HIGHWAY SAFETY
Driver Behavior - Key to Safe Highway Design

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FOREWORD

Through the many years of his activities in the rapidly expanding fields of automotive engineering and motor vehicle utilization, David Beecroft was a positive force for technical progress. He constantly brought to his associates the impression of a restless inner drive to secure action, and an eagerness, merging into impatience, to defeat delays in moving toward higher standards of excellence for the many diverse components that must be integrated and perfected to provide the desired end product, - efficient highway transport. He insisted that the attack on each problem accord with sound techniques, and believed that advance comes through research. In 1921, when President of the Society of Automotive Engineers, he said: "The roots of the present are always found in the past, and we must study the past if we are to proceed correctly in interpreting sanely the days that are to come."

We might, perhaps, modestly record the progress that has been made in highway transport development since Mr. Beecroft gave expression to this principle. After four decades of accelerated growth in the extent and varieties of services provided by the motor vehicle, it is self-evident that in this period no other single factor has so profoundly affected the pattern of social and economic life in these United States. A particularly impressive chapter of the record would disclose the realized strength that highway transport provided the United States for both defense and offense during World War II.

It is more consistent, however, with Mr. Beecroft's philosophy, to use the experience of the past to insure the complete rejection of the fatalistic suspicion that the current inefficiencies and hazards of highway transport are necessarily inherent.

If we are to gain mastery over highway transport as an efficient tool for national progress, and stop the toll that we are paying for its use in the tragic loss of life, the permanent injuries, and the financial costs of accidents that no nation, however wealthy, can afford, we must critically re-examine our policies and practices, particularly the thinking back of these, to find the causes that are responsible for our failures. We know we have taken many wrong turnings. Changing conditions require new horizons in our applied techniques as knowledge is unfolded and experience is more precisely interpreted. It is profitless to speculate upon what we might have done had we foreseen in the early years a reasonable fraction of the dimensions to which highway transport was so rapidly to grow, or had we anticipated more realistically its characteristics in actual operation.

It is a high honor to follow, in this series of papers, Mr. Paul G. Hoffman, who in 1947 presented the David Beecroft lecture. There is, in the general confidence of his fitness to carry the world-wide responsibility as head of the Economic Cooperation Administration, a recognition of his major contribution and efforts to bring highway safety into effective unity with our everyday living.

In the E.C.A. program the United States has accepted high international responsibility in the struggle to achieve democracy, which essentially means cooperation and coordination. The principle must be accepted and applied to every major feature of our national life if we are to be an example of our ideology worthy of the emulation of other nations. Highway transport consists of so many elements that we can only secure an excellent standard of service as we approach complete cooperation and coordination. On this premise, it appears to be responsive to the purpose behind the series of papers set in motion by Mr. Beecroft, to explore the present state of the art in the single field of highway design in relation to highway safety.

In this particular and limited field there is urgent need for a major shift in the approach to the determination of the geometric design. Since major changes in our thinking and in our policies applied in this field are indicated by the findings of intensive research now available, it may, by inference, be expected that need for major changes exists in other elements of highway transport. It is hoped that future papers in this series may present the record of the present, and also new concepts in the allied fields of motor vehicle design, motor vehicle administration, particularly driver licensing and driver training, traffic laws, enforcement and safety education designed to fortify driver behavior with disciplined attitudes of mind. These are all interrelated and interdependent, and our mastery of the whole problem of street and highway transport with safety depends upon mastery in each of these fields.

This paper purports only to record the devoted work of many individuals and many organizations to advance the cause of highway safety. The Action Program of the President's Highway Safety Conference, the extensive work of the Automotive Safety Foundation, that of the National Safety Council, and of many others, are reflected in the conclusions reached. The factual data are the product of the Department of Research of the Public Roads Administration under Deputy Commissioner H. S. Fairbank, and in particular result from detailed research of Mr. O. K. Normann, Mr. Carl Saal, Mr. C. W. Prisk, Mr. W. P. Walker, Mr. A. Taragin, and others who have engaged in the field of traffic research intensively and devotedly over many years.

The application of such data to design practices of Public Roads is the product of the Division of Design under Deputy Commissioner H. E. Hilts and his associates. There is particular response to the advance in design requirements by the Urban Division under Mr. Joseph Barnett.

The effort has been made to eliminate personal opinion, and to substitute conclusions supported by detailed observations of controlled research carried on over a sufficient period and with adequate repetition to justify confidence in the results. It is, however, not the intention to reflect an implication of finality. Continuing research will refine and illumine problems which are as yet obscure, but it is certain that driver behavior (en masse) is the key to safe highway design.

CONCLUSIONS

We have reached the point in our knowledge of the manner in which highways are used by the mass of traffic, to coordinate driver behavior under prevailing traffic conditions, and the geometric details of highway design. The degree to which the criteria so determined are accepted and intelligently applied in practice will determine the degree of safe efficiency of our future highways.

Our principally used street and highway systems are largely the product of the past one-third century. Most of the improved mileage has been built under public pressures and also legislative edict, to stretch the dollars over maximum lengths. In general, the design tolerances have been too meager for today's quantity and characteristics of traffic. Overloaded highways (by traffic capacity) are one of the chief underlying causes of highway accidents.

