

SAFETY AND SPEEDS AS AFFECTING HIGHWAY DESIGN

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SYNOPSIS

There has been considerable agitation in recent years for highways designed to permit "safe driving" at high speeds. It is claimed by some that much of our main road system is obsolete, and that we need to build safety into the highways to provide adequate accommodations for modern high speed traffic. Speeds of 90 to 100 m.p.h. today and even higher speeds in the future are advocated by certain engineers as proper bases for such design. In discussing these proposals it is pointed out by the author that there are other road requirements than those of the superhighway, and that available funds must be distributed equitably among all classes of highways. Moreover there may be a net loss in excessive vehicle operating costs resulting from high-speed travel, and traffic accidents are known to be numerous on the so-called "safe" straightaway stretches where higher speeds are possible. It is felt that none but a few very experienced drivers are really capable of driving safely at speeds over 50 to 60 m.p.h., and that the education and selection of drivers is of far greater importance than the provision of speedways. One of the greatest problems now confronting highway officials is the relief of traffic congestion, and maximum capacity on highways of heavy traffic is attained at speeds less than 50 m.p.h. Although the laying out of highways should include all the improvements of design economically feasible, there appears to be no justification for designing high-speed roads when such design will entail additional expenditures for construction. It is inconceivable that any considerable volume of traffic will move over a highway at speeds in excess of 50 to 60 m.p.h.

Many engineers and some laymen have advocated, particularly during the past year or two, the need for designing highways to permit driving motor vehicles at higher speeds, or, as it is frequently expressed, "to drive safely" at these higher speeds. Speeds of 90 to 100 m.p.h. today, and even higher speeds in the not distant future, are advocated as proper bases of such design. At the same time there have also been increasingly frequent notices and discussions of the excessively large numbers of highway accidents and fatalities, and it has been stated by many writers, in the technical press, periodicals and daily newspapers, that blame for such accidents may be laid in no small part to the highway structure.

The (highway) Accident Commission of the Department of Commerce of the United States, however, in a report to Secretary Roper, says (*New York Times*, Feb 18, 1937), "The outstanding cause

is high speed. Road surface conditions play only a minor part."

At the meeting of the Highway Research Board in November, 1936, the very pertinent question was asked by Prof. R. A. Moyer,¹ "What are the speed standards which should be adopted in the design of the various classes of highways of the future?" Upon the answer to this question, he said, centers much of the safety of our highways and the extent to which funds for highway construction may be used most effectively.

It is not infrequently stated that (because of speed limitations) highway engineering practice is not keeping abreast of motor vehicle design and present traffic requirements, that highways are in many cases obsolete even before their paved surfaces have begun to show signs of wear. It is doubtful, however, if in the present state of the art in this country,

¹ *Proceedings*, Highway Research Board, Vol 16, p 80 (1936)

with its vast network of all kinds of roads, all clamoring for improvement, where the construction and maintenance problem is so large and only in the earliest stages, and where all parts have to be kept going while improvements are being carried on, that any highway can properly be called obsolete

The alleged obsolescence is said to be due to

- Inadequate widths of roadway or rights of way
- Insufficient number or widths of traffic lanes
- Need of firm, wide shoulders.
- Obstruction of paved roadways by parked, stopped or slow moving vehicles (trucks on heavy gradients)
- Crossings of other highways or railways at grade, crossings of lines of travel
- Inadequate (obstructed) sight distances and other factors which would, if improved, facilitate driving at the high speeds of which modern cars are capable
- Inadequate recognition of the speed possibilities of the modern automobile
- Insufficient super-elevation of curves.
- Inadequate lighting at night

All this boils down to the idea, in the minds of those who talk about obsolescence, that every highway which does not afford clear uninterrupted smooth surfaces permitting automobiles to be driven at 100 m p h is obsolete, and the question is thus presented as to whether or not engineers are lacking in adequate appreciation of all the factors which should govern design

DIMENSIONS OF THE PROBLEM

Prof R A Moyer has pointed out² that the speed factor affects or may affect such details of design as curvature, super-elevation, road widths, and sight

² Proceedings Am Soc C E, May, 1937, p 941

distances, and so practically the whole design of first class highways

The question is important because of its effect on the expenditure of large sums of money Highway expenditures in the United States now amount to a billion and a quarter dollars annually on State highways and one billion on county and urban highways

It therefore seems desirable to review these questions and the arguments presented by recent writers and commentators The main questions which arise are

- Is engineering design abreast of modern highway traffic demands?
- To what extent is inadequate and improper design responsible for highway accidents?
- Are many of our recently constructed highways obsolete, and what constitutes obsolescence?
- To what extent should highway revenues be used for special facilities and for the few rather than for the extension of the net of reasonably good roads for general use?
- What economic or other justification is there for considering speeds in excess of, say, 50 or 60 m p h as a factor in design?

NEED OF CAREFUL AND COMPETENT STUDY

There can be no question, of course, as to the necessity and desirability of the most careful study of traffic requirements, both present and future, as well as of the effect of the design on ease and facility of traffic movement, and on the operation of vehicles, but there must also be recognition of the fact that it is not always possible to provide funds for expensive types of construction The designer, therefore, while remembering that he is building today a structure to meet traffic requirements and necessities for some years to come, not only has to recognize the limitations of available funds but

also the economic relation governing the cost, original cost plus interest and the deterioration due to time, of constructing some facilities today which may not actually be needed for several years. Competent engineers and designers also will not fail to take account of the desirability of providing for certain basic requirements, at the moment, while perhaps leaving the actual construction of certain parts of the structure to the future, and they will also recognize and properly balance the requirements of all users of the highways. Some of the recent criticisms are

CRITICISMS OF MODERN HIGHWAY DESIGN AND CONSTRUCTION

The New York *Times* of December 6, 1936 carried an article based on a press release of the Regional Plan Association (of New York) with head lines stating "German highways held up as model" and "Regional Plan group reports Reich progress surpasses this Country." The press release read in part

"Germany is building 5,000 miles of super-highways designed to permit safe automobile driving at a speed of 112 miles per hour. This provision for fast motor traffic is contrasted with modern road building in the United States where there are no highways over which half the speed contemplated by the German engineers can be maintained in safety. Germany has found a way to adapt her highways to the exigencies of national defense while in this country we have not yet served the purposes of peace."

The statement does not explain that Germany finds it necessary to provide for the exigencies of contemplated war even at the expense of the amenities of peace, or what is meant by "maintaining" this speed (112 m p h) "in safety" but it may be assumed to mean that the physical structure and condition of the highway permit this. No mention is made of the effect of density of traffic on this speed and the "Regional Plan" in its statement

disclaims the advocacy of such high speeds as desirable in the United States. It seemed, however, to be the intention to convey through this article the idea that American engineers or highway authorities are behindhand in their conceptions of such structures. The form of the structure, as now being built in Germany (Reichautobahnen), however, is not ahead of our ideas in this country. As a matter of fact the basic principle was developed here 25 years ago. It must be remembered, however, that this is a purely military undertaking by the Germans and has, so far as can now be judged, little if any economic justification, unless provision for war is such justification. The construction of these highways is understood to be part of the German unemployment relief program.

H A Phillips, writing of these highways in "Travel" of June 1937 says, "Bypassing of towns and villages is essential because Germany's smaller and older towns have narrow and winding streets. Curves are widened and well sauced so that they may be rounded at a speed of 60 m p h." There is here some discrepancy with the statement that these roads are designed for speeds of 112 m p h.

In a paper entitled "The Modern Express Highway" recently presented to the American Society of Civil Engineers (Proceedings, September, 1936), Mr Charles M Noble, the author, says in part

"The purpose of this paper is to emphasize that design should provide positive safety at the speeds of which vehicles are now capable or may be capable in the near future." Reference is made "to the enormous loss of life and property (by reason of accidents) on American streets and highways" and the need for studying improvements to meet "the increased speed of the present and future motor car."

