and Transit Industries During the War, Office of Defense Transportation, 1946.

employing motor busses handled approximately 95 percent more passengers in 1944 than in 1941. The total vehicle-miles traveled by all types of busses, including school and other nonrevenue types, increased from 2,820 million in 1941, to 3,365 million in 1943, and 3,799 million in 1944.

THE CONTRIBUTION OF PASSENGER CARS TO WARTIME TRANSPORTATION

In spite of the increased burden carried by public transit facilities, the private automobile proved to be an essential agency of wartime transportation, particularly in getting workers to the war plants.

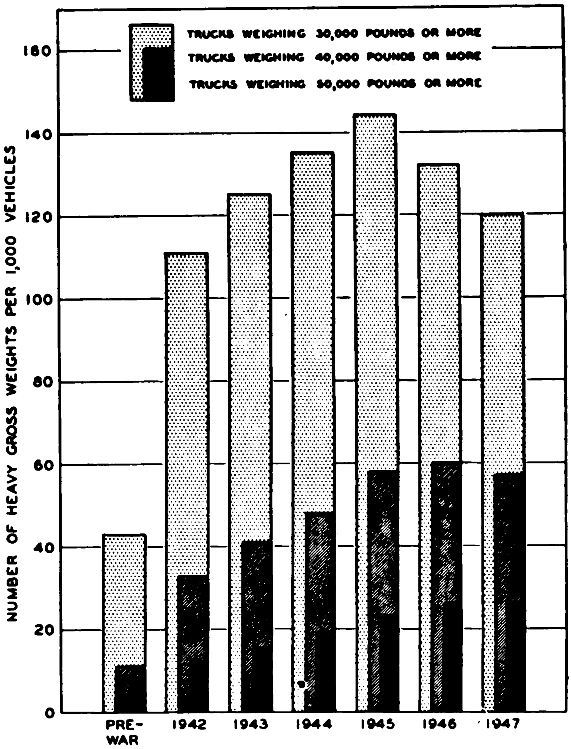


FIGURE 14.—Number of heavy gross weights per 1,000 trucks and combinations in a prewar period and in each year, 1942–47.

Many of the largest war industry establishments were situated in rural or semirural areas where mass transportation could not possibly be made adequate to serve all the workers needed. Other large plants, although situated in or near cities, could not be served adequately by mass transportation alone, because of the time required for many workers to get to and from work by the circuitous routes they would have been required to take.

As the war progressed this situation became more acute. New plants, military establishments, and other concentrations of employment were located in areas served inadequately or not at all by public transportation. Many war industries increased their employment and thus were required to recruit the added personnel from greater distances than before. Inductions into the military service, migration of workers, and other manpower stringencies caused still further increases in the distances from home to place of employment. All of these factors had the effect of increasing the dependence of the war worker on automobile transportation.

War worker use of automobiles

This critical situation prompted surveys of war-worker transportation by numerous agencies; and all of them pointed up the absolute need for the continued maintenance of the private automobile as a

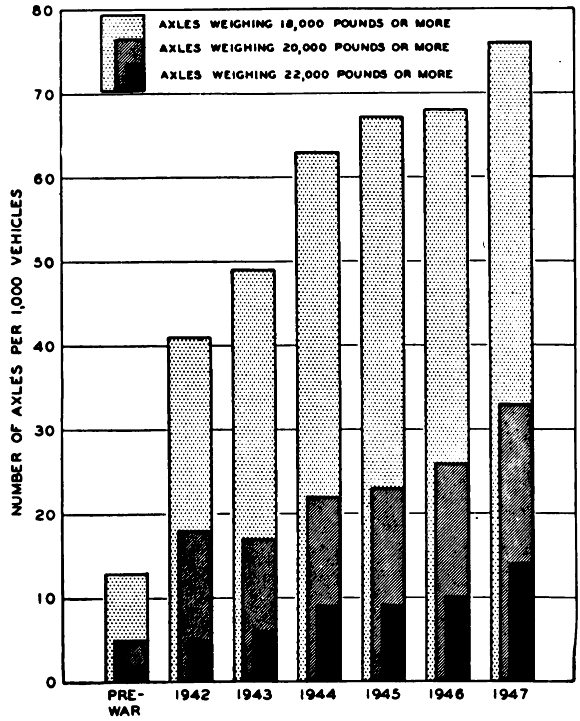


FIGURE 15.—Number of heavy axle loads per 1,000 trucks and combinations in a prewar period and in each year, 1942–47.

wartime transportation medium. A study of 749 war plants scattered throughout Michigan, made in 1942 by the State Highway Department, revealed that 75 percent of the workers in those plants traveled to and from their jobs by driving their own cars or riding with another private-car driver.[4]

Employee-transportation studies were also made by State highway departments in other States, generally in cooperation with the Public Roads Administration and the Highway Traffic Advisory Committee to the War Department. An analysis of studies made in 1942 at 94 war plants in 10 States, employing 225,000 workers, indicated that

[4] The Transportation of Materials and Workers in War Industries in Michigan, Michigan State Highway Department, 1942.

about 55 percent of these workers lived 5 miles or more from their places of employment; that about 73 percent of all employees traveled to and from work by private automobile; and that about 64 percent of the automobile users lived more than 5 miles from work.[5]

The results of studies in 13 States, conducted between 1942 and 1944 at 194 war plants, and covering 590,000 workers, indicated that 69 percent of the employees traveled to and from their jobs by automobile, 21 percent used mass-transit facilities, 8 percent walked, and 2 percent used other means, such as bicycles or boats.[6]

Supplemental gasoline rations for workers

Two policies of the utmost importance were adopted in support of the recognized need for worker transportation by private automobile. The first was the issuance, by the Office of Price Administration, of supplemental B and C gasoline rations to private automobiles. Just prior to the defeat of Germany and VE-day, there were outstanding approximately 14.5 million supplemental rations, issued for home-to-work and in-course-of-work driving, in which the travel allowance averaged 500 miles a month.[7] Passenger-car registrations during 1945 totaled 25.7 million. Although it is true that the privilege of supplemental rations was not infrequently abused, their importance to the war effort cannot be questioned.

Group riding

The second major policy was the promotion and encouragement of group riding in private automobiles. This was an essentially voluntary undertaking, except for the requirement (not always strictly enforced by the local war price and ration boards) that an applicant for supplemental rations for home-to-work driving must form a car club, or otherwise indicate that he was hauling passengers. Cooperators in this effort were the Office of Price Administration, which conducted a continuous promotional campaign, the Highway Traffic Advisory Committee, the Office of Defense Transportation, the managements of thousands of industrial plants, businesses, and governmental establishments, local committees, and civic groups. Although the campaign for group riding was less successful than some of its advocates had hoped, field studies[8] indicated that organized efforts, particularly in war plants, had resulted in more efficient use of passenger cars in home-to-work driving. Car-occupancy counts showed an increase between July 1942 and July 1944 from 2.2 to 3.3 persons per car at rural industrial locations. The general level of car occupancy was not raised to such a high figure, but it was materially higher than in prewar days.

THE MOTORTRUCK AS A PART OF THE ASSEMBLY LINE

Much of the success of our productive effort during the last war can be attributed to the availability and flexibility of motor-vehicle transportation. At the peak of production, many manufacturers of tanks, planes, ships, armament, and smaller items were operating on the basis of long-distance production lines which often traversed whole

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[5] From mimeographed release, War Worker Transportation, by the Public Roads Administration December 1942.

[6] These data were summarized from various releases by the Automobile Manufacturers Association, and were reported in Automobile Facts and Figures, 1944–45, p. 22.

[7] Office of Price Administration, Mileage Conservation Letter, April 1945.

[8] Review of Progress in Car Sharing, report No. 4, Highway Traffic Advisory Committee to the War Department, August 1944.

States before the final point of assembly was reached. This typically American procedure allowed more direct participation in the war effort by thousands of small plants through subcontracting and by millions of workers who might have otherwise been excluded. And while the procedure took jobs closer to the available labor force and minimized the need for personal transportation, it created additional demands on motor vehicles. Because of the unavailability of other transportation and because of the convenience and flexibility of trucks and combinations, a high percentage of materials and subassemblies flowed between parts of the production lines by motor vehicles. One

More than 70 percent of the workers in war plants depended on private automobiles for transportation to and from work. Congestion on the old roads leading to the Willow Run bomber plant in Michigan was later minimized by construction of an expressway.

study of a large number of war plants [9] revealed that these plants received 65 percent of their incoming freight and shipped out 69 percent of their outgoing freight by motortruck.

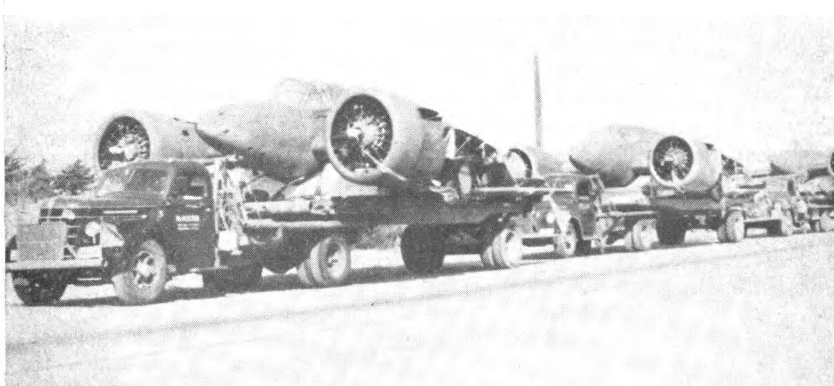
This is the record of motor-vehicle transportation in World War II. Should another such emergency arise, another record, differing in details but essentially of the same character, will be marked up. The decentralization of industry has continued during the postwar years; and has received official encouragement as a precaution against atomic-bomb and guided-missile attacks. It seems probable, therefore, that in a future struggle all forms of motor-vehicle transportation, and the roads and streets over which they travel, will be more essential to the war economy than in the preceding one.

[9] The Transportation of Materials and Workers in War Industries in Michigan, Michigan State Highway Department, Lansing, 1942.

EFFECTS OF WAR ON MOTOR-FUEL CONSUMPTION

Although the gasoline-rationing program was directed primarily toward the conservation of rubber, it resulted in great savings of motor fuel, a commodity much in demand for military use in the United States, on the high seas, and in combat areas. The great reduction in civilian highway use of motor fuel during the war years is illustrated in the following tabulation:

Year	Consumption in million gallons	Percentage of 1941
1941	24,192	100.0
1942	19,940	82.4
1943	16,004	66.2
1944	16,430	67.9
1945:		
First 7 months	10,173	74.3
Last 5 months	8.976	85.5
Total, 1945	19,149	79.2
1946	25,649	106.0
1947	28,216	116.6



During World War II the motortruck was part of the production line, often extending across many States. These airplane fuselages were hauled from Michigan to Texas for final assembly.