Highway design (geometric) to induce proper driver behavior in traffic streams will require rebuilding or rehabilitation of the major mileage of both the primary and principal secondary routes to more liberal standards. The cost will exceed annual expenditures heretofore reached, and will require a long period, - a minimum of fifteen years and probably longer. Carefully planned annual programs of rehabilitation are an emergency need.

The appealing angle of highways designed for safe operation, is that safe designs cost no more than unsafe designs if total costs are considered. The initial cost of constructing a highway is only one element, and far less costly than other elements, of the total annual cost of highway transport. The costs of owning, maintaining and operating more than 40 million motor vehicles are many times the expenditure for highway construction and maintenance. When these total costs to road users are considered, plus the value of lost time for the millions of passenger cars used for business and for all vehicles operated by paid drivers, and the value of saving in time on the investment of farmers, merchants and industrialists in their vehicles and in the merchandise carried, there are few highways indeed for which the small additional investment to design for safer operation cannot be justified on the economic basis of returns to road users. When there are added to these costs the cost of highway accidents that can be prevented by highways designed for safety, the economy of such highways is unassailable. Incidentally, highway engineers have too long wrecked professional conviction against the stone wall of comparative "per-mile" costs. We need a new concept that recognizes the actual passenger-mile and ton-mile services returned as the realistic measure of highway construction costs.

Highways designed for safety on the national scale will be realized all too slowly. There are many accidents which highways designed within cost possibilities cannot prevent. The only hope of maintaining the downward trend of accidents, particularly fatal accidents, is the vigorous application, enforcement and popular support of the Action Program of the President's Highway Safety Conference.

The Background of Highway Design

For too long, and in too great degree, highway design has been distorted by the tyranny of wrong concepts. Most important of these in its adverse impacts is the error of thinking of the motor vehicle as static in relation to the highway. In use the vehicle is dynamic and takes on very different qualities.

When the motor vehicle first appeared, it was held to be a legal interloper on highways whose function was to serve horse-drawn traffic. As the number increased, only minor concessions were made to its higher speed in the way of superelevated curves, - probably borrowed from prior railroad practice. The effects of railway engineering tenets upon highway design are evidenced by the meager tolerances which have been built into our roads, and which reflect operations on fixed tracks not subject to deviation from course. The motor vehicle in motion is not only highly flexible; at very low densities of traffic the operation begins to take on the character of the stream flow, and the individual vehicle loses its identity and its freedom. As an integral part of a traffic stream, each vehicle affects and is affected by, all of the other vehicles in its own flow line, and in contiguous streams. The old adage, - the proper study of mankind is man, - is not only scientifically correct, but is the only approach to the problem of highway design with maximum safety. Human behavior at the wheel, with foot on the accelerator rather than the brake, is the all-important criterion for highway design. The implication here is not an invitation to speed, or to design with the objective of high speeds. Driver behavior en masse reflects normally average rural speeds of 42 to 48 miles per hour when reasonable freedom is permitted. As cars are designed, the foot on the accelerator is the normal driving position, and through the accelerator the driver expresses not only his desire to reach an objective, but in addition a wide range of reactions that may be conscious emotions or unconscious reflexes. The driver en masse is not designed for high speeds with safety. Once the mean and range of human behavior are determined by precise measurements extended to thousands of observations until the general pattern emerges, the design limits thus fixed will have sufficient tolerance to provide for the usual departures from the norm. Highway capacity adjusted to traffic volume is a major factor in safe highway design. True economy is served only if this test is met, and thus safety becomes directly a measure of efficient as well as economical design.

The ratio of commercial vehicles to passenger cars has important effects upon the road capacity to carry traffic. In 1904 the ratio of trucks and busses to passenger cars was 1 to 78; by 1910 this ratio had become 1 to 45; in 1920, 1 to 7.3; 1930 1 to 6.5; 1940, 1 to 5.9; and it is expected that this year the ratio will be about 1 to 4.5, (Refer to Schedule I). The percentage of commercial vehicles in the total daily traffic flow is continuing to increase, and for this reason more adequate recognition of the requirements of such traffic must be incorporated in the design to insure safe, efficient operation of all traffic.

The influence of increasing the percentage of commercial vehicles upon the total capacity on multi-lane highways, under the favorable conditions of uninterrupted flow, is illustrated by the following:

Effect of commercial vehicles and grades on
practical capacities of multi-lane facilities

Commercial vehicles	Level terrain	Rolling terrain
Percent	Percent of passenger car capacity on level terrain	
None	100	100
10	91	77
20	83	63

On two-lane highways the limitations of capacity are more severe.

In the years just prior to 1946 the national fatality rate was about 12.0 deaths per 100 million vehicle-miles of travel. In January 1946, the rate was 12.4. The President's Highway Safety Conference was called in May 1946, and notwithstanding the bad record of the first three months of that year, the upward trend was halted and turned abruptly downward so effectively that the year ended with a rate of 9.8. The wholehearted support, and the devoted interest and efforts of organizations, officials and the public in putting into effect the action program developed through the Conference, are mainly responsible for the reduction in the fatality record to the estimated rate for 1948 of 7.8 per 100 million vehicle-miles. As this rate is lowered we must expect to reach a critical point at which a continuing decrease will prove impossible through education, enforcement and the other means which have been responsible for the splendid record made since May of 1946. In addition there must be the reduction, through the general use of higher standards of highway design, of the current fantastically high accident potentials. The astronomical number of accidents that do not happen is terrifying. As traffic volume increases the accident possibilities, that is, the pressures for accidents, build up in geometric ratio. The accident potentials can only be reduced with certainty by reducing the possible conflicts of traffic units.