"No other engineering structure has such a death record as the highway. The motor car designer has set a pace which the highway

designer has not anticipated properly New automobile models appear each year but new highways cannot be produced so quickly This imposes on the designer the task of producing a highway suitable for the car of ten or fifteen years in the future Today (1936) there is a large road mileage less than ten years old which is hopelessly obsolete so far as the safe and efficient operation of the present motor car is concerned The injuries and loss of life and property on American highways are issues squarely facing the highway engineer It is his duty to design the highways so that the traveling public is safeguarded "

The general assumption that, because passenger cars are built capable of attaining speeds of 90 to 100 m p h , that highways should be designed to meet these speeds, hardly accords with the statements of conservative manufacturers General Motors Corporation points out that the most important reason for having power what it is in modern cars, is the avoidance of strain on the mechanism by not using the full capacity By building in the ability to run at high speed, engineers make it practical to run at reasonable speed and get better performance, dependability and lower cost of maintenance

This, of course, does not prevent certain drivers from attempting to utilize the full power provided but it is certainly open to question whether public monies should be spent to encourage this recklessness The statement that the highway structure is responsible for a large toll of accidents is also not borne out by any known facts

John S Worley, Professor of Transportation Engineering of the University of Michigan, states in *Engineering News-Record* of December 10, 1936

"There is a crying demand for highways which will permit safe and rapid movement of motor vehicles over long distances "

Whether it is economically sound to meet this demand through the expenditure of public money at the general expense of the taxpayers, and so endanger

existing investments in already established means of safe and rapid transportation over long distances, he does not say He does, however, echo a similar statement made by the Honorable Murray D Van Wagoner, State Highway Commissioner of Michigan, who, at the 21st Michigan Highway Conference in February, 1936, said

"The State Highway Department is faced with the almost unanimous desire on the part of motorists for greater speed We find this expression of speed in every phase of modern times, in business, industrial and social activities "

The State Highway Engineer of Oregon, in an article in *Engineering News-Record* of May 23, 1935, said

"Improvement in the design of automobiles has a tendency to make highways obsolete the practice (in Oregon) now is to design all trunk highways, except through mountains, for vehicular speeds of 75 to 100 miles There is satisfaction that these standards of design have been justified by steadily increasing average speeds at which traffic is moving over major highways"

No mention is made, in this article, of traffic density or highway capacity as affected by speed, or speed as affected by traffic density There is also probably some economic relation between the original cost and annual cost of such highways and the costs of moving traffic, values of time saved, etc , to which no reference is made

In examining the standards of the Oregon State Highway Commission, courteously furnished by the State Highway Engineer, it is noted that the roads of that State are divided into seven classes, A to G, and that it is only for Class A roads that design standards have been established of 100 m p h in flat country, 75 m p h in rolling country, and 60 m p h in heavier topography and that the "recommended safe speeds" for roads so designed are, respectively, 65, 65 and 50 m p h The maximum curves are also given at 2°, 6° and 10°, respectively, for

the three classes and it is noted that these Class A roads are all designed with roadbed widths of 46 ft. It is further noted that on Class A roads the super-elevation of curves only gives "full compensation" at 70 m p h as a maximum, and where the critical (designed) speed is 70 m p h the super-elevation only gives full compensation at about 36 m p h.

There is evidently here a real recognition of economic limitations which modifies the statement, taken alone, that these highways are designed for speeds of 100 m p h.

In Proceedings of the American Society of Civil Engineers of December 1936, in a discussion of "The Modern Express Highway," Mr. T. T. Wiley states that

"The highways being built today are scarcely abreast of the car of today not to mention the car of the future. The highway engineer must exercise his imagination to visualize the conditions that will exist in the years to come, and base his work upon the conviction that the best design is scarcely good enough."

The context indicates that "best design" means "design of the highest type of roads which the present state of the art makes possible." Here again there is no discussion or mention of the fact that the designer, or at least the highest road authority, has many varied needs to meet and must do the best he can with the money available, which in fairness to all interests may or may not permit such "best design" to be translated into actual construction of all new or improved roads.

Rowland Rogers, writing in the *New York Times* of April 2, 1937, advocates that highway builders take a lesson from American railroad practice. He says

"Our American railroads have a low-accident record, both day and night. When they increased the volume of traffic and the speed of trains, they did not illuminate their rights-of-way but they did

"1 Build adequate roadbeds

"2 Provide adequate sight distance for the engineer

"3 Separate (divide) travel lanes (space between tracks)

"4 Eliminate sharp curves

"5 Reduce steep grades

"In principle and in safety practice, both the rail locomotive and the highway locomotive (automobile) moving from 30 to 60 miles an hour, deserve adequate roadbeds and safe rights-of-way both day and night."

Like many others he seems to ignore the very varied ability, intelligence (or lack thereof) and responsibility of the human element in the case of the automobile. One may wonder, especially in the case of single track lines what would happen if a hundred or two minds of very varying qualities were directing the operations of trains, deciding when to stop and start, at what speeds to travel, etc., or when they might violate the rules and get away with it. The physical condition of the roadbed, track, signals and cars would in that case have little to do with safety.

Mr. Arnold H. Vey, Traffic Engineer of the New Jersey State Highway Department, while recognizing the value of certain types of improvements as accident preventatives, notes the fallibility of the human element. In a paper presented to the Highway Division of the Am Soc C E in January, 1937, he said

"By applying known highway improvements such as controlled rights-of-way, physical separation or segregation of conflicting flows of traffic, adequate shoulders for stopping, pedestrian pathways, and modern lighting, it would be possible to reduce accidents by 75 per cent.

Such changes make it less possible for highway users to perform improper practices causing accidents. Even these improvements, however, are not cure-alls. It is necessary to cause drivers and pedestrians alike to acquire safe highway habits."

In this he does not discuss the increased risks due to higher speeds, and it seems dangerous to hold out the hope that accidents can be decreased by anywhere near 75 per cent by construction methods. In a very able discussion of this general subject, however, in a paper en-

titled "Highway safety exemplified by properly designed and constructed highways," presented at the meeting of the American Association of State Highway Officials at San Francisco, Cal, in December, 1936, Mr R E Toms, Chief of the Division of Design of the United State Bureau of Roads, says

"On the face of the record it would seem absurd to use the wealth of the nation in building so-called fool proof highways. A much more logical approach to the problem would be to expend the proper amount of effort to keep the fools off the highways"

Dr Miller McClintock is reported by the New York *Herald Tribune* as saying, at the national planning conference at Detroit on June 1st, 1937, that "the American street and highway system must be scrapped and rebuilt unless the automobile is to become a malignant growth" This, he says, "will cost \$57,000,000,000 but will pay for itself in 43 years" ³

There can be little valid argument against the exercise of foresight or reasonable planning for the future but the observation of the present writer is that little has been accomplished in the United States by long range planning or planning on a large scale. True, if our foresight were as good as our hindsight we might have avoided some of our present difficulties but the engineer has to be continually on guard to avoid fantastic gestures and limit himself to that degree of future planning which is within the range of reasonable possibilities of the then state of the art, and the dimensions of financial support.

These examples and quotations of only a few of the statements made within the past two years are sufficient to indicate the general types of criticisms which have been made, and ideas which have been advanced either to indicate that we do not know how to design proper highways or

do not do so. Let us look first at our demonstrated ability in design where the necessity exists and the funds are available

SOME EXAMPLES OF CONSTRUCTION TO MEET MODERN REQUIREMENTS

That American engineers, given the opportunity and money are quite capable of meeting the demands of modern highway traffic, is evidenced by the work they have done. Much of this work also shows an appreciation of future requirements.

The Westchester Parkway System was started nearly a quarter of a century ago, developing a 40-ft 4-lane highway with no (or very few) grade crossings with other highways and none with railroads, and protected from side encroachments or entrances. Of course the later sections built have reflected improvements in design (location) of the roadway but the general scheme developed ⁴ a quarter of a century ago was a broad gauge vision of the future and anticipated the present so-called "freeways," the Italian *autostrada* and the German super-highways (*autobahen*).

The New Jersey State Highway, Route 25 ⁵ from the Holland Tunnel to Elizabeth, a modern express highway 13 miles in length with a 50-ft roadway designed for and carrying very heavy traffic, through the congested areas of Jersey City, Newark and Elizabeth had no real precedents for its design, its avoidance of crossings at grade and developments of proper access roads without traffic crossings ⁶. Of course there was the precedent of the Westchester County Parkways in the matter of grade separations at other highway crossings, and the development of means of access and depar-

⁴ Jay Downer, Chief Engineer

⁵ Maj Wm G Sloan, State Highway Engineer (Originally Route No 1 Extension)

⁶ Highways as Elements in Transportation, F Lavis, Trans Am Soc C E. Vol 95 (1931), p 1020

³ See also *Engineering News-Record*, June 18, 1937, p 909

ture at these points, but this particular New Jersey highway, because of the nature of the traffic and the highly developed urban and manufacturing sections through which it passed, had to and did follow railway precedents, duly modified, rather than highway or parkway precedents both in its design and construction

Other examples of accomplished facts are the West Side elevated highway in New York City and its extension north-ically to connect with the Westchester County Parkways. The George Washington Bridge and its elaborate system of approach and connecting roadways as well as its general purpose as a by-pass route for traffic which formerly passed through New York City. The complicated Triboro Bridge which is not merely a bridge but a connecting traffic link between New York City and the Westchester and Long Island Parkways and through highway routes to the north and east. The 38th Street Tunnels in New York City and their carefully designed systems of approach highways between New Jersey and Long Island.

There are also the Long Island Parkways, the Wacker Drive and Lake Shore or Outer Drive in Chicago, the East Boston Tunnel and its approach roads, the Worcester-Boston highway with its dividing strip between opposing lines of travel, built several years ago, and others.

All these are examples of the highest types of the highway designer's art which will compare favorably with anything of the kind anywhere in the world. It therefore cannot be said with fairness and reasonableness that American engineers are not fully capable of meeting the situation or that they fail to realize not only what the present requirements are but also what future requirements are likely to be in reasonably providing both for traffic capacity and its safe conduct.