The volume of motor-fuel consumption dropped in 1943 to 66 percent of its 1941 value, and rose only a little in 1944. Although shortages of tires and gasoline were less acute in 1945, it was not until the termination of gasoline rationing, immediately after the surrender of Japan on August 14, 1945, that the highway use of motor fuel began rapidly to regain, and in 1946 to overtake, its prewar level.

Appendix I.—SIZES AND WEIGHTS OF VEHICLES

Postwar Increases in the Weight of Vehicles

It has already been shown, in figure 10, that the war proved to be only a temporary interruption to the long-term upward sweep of traffic volumes and that by 1946 the 1941 peak had been exceeded and by 1948 the volumes were about what would have been indicated by a projection forward of the prewar trend. The year 1941 was one of intense preparation for the war, and highway activity was at unprecedented levels, yet traffic volumes in 1948 were 18 percent higher, as can be seen from table 3, and this in spite of the fact that new automobiles had been scarce and costly since the war. These increases took place on all classes of roads and in all sections of the country. By classes of road, and by sections of the country, the increases of 1948 traffic over 1941 traffic were as follows:

CLASS OF ROAD	Percent	REGION	Percent
City streets	19	Eastern regions	5
Main rural roads	21	Central regions	21
Local rural roads	8	Western regions	34

Figure 16 shows, for the three sections of the country, the traffic for the year ending with each month from 1942 to 1948, inclusive, as a percentage of the traffic in the calendar year 1941. For example, during the 12-month period ending March 1948, traffic in the eastern section was about equal to that of the calendar year 1941, while in the central regions it was 14 percent higher and in the western regions 27 percent higher than 1941 traffic.

The postwar increase in trucking has been even more rapid. As can be calculated from table 8, the ton-mileage hauled in 1947 exceeded that of 1941 by 25 percent. Preliminary figures indicate that 1948 ton-mileage exceeded the 1941 figure by about 37 percent.

INCREASES IN AXLE LOADS

As previously mentioned and shown in figure 15, the trend toward increased frequency of heavy axle loads has continued unabated into the postwar period. For each 1,000 trucks, there were six times as many axle loads weighing 18,000 pounds or more, seven times as many weighing 20,000 pounds or more, and seven times as many weighing 22,000 pounds or more in 1947 as in the 1936–38 period when the prewar weighings were made. But this does not tell the whole story. Truck traffic volume in 1948 was approximately double that of 1936, and preliminary figures indicate that the frequency of heavy axle loads was at least as great as in 1947. A road carrying 600 trucks per day in the earlier year would have had, on the average, eight axle loads daily weighing 18,000 pounds or more, three weighing 20,000 pounds or more, and only one weighing 22,000 pounds or more. Assuming an average traffic increase, this same road in

1948 would have been carrying 1,200 trucks per day and would have been subjected daily to 91 axle loads of 18,000 pounds or more, 40 of which would have weighed 20,000 pounds or more and 17 of which would have weighed 22,000 pounds or more. Such frequencies of heavy concentrated loads as these produce severe pavement strains and frequently cause a pumping action at the joints of concrete pavements which removes support from the pavements and ultimately causes their failure.

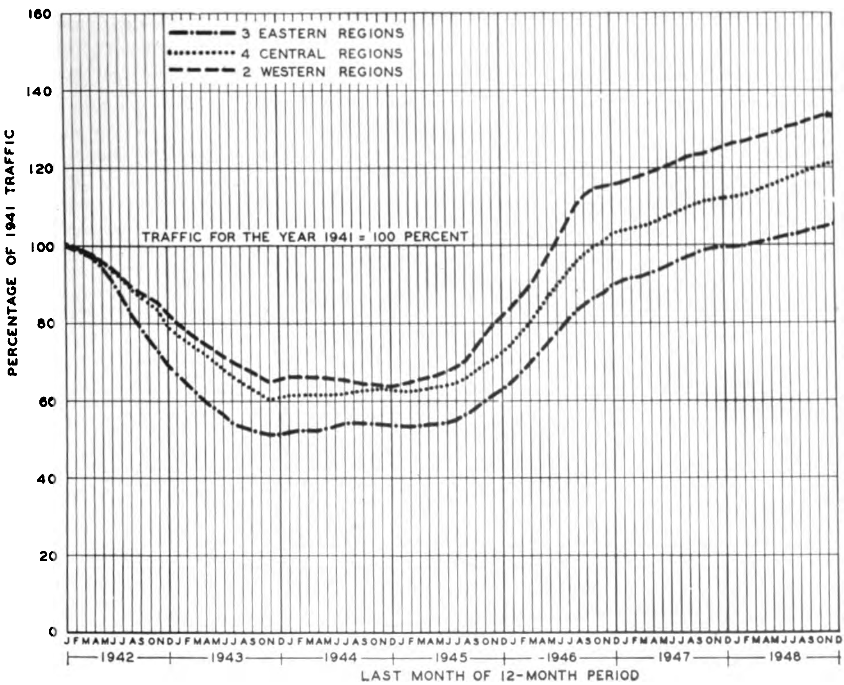


FIGURE 16.—Traffic on rural roads for the year ending with each month, 1942–48, as a percentage of the traffic in the calendar year 1941.

REGIONAL VARIATIONS

The example given in the preceding paragraph is based upon average conditions throughout the United States. In some regions the situation is much worse, as legal provisions and enforcement practices result in larger differences in the frequencies of heavy gross weights and axle loads. In the Middle Atlantic region, for example, the hypothetical road carrying 1,200 trucks per day in 1948 would have been subjected daily, on the average, to 182 axle loads of 18,000 pounds or more, 112 of which would have weighed 20,000 pounds or more and 60 of which would have weighed 22,000 pounds or more. Table 9 shows the frequency of heavy axle loads and table 10, the frequency of heavy gross loads by census regions for the year 1947. A comparison of these tables shows that it is not in the regions with the highest frequency of heavy gross loads that the greater frequencies of heavy axle loads occur. The Pacific region, for example, has the highest frequency of heavy gross loads, but axle loads of 20,000 pounds or more and 22,000 pounds or more are less frequent there than in any other region. This is due to the use of more axles per vehicle and better load distribution among the axles, a condition which is encouraged by State laws and enforcement practices.

These increased traffic volumes and weights, and increased frequencies of heavy concentrated loads, followed a long period in which highway maintenance was curtailed and new construction and modernization was entirely eliminated except for some projects regarded as of special importance in the prosecution of the war. It can readily be seen that the result was the serious obsolescence of our highways as a whole, and especially of the principal, heavily traveled routes, such as those that comprise the interstate system.

TABLE 9.—*Number of heavy axle loads per 1,000 trucks on main rural roads in the year 1947, by census regions*

Census region	Number of heavy axle loads per 1,000 trucks, weighing—		
	18,000 pounds or more	20,000 pounds or more	22,000 pounds or more
New England	126	74	40
Middle Atlantic	152	93	50
South Atlantic	74	32	12
East North Central	103	36	10
East South Central	54	22	9
West North Central	57	18	5
West South Central	43	15	5
Mountain	35	13	5
Pacific	44	9	2
United States average	68	33	14

TABLE 10.—*Number of heavy gross weights per 1,000 trucks on main rural roads in the year 1947, by census regions*

Census region	Number of heavy gross weights per 1,000 trucks, weighing—		
	30,000 pounds or more	40,000 pounds or more	50,000 pounds or more
New England	127	64	17
Middle Atlantic	116	55	14
South Atlantic	95	39	8
East North Central	154	76	45
East South Central	79	25	3
West North Central	123	55	20
West South Central	87	31	8
Mountain	90	52	31
Pacific	197	120	87

RECOMMENDED MAXIMUM SIZES AND WEIGHTS OF VEHICLES

VARIETY OF STATE LAWS

A condition that embarrasses the effort to achieve a reasonable uniformity of fitness for service in the highways of the United States is the continuing variety of State laws governing the maximum sizes and weights of vehicles legally permitted to use the highways. The fact that the law of a State fixes particular limits upon the sizes and weights of vehicles that may be legally operated on the roads of the

State is a matter to be reckoned with by the highway authorities, if for any reason it appears that highways should be designed to accommodate vehicles of maximum size and weight either larger or smaller than the existing law allows. Presuming that highways throughout the Nation should be built to standards uniformly adequate in all States, the variety of size and weight laws persisting, highway authorities of many States are unavoidably confronted with the necessity of justifying any decisions they may reach as to road standards that appear inconsistent with the existing State law.

More serious than its effects upon highway design policy, however, is the effect of this variety of State vehicle regulatory laws upon the flow of interstate traffic. When different dimensions and weights are fixed as the largest permissible in each of two States, vehicles that can legally be operated in one can be operated in the other only in violation of law. The difference in the laws becomes a barrier obstructive of a desirable freedom of movement from one State to the other

WARTIME LIMITS

The unfortunate effects of such differences in State laws are never more apparent than in wartime. In an effort to surmount the difficulties presented by the variety of laws existing at the outbreak of World War II, the President early recommended in letters to the Governors of all States that they arrange in some manner to accept in their States, as permissible for the duration of the war, movements of vehicles conforming to a certain few dimensional and weight limits.

These limits, which became known as wartime limits, were either in some manner adopted or tolerated in all States while the war continued.

The limitations thus proposed and accepted were as follows:

Height	12 feet 6 inches.
Width	96 inches.
Length:	
Single vehicle	35 feet.
Combination vehicle	45 feet.
Axle load:	
Single axle	18,000 pounds.
Total on axles spaced less than 10 feet apart	32,000 pounds.
Gross weight:	
Vehicles of 2 axles	30,000 pounds.
Vehicles of 3 or more axles	40,000 pounds.

This hurriedly arranged uniformity of vehicle regulation was far from satisfactory, either as assurance of the unobstructed movement of war traffic or as a measure of highway conservation. The 18,000-pound axle load limit was soundly based upon the prevailing load-supporting capacity of the highways. This accepted, the limit of 30,000 pounds as the maximum gross weight of a two-axle vehicle was inconsistent and unattainable if the axle limit were observed, since to realize the total load permitted would have required an impracticable loading of the front axle. This inconsistency existing, highway haulers of important war shipments might be, and they doubtless were forgiven if they complied with the 30,000-pound gross load limit and violated the axle-load limit.