We know that major reductions in the fatality rate can be made by providing properly designed, modern highway facilities, as is evidenced by the record of highways on which the accident potentials are greatly reduced. The following highways carry large volumes of traffic and have fatality rates as low as one fifth or one third the national average because of the controlled access design in which conflicts of all kinds, - cross traffic, pedestrians, and traffic entering along the roadsides, - have been materially reduced or eliminated.

Facility	Rate (Deaths per 100 million vehicle-miles)
Merritt and Wilbur Cross Parkways (1946)	2.5
Chicago Outer Drive (1946)	2.9
Riverside Drive (California) (1941-44)	3.0
Arroyo Seco Parkway (1941-44)	3.9
Metropolitan New York Parkway System (1938-1948)	2.5
Pentagon Network, Washington, D. C. (1942-48)	1.5

The Pentagon Network is composed of 17 miles of one-way through roads, 7.7 miles of one-way connecting ramps and 2.3 miles of two-way local service roads, - a total of 27 miles - on which the vehicle mileage for the period of slightly more than six years since its construction is estimated at 337,500,000. Five persons, three of whom were pedestrians, have been killed during this period. Further reference will be made to the observations of driver behavior on the roads of this system.

Under the inspired, at times militant, leadership of Mr. Robert Moses, the Metropolitan New York Parkway System has set an example of highways designed on a scale commensurate with traffic requirements of reasonable speed with safety. The system, steadily expanding, now consists of 164 miles of multi-lane roadway, much of which is divided. The obstacles which have been met are somewhat indicated by the required 208 bridges. There are two details of design that cannot be overcommended that have been or are being put into practice as safety measures. One is the installation of center curbs on the earlier undivided parkways. These have successfully eliminated the deadly head-on collisions. The other is the installation of paving blocks to support heavy vehicles on the shoulders when disabled.

The Action Program of the President's Highway Safety Conference lays great and proper stress upon the acceptance of individual responsibility for safety on the highways. Educators are increasingly stressing the importance of "true personal participation" in contrast to activity unrelated to the subject of study. Contrariness and individualism in respect to a desirable course of conduct disappear once the individual accepts his responsibility for safety of himself and others on the highway.

The responsibility of the individual toward the public to preserve highway safety should be activated by school instruction, town meetings, community forums, local coordinating and action committees, support by the press, discussion groups, - all of which are calculated to impress the individual with his responsibility to the public and in this way mould or remould the habits and attitudes relating to safety on the highways.

When these approaches to the problem of accidents have been used, there still remains the very pertinent query, "What is the proper attitude of the public toward the driver?" Basically, the individual driver has his limitations of habits, of capabilities, and the handicaps of his own perception and reaction times. Each driver in a stream of traffic, in a high degress loses his freedom of action, and is circumscribed by the action of others. His performance is limited by, and becomes part of, the traffic flow, which is a composite of the reactions of a multitude of drivers. Thus, the responsibility of the public to the individual driver is, first, to determine the characteristics of traffic flow lines, and second, in harmony with this knowledge, to provide the facilities for safe use. The dynamics of these speeding streams of traffic most directly influence the design features which we term geometric. These are alignment, profile, plan of intersection, clearances, horizontal dimensions of the highway cross-section, and the many details which we group under the general term of highway design.

Principal Hazards of the Design Characteristics of Existing Highways

The outstanding hazard of our streets and highways is undercapacity for the traffic load. Nearly half of the rural highways carrying 1,000 vehicles per day and over are less than 20 feet in width. On each mile of such highway, over 60 times per hour, or once each minute, a vehicle is encroaching upon the left lane when meeting an oncoming vehicle. Expanding these figures to the many miles of rural highways in this country, the accident potential reaches unrealized dimensions. The length of time that a vehicle in passing another vehicle occupies the lane used by the oncoming traffic, depends upon the width of pavement. On an 18-foot pavement vehicles occupying the left lane require 43 percent longer in passing than on pavements 24 feet wide. The pavement of the lesser width is not only more hazardous, but provides only 70 percent of the capacity of the 24-foot pavement.

Adequate shoulders are necessary to the efficiency of motor vehicle operation. They are effective in increasing the traffic capacity of the highway, since bituminous treated shoulders four feet or more in width, adjacent to 18- and 20-foot pavements, as compared with grass or gravel shoulders, increase the effective surface width approximately two feet. Increasing the effective pavement width results in fewer vehicles encroaching upon the left lane of traffic, and thus increases the traffic-carrying capacity of the highway. Shoulders also play a very important role in accident prevention in both rural and suburban areas where pedestrians are involved. In 1947, 25 percent of all rural pedestrian fatalities occurred while pedestrians were walking on the roadway.