Engineers in this country also have been among the first to recognize the eco-

nomie aspects of the problems of highway transportation, relation of construction costs and design to costs of delays, values of rise and fall, limitations of gradients and effect of these on operating costs of vehicles, effects of curvature, etc., as well as the effect of construction methods and types on maintenance and subsequent annual costs.

Much, perhaps most, of this work, however, represents attempts to overcome traffic difficulties in congested traffic areas in the vicinity of large cities or metropolitan areas and each case has presented a special problem in itself. These cases almost inevitably involve extremely heavy expenditures as, for example, the \$40,000,000 which was the cost of the 13 miles of Route 25 New Jersey, from the Holland Tunnel to Elizabeth, which did not include the expensive connections of Routes 29 and 22.

A cost of from \$500,000 to \$1,000,000 per traffic lane per mile, comparable to the cost per track mile of metropolitan rapid transit subway and elevated lines, may be thought of as a round figure for the cost of such construction. This, again, may be compared with a cost of from \$50,000 to \$100,000 per mile as the cost of ordinary first class high type two-lane highways in not too difficult terrain in the open country and of course without the elimination of grade crossings.

In reference to speed, however, it should be noted that because of the density and volume of traffic on these highways speeds of 35 to 40 m p h are about the maximum obtainable.

OTHER GENERAL HIGHWAY REQUIREMENTS

While the need for these expensive constructions in congested areas of many of the large cities of the country is being acutely realized, there is also a demand for through express highway routes in the open country. It is proposed that many of these routes should be four-lane high-

ways with a separating strip between traffic in opposite directions, highways with grade crossings eliminated or permitted at only long intervals, and with a strip of land on either side which would guard against encroachments and prevent the erection of buildings abutting directly on the highway. These are the so-called "freeways" to which reference has been made frequently during the past year or so.

Such roads, designed and laid out to meet these requirements, need not, of course, be entirely completed at the beginning but it is advocated, and with a good deal of reason, that where the necessity is apparent, complete designs should be made in the first instance, and the necessary rights-of-way obtained.

It has been suggested that there be a system of trunk lines of this character laid out on three or four routes crossing the United States from east to west and other routes from north to south.

In New York the Superintendent of Public Works has proposed to the Legislature of that State the construction of a system of 927 miles of four-lane trunk highways (without the elimination of grade crossings with other highways), crossing the State in both directions, north and south and east and west, to be built at a cost of some \$300,000,000 and the Merritt Parkway is actually under construction in Connecticut from the end of the Westchester County parkways in New York to Bridgeport, Conn.

It is evident, therefore, that American engineers are also fully cognizant of the needs of this phase of the situation and the requirements of highways for through routes in the open country when money is made available.

Incidentally, it may be noted that one short section of such a four-lane highway now proposed by the State of New York, with exceptionally heavy grading but having no bridges or structures of any

importance, is estimated to cost around \$300,000 per mile.

Before leaving this phase of the subject it may perhaps be worth while to refer to what is probably the outstanding development of recent years in the construction of multiple lane highways, namely, the actual physical separation of lines of traffic moving in opposite directions.

This, of course, has come about through the increase in travel on such highways and the fact that smooth pavements, good alignment and favorable gradients make faster driving possible. It was not foreseen by highway builders of only a few years ago but was adopted wherever possible as soon as its need was apparent. It is, however, hardly fair to the road builders of a few years ago to accuse them of negligence or lack of vision for not having foreseen this need. Neither is it correct to say that highways which do not have the dividing strip are obsolete. On these roads there must be more care in driving and it is not unreasonable to ask that there should be

DISTRIBUTION OF HIGHWAY FUNDS

Criticism is made of the design of these main line highways, both urban and interurban, and it is claimed that due consideration is not being given to the speed capacities of modern automobiles, that is, in providing long sight distances, and freedom from obstruction. Roads of high character, however, have become necessary because of the need of accommodating large volumes of traffic, and maximum traffic capacity is not attained with vehicles moving at extremely high speeds.

No doubt many of the proposals for super-highways, parkways, freeways, and express highways have merit and may be economically justified by savings in the costs of operation of the vehicles using them, but highway officials are compelled to have constantly in mind the requirements of all the people in the ter-

ritories over which they have jurisdiction, and the need of making a fair distribution of such funds as may be available. They must consider the farmer going to market as well as the pleasure seeker and fast driver.

A notable example of adequate appreciation of this part of the problem is the recent report of the New York State Highway Survey Committee which first made a most comprehensive survey of the highway needs of the State and the present and probable future use of the highways, and then proposed the following program of constructing, reconstructing and rehabilitating the highway net-

(a) State Highway Reconstruction Program (5 yrs)	\$138,000,000
(b) Construction to Complete the State System and including parkway construction outside cities (8 yrs)	80,000,000
(c) Arterial streets and by-passes outside New York City (5 yrs)	35,000,000
* (d) Construction to complete County Road System and reconstruction	124,000,000
* (e) Construction to complete Town Highway System	66,500,000
* (f) Arterial Highway System in New York City	60,000,000

* Time within which system will be completed not shown

A similar study was made and program proposed for a coordinated highway net by the State Highway Engineer of New Jersey in a most comprehensive report made to the State Highway Commission of that State in 1926. There are, of course, many other similarly comprehensive studies so that this phase of the problem has also received attention.

GENERAL HIGHWAY REVENUES

It is not necessary in the present discussion to go into much detail in the matter of highway revenues and expenditures but a few general figures will indicate the dimensions of the problem.

The total highway revenues for the whole of the United States for 1935 are stated by H. Tucker in the *New York Times*, December 6, 1936, to be

<i>For State Highway Systems</i>	
Federal appropriations	\$277,788,551
Traffic taxes*	950,456,000
<i>For County Roads and City Streets</i>	
Property Taxes (estimated)	1,000,000,000
	<u>\$2,228,244,551</u>

* \$135,710,214 diverted to other than highway purposes

In the whole of the United States the amount of taxes diverted to other than highway purposes is approximately 15 per cent.

The sources of revenue for State, County and urban streets and highways vary but some general idea of what this variation is, is shown by the following figures presented by Thos. H. MacDonal, Chief of the United States Bureau of Public Roads, at the December, 1936, meeting of the Highway Research Board. These figures are for nine States and are for the years 1930-1933.

<i>State Highways</i>	
Motor vehicle taxes	\$139,000,000
Federal aid	33,000,000
Property taxes	10,000,000
<i>County Roads</i>	
Motor vehicle taxes	\$28,000,000
Property taxes	69,000,000
<i>Urban Streets</i>	
Motor vehicle taxes	16,000,000
Property taxes*	156,000,000
Miscellaneous	14,000,000

* \$111,000,000 special assessments

It is estimated that there are 3,000,000 miles of roads in the United States of which only 14 per cent or 422,582 miles are included in State highway systems. These latter are classified (New York Times, December 6, 1936) as follows:

	Miles	Per Cent
High type	114,144	27
Intermediate	87,677	21
Low type	114,213	27
Unsurfaced	106,548	25
	<u>422,582</u>	

The problem of bringing all these roads up to a reasonable standard of usability is a large one and would seem to require more attention than the building of speedways

THE GENERAL PROBLEM OF TRANSPORTATION

In considering the appropriation and application of highway funds, that is, public monies, to special needs, to encourage speed or even to facilitate movement, some consideration should be given to the transportation problem of the country. The efficient maintenance and operation of our railway net is today, and so far as we can see into the future, an essential, even a vital need of our industrial and economic well being. We should then give due consideration to the place of the highway, at any rate to that of trunk line highways and main travel routes as part of the general transportation system of our country. So long as we have transportation needs of all kinds to be met, it is at least questionable how far we should go in duplicating facilities. This may be increasingly important when we consider the ever increasing control of the railways by Federal authorities and the not improbable eventuality of governmental operation of the railways.

John S. Worley, Professor of Transportation Engineering of the University of Michigan, states in *Engineering News-Record* of December 10, 1936

"Motor vehicles have been improved mechanically so as to make them capable of traveling over long distances at high rates of speed with a high factor of safety and economical cost of operation. They are required (however) to be operated over highways which do not provide complete safety of operation and do not permit the full benefit of the very efficient vehicles we now have at our disposal."

In evaluating this statement there should be some thought of national econ-

omy as well as that of the motor vehicle and its users.

Dr. Harold G. Moulton, President of Brookings Institute, quotes⁷ Joseph B. Eastman as stating "The time has surely come to deal with these matters with an eye to the general welfare of the community which, in the end, foots the bills." Reasonableness would seem to require that we consider the country as a whole (and the same arguments apply generally to almost any State as a whole) giving due consideration to at least two criteria to be applied to the expenditure of public funds for these main and trunk line highways.