The limit proposed for the gross load of a three-axle vehicle, at 40,000 pounds, was at least attainable in a vehicle without infringement of the axle-load limit; but both of the gross weight limitations were inadequate from the viewpoint of bridge protection by reason of their failure to take account of the length of the vehicle. And for governance of the size and weight of vehicles and vehicle combinations of more than three axles the wartime agreements provided no guide whatever.

RECOMMENDATIONS OF THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS

For many years prior to the war, the American Association of State Highway Officials had attempted to find a satisfactory basis for uniform regulation of the size and weight of vehicles. The association had at intervals offered recommendations concerning limits suitable for adoption, the successive recommendations differing mainly in consistency with the change of vehicle tire equipment from the early solid rubber to the later pneumatic type.

Policy on limitations

After the war the association renewed its consideration of the matter and by majority vote of its State highway department membership adopted as a policy, published April 1, 1946,[1] the following recommended limits:

Height ---- 12 feet 6 inches.
Width [2] ---- 96 inches.
Length:
- Single truck ---- 35 feet.
- Single bus (2 axles) ---- 35 feet.
- Single bus (3 axles) ---- 40 feet.
- Truck-tractor with semitrailer ---- 50 feet.
- Other combinations (not more than 2 units) ---- 60 feet.

Axle load ---- 18,000 pounds.
Group axle load:

Distance in feet between the extremes of any group of axles	Maximum load in pounds carried on any group of axles	Distance in feet between the extremes of any group of axles	Maximum load in pounds carried on any group of axles	Distance in feet between the extremes of any group of axles	Maximum load in pounds carried on any group of axles
4	32,000	22	45,700	40	60,800
5	32,000	23	46,590	41	61,580
6	32,000	24	47,470	42	62,360
7	32,000	25	48,350	43	63,130
8	32,610	26	49,220	44	63,890
9	33,580	27	50,090	45	64,650
10	34,550	28	50,950	46	65,400
11	35,510	29	51,800	47	66,150
12	36,470	30	52,650	48	66,890
13	37,420	31	53,490	49	67,620
14	38,360	32	54,330	50	68,350
15	39,300	33	55,160	51	69,070
16	40,230	34	55,980	52	69,790
17	41,160	35	56,800	53	70,500
18	42,080	36	57,610	54	71,200
19	42,990	37	58,420	55	71,900
20	43,900	38	59,220	56	72,590
21	44,800	39	60,010	57	73,280

[1] Policy concerning maximum dimensions, weights and speeds of motor vehicles to be operated over the highways of the United States, American Association of State Highway Officials, adopted April 1, 1946.
[2] A width of 102 inches is recommended for future adoption when the widening of existing narrow surfaces permits.

Factors considered

In deciding upon these recommendations the highway officials, members of the association, were influenced by several considerations. Foremost in their consideration was the essential protection of existing road and bridge structures against undue damage by vehicles excessively large and heavy, and the necessary avoidance of highway usage by vehicles unduly hazardous to other traffic. A further consideration was the possibility of deciding upon a single system of limitation that would have reasonable prospect of early uniform adoption by all States. A third consideration, taken in recognition of the tendency of efficient practice in vehicle design and operation to move toward the supply and usage of vehicles of greater load-carrying capacity, was the adoption of limits which, while affording sufficient protection for existing roads and bridges, would allow for a reasonable enlargement of the vehicles in prevalent use, and serve as the basis of the advanced standards desirable of adoption for highways and bridges to be built in the future.

PUBLIC ROADS ENDORSEMENT OF POLICY

The Public Roads Administration endorses the limits recommended by the association. Without regard to their incorporation in the laws of the States, it recommends their adoption as the safe and reasonable basis of highway and bridge design standards to be employed in the future construction of all States. It discounts the probability of any future change in regulatory laws or in transportation practice that will cause the undue obsolescence of roads and bridges adequately designed for the accommodation of traffic including a probable frequency of occurrence of vehicles of the maximum sizes and weights provided for.

Considerations in regard to size

This endorsement is based upon the following considerations with reference to each of the proposed limits:

The height of 12 feet 6 inches is the maximum safely consistent with vertical clearance of 14 feet. The difficulties of providing at bridges and structures, particularly in cities, clearance in excess of 14 feet warrant the expectation that such clearance will be the greatest that can be generally provided.

The width of 96 inches is the greatest that can be accommodated on the narrower thousands of miles of existing highways. A width of 102 inches, proposed for eventual adoption, is sufficient to permit desirable improvements in the mechanical and body design of vehicles, and is consistent with lane widths of 11 and 12 feet for highways of light and heavy traffic density, which are regarded as reasonable highway design standards.

Lengths of 35 feet for single vehicles and 50 feet for tractor-semitrailer combinations are consistent as limits for the two classes of vehicles from the viewpoint of the off-tracking of rear from front wheels that occurs in turning movements, the amount of such off-tracking being substantially the same for vehicles of each class at the limiting lengths. There is no observable tendency of truck design or truck operational practice to exceed these limits. The limit of 40 feet suggested for three-axle busses is desirable for the encouragement of improvements in the design of bus bodies and equipment. It will not require any alteration of highway design consistent with the 35-foot length recommended for trucks, provided that, as recommended, the longer bus is carried on three axles.

Length of 60 feet for two-unit combinations other than tractor-semitrailers is consistent with the 35- and 50-foot lengths proposed for the other classes of vehicles in the fact that it involves approximately the same amount of off-tracking. It is essential to permit a distribution of the heavier of probable highway freight loadings consistent with reasonable standards of road, bridge, and vehicle design. There is substantial warrant for the belief that such a length will be required and efficiently used in future civil transport operation, as it is already equaled and exceeded in the design of military vehicles. No confirmation has been found in extensive traffic observations of the fear that vehicles of such length will be unduly difficult or dangerous to pass.

Considerations in regard to loads

An axle load of 18,000 pounds is the heaviest that can be allowed. Such a limit should be rigidly enforced for the protection of existing road surfaces, most of which will not carry heavier loads without damage and unreasonable shortening of their normal service lives. If future roads were designed to support heavier axle loads it would be years before the replacement of existing surfaces would permit vehicle loading to the higher axle limit. The 18,000-pound axle-load limit will not unduly restrict the design and efficient loading of vehicles if laws are amended to permit the lengths and group axle loads recommended. By encouraging the provision and use of multiple-axle vehicles for movement of the heavier loads, the 18,000-pound limit in combination with the length and group axle-load limits recommended will permit more effective braking and make for greater safety in vehicle operation.

The tabular values of group axle loading recommended are safe for H15 bridges which, with few exceptions, are the strongest of existing bridges. Fixed gross-load limits corresponding to classes of vehicles, still provided in the laws of some States, should be abolished as rapidly as possible and group axle-load limitation equivalent to that recommended should be substituted. Existing roads and bridges will be equally adequate for gross vehicle weight greater than the highest value allowed in the recommended table if vehicle length and number of axles are correspondingly increased and the 18,000-pound axle-load limit is faithfully observed.

Size and Weight of Military Vehicles

The limitations placed on the design of military motor vehicles are prescribed in Army Regulations No. 700–105, section II. The limitations imposed upon the design of Air Force and Navy motor vehicles are essentially the same as those included in the Army regulations.

In general, there are two sets of limitations on the size and weight of military motor vehicles, one applying to general-purpose and special-equipment vehicles and the other to special-purpose and combat vehicles. The first group includes the bulk of the military vehicles.

They are designed for normal highway operation and compare in size and weight with the civilian trucks and combination units in common use. The second group includes a relatively small number of military vehicles which are designed and intended to meet specialized requirements for which no general-purpose vehicle chassis can be adapted. Tank transporters and tanks are examples of vehicles in the second group. Frequent use of highway facilities by these vehicles is not expected.

The limitations of size and weight placed on military general-purpose and special-equipment vehicles by Army Regulation No. 78–105 are summarized in table 11.

The general-purpose limits exceed those recommended by the American Association of State Highway Officials only in the length and maximum gross weight permitted for combinations other than tractor-semitrailers.

The greater length permitted (65 versus 60 feet), in view of the probable small numbers of vehicles of the permitted dimension, will present no serious traffic problem on existing roads and will require no alteration of new road design standards adequate for 60-foot combination vehicle length.

TABLE 11.—*Army size and weight limitations on military vehicles*

Size or weight item	General-purpose and special-equipment vehicles
Height...feet	11.0
Width...inches	96
Length:	
Single vehicle...feet	35
Truck-tractor with semitrailer...do	50
Other combinations...do	65
Gross vehicle weight...pounds	[1] 78,000
Axle load...do	[2] 18,000

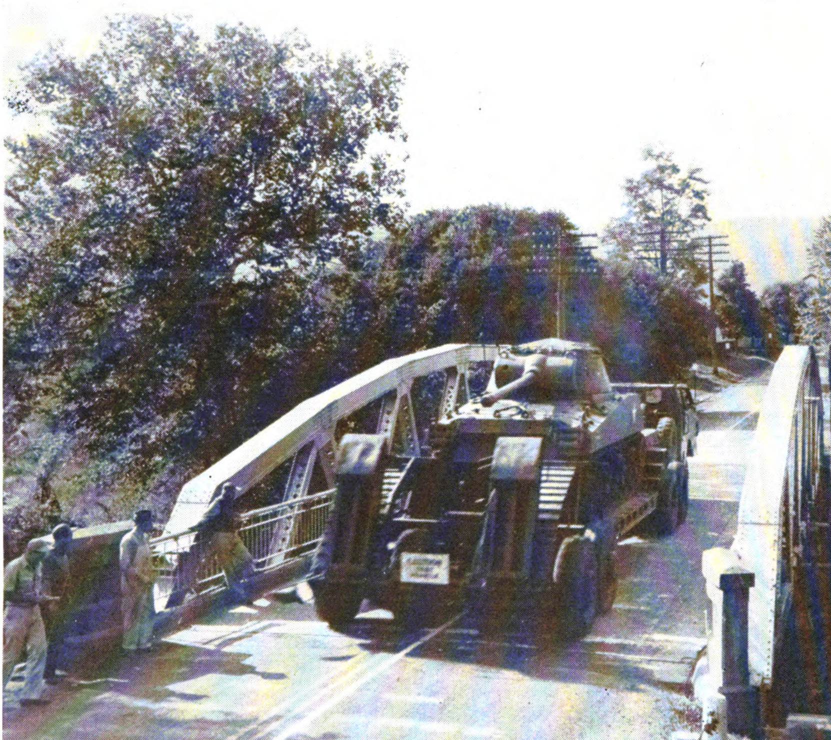
[1] 36,000 pounds if 10 feet or less from extreme front axle to extreme rear axle of vehicle and 850 pounds for each additional foot of this dimension.
[2] 16,000 pounds if spaced between 3½ to 7½ feet from the nearest adjacent axle; 18,000 pounds if spaced more than 7½ feet from the nearest adjacent axle.