Were adequate shoulders available of the character necessary to provid usable footpaths, many lives would be saved. To gain the advantage of adequate shoulders, there should be no vertical obstructions such as retaining walls, bridge trusses, utility poles, guard rails, parked vehicles or other objects near the traveled way. Obstacles at the edg of a ten-foot lane cause vehicles to travel 2.6 feet further from the edge of the pavement than when the obstacles are not present. Even fo lanes twelve feet wide the same positioning of obstacles causes vehicl to travel 1.8 feet further from the pavement edge. Obstacles four feet or more from the pavement edge have only minor effect. The roadside obstacles, therefore, have the effect of reducing the pavement width. Adequate width of shoulder and a suitable surface for parked vehicles are necessary for every highway regardless of its width. On the Merrit Parkway in Connecticut, two-thirds of the fatalities resulting from collisions between vehicles have involved a parked vehicle on the roadway. The German Autobahnen were built with divided paved roadways, eac 29.25 feet in width, thus providing capacity greatly in excess of norma requirements. The shoulder width was one meter. In 1938, after a very few years of use of a limited mileage, the Inspector General, Dr. Fritz the official in charge, stated that the decision had been made to add wider shoulders because of numerous accidents caused by vehicles standi on the pavements. This experience is compelling in establishing proof of the danger inherent in the vehicle parked on the roadway. Every othe element which we rate as contributory was absent, and the standing vehic per se was the cause of the accidents.

Where sight distances on two-lane roads are so short that passing would be hazardous, it is customary to stripe no-passing zones. Observations were made on a 3,400-foot length of highway, of which about one fourth was marked "no passing" by reason of sight distances below 400 feet. Of the total number of passings made within this 3,400-foot length, more than ten percent were started or completed in the restricted zone. On roads where no-passing restrictions comprise as much as 40 percent of their length, the volume of traffic that can be satisfactorily and safely accommodated is only about 80 percent of that which can be carried on a similar highway free from sight distance restrictions.

The road margin is the critical line of hazard on many of our existing highways. Recognition of this situation appears in a project just initiated in Michigan, in which a study of the locale of accidents with respect to taverns, gas stations, restaurants and other roadside establishments is to supplement the more conventional facts analyzed in studies of traffic accidents. The unrestricted use of the road margin for entrance and exit at such locations causes driver confusion, disorderly parking and other operating hazards. The growth in the number and popularity of outdoor drive-in theaters is but a single example of the commercial exploitation of the roadside. The safety of motoring audiences as they enter or leave these establishments in large numbers, has become a necessary concern of highway authorities because of the effect on operating conditions on the adjoining highways. The most difficult obstacles the highway engineer faces in his effort to build safety into the highways are the lack of legal authority and effective legal machinery provided to acquire sufficient right-of-way and to control the entrance to the public highway from abutting property.

A characteristic serious fault of drivers is that of following too closely a car traveling in the same lane. The speed and the interval between the cars do not permit adequate perception and reaction time for the rear car to stop if the car ahead is brought to an unexpected stop. This type of accident has the potentials of a whole series of accidents, of tying up traffic, of causing much property damage, and sometimes serious or fatal accidents. The grave implications of this very common practice are indicated by Schedule VI. The perception and reaction times vary with individuals, but a safe assumption would hardly be less than 1.5 seconds. Tests of drivers have shown that the minimum reasonable reaction time alone is 3/4 of one second.

The average time spacing between vehicles following at the same speed, for all speeds and for both two- and four-lane roads, is 1.58 seconds; 16.2 percent of the traffic will have a time spacing of 0.75 seconds or about one half the average.

The Components of Road Design for Safe Operation, as Indicated by Driver Behavior

Alignment

The alignment must be adjusted to the volume and type of traffic, the driving characteristics of the operators, and the dynamic effects of the mass movement. The alignment selected, whether the highway be two, four or more lanes wide, determines how effectively and safely the completed facility will meet the demands of traffic. Sight distances between 1,500 and 2,000 feet long are essential on any rural two-lane highway. The percentage of the length where sight distances of this magnitude should be available will depend on the volume and type of traffic which the highway must accommodate. On our main highways carrying high-speed through traffic, a sight distance of at least 1,500 feet should be available on a minimum of 60 percent of the route length, if the highway is to accommodate peak traffic volumes as high as 500 vehicles per hour with safety. If it is unavoidable to introduce curvature which restricts the sight distance, it is essential to select an alignment free from sudden changes that come as a surprise to the operator. Curves at the ends of long tangents are definitely more hazardous than the same curves located where the general alignment is made up of a series of curves.

Practical Working Capacities

Accidents are inevitable on overloaded highways. Safe highways must have sufficient capacity to permit drivers to operate at reasonable speeds. On main rural highways drivers generally accept as reasonable, average running speeds of 45 to 50 miles per hour during the peak volumes. On urban expressways, a speed of 30 to 35 miles per hour during peak traffic volumes is reasonable.

The working capacities for modern rural roads in terms of passenger cars per lane are 450 per hour for a two-lane road, and 1,000 per hour for the lanes in the direction of heavier travel on multi-lane roads. At these traffic volumes, under ideal roadway conditions, the drivers who so desire can safely travel at the above speed on rural roads, although the average speed of all vehicles at any given point will be about 42 miles per hour compared to an average speed of about 48 miles per hour during low traffic densities.

In urban areas the maximum practical working capacity for a modern multi-lane expressway is 1,500 passenger cars per hour for each lane in the direction of heavier travel. At this volume, drivers who so desire can safely average 35 to 40 miles per hour, and the average speed of all vehicles will be between 30 and 35 miles per hour. At this working point, unusually high volumes that occur frequently for short periods can be handled without complete congestion.