- A The relation of the highway net to other forms of transportation, and an equitable distribution of public funds based on this relation
- B The relation of the trunk line highway net to secondary or other highways, and the equitable distribution of available funds to all the roads

It should be kept in mind that this present discussion refers to main routes and trunk line highways and does not take into consideration land access or property development roads which are mostly paid for by property assessment or local community taxes. It must be remembered, however, that while these third and fourth class roads permit access to property they also permit owners of the properties to receive supplies, often previously hauled over main transportation routes, and to ship away from such properties goods or commodities produced there. Such roads, therefore, evidently deserve economic consideration.

COSTS OF HIGH SPEEDS

Prof. R. A. Moyer calls attention in *Proceedings Am Soc C E*, May, 1937, p. 940, to the very greatly increased costs

⁷ *Railway Age*, November 14, 1936

of vehicle operation due to high speeds
He says

"Fuel costs at 70 m.p.h. are almost double the costs at 40 m.p.h. and there are indications that at 100 m.p.h. the cost is three times as much as at 40 m.p.h. for the same car"

Costs of oil, tires, and repairs follow a similar trend and he calls attention to the fact that in automobile races, where speeds of 100 m.p.h. or more are maintained for only 500 miles, engine breakdowns are frequent

As confirming this, it may be noted that in the Vanderbilt cup race held on July 5, 1937, on a special course at Westbury, L. I., only 12 out of 30 cars finished the 300 mile race, that the average speed of the winning car was 82.6 m.p.h. and that of the slowest car which finished, 68.6 m.p.h.

It has already been pointed out that conservative manufacturers consider that car design for speeds of 100 m.p.h. is necessary, not that cars be driven at that speed but to provide the necessary factor of safety, for long service, at moderate speeds, without breakdowns, for economic operation and to keep the strain and tension on the driver within ordinary physical limits

The German Government recently (1937) made a test to try to determine the economic difference in operation over the ordinary highway between two cities about 100 miles apart and the new super-highways. They found, among other things, that while an average speed of 74.4 m.p.h. could be and was maintained on the super-highway as compared with an average speed of 44.4 m.p.h. (maximum speed in both cases 80 m.p.h.) on the ordinary highway, the gasoline consumption on the super-highway which had better surface, better alignment and required no stops was 5.5 gal. as compared with 5.95 gal. on the ordinary road

ACCIDENT RECORDS

That accidents on highways, due to the operation of motor vehicles, is a most serious problem has obtained general recognition and publicity in recent years. Figures from different sources vary somewhat but those given below may be considered nearly enough correct to indicate the dimensions and characteristics of the problem

The National Safety Council reports that in 1935 there were 825,000 accidents to motor vehicles on highways, resulting in 37,000 fatalities, 105,000 permanently disabling injuries, and 1,180,000 temporary disabilities

The fatal accidents were classified (partly estimated) as follows

Due to collisions with	
Pedestrians	16,150
Other motor vehicles	9,650
Railroad trains	1,600
Street cars	250
Fixed objects	4,300
All other vehicles	550
	<hr/>
	32,500
Non-collisions	4,500
	<hr/>
	37,000

In the first quarter of 1937 there was a very decided increase, of about 25 per cent, in the motor vehicle accidents as compared with the first quarter of 1936

The classification as between types of vehicles, of fatal accidents, in 1936 is given as:

	Per cent
Passenger cars	77
Commercial cars (trucks)	18
Taxis, buses, motorcycles	5

This is some, very slight, indication of the effect of the skill of the driver on freedom from accident. Comparing driving by day and night, the *New York Times* on November 22, 1936, said, "last year 21,480 people were killed in accidents between 6 00 P.M. and 6 00 A.M., that is, at night, and 14,620 between

6 00 A M , and 6 00 P M , or during the day ”

The National Safety Council in its 1936 report (p 30) states that “the open road should now be recognized as the location of today’s most serious traffic safety problems Between 1924 and 1935 deaths from motor vehicle accidents in cities increased 27 per cent, whereas rural fatalities increased 150 per cent ”

As long ago as March of 1924 the *Engineering News-Record*, commenting on the agitation at that time for the elimination of grade crossings of highways with railways, said in an editorial “the really dangerous place is straightaway pavement in an excellent condition of service ” This is equally true today, over 13 years later, and is an interesting comment on the fact that improvements in alignment, gradients, surface, etc , do not necessarily insure safety

The effect of speed on fatalities is shown by the following tabulation of fatalities due to vehicular accidents at various speeds

0 to 20	m p h	1	accident in	61	is fatal
20 to 29	“	1	“	42	“
30 to 39	“	1	“	35	“
40 to 49	“	1	“	25	“
50 and over	“	1	“	11	“

It is stated that 9 out of 10 vehicles involved in fatal accidents were going “straight ahead” and in non-fatal accidents 8 out of 10 contemplated no turning movement

The report “Motor Vehicle Speeds on Connecticut Highways,” Yale University, 1936 by Charles J Tilden, also points out the fact that not only is the severity of accidents increased with the increase in speed but the chances for such accidents also increase It was concluded from the observations made that high speed drivers have 45 per cent more accidents than do low speed drivers

To what extent is the highway structure itself responsible for these accidents?

Mr E C Lawson, Assistant Commissioner of Highways of the State of New York, in *Civil Engineering* of March, 1935, referred to the fairly well known fact that only about 5 per cent of all accidents are attributed to highway design, and that more accidents occur on straight roads than on curves

In the Proceedings of the Highway Research Board for 1935 Vol 15, p 430, it is stated by Arnold Vey, Traffic Engineer of the New Jersey State Highway Commission, that probably 85 per cent or more of all accidents on highways are chargeable to some improper action on the part of the driver or drivers involved

Mr Charles M Noble, however, states (Proceedings Am Soc C E September 1936) “many more accidents are chargeable to the highway itself than statistics indicate The failure to attribute accidents to faulty road design is due to several causes the principal of which is the subtlety of the problem—officials are not always trained to analyze the basic cause of accidents ”

In Proceedings of the Am Soc C E for February, 1937, Mr J C Carpenter of the United States Bureau of Public Roads, compares the accident records on three roads in Texas, two old and one new, each of about the same length, the new road having excellent alignment, low degree curves, better sight distances, pavement 22 ft wide in excellent condition, fairly comparable traffic During the fiscal year ending August 1936 the accident records on those three roads were:

Date constructed	Old Roads		New Road
	1924	1922-1927	1934
Total accidents	15	45	64
Total killed	2	10	10
Total injured	26	48	49

Mr Carpenter points out also that good alignment and smooth pavement are likely to induce sleep and that 25 per cent of the accidents are caused by over-

taking other automobiles, a difficulty which will not be remedied by dual roadways or other devices for "building safety into highways" On all roads speed is responsible for a large percentage of the accidents

Park Commissioner Robert Moses of New York, commenting in December, 1936, on accidents on the New York City and Long Island Parkways, is reported to have said, "Considering their traffic load the parkways are the safest arteries in the Metropolitan area" but he announced that "speed limits would have to be reduced and that police action is needed to cut down speeding" Such accidents as do occur, he said, "are the result of speed rather than bad lighting or improper construction"

The present writer pointed out (Proceedings Am Soc C E November 1936), "There should be taken into consideration from the standpoint of safety the effect on the driver of a monotonously even surface There is some evidence that this may tend to dull the senses and produce a state of at least semi-somnolence which does not develop in driving over roads where vigilance is obviously necessary"

This, of course, does not mean that we should go out of our way to build roads with crooked alignment and rough pavements but it does indicate that the reverse is not entirely warranted because of probable decrease in accidents on this account

The experience in England corresponds very closely to that of the United States In England and Wales, in the 5 years 1926 to 1932, inc, the "Failure of the Human Element" is stated to have caused about 84 per cent of all the accidents These were divided

	Per Cent
Drivers	32
Pedal cyclists	12
Pedestrians	39

The rest of the accidents were divided

	Per Cent
Vehicle defects	52
Road defects ..	56
Weather and misc	51

In a paper entitled "Road Design and Road Safety", presented to The Institution of Civil Engineers in December, 1936, F C Cook states that in Great Britain the total casualties on the road in the year 1935 were 6,502 killed and 221,726 injured.

This very interesting paper not only analyses the accidents and their causes but also the effect on accidents of remedial measures of design and construction, but the author concludes, among other things, that "The overwhelming majority of road accidents are due to the personal element and occur in circumstances for which the road user is primarily responsible" He further states that "out of this total of 6,289 accidents, 4,094 (two-thirds of the whole) occurred on the open road under conditions in which there was apparently ample visibility, whilst 1,883 were at junctions and 253 on bends and hills described as having 'bad sight lines'"

Mr Gilmore D Clarke, Landscape Architect to the Westchester County Park Commission and to the New York City Department of Parks, writing in Civil Engineering of April 1937 says

"It need hardly be stated that motorists are not capable of driving safely at that high rate of speed (100 m p h), and it is safe to predict that ordinary driving speeds probably never will exceed 50 m p h At present we cannot afford to design roads for speeds much greater than this In the first place curves superelevated for even this speed are exceedingly dangerous in the winter months and, in the second, the capacity of a road upon which high speeds are permitted is materially reduced"

A very interesting report on certain aspects of accidents at grade crossings of highways with railways was made by Warren Henry, Assistant Chief Engineer

of the Illinois Commerce Commission, at the Annual Highway Conference at the University of Michigan on February 17, 1937.