The greater maximum gross weight permitted (78,000 versus 72,600 pounds) is consistent with the greater length limitation. Vehicles conforming to these greater limits of length and maximum weight will generate in H15 bridges approximately the same stresses as vehicles conforming to the lesser limits of length and weight recommended by the association.

For the various special-purpose vehicles for which the Army regulations permit designs exceeding in dimensions and weight the limits prescribed for vehicles intended for regular highway use, considerations of combat effectiveness are paramount in the determination of size and weight. Their occasional regulated use of roads in times of peace will present no serious traffic problems and all lesser considerations of convenience, necessity, and economy must yield to their exigent use in war.

Appendix II.—TRAFFIC DETERMINANTS OF INTERSTATE HIGHWAY STANDARDS

Highways are avenues of transportation. Within limits of feasibility they should be adjusted in the various elements of their design to the justifiable needs of traffic. Failure to effect such adjustments



This bridge on U S Route 30 in Pennsylvania, designed for about H20 loading, is strong enough to carry infrequent loads as heavy as the 152,000-pound tank transporter and tank. For adequacy, the bridge should be wider than the approach pavements.

in highways previously built, because of a deficiency of traffic information and knowledge of road-traffic relationships, have been the cause of much of the present highway obsolescence.

Significant advance has been made in the last 10 years in the development of improved highway design standards as a direct result of more exact information concerning road usage, motor-vehicle performance, and driver behavior in the presence of various traffic conditions and roadway characteristics. This information is used as a base for determining the features of road design that are most directly affected by the increase in volume and speed of traffic, features in which there has been the highest degree of obsolescence in the older highways. These roadway features relate to the alinement and profile, the plan of intersections, the clearances, and the horizontal dimensions of the highway cross section.

Many of the recent studies have been devoted to the dynamics of highway movement; and the results of these studies, combined with the evidence of traffic growth and distribution and other information resulting from the State highway planning surveys, form the basis of the geometric highway standards, previously described, which have been employed in rating the deficiencies of the interstate highway system, and estimating the cost of its adequate improvement.

WIDTHS OF SURFACES AND SHOULDERS

No features of a highway have a greater influence upon the safety and comfort of driving than the width and condition of the surface. On two-lane roads the width of pavement is most critical when vehicles meet, as it is then that drivers must allow sufficient clearance between vehicle bodies to assure complete safety, while at the same time maintaining a comfortable margin of safety from the pavement edge. The clearances necessary for safety at the speeds that vehicles are operated, added to the combined widths of the two vehicle bodies, constitute the needed pavement width.

Lane widths

Most of the freight-carrying vehicles now using public highways are 8 feet wide. The results of investigation of the transverse positions of vehicles in motion show that lanes 12 feet wide are the minimum that will provide ample clearances between commercial vehicles as they meet one another. This lane width will also be adequate in case the width of commercial vehicles is increased to 8.5 feet. It is only where the traffic streams are composed almost entirely of passenger cars that lane widths of 11 feet are satisfactory.

Roadside obstructions

These investigations also reveal that any objects such as retaining walls, bridge trusses, or headwalls adjacent to a roadway constitute a safety hazard and are an obstruction to the free movement of traffic, unless they are 6 feet removed from the normal pavement edge. If they are 3 or 4 feet away, however, their effect will not be critical enough to justify greater clearances from the normal pavement edge on long bridges and underpasses.

Shoulders

Shoulders capable of supporting all types of vehicles standing on them or passing onto them infrequently and in emergency at high speed during any weather conditions are essential for traffic safety. Adequate shoulders are also essential to realize the full capacity of the surface width. Without adequate shoulders, one disabled vehicle can reduce the capacity of both two-lane and multilane highways during peak periods by as much as 60 percent.

A shoulder width of 6 feet is required to insure that lateral obstructive objects will not decrease the effective pavement width; and an additional 4 feet, or a total shoulder width of 10 feet, is required to permit and encourage drivers of disabled vehicles to stop clear of the traffic lanes so as not to constitute a traffic hazard.

Effect of vehicle length and off-tracking on curves

When a vehicle makes a turn, the rear wheels follow a path having a shorter radius of curvature than the path followed by the front wheels. The distance between the two paths is known as the amount of off-tracking. As a result of off-tracking, vehicles negotiating horizontal curves occupy a greater width of roadway than they do in following a straight course.

The amount of off-tracking increases with the length of vehicle and varies inversely with the radius of the curve. The off-tracking of passenger cars is insignificant on modern highways except at intersections and on the ramps at interchanges. The off-tracking of trucks and truck-trailer combinations, however, is much greater than for passenger cars and governs the amount by which the normal lane widths must be widened on the sharper curves. In some cases, it establishes the minimum curvature which it is practical to employ for the design of intersections at grade and at interchanges. The off-tracking of the larger vehicles that are likely to use the interstate highway system is not sufficient to require lane widths in excess of 12 feet on any curve up to 9 degrees, which is the absolute maximum permitted in the design standards for the system. It is significant that on the sharper curvatures which may be employed in the vicinity of intersections and interchanges, the 35 feet for single-unit trucks, the 45 feet for tractor-semitrailer combinations, and the 60 feet for truck-trailer combinations proposed as limits of lengths by the American Association of State Highway Officials, off-track approximately the same amounts on correspondingly sharp curves. The off-tracking of these vehicles varies from about 0.8 foot on a curve with 500-foot radius to about 7 feet on a 50-foot radius.

SPEED AND NUMBER OF TRUCKS DETERMINE GRADE LENGTHS AND HIGHWAY CAPACITY

Commercial vehicles occupy a greater road space and influence other traffic over a larger area of highway than do passenger cars because they are larger and generally travel at lower speeds, especially on grades. When a highway is operating at its capacity the total number of vehicles is therefore less, if there are any commercial vehicles, than if traffic is composed entirely of passenger cars.

Effect of trucks on capacity

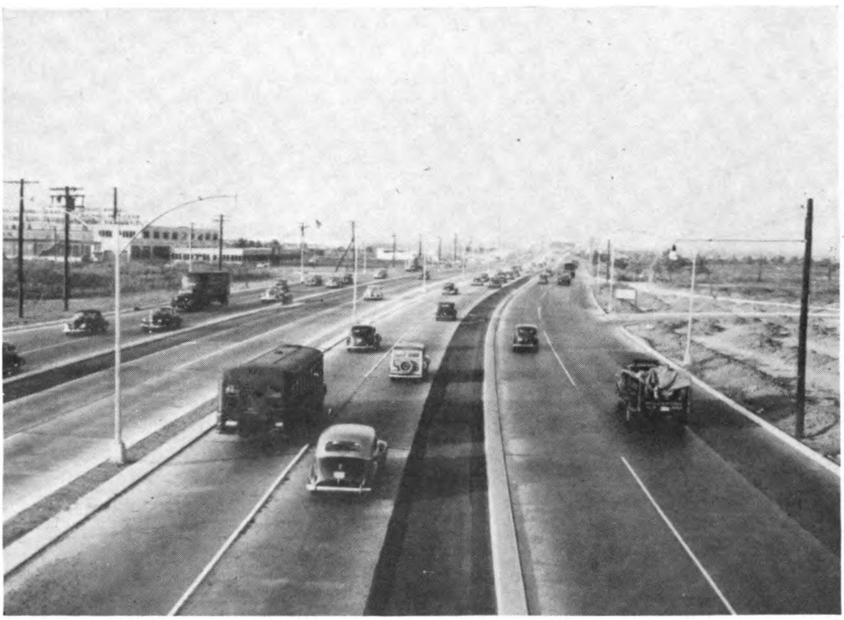
In relation to highway capacity, one commercial vehicle has approximately the same effect as two passenger cars in level terrain and four passenger cars in rolling terrain. In mountainous terrain the effect of one commercial vehicle may be as great as eight passenger cars.

On individual grades trucks affect the safe and efficient flow of traffic because they go so slowly upgrade that long queues of passenger cars are formed behind them and then go so fast down the other side that none can pass. This type of congestion tends to cause the drivers of passenger cars to take risks in passing the trucks at points where sight distances are inadequate.

Added lanes

One means available to the highway designer for elimination or lessening of the congestion that is created by heavy vehicles crawling up hills is the construction of added lanes or truck lanes on the uphill side of the grades. This method has been employed by several States with excellent results.

When the traffic volume on a two-lane road does not exceed 300 vehicles per hour the congestion on grades resulting from slow-moving vehicles in numbers normally found on main highways is not sufficient to justify the construction of a third lane, regardless of the alinement and profile, for grades up to 7 percent.



The war proved to be only a temporary interruption to the long-term upward sweep of traffic volumes. This dual-dual section of U S Route 1 near Newark Airport, New Jersey, now carries about 70,000 vehicles a day.

Where the alinement and profile are such that sight distance does not restrict the performance of passing maneuvers, added lanes are not justified for hourly volumes below 500 vehicles. But this is seldom the case, because sight distance is commonly restricted at the crests of hills. With the sight-distance restrictions that are normally present on sections that include grades, an added truck lane is justified under the conditions shown in table 12.

Where the traffic volumes approach those that require a four-lane divided highway, the added lane will provide temporary relief only and, under these conditions, in some instances at least, the construction of a divided four-lane highway is the more feasible solution, especially if the level sections of the highway have a poor alinement.

VARIATIONS OF TRAFFIC VOLUME AND CRITICAL HOURLY VOLUME DETERMINE REQUIRED HIGHWAY CAPACITY

Certain general facts pertaining to the volume and pattern of traffic movement are widely known. The daily pattern is one with which everyone is familiar; and the morning and evening rush hours, with intervening lulls, are accepted facts of the traffic day. Also, the fact that traffic on certain days of the year is much heavier than that on other days is a matter of common knowledge. The manner in which these variations in flow are related to the traffic-carrying ability of a roadway facility is not so readily apparent.

TABLE 12.—*Traffic volumes for which a truck lane is justified for gradients of various lengths on 2-lane highways*

Gradient	Traffic volume exceeding—	Length of grade
3 percent	550 vehicles per hour	Over 1,100 feet.
4 percent	500 vehicles per hour	Over 800 feet.
5 percent	400 vehicles per hour	Over 600 feet.
6 percent	400 vehicles per hour	Over 500 feet.[1]
	350 vehicles per hour	Over 4,000 feet.
7 percent	350 vehicles per hour	Over 500 feet.[1]
	300 vehicles per hour	Over 4,000 feet.