Lane Widths

The lane widths used for the design of our highways must be based on vehicles in motion, - not on the actual size of the vehicles standing still. Most of our main highways have sufficient traffic of commercial vehicles to require 12-foot lanes for safe operating conditions. Eleven-foot lanes must only be considered for highways carrying less than 1,000 vehicles per day. The reduction in capacity by narrowing lanes is not only unsafe; it is definitely uneconomical; i.e., the cost of the additional width is less than the proportional increase in capacity.

Effect of lane width on capacity

Lane width	2-lane rural roads: At possible capacities	2-lane rural roads: At practical capacities	Multi-lane express-ways at practical urban capacities
Feet	Percentage of 12-foot lane capacity		
12	100	100	100
11	88	86	97
10	81	77	91
9	76	70	81

Two-Lane Highway Limitations

The accident experience on two-lane highways shows that the death rate per million vehicle-miles increases with an increase in the traffic volume. Operating conditions on the average two-lane highway are not satisfactory when traffic volumes exceed 4,000 vehicles per day in flat terrain, or 3,300 vehicles per day in rolling terrain. It is only for extremely low daily traffic volumes that a two-lane highway can safely accommodate a vehicle traveling over 60 miles per hour, regardless of excellent alignment. Design speeds that exceed 60 miles per hour, to provide safe operating conditions require four-lane divided highways if the volume exceeds 3,000 vehicles per day. On free-flowing highways where the higher speeds are safer, this very fact automatically lowers the top range by permitting a constant rate which satisfies most drivers. The average actual rate for two-lane highways of modern superior design is about 48 miles per hour.

There is confusion of the terms "overload" and "congestion." Congestion approaching stagnation may lower the serious accidents, but at the same time it defeats the utility of highway transport. Any concept that congested highways are safer completely overlooks the fact that each route has its own characteristic pattern of daily use. It may have an hour or a fraction of an hour once or twice daily of congestion at peak traffic periods. These periods of congestion causing stagnation or incipient stagnation may be productive of numerous but not fatal accidents. The remainder of each 24 hours constitutes 90 to 95 percent of the time, during which there are much longer periods when the route is overloaded and a breeder of accidents.

Multi-Lane Highways

Multi-lane highways of the divided type will accommodate three to six times as many vehicles per lane as a two-lane highway, and provide greater safety. For average conditions, the width should be increased from four to six lanes when the volume exceeds 18,000 vehicles per day in rural areas, or 32,000 vehicles per day in urban areas. In certain areas of the country where seasonal, daily and hourly fluctuations in traffic flow vary from the average condition, the practical capacity of a four-lane divided highway might be as much as 30 percent higher or lower than the above volumes.

Shoulders are Essential

Shoulders that will accommodate disabled vehicles and that may be used by moving vehicles in cases of emergency during any weather conditions, are essential for safety on main highways. Adequate shoulders are also essential to realize the full capacity of the surface width. Without adequate shoulders, one disabled vehicle can reduce the capacity of both two-lane and multi-lane highways during peak periods by as much as 60 percent. There is at least one disabled vehicle for every 20,000 vehicle-miles of travel on our main highways.* Furthermore, adequate shoulders increase the effective surface width for traffic when no disabled vehicle is present. Without a place of refuge outside the traffic lanes, one disabled vehicle can reduce the capacity of a highway by more than one lane, especially if the lanes are less than 12 feet wide.

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*On the Oakland Bay Bridge, for example, during the peak hour, when 6,700 vehicles use the six-mile structure, an average of two vehicle breakdowns can be expected, which will seriously affect the traffic capacity of the bridge.

The disabled vehicle blocks one lane and reduces the capacity of adjoining lanes by restricting vehicle speeds. It may block all lanes in one direction, and completely block traffic in that direction. The maximum capacity of a traffic lane with vehicles moving at 20 miles per hour is only 87 percent of its capacity at 30 miles per hour. At ten miles per hour a lane has only about 50 percent of its 30-mile-per-hour capacity. A minor accident which causes a reduction in speed can result in complete congestion when a facility is operating near its capacity.

Curbs and Lateral Clearances

Any vertical member adjacent to a roadway constitutes a safety hazard and is an obstruction to the free movement of traffic, unless it is six feet removed from the pavement edge. High vertical curbs of the so-called non-mountable type fall within this category, and if they are required they also should be separated from the traveled way by six feet to have no effect on traffic, but if they are three or four feet away their effect will not be critical. A low sloping curb may be used adjacent to the roadway surface in conjunction with a high curb further removed.

Drainage

The provision of side ditches, gutters and drainage structures sufficient to prevent mud and debris from washing onto or collecting on the roadway surface during storms, is a necessary safety measure. Such foreign materials constitute hazards within themselves by creating slippery pavement conditions, but of greater importance is the hazard created by drivers who, in attempting to avoid such materials, bring their vehicles into the paths of other vehicles. In the colder regions the formation of ice on pavements as a result of water collecting in poorly drained places presents a serious safety problem.

Highway Intersections

To provide safe operation at intersections, on rural through roads carrying an average traffic of 5,000 vehicles per day and over, the grades should preferably be separated at intersections with other major roads.