A detailed investigation in Illinois of crossings, crossing protection and the actions of drivers, showed that there, also, the human element was the most important factor

This analysis, which is lengthy and detailed, is particularly interesting as showing the general diffusion of accidents at all types of crossings. Then taking one particular crossing, protected by mechanically operated lights, it was found that the warning was practically disregarded by some 49 per cent, or nearly half, of all the cars which reached the crossing after the warning signal first flashed. Even up to 10 sec before the train arrived, about 15 per cent of the cars which reached the crossing proceeded to cross. All this in spite of the fact that cars are required by Illinois State law to stop for red lights at railroad crossings as they are elsewhere.

While automobile drivers persist in taking such chances with their own lives, with the lives of passengers in their cars, and with the lives of crew and passengers on the train, it is utterly futile to talk about "building safety into highways."

DESIGN TO AVOID ACCIDENTS

It seems to the writer, therefore, reasonable to conclude.

- a That fatal accidents on highways are to a large extent due to the operation of private passenger cars
- b That high speed of operation is an important factor in the causation of accidents, this especially, in view of the fact that collisions with pedestrians and other motor vehicles are the cause of about 70 per cent of all fatalities

It is, therefore, at least doubtful if the design of highways to permit or facilitate the driving of cars at high speed, or at least design which increases cost to obtain these purposes, is sound practice. It is also doubtful if highways as they exist today are in themselves greatly responsible for accidents.

It is true perhaps that with our present methods of reporting, all the causes of accidents are not made evident, and it is quite possible that defects in the road itself may have been contributory causes in some cases. It is difficult for the present writer, however, to believe that defects, or lack of perfection of structure of the existing highways, are major or even important causes of highway accidents.

Here reference should be made to the elimination of grade crossings of highways with railways. Each of these crossings is a problem in itself, having as main factors to be considered, volumes of traffic on both routes, as well as sight distances, etc. The elimination of many of these crossings is desirable but this, it seems to the writer, is an entirely different problem from that herein generally referred to which has to do with the layout, alignment, gradients, etc., of highways to permit or encourage high speed driving.

It is also at least interesting to speculate whether or not nearer approach to perfection in the highway structure and its design to permit or facilitate the driving of cars at high speeds is desirable either from the standpoint of safety or that of sound practice, or warranted by any economic consideration.

The writer considers it a fallacy to think, as some writers have stated, that highways designed for speeds of 100 m p h offer a factor of safety to drivers at moderate speeds. (See previous note on Oregon Highways.)

There is little doubt, where traffic demands make it necessary, highways of

high class types have to be built. The traffic requirements in these cases make it inevitable that on long sections of such routes the highest speeds of which modern cars are capable can be attained but it certainly is a matter for grave consideration as to how far we should go in projecting good alignment, low rates of gradient, and other improvements requiring large expenditures of public monies for heavy excavations, embankments and drainage structures, solely or largely to permit high speeds for a limited number of highway users and, so far as can now be judged, increasing the probability of accident. The necessary curve elevations for the high speeds may also be a danger factor to cars driven at lower or normal speeds.

As a matter of fact, where traffic demands are such that these expensive highways are required, the traffic density at times of maximum demand is such that speeds of 35 to 40 m p h are probably the most that can be attained. Why then should such highways be designed so that at time of light traffic demand, which includes the night and early morning hours, speeds of 90 or 100 m p h can be attained with "safety"?

What then are the conditions, if any, where design should take cognizance of speeds of 90 or 100 m p h or of speeds in excess of, say, 50 to 60 m p h which can probably be assumed to be the usual maximum, certainly the safe maximum today, for a large majority of drivers?

In considering this problem those who advocate designs based on higher speeds seem to have developed two main reasons

- a That the difference in cost may be negligible and that the added factor of safety is worth this added cost
- b That there is an ever increasing tendency to build automobiles capable of attaining the higher speeds,

therefore, the highway engineer is neglecting his duty in not building to meet the demands which may be made by the drivers of such cars

DIFFERENCE IN COST AS AFFECTED BY SPEED

As to difference in cost, this probably will be affected by two major items

- 1 *Grading and Drainage* That is, the formation of the roadbed to permit longer sight distances due to easier horizontal curvature, longer, flatter vertical curves, and low rates of gradient
- 2 *Obstructions* Primarily, the elimination of crossings at grade with other highways or railways, providing wider shoulders, taking of additional rights-of-way to prevent encroachment, etc

SPEED CAPACITY OF VEHICLES

As to the second reason, the consideration of high speeds because automobiles are built which permit these speeds, and that the tendency of car design and construction is toward even greater speed possibilities and flexibility and ease of operation. This gives no consideration to the fact that there are two factors which have to do with the speed at which automobiles are driven, namely, the driver and the car.

It is the belief of the writer, although he has no definite proof of the fact, that a very large proportion (probably over 80 per cent) of the drivers of passenger automobiles (private cars) are incapable of driving with any degree of safety at speeds in excess of 40-50 m p h, very likely a good deal less than this. Furthermore, it seems doubtful if ordinary drivers of private cars, who do not make driving their business, will, as a class, at any time in the near future, be capable of driving safely at speeds above 40-50

m p h , no matter what the road conditions may be or what improvements there may be in cars

It is claimed by Mr C M Noble, Proceedings Am Soc C E May, 1937, p 945, that the improvements in design of cars, steering, brakes, reduction in vibration, etc , have eradicated all sense of speed value, with complete lack of nerve tension and fatigue for the operator That this is to some extent true cannot be successfully contradicted, and yet it is the writer's observation, both as a driver himself (for nearly 30 years) and as an observer of professional drivers (chauffeurs) of private cars that it is only rarely that speeds of 60 m p h are exceeded even with modern cars

It may be admitted as true that accidents due to failure of the car mechanism, including tires, have been greatly reduced but they are far from being eliminated and it must, or at least should be, assumed that some element of failure may be present in any car It is of course also true that elements of failure are always present in even the best of drivers and to a greater degree in others less skillful

Taking these elements together, therefore, it seems inadvisable to permit or encourage driving at speeds over 50 or 60 m p h.

EFFECT OF SPEED ON HIGHWAY CAPACITY

Mr Chandler Davis has pointed out in Proceedings Am Soc C E March, 1937, p 592, that at speeds of 100 m p h 836 ft is required for an emergency stop of a car in first class condition with modern 4-wheel brakes (Longer distances for cars less well equipped or with drivers not fully alert mentally) This prescribes the spacing of cars and works out about 7 cars per mile if a speed of 100 m p h is to be maintained, an obviously absurd condition when applied to the expensive roads which may permit such speeds

He calls attention to the fact that the United States Army, after careful study, has established a spacing of 30 yards between trucks, moving in companies, at 40 m p h , that is, 54 trucks per mile of highways

In view of the fact, therefore, that money is not now available, and apparently for many years will not be available, to anywhere meet the general requirements for all highway users, it appears to be most unsound to build unnecessarily expensive highways of very limited traffic capacity to meet the demands of only a small proportion of all drivers

It is probably true that many drivers do not preserve the theoretically safe stopping distance between cars going at given (high) speeds, expecting to utilize some of the stopping distance of the car ahead This, however, is not safe practice and if we are considering design for safety it may well be considered sound practice to stay within the limits of the ordinary capacity of drivers which probably is below 50-60 m p h

In discussing "Design Principles and Traffic Speeds" Mr E C Lawton, in *Civil Engineering* for March, 1935, gives the following example of distances required for the safe passing of vehicles proceeding at speeds of 40 to 50 m p h

"If a vehicle (No 1) is proceeding at a speed of 48 miles per h behind another vehicle (No 2), proceeding in the same direction at a speed of 40 miles per h while a third (No 3) is approaching in the opposite direction at a speed of 40 miles per h, a time interval of 40 sec and a sight distance of 2006 ft will be required for No 1 to pass No 2"

He further points out that

"With the present trend toward high speed for both private automobiles and trucks, the eight-mile difference in the rate of speed is a common occurrence on highways outside of cities and villages Under the conditions noted, it is evident that only 2½ operations of passing, theoretically involving 7½ vehicles, could occupy a given mile of highway at any one time

Of course, from a practical point of view it seldom happens that three identical operations are under way at the same moment on any one mile of public highway. On the other hand, it will be clearly evident that where there are many operations involving the passing of vehicles on any given mile of two-lane pavement, the safe capacity of the roadway is indeed limited."