[1] For length of grade over 4,000 feet, a 4-lane highway is required.

Investigations of the fluctuations in traffic movement show that a highway planned to accommodate the traffic demand during the peak hour of the average day of a year will be congested, on an average, during 160 days of the year. Also, if the road is planned to take care of the traffic during the average hour of any day the demand during the peak hour of that day will be more than double the capacity of the highway. It is apparent then, that the roadway should be designed to accommodate the traffic that moves during most of the heavier hours of the year, but that it is uneconomical to plan for the infrequent extremes that occur from time to time throughout the year.

Comprehensive studies have shown that it is uneconomical to design the average highway for a greater hourly volume than that which is exceeded during only 30 hours each year, and little will be saved in the construction cost and a great deal lost in expediting the movement of traffic if the highway is designed to accommodate fewer vehicles than the volume exceeded during the 50 highest hours of the year.

For the interstate highway system the thirtieth highest hour of the year has been selected as the criterion for decision upon the adequacy of existing facilities and for determinations of geometric features of the highways, such as the number of traffic lanes, maximum gradients, and curvatures, that are required to accommodate traffic using this system.

As a result of the variation in traffic flow, highways in certain sections of the country require considerably higher geometric standards than others, for the same total annual traffic volumes, in order to provide the type of service which this system of highways is expected to render.

STOPPING DISTANCES DETERMINE MINIMUM SIGHT DISTANCE REQUIRED

Proper highway design requires that the length of highway ahead visible to the driver of a vehicle be sufficiently long at all times to enable a driver to bring his vehicle to a safe stop in advance of an object unexpectedly appearing on the road surface. In accomplishing such a stop the driver must perceive the object, react to his decision that a stop is necessary, and apply the brakes. Following these actions the vehicle requires a period of time to come to rest, the needed time depending on the speed of the car and the condition of the braking system. The distance that the car travels during these periods is termed the stopping distance. The distance within which all but the few vehicles with brakes in poor condition can stop when traveling at the maximum reasonable speed which the highway should be capable of accommodating is the needed sight distance.

The minimum sight distances in table 13 are sufficient for emergency stops where vehicle speeds do not exceed the design speeds as shown in the table. For safe operation sight distance at least as great as these minima must be provided at all points on a highway, and at intersections the driver who is about to enter the highway must have a clear view in either direction, right and left, equal to the safe stopping distance for the design speed of the highway.

Provision of these adequate stopping sight distances places certain limitations on many of the geometric features of the highway, such as maximum curvature, rates of change in gradient at crests, width of cuts, clearances to lateral obstructions along the traveled way, and the combination of many of these features with one another.

TABLE 13.—*Minimum sight distances*

Design speed	Stopping sight distances for 2-, 3-, and 4-lane highways	Passing sight distances for—			
		2-lane highways		3-lane highways	
		Desirable	Absolute	Desirable	Absolute
	Feet	*Feet*	*Feet*	*Feet*	*Feet*
30 miles per hour	200	600	500		
40 miles per hour	275	1,100	900		
50 miles per hour	350	1,600	1,400	1,100	900
60 miles per hour	475	2,300	2,100	1,500	1,300
70 miles per hour	600	3,200	2,900	2,000	1,800

RELATION OF TRAFFIC VOLUME, OPERATING SPEED, AND PASSING SIGHT DISTANCE TO HIGHWAY CAPACITY

The maximum possible capacity of a highway is attained when the lanes are completely filled with vehicles following each other at a minimum distance. Under this condition all vehicles will be moving at the same speed, which is established by the speed of the slowest driver on the road.

Effect of traffic volume

The high degree of restraint placed upon every motorist when the possible capacity has been reached, or even approached, results in driving conditions that are wholly intolerable. Drivers are entitled to exercise some freedom in their selection of speed and their ability to maneuver. The extent to which this liberty may be exercised is dependent primarily upon the volume of traffic using the highway and also, for two-lane roads, upon the portion of the highway where sight distances are adequate for overtaking and passing. Other elements such as narrow lanes and narrow shoulders also provoke congestion, but on highways built to the adopted standards for the interstate highway system these inferior features are not present.

Practical working capacity

The maximum volume of traffic that will permit a reasonable degree of freedom from congestion may be termed the practical working capacity of the facility. Its magnitude depends in large measure upon local conditions. For rural areas operating conditions are satisfactory so long as drivers who so desire may travel at average speeds of 45 to 50 miles per hour without undue hazard. On roads having a lane width of 12 feet and excellent alinement, such speeds can be attained with the traffic volumes shown below, for highways of different numbers of lanes:

Two-lane highways: a total of 800 vehicles per hour.
Three-lane highways: a total of 1,400 vehicles per hour.
Four- or more-lane highways: 900 vehicles per hour per lane for the lanes in the heavier direction of travel.

These volumes include a normal percentage of trucks. The average speed of all traffic under these volume conditions will be about 40 miles per hour. Where a lower average speed is satisfactory, as is the case on multilane expressway facilities in urban areas where flow is uninterrupted, a volume of 1,350 mixed vehicles per lane per hour is practicable. The average speed at this volume will be about 30 miles per hour but drivers having a desire to do so would be able to average 35 to 40 miles per hour in safety.

Passing sight distance

Sight distances that restrict passing maneuvers are a serious detriment to the capacity of two- and three-lane roads. Where passing sight distances are inadequate, drivers are restricted in their freedom of movement in much the same manner as when the lane used for passing is filled with oncoming vehicles. The reduced capacity resulting from short sight distances can be determined by using as a criterion the percentage of the total highway on which sight distances are insufficient to permit passing maneuvers to be performed safely.

Studies have shown that few vehicles are passed when their speed is above 50 miles per hour, and that the majority of cars are moving slower than 45 miles per hour when they are passed. Sight distances within the range of 1,500 to 2,000 feet are those most widely needed to meet the requirements for passing vehicles traveling below 50 miles per hour. The distance required to complete a passing maneuver is slightly longer if the vehicle passed is a commercial vehicle than if it is a passenger car, if the speeds of each are the same. Commercial vehicles, however, usually travel at lower speeds than passenger cars. Hence, the sight distance lengths quoted above are usually ample on roads where there are trucks and truck-trailer combinations.

Where sight distances within the range of 1,500 to 2,000 feet are not continuously available throughout the length of a two-lane highway, practical capacities are reduced as shown in table 14, where operating speeds of 45 to 50 miles per hour are desired.

These observed facts of the relation of the degree of continuity of passing sight distance to highway capacity are the basis of the sight-distance standard adopted for the interstate highway system. The standard requires that 1,500 feet of sight distance shall be available on percentages of the length of highway sections rising from 16⅔ to 100 percent as the volume of traffic to be served increases from 500 to 800 vehicles in the thirtieth highest hour of the year.

TABLE 14.—*Effect of restricted sight distances on practical capacity of 2-lane roads*

Percentage of total length of highway on which sight distance is restricted to less than 1,500 feet	Practical capacity for operating speed of 45-50 miles per hour
0 percent	800 vehicles per hour.
20 percent	770 vehicles per hour.
40 percent	715 vehicles per hour.
60 percent	645 vehicles per hour.
80 percent	555 vehicles per hour.
100 percent	450 vehicles per hour.

VERTICAL CLEARANCES OF BRIDGES

The design standard providing that all bridges on the interstate system shall have a clear height above the surface of not less than 14 feet, and of not less than 12½ feet above the outer edges of the shoulders, is based on an allowable height of 12½ feet for vehicles plus a reasonable clearance between the vehicle and the bridge.

Data obtained by Nation-wide planning surveys indicate that the occurrence of loaded trucks and combination units of 12½ feet and over and of 14 feet and over is as follows:

	Percentage	
	Over 12½ feet	Over 14 feet
Single units	0.3	0.03
Truck-tractors and semitrailers	2.4	.2
Trucks and full trailers	6.7	.5
All trucks and combinations	1.1	.1

The above tabulation shows there is little demand for bridges to accommodate vehicles higher than 12½ feet and practically no demand for a height that will accommodate vehicles over 14 feet high. The demand for vehicles over 12½ feet actually involves only a few commodities. The principal demand for vehicles over 12½ feet stems from auto carriers which, when loaded in the most efficient manner as now practiced, have a total height of 13½ feet.

The tolerance of 1½ feet between the allowable height of 12½ feet for vehicles and a 14-foot bridge height is necessary to provide for:

1. The resurfacing of the pavement, which over a period of years may result in several inches of increased thickness.

2. Accumulation of ice and packed snow.
3. Emergency movement of special construction and industrial equipment.
4. The springing action of vehicles.

AXLE LOADS DETERMINE REQUIRED ROAD-SURFACE STRENGTH

So far as vehicular effects are concerned, the load carried on a single axle is the principal determinant of the required load-supporting capacity of roads. Road load-supporting capacity is a composite result of the composition and depth of the subgrade or foundation, base, and surface or pavement provided. The supporting capacity of any combination of foundation, base, and surface is affected by variations of water or moisture content in any of the three elements of the structure. Supporting capacity of some of the materials employed, particularly portland cement concrete, is also affected by variations of temperature. The numerous combinations of variables involve complexities of relation and result which are imperfectly understood.

Static loads

It is known that the effect of two loads statically applied upon a road surface is not greater than the effect of either of the loads singly if the two loads are separated by not less than about 40 inches. Hence, for the estimation of vehicular effects the axle-load determinant is considered to be the total load transmitted to the road by all wheels the centers of which are included between two parallel transverse vertical planes 40 inches apart, extending across the full width of the vehicle.

Whether, and in what degree, the road effect of closely spaced loads dynamically applied differs from the known effect of static application, is not established.

Effect of weather

Roads which in certain conditions (especially conditions of moisture content) will support a particular axle load, under more adverse conditions will fail when subjected to considerably lighter axle loads; hence the common necessity to reduce axle loads in the spring when, as a result of the melting of frost, elements of the road structure are heavy with moisture.

Warping of concrete

Concrete pavements warp or bend downward at their edges when, as commonly on a warm day, the temperature of the upper surface is higher than that of the bottom of the slab. Conversely, when the temperature of the upper surface is lower than that of the bottom of the slab, as often it is at night, the edges of the slab bend or warp upward to such an extent that they are no longer in firm contact with the foundation. Hence, a given load applied at the edge of a concrete road slab may differently affect the slab according as the slab at the time is or is not in intimate contact with its foundation.