Chief among the reasons for safety violations at intersections is congestion. The driver whose patience is exhausted is here the dangerous operator. Aside from relief of congestion there are a number of measures that aid in minimizing hazards at intersections. Among these measures the following rank high:

> Corner sight distances consistent with the operating speeds of traffic, with due consideration of the method of traffic control employed.
>
> Safety islands for pedestrians at busy intersections where streets are wide and pedestrian traffic is heavy.
>
> Separated turning lanes, especially on high speed or moderately high speed divided highways to enable turning vehicles to decelerate and stop, if necessary, clear of the lanes used by through traffic.

Railroad Grade Crossings

All main line railroad grade crossings of highways which carry substantial traffic flows should be separated. Because of the cost and the pressures for other highway improvements, the elimination of crossing hazards by construction of separation structures will be delayed at many locations. Consequently, grade crossing protection should proceed rapidly. Particularly effective are the installations of the short-arm automatic gates. These have some obvious maintenance and cost advantages over the long-arm gate installations, and provide a barrier which experience has proven adequate. Though the short-arm gate and flashing signal is somewhat more expensive than the flashing signal installation alone, this type should be uniformly used for all main-line crossings at grade, regardless of the number of tracks. This position is reflected in the present policies of the Public Roads Administration.

Loading Recesses

The destined function of practically all of our highway mileage, both new and old, is to provide service to all classes of traffic. The peculiar needs of commercial and mass transit vehicles, not only in their steady flow movements, but at their terminals, transfer points and roadside stops, require attention in shaping the physical features of the roadway. The frequent stopping of transit or commercial vehicles in the moving traffic stream is a serious traffic hazard. Wherever possible, and in all instances on new highways designed as routes for mass transit, proper facilities for transit vehicles off the through lanes for passenger loading and unloading should be provided. These roadways should be designed to expedite movements of the transit vehicle as well as those of the more numerous private passenger car. Through the provision of more attractive and convenient mass transportation, there is the possibility of shrinking our urban traffic problems to more moderate limits. Efficiently designed off-street loading bays and terminals for trucks serve a similar purpose, particularly in the central core of our cities where street space is wholly inadequate for the moving traffic.

Uniform Signs and Signals

Traffic control devices, though relatively inexpensive accessories to street and highway design, are significant aids to safe highway operation. Well designed and located highway signs, signals and markings eliminate or relieve many of the elements of surprise that characterize certain combinations of design and traffic operation features. The planning of new highway facilities should always be accompanied by thought as to the traffic control, to hold restrictive measures to a minimum. Such preliminary considerations also offer certain correlative benefits in the joint planning of design and control elements on the new facility. The control will thus be tailored into the design at the most appropriate stage, and not left for piecemeal application after completion of the construction. The Manual on Uniform Traffic Control Devices should be rigorously followed. The Manual has become the single legal standard for use on all Federal-aid projects.

Speed Control

Reasonable speed is a necessary element of efficient highway transportation, yet speed is so frequently pointed to as a traffic accident cause that the dictum has wide acceptance that traffic accidents and higher speeds go hand in hand, and that there can be no one facility that possesses the characteristics of speed and safety. Numerous attempts to relate speed and accidents have had but meager success. Speed definitely increases the severity of accidents, and it has been demonstrated from studies in New York, New Jersey and Connecticut that fast drivers are guilty of more traffic violations and are involved in more accidents than those who operate at more moderate speeds. But we also find that our modern highways with excellent safety records are accommodating traffic speeds definitely above those found on routes of inferior design.

The answer is certain. The newer facilities have been purposely planned to meet the higher speed demand, and are distinguished by uniformity in those design features that relate to safe accommodation of faster-moving traffic.

Safe vehicle speeds thus depend in large measure on characteristics of the roadway. With approximately 400 billion vehicle-miles of travel annually, it can hardly be expected that police activity on speed law enforcement will be effective for more than a small fraction of this total. Speed controls, where applied, must be adapted to the circumstances. On our highway systems, both urban and rural, there is a wide range of ability to accommodate speed. This is true not only for the nation but for any State, or for any appreciable length of highway within a given State. Thus, the establishment of a uniform legal speed limit for rural and urban areas is not a solution. Such a policy is unsound. A limit set at the maximum safe speed for the poorest section of highway is obviously an invitation to disregard the law. Thirty-seven of the States now exercise the authority to post speed limits differing from the speed that has been set as a general maximum. The rural State-wide daytime limits range from 25 miles per hour in one State to no limit in 14 States. Of the 29 States having general limits above 50 miles per hour, all but four are using the device of zoning to encourage judicious use of the highway with respect to speed. Much more needs to be known about the principles of successful zoning, but sufficient study has been given to determine that the signing must be realistic and possess considerable self-enforcing value. The establishment of frequent unwarrantedly low limits breaks respect for the entire zoning device, which is reflected in abuses of other essential traffic regulatory measures. (Refer to Schedule II for safe speeds on curves.)

Rural State-wide Speed Limit	No. of States	No. of States with Rural Speed Zoning Authority
No limit	14	10
60 mph	8	8
55 mph	7	7
50 mph	10	7
45 mph	4	3
40 mph	2	0
35 mph	2	2
25 mph	1	0
	48	37

Efficient Operating Grades for Trucks

Schedule III shows the distance that light-powered trucks with gross loads of 30,000 pounds, and medium-powered trucks with gross loads of 40,000 pounds, can go up various grades before their speeds are lowered to 30 miles per hour.