In the Proceedings of the Highway Research Board for 1935, Vol 15, pp 472-4, it is pointed out that the free moving speed of vehicles on a first class highway, with from 0 to 10 per cent of trucks, is nearly constant and equal to about 43 m p h

A report of tests made by the Transportation Committee of Yale University cooperating with the Connecticut State Highway Commission states that observations in Connecticut in 1933-34 showed average speeds in winter of about 43 5 m p h and in summer 39 to 40 m p h. Mr. M. A. Conner, Commissioner of Motor Vehicles, states that about two-thirds of the motorists, of their own volition, travel at a rate of less than 45 m p h

NEED OF HIGHWAY CAPACITY

As a matter of fact the great highway need of today is capacity to meet traffic demands. Apparently also, and so far as can be judged by even the most farsighted engineers and highway authorities, this is going to be the most important need for some years to come. Furthermore, it is an accepted fact that maximum capacity is only achieved at comparatively low speeds, probably at speeds less than 30 m p h

The Superintendent of Public Works of the State of New York, in his annual report for the year 1936 (published May 1937), after enumerating the benefits of good roads says (p 5) "In spite of these indisputable assets which follow good roads, highway construction in practically every State in the Union has

lagged behind the traffic demands. The New York State Highway System is trailing present day requirements (of traffic capacity) the falling behind in highway construction has been especially noticeable during the past three years" (See note elsewhere in regard to gas tax diversion in New York)

SUPER-ELEVATION OF CURVES

There seem to be very decided differences of opinion in regard to the proper degree of super-elevation for curves, one theory being that it should permit the operation of cars with safety, i e, without side slip, in ordinary weather at the same rate of speed as is possible, or usually attained, on tangents on the same road

In easy country where flat long radius curves are the rule, this is probably practical but it is generally impractical in rolling or hilly country, and entirely so in even fairly rough country, to elevate the outer rim of sharp curves for the higher speeds

Curve elevation on railways is a compromise between that necessary for high speed passenger trains and that which will not unduly increase the resistance of slower and heavier freight trains. This may mean a slow order or slow signal for some passenger trains. It does not seem unreasonable to expect automobiles to obey proper signals or signs and slow down for sharp curves which may not permit speeds of even 50-60 m p h

There is a certain body of opinion which objects to variation in alignment, gradients and sight distances which require slowing down from whatever may be considered normal speeds on the greater part of the highway length. The writer is, however, of the personal opinion that such objections are not valid

Transition Curves: There is some difference of opinion as to the value, if any, of transition curves, or spiralized curves

on highways Inasmuch, however, as the modern passenger car is a very flexible easily controlled machine which occupies only 6 ft or so of width on a 10 or 11 ft lane, it seems to the writer to be an excess of refinement to introduce the transition curve in designs of highway alignment Even as a means of better fitting the alignment to topography it seems doubtful if spirals are likely to have much, if any, justification

The conditions which prevail on a railway where extremely heavy masses, with practically rigid connection between the wheel flange and rail, have to be changed in direction, do not prevail where the direction of the ordinary motor car weighing only a ton or two, moving on flexible rubber tires has to be changed Even with heavy trucks there is little comparison with the requirements for changing the direction of a heavy locomotive and train on a railway track

UNIFORMITY OF STRUCTURE TO PERMIT UNIFORM SPEED

Several writers have expressed the opinion that highways should be designed so that uniformity of speed may be maintained, that curves be so developed that drivers reaching them after having driven for some distance over straight or nearly straight stretches of road shall not have to materially decrease their speed

Mr E C Lawton, in *Civil Engineering*, March, 1935, after calling attention to the requirement of the New York State Highway Department for "sight graphs" to accompany maps of proposed new construction, makes the following comment

"When the motorist comes to a place where the sight distance is suddenly restricted, in a section of road where vision previously has been ample, the travel hazard has been increased Such unfavorable combinations are immediately disclosed by the use of the sight-distance graph Whenever special conditions unexpectedly reduce the vision at isolated lo-

cations, considerable time and money are expended to eliminate or improve them, particularly on main routes On the other hand, where a number of unfavorable situations rather close together are encountered in mountainous territory, the motorist is prepared by the gradual reduction in vision to operate his car in a safe and rational manner This feature of gradual reduction in vision is very important in highway design, particularly in rolling and mountainous country where the vision may be restricted for considerable distances"

Given all the conditions to which reference has previously been made, there seems to be no adequate reason for the assumption that road conditions should permit uniform speeds If curves are to be super-elevated such super-elevation should be gauged to meet the needs of the moderate or average driver, and proper signs should give drivers adequate notice of any change

Reference has been made to railroad safety as compared with highway safety but every locomotive driver has been trained from his first days on the railroad to watch for signs and signals He never knows when he may have to apply his emergency brakes, or at least to slow down Locomotive drivers are not only traditionally keen and alert, but are picked men whose physical condition is continuously checked It is little to ask of any driver of a high powered car, or for that matter of any car on the highway, to be ever on the alert for signs or signals requiring him to slow down or stop

Signs and warnings on highways should, of course, be conspicuously and clearly displayed, and there should be every endeavor made to have them uniform, but it seems to the writer that there is every reason for asking and expecting the drivers of motor vehicles to look out for, see and obey signs

The National Safety Council in its 1936 Report (p 26) says "The careful, skillful driver, however, rarely has an accident, even on a defective highway"

Here again it should be repeated that the fact that drivers can be warned and that warnings should be obeyed, is no reason for introducing unnecessary hazards or for not attempting, within reason, to remove hazards, but fair and reasonable judgment has to be exercised here as everywhere else

EFFECT OF SPEED ON DESIGN OF VARIOUS TYPES OF ROADS

Super-Highways or Arterial Highways This class of highways may be considered to include those built to relieve congestion in and in the vicinity of large cities. It is doubtful if, from the very nature of such highways, speeds in excess of 40-45 m p h can be considered. Such highways are designed for large volumes of traffic the general speed of which cannot properly exceed 40-45 m p h

There has been some criticism of the slow signs on the West Side elevated highway in New York where on good alignment normal speeds of 35-45 m p h are permitted but where at certain points where sharp reversed curves have been built signs require slowing down to 20-25 m p h. So far as the writer knows, and has observed, these slow signs offer little difficulty and it seems doubtful if they decrease traffic capacity.

Parkways and Freeways Highways of this class are also designed to accommodate large volumes of traffic and are only justified where such traffic exists. They are located in more open country, generally in the vicinity of large cities, forming arteries of approach through more or less built up areas. They are characterized by freedom from interruption of the flow of traffic by reason of the elimination of all or nearly all obstructions such as crossings of railways or other highways at grade, exits and entrances being only permitted in the direction of the traffic flow and at fairly long intervals.

On these roads good alignment, moderate rates of gradient and consequently long or fairly long sight distances are desirable. Being located in open or less densely built up country, costs of rights-of-way are usually not unduly increased by providing for reasonably good alignment. Both alignment and gradients, however, have to be a compromise between topographical restrictions, costs of rights-of-way and costs of construction.

They, therefore, in themselves may permit the attainment of high speeds. It is doubtful, however, on account of the large volumes of traffic which they carry, and which justify the expenditures necessary to provide them, that speeds of over 40 to 45 m p h need be considered in their design, inasmuch as this is about the highest speed at which large volumes of traffic move.

On account of the cost of these so-called "Freeways," the necessary acquisition of expensive rights-of-way, and the destruction of taxable values of lands so appropriated, it is doubtful if such highways will, for a good many years to come, form an appreciable part of the mileage of our highway system.

The development of encroachments, however, especially gas stations, eating places, etc., with their attendant risks and reduction of highway capacity is one which is receiving considerable attention and in order to provide for such places, which are an accommodation to motorists, it has been suggested that definite setbacks be provided along important highways so that cars need not be parked or stopped on the pavement.

Even with this provision, however, care will always be necessary to avoid collisions with stopping or starting cars and this is a precaution which drivers may well be expected to exercise.

Traffic conditions and the number of accidents on the Long Island Motor Parkways have made it necessary not

only to restrict speeds but to use a sufficiently large police force to enforce the restrictions. As the result of several serious accidents in which speed had been a factor, these restrictive regulations were recently put into effect and in explaining them Commissioner Moses (New York *Times*, December 20, 1936) is reported as stating, "The parkways are the safest arteries in the Metropolitan area and such accidents as do occur are the result of speed rather than bad lighting or improper construction."

Main Trunk Highways These may be considered, for the purpose of this discussion, as either four-lane or two-lane highways in the open country.

Modern design of such highways calls for high class pavements, lanes at least 10 ft wide (with some tendency to widths of 11 or 12 ft), separation of traffic moving in opposite directions, (at least on 4-lane roads), fairly good alignment and reasonable rates of gradient. Most of such roads will probably avoid crossings of railways at grade, but will not usually avoid grade crossings with other highways, though the most important of these will be protected by signal lights.

It must be borne in mind that the elimination of grade crossings with other highways not only involves very costly construction but lack of convenient access to main highways which may be a hardship to rural communities. The desirability of eliminating crossings with railways has already been referred to.