Action of repetitive loads

A road which will support a particular axle load in single or very infrequent application may fail or rapidly deteriorate under frequent application of the same or even lesser loads. Some of the road effects of vehicular load are cumulative.

Applied loads may cause slight movements of the stone particles composing a so-called nonrigid road surface. If, by reason of the

Photo by Ansgar Johnson

Because this section of Idaho State Route 25 lacks adequate foundation, the surfacing breaks up regularly every spring. The mud has been scraped aside and replaced by sandy soil as a temporary expedient. On such roads, the spring break-up means a seasonal restriction on permitted loads, yet 30 percent of the 2,300 vehicles using this road daily are trucks.

manner of load application, these movements tend to occur in the same directions under successive load applications, the condition of the road surface may rapidly deteriorate. In this manner corrugations are formed in gravel road surfaces.

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Tests of beams made of portland cement concrete have shown that such a beam can be broken by frequent and rapid application of a load barely more than half as great as the load required to cause rupture in single application. So, it is known that concrete is a material which, like many others, suffers fatigue under repeated stress. Concrete pavements undoubtedly suffer such fatigue under the repeated application of vehicular loads. Without question, the load that a pavement will withstand in frequently repeated application is not as great as the heaviest load it would support once or infrequently applied. Precisely the degree of such fatigue of the road slab, i. e., what load repeated in what frequency on a slab of given dimension will rupture the slab, has not been determined, and the desirable eventual determination will be extremely difficult. Meanwhile, the great variety of conditions under which concrete roads exist and are built precludes even an approximate generalization of the effects of fatigue.

Cracking of concrete

It is a matter of common observation that cracks form progressively in concrete pavements throughout their life. Many of these cracks result from causes other than vehicular loads. Some, undoubtedly, are caused by loads, but a load-induced crack is rarely noticed and may be unnoticeable at the moment of its formation. Hence it is practically impossible to impute observed cracking to particular load causes. The most that can be said with assurance is that concrete pavements of presently designed dimensions are cracked by vehicular loads, that they are probably cracked by loads less than those which theoretically they should support in single application, and that ordinary prudence requires safe allowance for the possible effects of repeated application in the limitation of axle loading.

Joint pumping

Another phenomenon associated with concrete pavement, to which the axle loading of vehicles is known to contribute, is the occurrence known as joint pumping. Some jointing of concrete pavements is unavoidable. If the joints are omitted, cracks form as a result of temperature contraction. Where either joints or cracks exist, surface water may penetrate to the soil subgrade, or water may reach the subgrade at the joints in other ways. When a vehicle passes over the pavement at a joint the edges of the slabs forming the joint are bent slightly downward by the load. If, then, there is free water in the vicinity of the bottom of the joint, the downward pressure of the bending slabs tends to force it upward and out of the joint onto the surface of the pavement. If the subgrade soil is of such character that it enters into suspension in the water that collects, some of the soil will be pumped out with the water. By such pumping action, frequently repeated, portions of the subgrade may be gradually removed, leaving the pavement slab without subgrade support in the vicinity of the joint. Lacking such support, the pavement may crack near the joint under a passing load heavy enough to overtax its unsupported strength.

Joint pumping, as will be seen from this description, is not caused by vehicle load alone. Detrimental pumping occurs only in the presence of water and subgrade or foundation material that the pumped water can carry with it. On the other hand the pumping action does not occur in the absence of some loading adjacent to the joint. From widely distributed observations the conclusion has been reached that detrimental pumping is generally associated with a substantial frequency of axle loading in excess of 14,000 pounds. Moreover, loads of that magnitude, frequently repeated, are likely to overtax the strength of pavement slabs of the usual thickness when long continued pumping has deprived them of subgrade support.

The fact that joint pumping has been observed to occur under certain conditions associated with axle loading in excess of 14,000 pounds is not a sufficient reason to suggest the limitation of all axle loads to 14,000 pounds as a maximum. It is, however, a definitely observed fact associating a particular type of road damage with a particular magnitude of axle loading. In association with the conclusions drawn from the long experience of many highway authorities, it suggests that the limitation of axle loading should be fixed at no greatly superior weight. Among the other lessons of experience are those gained from many observations of the difference in damage occurring on heavily and lightly loaded lanes of the same pavements, from the quick occurrence of more extensive damage to pavements suddenly subjected to heavier axle loading, and from the differences in maintenance expense for similar pavements lightly and heavily loaded.

Adherence to 18,000-pound limit necessary

These lessons of experience have brought highway officials almost unanimously to the conviction that the axle-load limit of 18,000 pounds presently fixed by law in 34 States should not be exceeded, but rather should be more rigidly enforced as a prudent measure of existing road preservation.

If the 18,000-pound limit should be enforced for the protection of existing roads, the need for such limitation will certainly continue for many years during the normal life of the existing roads.

The question then arises: Should new roads henceforth built be designed to support heavier axle loads? If so, they will have to be made stronger than the great majority of existing roads. If new roads are built of such greater strength, what assurance is there that future vehicle-operating practice will not demand still greater strength? It is an incontestable fact that the highway system cannot be efficiently designed and administered to serve an uncertain and increasing axle loading.

Additional evidence supporting 18,000-pound limit

Impressed strongly by this fact, and holding the conviction that 18,000 pounds is the heaviest axle load the generality of existing roads will safely support, highway officials have also the evidence of their frequent vehicle weighing to convince them that axle loading in excess of 18,000 pounds is not an essential concomitant of greater pay loads for vehicle operators. Additional gross weight and pay load can be readily accommodated if the number of axles is increased. The evidence to this effect is extensive. Its gist is sufficiently conveyed by the following comparison of the relation between the average axle loading and gross weight of all loaded heavy trucks and combinations weighed during 1947 in two States in which different transportation practices have developed in the presence of materially different laws:

	New Jersey	California
Average gross weight of all loaded vehicles weighed.........pounds..	45,513	54,075
Average number of axles, all loaded vehicles weighed..........	2.94	4.77
Average axle load of all loaded vehicles weighed.........pounds..	15,482	11,347

It is apparent that in California, where the law prescribes an axle load limit of 18,000 pounds, a maximum gross vehicle weight of 76,800 pounds, and a maximum length of 60 feet, the average gross vehicle weight of vehicles in use is greater, while the average axle load is less than the corresponding weights of vehicles in use in New Jersey where the law prescribes no limit of axle load, a maximum gross vehicle weight of 60,000 pounds, and a maximum length of 50 feet.

Since an axle-load limit of 18,000 pounds is now, and for years to come will be, essential for the protection of existing roads; since a large mass of evidence exemplified by the above comparison indicates clearly that such an axle-load limitation need not unduly limit either the gross weight or pay loads of vehicles; and since the necessities of efficient design and administration of the highway system require fixation of axle loading, the conclusion is strongly supported that 18,000 pounds should be adopted as the maximum axle load permissible under the laws of all States, that this limit without future increase should be rigidly enforced, and that highways built in the future should be designed for the normal support of axle loads of that magnitude in the frequency of their probable occurrence.

AXLE-LOAD COMBINATIONS AND SPACINGS DETERMINE REQUIRED BRIDGE DESIGN

Unlike roads, bridges are affected by the gross weight of vehicles as well as by the load on each axle. The effect of gross weight, however, is not that of a weight applied at a single point, but rather that of a weight distributed over a significant length—the length of the over-all wheel base—and applied to the bridge within that length at points separated by the distances between axles. Some of the stresses generated in a bridge are responsive to separate axle loads; others are determined in their amount by the magnitude and spacing of all the axle loads applied by a vehicle. Stresses generated by single axle loads are critical mainly in the floor system of the bridge; stresses generated by groups of axle loads are critical in the larger supporting fabric, such as the trusses or main girders. In the latter parts, vehicles of widely different total weight may generate identical stresses if the lengths and axle spacings of the vehicles differ appropriately in relation with their weights.

Distribution of weight important

So, for the design of a bridge it is not sufficient to know the maximum gross weight of the vehicles that are expected to use it. Some assumption must also be made of the manner in which the gross weight will be distributed and applied through axles of definite spacing. Similarly, whereas an existing bridge may be adequately protected against the danger of overstressing by the posting of a single weight limit, if the limit posted corresponds to the load that may be safely carried on the shortest vehicle, such posting will prohibit the use of the bridge by longer vehicles of substantially heavier weight that could safely use it.

Since both the weight and length of vehicles in combination determine their effects upon bridges and since the weight-length relation varies so widely among all the vehicles that will use a bridge—and since, further, vehicles of different weights will have exactly the same effect if their lengths are varied in proper relation to their weights, there is no single answer to the question as to what weight of vehicle a particular bridge will safely support.

Conventional design loadings

In the design of highway bridges certain conventional vehicular loadings are assumed. The magnitude of the assumed loading is described by a designation involving the letters H or H and S and numerals expressive of weight. The combination expresses loading equivalent to that of a vehicle or combination of vehicles of definite weight and length. Thus, H15 loading is equivalent to the weight of a single vehicle of 15 tons total weight carried on two axles, 14 feet apart, one loaded with 12 and the other with 3 tons. H20–S16 loading is equivalent to the loading of a tractor-semitrailer combination of 36 tons total weight carried on three axles, separated by distances of 14 feet and loaded with 4, 16, and 16 tons, respectively. An H20–S16 bridge is a bridge designed for H20–S16 loading. An H20 bridge is a bridge designed for H20 loading.

But the fact that an H15 bridge is designed to support a vehicle of 15 tons or 30,000 pounds total weight does not mean that it will, with equal safety, carry every vehicle of 30,000 pounds total weight nor that a vehicle of 30,000 pounds total weight is the heaviest vehicle it will safely support. Such a bridge would be overstressed by a 30,000-pound vehicle having a wheel base of less than 14 feet; it would carry without any overstress a combination vehicle weighing 60,000 pounds having an over-all wheel base of 42 feet and axles appropriately loaded.

Fallacy of gross-weight control

Herein lies the fallacy of laws aiming to control the gross weight of vehicles by specified fixed limits of weight corresponding to certain classes of vehicles, such as 30,000 pounds for two-axle vehicles, 40,000 pounds for vehicles of three or more axles. Such limits are unnecessary for the protection of roads which, as previously explained, are affected by axle loading rather than gross load. They permit the operation of vehicles that will generate in some bridges stresses greater than those contemplated in their design, and more frequently, if they are enforced, they will prohibit the operation of many heavier but safer vehicles.