Gross loads of 40,000 pounds on medium-powered trucks will probably not occur with sufficient frequency on most of our main rural highways to justify basing the road design on these vehicles alone. Light-powered trucks with gross loads of 30,000 pounds will occur, however, with sufficient frequency on most main highways to affect seriously the operation of passenger vehicles on the highway unless they are considered when selecting the alignment and other design features of the road. It will be noted that the length of grade that reduces the speed to 30 miles per hour is approximately the same for the lighter-powered trucks with the gross loads of 30,000 pounds as for the medium-powered trucks with gross loads of 40,000 pounds.

A third lane on the uphill side will prevent the slow-moving trucks from unduly interfering with other traffic if the third lane is started at the distance from the bottom of the grade, as shown by the table. In certain types of terrain, however, especially where the road is located on the side of a steep hill or mountain, it may be impractical to provide an additional lane. Since the problem must be met on main routes, there are the alternatives of improved alignment for routes of light travel, or a new one-way, two-lane roadway on a separate location. In the latter case the old plus the new roadway would provide two lanes in each direction.

Far too little attention is given the fact that farm production is moving to the markets and to the railroads in trucks. In a constantly increasing degree the secondary or farm-to-market roads must be designed for truck operation, and efficient, safe operation requires low gradients. The lowest unit cost item in road construction today is earth excavation, and there is no reasonable excuse to neglect the economy that will accrue to the farms by designing farm-to-market roads requiring additional excavation to provide low grades and good alignment.

From the angle of safety only, the most serious result of grades is the restricted sight distance at the crest, or of the erroneous design policy, quite generally practiced, of introducing short sight distance curves to lower the percent of gradient.

The Less than Traffic Speed Driver

On week ends and holidays the most fervent anathemas of other drivers are directed toward the driver who fails to maintain the average traffic speed. This attitude mistakes the effect for the cause. The collection of a queue of cars with frustrated drivers behind a car moving slower than the average traffic speed is a sure indication of an overloaded highway. The same conditions apply as in the case of the slow moving truck. The fault is the highway, not the slow driver. Too narrow traffic lanes and too restricted sight distances are the most common defects. The slow driver is not likely to disappear from the roads; the remedy lies in eliminating his accident potential by improved road design.

Capacities of Two- and Four-Lane Express Highways

At the present time our main highways carry about 20 percent commercial traffic. During peak hours, however, commercial vehicles are generally in the neighborhood of ten percent of the total traffic. In rural areas, two-thirds of the traffic is generally in one direction during the peak hours. In urban areas, the distribution by direction wi generally vary from two-thirds in one direction in the outlying areas to an equal distribution each way in the central business districts. It is generally not feasible to obtain a perfect alignment having no sight distance restrictions on two-lane highways. Even in flat terrain it is difficult to obtain more than 80 or 90 percent of the road with a sight distance over 1,500 feet, and in rolling terrain it is difficult to obtai more than 60 percent of the road with a sight distance over 1,500 feet. The total hourly capacities for two- and four-lane highways in rural and urban areas are for these average conditions, as shown by Schedule IV.

When relating the hourly design capacities to annual traffic volumes, fluctuation in traffic flow must be considered. Comprehensive studies of the fluctuation in traffic flow on rural highways show that the traffic density somewhere between the 30th to the 50th highest hourly traffic volumes of the year should be selected for design purposes. On the average rural highway the 30th highest hour of the year is about 15 percent of the average 24-hour traffic volume. In urban areas it average about 12 percent of the annual average traffic volume. Schedule V shows the annual traffic volumes that can be used for design purposes at locations where there is the average fluctuation in traffic flow. Values as much as 30 percent higher or lower than these may be applicable to a specific project, depending on the seasonal, daily and hourly fluctuation, and the distribution of peak-hour traffic by directions.

A four-lane expressway of modern design with controlled access will accommodate as much traffic at approximately twice the average speed as

(1) Five ordinary city streets, each 40 feet in width with parking prohibited.

(2) Eight ordinary city streets each 42 feet wide with parking on both sides.

(3) Five ordinary city streets each 68 feet wide with parking on both sides.

(4) About three ordinary city streets each 68 feet wide with parking prohibited.

By "ordinary city streets" is meant those that have the average amount of left-turning movements and pedestrian interference prevalent in downtown areas.

Brakes

The hazardous conditions created by too short spacing between cars following in the same lane are emphasized by the studies of brake performance. Safe vehicle performance depends to a greater degree upon adequate, well maintained brakes than upon any other single element of vehicle design. Likewise, the brakes betray most surely driver or owner failures and neglect. Studies by the Public Roads Administration just before the war disclosed that over 40 percent of the passenger cars tested on the highway had zero pedal reserve, i.e., the pedal was flat on the floor board after an emergency stop from 20 miles per hour.

Brakes are a common alibi in many accidents, sometimes the true cause, but more often not. If the brakes fail, the responsibility lies usually with the driver. He has not maintained them properly.

The widely distributed studies of brake performance show that the condition existing in 1942 was not a rosy one. It is probably worse today. Only 62 percent of the passenger cars, 18 percent of the two-axle trucks, and three percent of the three-axle combination units could stop in 30 feet or less from a speed of 20 miles per hour.