It is probable that in ordinary fairly easy country such roads might be expected to have curves with at least 1,000 ft radius, maximum gradients of 3.5 per cent to 5.0 per cent (the maximum to avoid slowing up of trucks with consequent reduction of traffic capacity) and sight distances of not less than 1,000 ft, sufficient under normal traction conditions to permit stoppage of a car with good brake equipment travelling at 100

m p h after the driver perceives the need of stopping.

It is not, however, reasonable to expect the establishment of such conditions as this in many parts of the United States except in the prairie regions of the Mississippi valley. As an example may be cited a 4-lane highway of the highest class, for which contracts were let by the State of New York early in 1937. The section referred to is a part of the main trunk highway on the west side of the Hudson River, and located near West Point about 70 miles north of New York City. It is a 4-lane highway with division between opposing lines of travel, heavy concrete pavement, and is located in hilly to almost mountainous country, has fairly long sustained gradients of 7 per cent in which are short stretches of 7.6 per cent and 8.0 per cent, there is one curve of 410 feet radius on 5.48 per cent gradient, and minimum sight distances at the summit vertical curve of 425 ft.

It is very evident of course that this highway will not permit, even if there were no other traffic, safe driving at 100 m p h and yet, so far as the details of location are concerned, and assuming that it is necessary to build the highway through this territory, there can be little criticism of the standards adopted, when the topographical conditions are taken into account. According, however, to some of the citations made at the beginning of this paper this highway is obsolete before it is built.

Where then, in view of all the statements previously cited that 100 m p h should be a normal standard of design, should this be applied?

As a matter of fact, the proposed network of 4-lane highways which it is proposed to build in the State of New York is said to be necessary to take care of a large volume of traffic.

It is a pretty well established fact that fairly large volumes of traffic on good

roads do not, and probably cannot, move at speeds over 40 to 45 m p h. If traffic is very dense it tends to move at somewhat lesser speed, if not very crowded, speeds up to perhaps 55 m p h may be attained.

It is evident that in easy country permitting long tangents, long radius curves and easy gradients, such roads in themselves permit the driving of cars at high speeds, but there is always the danger of the entry onto the road of vehicles from driveways to private property and from cross roads. Omitting from consideration other traffic it would appear that speeds of over 90 to 100 m p h are inherently extremely dangerous and even 50 to 60 m p h involves the taking of chances on such highways. As a matter of fact the Oregon State Highway Commission recommend 65 m p h as the "safe" driving speed on such roads, (designed for 100 m p h) presumably for drivers capable of "safe" driving at that speed.

It would then appear that in more difficult country there can be no valid reason for adopting standards applicable to high speed for roads of any type, and even in easy country it is doubtful in any expenditure, certainly no very large expenditures, are warranted solely to permit high speeds.

Secondary Roads In view of the foregoing it hardly seems necessary to discuss the design of secondary roads for high speeds. The writer, however, happened recently to travel over a road in Virginia which may be considered typical of the so-called obsolete road. The car was a heavy passenger car of the latest model of one of the more expensive makes driven by a very skillful professional driver.

The section driven over, about 40 miles in length, runs through farming country of diversified topography. There are some quite long stretches of tangent through gently rolling country, other

stretches with a fair amount of curvature in heavier rolling country, and certain sections in fairly stiff hilly country.

The pavement is of a light type of bituminous macadam about 18 to 20 ft wide, shoulders about 3 ft wide, built 10 to 20 years ago, and with a surface today which can be classified as only reasonably good. It is laid practically on the surface of the ground with the minimum amount of grading so that the profile in places is quite irregular with short vertical curves and in places quite short sight distances. It carries an average traffic of about 1,000 cars per day of which 20 per cent are trucks.

It is possible for a reasonably good driver to attain speeds of 50 to 55 or even 60 m p h over about 60 per cent of the distance. On the balance, it is necessary, for reasonably safe driving, and not considering other traffic, to slow down to say, 40 m p h and in a few places to 30-35 m p h.

OBSOLESCENCE

According to some of the citations made at the beginning of this paper this road is evidently, in the opinion of the writers quoted, now obsolete and would be considered dangerous, but in the opinion of the present writer it is neither, and presents today a reasonably good highway for reasonable drivers for reasonable public use. Unless the traffic should greatly increase it needs only reasonable maintenance of the pavement for some years and then perhaps gradual attention in improving certain sections over a period of years.

We shall have in the United States for many years to come, for many more years than we can now look forward to, roads of all classes and of infinite degrees of usability. Until the whole network is complete, therefore, the use of the term obsolete does not seem to be applicable.

Obsolescence is generally considered by engineers as referring to that stage of development where an old structure or machine can be economically replaced by a new one by reason of the increased capacity or more efficient operation of the latter in producing sufficiently lower costs to warrant the replacement

In this sense, therefore, a highway can only be considered obsolete when the cost of its replacement is warranted by demands for additional traffic capacity or by such increase in operating efficiency or safety of the vehicles expected to use it as will warrant the expenditure. In view of the fact that traffic in any considerable volume cannot move on any highway at speeds in excess of 40 to 50 m p h, its unsuitability for speeds in excess of this cannot properly be considered a factor of obsolescence

SAFETY

It seems entirely correct to state that all roads which are passable are "safe" for private cars in reasonably good condition, which are carefully driven by competent drivers. Trucks on construction jobs move, even when loaded, over the roughest surfaces

What then is meant by "building safety into highways"?

For the purpose of this present discussion, this will be considered as referring to the design and construction of new roads or complete reconstruction of old ones. It does not consider at this time incompetent or careless work or improper maintenance, either or both of which might be contributory causes of accidents on highways as elsewhere

On new work the writer understands "building safety into highways" means making such roads safe for such types of motor vehicles as may use them, driven at moderate rates of speed, by competent drivers. Such drivers may expect to find on ordinary highways at

certain places sharp bends or curves, may expect to find other cars entering or leaving the highway, or possibly cars parked or stopped, obstructing the main travelled way

All of these obstructions, or any of them, however, tend to reduce the traffic capacity of the highway and when or if greater capacity is needed some or all may need removal as an economic necessity. Even in the original design the competent engineer will, of course, provide for such capacity as may be expected to be needed at some reasonable future date, not merely that existing at the moment. These are matters of economics, however, rather than of safety

Consideration must be given also to the fact that under modern conditions, where the motor vehicle has come to be used almost universally as a means of transportation, and pays a fair proportion of taxes for road upkeep, motorists have come to expect better conditions than this, at least on main through routes. They expect on such routes smooth pavements, fairly long sight distances and reasonable freedom from the obstruction of stopped vehicles, conditions which permit driving much of the distance on highways of the first class at a maximum speed of 50-55 m p h and sustained average speeds of, say, 30-40 m p h where there are not too many towns to be passed through

It seems reasonable to expect also that on important main through highways at crossing with other important highways, there will be a separation of grades, at others traffic lights, and at less important crossings warning signs. Two factors may govern the decision as to which of these may be feasible and/or desirable, namely, availability of funds and economic justification. (See *Highways as Elements of Transportation Trans Am Soc C E Vol 95 (1931) p 1020*) Here also safety is a further important consideration inasmuch as acci-

dent records show a fairly large proportion of accidents at intersections. The cost of accidents and the economic value of prevention may be evaluated. There should be also, of course, on all roads warning sign of sharp curves, steep gradients, changes in general character of the road or pavement, and any other features which require slowing up, watchfulness or more careful driving.

GENERAL OBSERVATIONS

The writer wishes to repeat and perhaps emphasize the fact that he does not minimize in the slightest degree the need for continued and continuous study and adequate consideration of all the factors governing highway design, and nothing in this paper should be construed as absolving those responsible for the planning of new highways or the maintenance of old ones from making and keeping them safe for reasonably careful driving.

He pointed out several years ago the need of coordinating design and construction with operation and that may be considered to include safety and ease of operation as well as costs of operation.

Highway design can be divided into two main elements, (a) the location and (b) design of structures and pavement. Location is used in the old railroad sense of the adaptation of alignment and gradients to topography. Alignment and gradients affect safety of operation only in limited degree. They may affect economy of operation.

The densest passenger traffic on any railroad in the world, the New York subways and elevated lines, has been and is carried safely for years at fairly high speeds over curves of 135 ft. radius (90 ft on the old elevated lines).

Curvature and gradients do, however, cause increased expense of operation of railroad trains. It is probable that they do also to motor vehicles on highways. They certainly tend, in some cases of

sharp curves and heavy gradients, to decrease highway capacity, that is, they decrease the maximum number of motor vehicles which can pass over the highway in a given time.

Much may be done by the careful locating engineer to increase safety by careful adjustments of curvature and gradients, especially combinations of the two. Here, as Wellington remarked in *Economic Theory of Railroad Location*, skill with the transit or at the drafting table may lessen the use of the steam shovel.

Other factors of highway location and design, which may affect safety, are changes in characteristics from good alignment and easy gradients to heavy curvature and steep gradients, and perhaps more particularly abrupt changes of gradient without adequate vertical curves. There should not only be adequate warnings of such changes in the character in the alignment but possibly also a transition section may be worked out by the use of the transit and a few brains to permit the motorist to accustom himself to the change.