For example, a State in which there are many bridges of H15 design standard, if its laws limit gross weight at 30,000 and 40,000 pounds for vehicles of two and three or more axles, respectively, will permit the overstressing of its H15 bridges by vehicles of 30,000 pounds gross weight and wheel base less than 14 feet; and it will, supposedly at least, prohibit the operation of many vehicle combinations of the greater lengths which would be less onerous in their demands upon the bridges despite the fact that their gross weights might materially exceed 40,000 pounds.

Interstate system design loading

These are the reasons that underlie the recommendation of the American Association of State Highway Officials which proposes to limit the gross weight of vehicles by the limitation of constituent group axle loads conforming to a table of weights corresponding to a range of axle group spacings. The values in the table have been calculated in such amounts as to permit the operation of vehicles of various lengths and corresponding weights, all safe in respect to the capacity of H15 bridges.

Bridges of H15 design now so greatly predominate among existing bridges, on even the principal highways, that no higher limits of vehicle gross weight can be reasonably permitted. The design standard proposed for bridges on the National System of Interstate Highways is H20–S16. Bridges of this standard are designed to support loading equivalent to that of a tractor-semitrailer combination of 28-foot over-all wheel base, weighing 72,000 pounds. Such a bridge would be equally safe for a combination vehicle weighing 100,000 pounds if its over-all wheel base length were 54 feet and the constituent axles were appropriately loaded. The statement that it would be equally safe means that it would support such a vehicle without stress in excess of the design assumption, which involves an ample factor of safety to allow for uncertainties of material and construction and for the effects of fatigue induced by repetition of stress. In war or other emergency such H20–S16 bridges will support without danger the infrequent application of vehicles of appropriate length and weight distribution grossing from 160,000 to 200,000 pounds, depending upon the vehicle wheel base, the length of bridge span, and the number of load repetitions.

PROTECTION OF ROADS AND BRIDGES AGAINST OVERLOADING

For reasons stated in the preceding pages it is proposed to build road foundations and surfaces on the interstate highway system for the support of 18,000-pound axle loads, and to build bridges of H20–S16 design. Costs of improving the system have been estimated for roads and bridges conforming to these standards.

If heavier loads are to be permitted, the contemplated design of roads and bridges should be strengthened and the estimated costs should be correspondingly increased. The roads and bridges actually built should be designed for the safe support of loads to be permitted. When so built, they must be protected against overloading by appropriate laws adequately enforced. Unnecessary and costly damage will result from failure to heed this injunction.

Appendix III.—REPORT OF THE SECRETARY OF DEFENSE ON HIGHWAYS FOR THE NATIONAL DEFENSE TO THE COMMISSIONER OF PUBLIC ROADS

March 11, 1949

1.—GENERAL

A. The Federal-aid Highway Act of 1948 (Public Law 834, 80th Cong.), among other things, directed the Commissioner of Public Roads to cooperate with the State highway departments in a study of the status of improvement of the National System of Interstate Highways and to invite the cooperation and suggestions of the Secretary of Defense and the National Security Resources Board as to their indicated or potential needs for improved highways for the national defense. Accordingly, the Commissioner of Public Roads requested the advice and recommendations of the National Military Establishment.

B. This report is confined to the over-all requirements. More complete details and specific requirements will be developed and coordinated as plans and requirements become firm.

C. The over-all highway needs of the National Military Establishment have been subdivided into eight general categories, each of which is defined and discussed separately, as follows:

(1) Connecting system of highways interstate in character.
(2) Urban arterial system.
(3) Defense service roads.
(4) Access roads.
(5) Installation roads.
(6) Excessive military damage to highways.
(7) Size and weight characteristics and movement of military vehicles.
(8) Highway maintenance.

D. Based on World War II experience, recommendations are made with the view to presenting suggestions as to a way in which the indicated needs could be provided for effectively and with the greatest economy.

E. In general, reference is made only to those needs which it is believed have a military significance that would not be provided for by the normal pattern of planning for and construction of highways to meet local peacetime civil needs.

2.—CONNECTED SYSTEM OF HIGHWAYS INTERSTATE IN CHARACTER

A. Definition

(1) The "connected system of highways interstate in character" as used in this report is composed of the National System of Interstate Highways and other highways of strategic importance.

(2) The National System of Interstate Highways is that system of highways designated in accordance with the Federal-aid Highway Act of 1944 (Public Law 521, 76th Cong.) limited to 40,000 miles in total extent and so located as to connect by routes, as direct as practicable, the principal metropolitan areas, cities, and industrial centers, to serve the national defense, and to connect at suitable border points with routes of continental importance in the Dominion of Canada and the Republic of Mexico.

(3) "Other highways of strategic importance" are existing highways other than the National System of Interstate Highways which because of their strategic location and points or areas served would potentially become major highway transportation lines of communications in the defense of the United States.

B. Discussion

(1) The National Military Establishment considers a relatively small "connected system of highways interstate in character," constructed to the highest practical uniform design standards, essential to the national defense. Because of the time required, and cost, such a system must be planned for and constructed during peacetime.

(2) The transportation utilization experience of the military forces during World War II was the basis for recommendations as to routes that should become a part of the National System of Interstate Highways. It is believed that this system will, in large part, provide the principal system of connecting highways to serve the national defense.

(3) However, as weapons and methods of warfare change there will be a significant change in the strategic importance of a relatively small mileage of connecting highways not a part of the National System of Interstate Highways. These other highways should be identified and given equal priority in design and construction within practical economic limits. The total mileage of "other highways of strategic importance" as foreseen at this time will not exceed 2,500 miles. It will be an exception if any of the "other highways of strategic importance" are selected which are not now a part of the Federal-aid system of highways. However, it is believed provision should be made for adding such sections of highways which are not on the Federal-aid system without regard to any mileage limitation.

(4) The general location and extent of these strategic routes are the subject of continued consideration and the Commissioner of Public Roads will be currently advised, within security limitations, as to the location and potential traffic considerations which might be helpful in the improvement of such highways.

(5) There are, of course, economic considerations which should be given to the identification of a connected system of highways which will most effectively serve the national defense within certain projected periods of time. Subject to the development of more complete basic information the Department of National Defense considers the National System of Interstate Highways and certain other routes of high strategic importance to be the principal "connected system of highways interstate in character" essential to the national defense.

(6) In the improvement of this "connected system of highways interstate in character," it is considered important that wherever feasible there be incorporated in their design and construction the controlled or limited access principle. This is considered important

to preserve the effectiveness and efficiency of the system by preventing ribbon development with direct access and cross traffic, which will ultimately create excessive congestion, and to make possible the exercise of a high degree of control over its use for high priority civilian and/or military traffic in event of an emergency.

(7) The relative importance of correcting the various classes of major deficiencies of the "connected system of highways interstate in character" should be based on practical economic and defense considerations and should be made the subject of continued coordination.

C. Recommendations

(1) That necessary scheduled planning and action be taken to improve to the highest practical uniform design standards the designated National System of Interstate Highways and other officially designated highways of strategic importance as a matter of high priority in the Federal-aid highway construction program.

(2) That all highways of the defined "connected system of highways interstate in character" incorporate in the functional design the principle of controlled or limited access unless such construction is found to be not feasible.

(3) The relative importance of correcting the various classes of major deficiencies on the defined "connected system of highways interstate in character" be made the subject of continued study and coordination between the Public Roads Administration and the National Military Establishment.

3.—URBAN ARTERIAL HIGHWAYS

A. Definition

(1) "Circumferential highways" are highways circumferential in character with respect to the center of the metropolitan areas which are extensions of or connections with urban arterial highways of the National System of Interstate Highways and/or other principal rural highways and which serve as many as possible of the transportation terminals, industrial, metropolitan, and residential areas for the efficient flow of large volumes of traffic.

(2) "Radial highways" are those important urban extensions of the National System of Interstate Highways or other principal rural highways which approach the metropolitan and business areas along radial lines.

B. Discussion

(1) The National Military Establishment considers that urban arterial highways should be given equal consideration in their development to the highest practical standards with the National System of Interstate Highways and other strategic highways.

(2) Methods of modern warfare require the rapid movement of military forces through or around urban areas and may require movement of much of its civilian population and industry. Air attacks directing missiles of extreme reaction can render highways in areas with concentrations of tall buildings and structures of little use.

(3) Circumferential routes in large cities are potentially of greatest value to national defense from the standpoint of the movement of cargo and personnel by highway transportation when located in the

outer development adjacent to smaller buildings and serving as many as possible of the transportation terminals and industrial areas.

(4) Radial highways so constructed as to serve efficiently the local civilian economy and with appropriate connections to circumferential highways will, it is believed, serve effectively the national defense.

(5) In the construction of the above referred to radial and circumferential routes, it is important that they incorporate the controlled or limited-access characteristics or have wide rights-of-way which would make possible the exercise of priority in their use and in event of bombing would reduce to a minimum the rubble that would fall on at least a portion of the traveled way.

(6) Correcting the various major deficiencies in critical urban areas should be a matter of continued coordination between the Public Roads Administration and the National Military Establishment.

C. Recommendations

(1) Necessary scheduled planning and action be taken to improv to the highest practical uniform design standards circumferential and radial highways as a matter of high priority in the Federal-aid highway construction program.

(2) All circumferential and radial highways incorporate in the functional design the principle of controlled or limited access or have wide rights-of-way.

(3) Correction of the various major highway deficiencies in critical urban areas as viewed from a defense standpoint be made the subject of continued study and coordination between the Public Roads Administration and the National Military Establishment.

4.—DEFENSE SERVICE ROADS

A. Definition

(1) "Defense service roads" are roads that normally exist and are open for use, but because of the size or weight of vehicles or traffic volume generated by or the lay-out of a defense facility, industry, or military installation, may have to be reconstructed, relocated, supplemented, or otherwise improved from the boundary of such installation or area to a suitable highway, railroad, or waterway.

B. Discussion

(1) In peacetime there are a very few existing and newly constructed military installations or facilities which generate traffic having size, weight, and/or volume characteristics that exceed the capabilities of existing roads or streets serving them. During a war there are many expanded and newly constructed installations and facilities which generate traffic exceeding the capabilities of existing roads serving them.

(2) Experience of World War II would indicate that only a small percentage of this type of highway requirement can be determined and construction justified in advance of a national emergency. However, during the early part of the last war plans and funds were not available for immediate action when definite locations and potential traffic information were available. In some cases plants were completed before plans were made for highways to service them. There resulted unnecessary production delays and expense in providing adequate highway facilities.

(3) Necessary action should be taken so the highway construction authorities can make surveys and prepare plans while plans for the military or industrial site are being prepared. Construction of necessary highways should follow at the earliest possible date after construction or expansion of the installation or facility is an established fact. In this way provision can be made for traffic turning movements, entrance gates, parking areas, highways for initial needs, and right-of-way for highways to serve planned expansion.