Abrupt changes in the character of the pavement should also be avoided in the interest of safety, either changes in the type of the pavement, transition from pavements with good traction to others which may be "slippery when wet", changes to narrow widths and so on. Such changes in character must be inevitable on many roads for many years to come and, of course, here also appropriate signs should be erected and the motorist should be expected to watch for them. The somewhat common custom of leaving narrow bridges at intervals along otherwise improved highways seems inexcusable except in the case of some long and very expensive structures.

It is, of course, to be expected that there will be improvements in design, since the science or art of highway building must progress as do almost all other

matters with which we have to deal. Those responsible for the building of new highways, especially roads with expensive pavements, should have an adequate realization of the fact that they are building structures for which a long life is to be expected and which are to be used by vehicles which are constantly and rapidly being improved. Every reasonable provision should, therefore, be made for the continued usefulness of the structure for some time in the future.

It is also fairly evident that having in mind the vast amounts being spent annually on our highways, the great need for additional traffic capacity which is pressing, and the needs of many kinds of users, that the highest type of engineering judgment, coupled with business sense and ability should be brought to bear in the laying out and design of the highway net as a whole.

Giving all due consideration to the future, however, it hardly seems to the writer that there is any reason for assuming higher rates of speed than 50-60 m p h in the design of any road, and even lower speeds than this in difficult terrain. It seems doubtful if the time is here, or likely to be here soon, where too much money should be spent in the removal of obstacles to fast driving unless in badly congested areas this can be shown to be economically justified. An adequate uniform system of signs and markers should be sufficient to warn careful drivers of changes in character or of surface alignment, or other reasons for watchfulness.

It is doubtful if provision for higher speeds provides a factor of safety in the highway structure but, on the contrary, may tend to encourage unsafe driving, and increase the accident risk. Both the National Safety Council in the United States and authorities in England note the increasing prevalence of accidents on the open straight stretches of highway where visibility is good.

While it goes without saying that continuous improvement may and very likely will be made in the design and construction of future highways of all classes, this does not mean in the true sense of the word that any highways are obsolete.

The fact that it is possible to drive modern cars at 100 m p h does not mean that it is normally safe to drive them at this speed even on the best of highways, especially when the road is occupied by other vehicles. Additional power over ordinary requirements permits flexibility and ease of driving but is a reserve force rather than one to be commonly used.

Admitting that the condition of the highway structure may be a greater contributing cause to accidents than present forms of reports or the matter of their making indicate, there is still overwhelming evidence that the human element is the great and predominating factor in highway accidents.

While it is undoubtedly the duty of the engineer to build and maintain highways so that they are safe for the normal traffic, normally conducted, which they are expected to carry, he cannot "build safety into highways" or "build accident proof highways" which will overcome the differences in drivers, their limited capacity and the general unreliability of many of them.

Even if it might be admitted that design for speeds of 100 m p h is desirable on some highways, the additional cost of this (over design for 50-60 m p h) must be weighed against the needs of the whole highway net and the present urgent need for greater traffic capacity. Provision for any special traffic requirement must be weighed and adjusted with the requirements of the whole highway net. In this connection due consideration should be given to the added cost of operation of motor vehicles at high speeds and the small proportion of operators who may be properly allowed to drive at such speeds.

One of the most important elements in highway construction is consideration of low annual cost per vehicle mile or per ton mile rather than provision for unduly high speed

While no one can deny the need of studying future requirements, it is probably not desirable to anticipate *unduly* future traffic needs in present day expenditures, first, because of the difficulty in obtaining money to meet even today's known traffic demands, second, because of the difficulty of forecasting future trends in highway traffic and, third, because of the added cost of interest charges for facilities or types of construction carried out now which may not be utilized for some time

It is in this last named phase of the situation in which mature judgment based on experience must be brought into play, evaluating the design of today in the light of the experience of the past and reasonable provision for the future

CONCLUSIONS

The prevalence of accidents on highways is a matter of grave concern not only to engineers and highway authority but also to the general public. It may be admitted that defects in the highway structure, faults of design or construction or maintenance may be contributory to the heavy toll of lives, personal injuries, and damage causing heavy loss

DISCUSSION ON SPEED AND HIGHWAY DESIGN

PROF N W DOUGHERTY, *University of Tennessee* There has been so much loose talk within the last few years regarding 100 m p h speeds and super-highways with suggestions that our present investment should be junked and that we start all over again, that I think it is high time for more thoughtful people to point out the inherent difficulty in such high speeds and the super-highway

but there is overwhelming evidence to show that most of this is probably due to the human element, to improper or incompetent driving of the vehicles. Excessive speed is one important contributory cause. It seems probable that the large majority of drivers are not ordinarily capable of driving at speeds in excess of 30 to 50 m p h

The writer is of the opinion that where the location or design of highways for speeds of over 50 to 60 m p h involves added expenditure for the requirements of this additional speed such expenditures are not justified

The great need of today and very likely the great need for several years to come is increased traffic capacity. Maximum capacity is only achieved at speeds considerably less than 50 m p h. There should be recognition of the fact, however, that on uncongested highways speeds of 50-60 m p h may be permissible for competent drivers

It is possible that if and as funds become available, sufficient highway traffic capacity may be provided so that a freer movement of vehicles may be realized. The expenditure of funds for this purpose, after reasonable provision has been made for highway users of all classes, may be economically justified by savings in time and possibly also in costs of operation if the speed at which cars can be most economically operated is more closely attained

I do not doubt the ability of the motor vehicle manufacturers to produce a vehicle which can travel from 80 to 100 miles an hour, and at a reasonable fuel cost. I do not see much prospect, however, of making drivers over and changing their reaction time to fit with these high speeds. With a reaction time of one-half second, a vehicle can leave the highway and be far into the adjacent field be-

fore the driver can make a move. When Professor Moyer points to the fact that on a speedway built for the purpose, no more than 50 per cent of the selected racing drivers finish more than 500 miles, the fatality is too great.

Improvements in alignment and grades are needed for the modest speeds of the average driver, but to suggest that all we have done should be junked is very misleading.

Mr. Lavis has reviewed this attitude and I am in general agreement with his conclusions.

PROF. A. DIEFENDORF, *University of Pittsburgh*. A wise highway program is one which spends its income in such a manner that its construction and maintenance will serve the greatest number of citizens. It does not consider political expediency or patronage as paramount to actual service. Its operation should be similar to that of any well organized corporation, the stockholders, the motorist public, receiving dividends in service.

The so-called super-highway (an undefinable term) which will permit motorists to travel thousands of miles at maximum motor car speeds of say 100 m.p.h. can be built, but at prohibitive costs, and with use limited to ideal weather conditions and to high speed vehicles. Can the motorist today safely travel at these speeds, even though the highway conditions are suited to high speeds? He can not. Should the motorists be lulled into any let up in his mental alertness while driving at this speed say for one second, he has travelled 146 ft and if his car has left the highway in any of this distance the result is not hard to imagine. I believe that a safe speed has been reached at 50 m.p.h. and that our physical and mental limitations will keep it there.

Pennsylvania is now facing a problem of this type in the new proposed

South Penn Tunnel Highway. This proposed highway runs from Irwin, Penna. on Route Number thirty to Middlesex, Penna. on Route eleven. It is a new short route low gradient highway, a direct east-west road from Pittsburgh to Harrisburg. It will have four 11-ft lanes separated by a 6-ft planting strip between the center lanes. Maximum grades are to be 3 per cent, curves will be limited to one per mile with 6 deg. maximum curvature. There are to be no railroad or highway grade crossings. No mention has been made concerning vehicular speeds but Mr. Marshall, the chief engineer has been quoted as saying that there will be no speed limit, and the route will be privately policed.

The tunnel highway will be located on the southern and western slopes of the hills reducing adverse conditions of snow, ice, and fog.

The estimated cost of the highway is \$50,000,000. It will be privately financed with no burden on the State road funds. Through tolls collected at each of the nine tunnels en route the highways are to be self supporting and when paid for are to be turned back to the state as a free road.

This project may in time answer some of the questions brought up in Mr. Lavis's paper. A high speed so called super-highway will be built without any unusual disturbance of a normal program and should the demand warrant other similar projects, a super-highway plan may be paid for by the people who demand it. In our case Routes 22 and 30 will be open and free for those who care to use them.

MR. O. L. KIPP, *Minnesota Highway Department*. In connection with this paper it would be interesting to be able to obtain information concerning drivers which is not being obtained at the present time. Many do not drive sufficient

mileage during the course of a year so that reaction is automatic or sub-conscious and consequently, to a certain extent at least, such occasional drivers must think out every action necessary. It appears that the thinking time, added to the reaction time of the driver, might be a

factor in determining safe speeds or safe speed limits. As a result of reading this paper there appears to me to be one way in which we can help the future possibilities and that is by having ample right of way and keeping encroaching industries as far away as possible.