(4) Design standards for defense service roads to installations and facilities will vary with the vehicle size and weight characteristics and volume of traffic generated. Accordingly, each should be made the subject of a separate study and constructed to provide effectively and economically the essential highway transportation facilities to a suitable highway, railroad, or waterway.

(5) A preliminary survey indicates that there are an estimated 100 miles of this type of service road to installations of the National Military Establishment which now or will in the next 3 years need improvement.

(6) In event of mobilization, there will be an estimated 2,500 miles of improved service roads required.

C. Recommendations

(1) Enactment of legislation which will authorize the Public Roads Administration to provide for the improvement or construction of a small mileage of officially designated defense service roads during peacetime.

(2) Enactment of Federal highway legislation which will provide for the advance preparation of defense service road plans at the time the final installation or facility plans first become firm and are officially certified as such.

(3) Enactment of legislation which will provide for the immediate diversion of a reasonable amount of Federal-aid highway funds, appropriated for normal highway construction, for plans and construction of officially designated defense service roads, in event of a national emergency established by total mobilization of the Armed Forces.

5.—ACCESS ROADS

A. Definition

(1) "Access roads" are roads that are potentially required but normally do not exist, the construction of which is required to provide access by highway transportation from a suitable highway, railroad, or waterway to material resources or processing points not available from the peacetime economy.

B. Discussion

(1) Access roads are defined and discussed separately because they are normally new highway facilities and their requirements are directly related to the provision for and supply of natural resources.

(2) These roads include such highway facilities as will be required during wartime to provide material resources required in excess of those needed for the peacetime economy or which cannot be obtained for the civilian needs economically. It will generally require considerable time to make surveys and prepare well-engineered plans for such roads.

(3) Determinations as to necessity should be made during peacetime. Preliminary plans for construction of necessary roads should be prepared and held for implementation if a major war becomes imminent.

(4) Certifications as to the essentiality for such roads should be the responsibility of an agency having over-all responsibility.

C. Recommendations

(1) Enactment of legislation which will provide for the advance preparation of access road plans during peacetime when highway service to the area is certified by the appropriate Federal agency as essential to a major war effort.

(2) Enactment of legislation which will provide for the immediate diversion of a reasonable amount of Federal-aid highway funds, appropriated for normal highway construction, for construction of the necessary access roads in event they are required for total mobilization of the Armed Forces.

6.—INSTALLATION ROADS

A. Definition

(1) "Installation roads" are roads or streets within the boundary of a military installation or industrial site which are controlled, constructed, and maintained to serve the facilities and traffic within that installation or industrial site.

B. Discussion

(1) These roads are designed and constructed to serve facilities and traffic within the boundary of a military installation or industrial site. They do not include public roads passing through a military installation or industrial site which are constructed and maintained by local street or highway authorities. The cost of construction and maintenance of installation roads is included in the funds appropriated for construction and maintenance of buildings and other facilities. Actual construction and maintenance is provided for by contract, installation personnel and facilities, or Military Establishment personnel and facilities.

C. Recommendations

(1) That the above indicated procedure be continued.

7.—EXCESSIVE MILITARY DAMAGE TO HIGHWAYS

A. Definition

(1) Excessive military damage to highways is that caused by the movement of military vehicles or units when such movement is for the direct defense of the United States, or if in peacetime, use of the highways or streets has been authorized by the responsible State or other government agency at the request of responsible military authorities, and which does visible damage in excess of that caused by normal military and civilian vehicle use.

B. Discussion

(1) Large Reserve, National Guard, and/or Regular Military Establishment units or combination movements for maneuvers, exercises, or defense of the United States cause excessive damage to some of the streets and highways used.

(2) Requests made to State authorities for occasional movement over highways of Military Establishment vehicles, designed for off-road operation in a combat zone, have been refused because of their excessive axle and gross weight. The fact that there are no Federal funds currently available for repair of the possible damage if the highway engineer does not give proper allowance for deterioration of surface or structures, is believed in large part responsible.

(3) In at least one case there is need for movement of a few combat vehicles, for test purposes, over a city street and rural road, approximately 4 miles to the test area. The cost of improving facilities to accommodate these occasional loads or the purchase of new areas for testing does not at this time appear to be economically justified. However, the occasional but continued use of the same road causes damage in excess of the normal use for which the pavement was designed. It is therefore believed more fitting to pay part of the cost of repair of such city streets or rural roads until the condition can be otherwise corrected than to build new facilities.

(4) Provision for immediate repair of such damaged portions of highways is necessary to help obtain permission to use them occasionally during peacetime, or if for defense, so they can be repaired without delay.

(5) Federal funds were available for reimbursement for such damage to highways during World War II, and it is understood that the State highway departments' claims were not unreasonable.

C. Recommendations

(1) The Commissioner of Public Roads be authorized to reimburse the State or other local highway departments for excessive and visible damage to public highways caused by the movement of Military Establishment vehicles or units when such movements in wartime are for the direct defense of the United States or in peacetime have been authorized by the responsible State or local highway authorities and the excessive damage claim has been verified by the Military Establishment as appearing to be a fair and just claim. Final decision as to the amount of such claim should rest with the Commissioner of Public Roads.

8.—SIZE AND WEIGHT CHARACTERISTICS AND MOVEMENT OF MILITARY VEHICLES

A. Definition

(1) "General purpose vehicles" are motor vehicles of the Military Establishment designed to be used interchangeably for movement of personnel, supplies, ammunition, or equipment, or for towing artillery carriages, trailers, or semitrailers, and used without modification to body or chassis to satisfy general automotive transport and administrative needs.

(2) "Combat vehicles" are tracked vehicles of the Military Establishment with or without armor and/or armament, which are designed for specific fighting functions, or wheeled vehicles which develop similar critical loads.

B. Discussion

(1) Subject to the improvement of highway systems, the development of additional factual information on the economics of motor-

vehicle size and weight for highway use and on trafficability of soils for vehicles for off-road use, the following "General specifications and limitations in design" reflect the highway design requirements:

(a) *General-purpose vehicles*

1. Height: 132 inches.
2. Width: 96 inches.
3. Length:
   a. Single vehicle: 35 feet.
   b. Truck tractor and semitrailer: 50 feet.
   c. Other combination: 65 feet.
4. Axle load: No axle spaced between 3½ to 7½ feet of nearest adjacent axle will carry more than 16,000 pounds. No axle spaced more than 7½ feet from the nearest adjacent axle will exceed 18,000 pounds.
5. Gross vehicle weight: The gross vehicle weight of any general-purpose vehicle will not exceed 78,000 pounds. The gross weight of the vehicle or combination of vehicles will not exceed 36,000 pounds if the distance from extreme front axle to the extreme rear axle is 10 feet or less and will not exceed 850 pounds for each additional foot of this dimension.

(b) *Tracked combat vehicles*

1. Height: 150 inches.
2. Width: 144 inches.
3. Gross vehicle weight: 160,000 pounds.
4. Ground pressure: 12.5 pounds per square inch.
5. For vehicles less than 60,000 pounds: Weight per linear foot, in pounds, equals 3,000 plus 0.06 times (gross weight, in pounds, minus 8,000).
6. For vehicles 60,000 pounds or over: Weight per linear foot, in pounds, equals 20,000 times gross weight in pounds; divided by (160,000 plus gross weight in pounds).

(2) Movement of vehicles of the general-purpose type would be frequent and similar to normal civilian traffic movements.

(3) Movement of vehicles of the tracked combat-type or wheeled combat vehicles which develop similar critical loads would be infrequent and controlled.

(4) Highway facilities which will accommodate the above-described vehicles and types of movement would potentially be of greatest direct benefit to the national defense. Minimum uniform design standards should be established for all highways of the "connecting system of highways interstate in character" and these standards should provide for the efficient and frequent movement of vehicles within the design limitations of the above-described general-purpose military vehicles and the infrequent movement of combat-type military vehicles.

(5) During the early part of World War II highway traffic regulation varied among the several States and thus impeded the free movement and efficient utilization of available equipment transporting material essential to the war effort. Later, nearly uniform but in many instances temporary uniform regulations were adopted. Since the end of the war the more restrictive prewar regulations have been liberalized in some States. However, there remain many variations in State laws governing the use of principal Federal-aid highways.

(6) The accomplishment, during peacetime, of uniform traffic regulations would be of material assistance to the National Military Establishment in the event of any future emergency. Of particular importance is the accomplishment, during peacetime, of uniform highway traffic regulations which will make possible the efficient and effective movement of the general-purpose-type military vehicles on the "connected system of highways interstate in character."

C. Recommendations

(1) Design standards for the "connected system of highways interstate in character" provide for the efficient and effective frequent movement of vehicles within the general specifications and limitations in design for general-purpose vehicles.

(2) Design standards for the "connected system of highways interstate in character" provide for the infrequent and controlled movement of vehicles within the general specifications and limitations in design for combat vehicles.

(3) Necessary steps be taken in keeping with improvements and the capability of the highway system to establish during peacetime uniform highway traffic regulations governing the use of interstate highways and particularly the "connected system of highways interstate in character."

9.—HIGHWAY MAINTENANCE

A. Definition

(1) Highway maintenance is defined as the maintaining or keeping of a highway in its original condition commensurate with its life expectancy and open for the normal and safe movement of traffic.

B. Discussion

(1) All highway construction not essential to the effective prosecution of a war should be discontinued during any such period of emergency. Every effort should be made to keep to a minimum the need for new highway facilities by coordinated planning for and selection of new sites, where little or no new highway construction is required.

(2) This policy will reflect itself in the need for wise planning for the adequate maintenance of heavily traveled roads serving industry, military installations, agricultural areas, and the strategic highways to or through critical areas. Failure to provide essential maintenance will result in essential new construction or reconstruction with its interference to traffic and greater demands for critical materials and manpower.

(3) To keep to a minimum the need for expenditure of critical materials and manpower during a national emergency the principal streets and highways in urban areas, the National System of Interstate Highways, and other identified strategic routes should be maintained at a high level during peacetime.

(4) Investigations should be made as to maintenance items that would be in short supply due to their source or transportation requirements with the view to learning the advisability of stock piling a limited quantity of certain items. Particular consideration should be given to the stock piling of bridge material.

C. Recommendations

(1) That the Commissioner of Public Roads take whatever action may be necessary to assure the continued high level of peacetime maintenance of the principal urban and rural Federal-aid highways.

(2) That the Commissioner of Public Roads initiate the necessary action to determine the advisability and extent to which critical maintenance items can and should be stock piled during peacetime.

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