There is abundant confirmation that the braking systems of passenger cars and especially commercial vehicles are too commonly poorly maintained or grossly inadequate. An analysis of the results indicates that this level of performance can be greatly improved. Passenger cars and two-axle trucks can be made to stop from 20 miles an hour in 30 feet or less. The combination units now on the road may not be able to do that well, considering the lag that exists between the time that the pedal is touched until the brake shoes actually contact the drums. However, it is certain that with proper maintenance of well-designed braking systems, a much better showing can be expected. It is heartening, in this respect, to read that the Pennsylvania Motor Truck Association's Engineering Subcommittee has been able to stop a 62,000-pound, two-axle tractor and tandem axle semi-trailer in an average distance of 27 feet, 9 inches. There is every indication that the automotive engineers who cooperated in the tests have succeeded in reducing to a marked degree the inherent brake lag.

The tests of vehicles as they are now operating on the roads clearly show that the proper maintenance of brakes is not as yet being generally accomplished, and that a more stringent enforcement policy is

The importance of brakes in relation to driver behavior is emphasized by Schedule VI showing distance spacing and time interval between cars traveling in the same lane. If the driver behind has instant perception time, which is impossible, and the average reaction time of 3/4 second, if his speed is only 30 miles per hour, he has 2/3 second for his brake to stop his car if the car ahead stops suddenly. Under such typical circumstances, when an accident occurs do the driver's brakes fail to work, or does the driver fail to work the brakes? The answer is one major reason why insurance rates are going up.

The Paradox of Driver Behavior

"We know so much about roads that is not so," has long handicapped correct thinking. We do know now much of driver behavior that without positive proof we think could not be true. For example, the relationships of accident frequency and accident potentials with the details of highway design have been described. The accident rate on two-lane rural highways carrying less than 1,000 vehicles per day is approximately half that on similar highways where the volume is in the 8,000 or over vehicles per day range. That is, on overloaded highways or under-designed highways the accident rate increases with traffic volume. On such highways, we would logically think drivers would become more careful. Paradoxically, driver behavior becomes worse as the road becomes more inadequate to carry safely the traffic volume. Under conditions where the driver should become more responsible he becomes less so. Contrariwise, evidence supports the conclusion that as the standard of design is raised, driver performance becomes more responsible. This observation of driver behavior undoubtedly reflects the ability of the average mind and nerves to function more safely if tension beyond necessary alertness is relieved, and apprehension is absent.

Here is the record of traffic operation that has emerged from the studies on the Pentagon System of roads over the past six years. The system was designed and built by Public Roads to serve an estimated population of 50 thousand office workers in the new defense establishments, all of which were transferred almost overnight across the Potomac River to a previously unoccupied area in Virginia. The problem was to move the major part of this population in and out daily by motor vehicle over the existing three Potomac River bridges.

Excluding the traffic over Memorial Bridge which uses Lee Boulevard, and other traffic which does not actually traverse a portion of the 17 miles of through routes, it is estimated that there are now 85,000 trips per day. Including the traffic on roads immediately tributary to the system, daily about 110,000 vehicles use these roadways. This is a conservative figure since the three bridges which the system serves are now carrying an average traffic of more than 139,000 vehicles per day and a peak month traffic of 149,500 vehicles per day. The system produces about 67 million vehicle-miles of travel per year. In the six-year period, five fatalities have resulted from this operation, three of whom were pedestrians. Only one fatality was caused by a vehicle traveling at a relatively high rate of speed, leaving the road and overturning. For this six-year period the accident rate is 1.5 fatalities per 100 million vehicle-miles. In this experience lies the assurance of what can be accomplished through safe road design, but the record of driver behavior is the astonishing feature.

During the war there was a 35 mph speed limit on both the Pentagon network and Shirley Highway. The 35 mph speed signs were not removed until several months after the war. Prior to their removal, speed studies were conducted at several points on the network and on the Shirley Highway. These studies were repeated after changing the 35 mph signs to speed limit signs of 40 mph on the network and 50 mph on the Shirley Highway.

Changing the speed limit on the network from 35 to 40 mph had no effect on the average speed but reduced the number of vehicles traveling over 50 mph by eleven percent and those going over 40 mph by 20 percent. Changing the signs on the Shirley Highway from 35 to 50 mph reduced the number of vehicles traveling over 50 mph by 32 percent.

On the through routes of the Pentagon network, where there are no traffic police, no traffic control lights and no enforcement of the 40 mph posted speed limit, the average speed is 37.6 mph, and twelve percent of the vehicles exceed 45 mph. On Lee Boulevard, where safe speeds are much lower and the posted speed limit of 35 mph is enforced by frequent patrolling by traffic police, the average speed during light traffic volumes is 37.8 mph, with eleven percent of the vehicles exceeding 45 mph and 36 percent exceeding 40 mph. Thus on the network where drivers can legally maintain reasonable speeds at all times, they travel no faster without enforcement than they do on Lee Boulevard where safe speeds are not as high and the normal enforcement is present. Furthermore, three times as high a percentage of the drivers exceed a five mph tolerance of the posted limit on Lee Boulevard as on the Pentagon network.

The present volume is 800 per lane at locations where three lanes are available for movement in one direction. At the principal mixing lanes, a flow of 1,150 vehicles per lane occurs where four lanes are available for one-direction movement. The principal mixing lanes are now loaded to their possible capacity at certain peak periods. Other points on the ne work are loaded to approximately two-thirds of their practical safe capacities. All three bridges are loaded beyond their practical, safe capacities, and at times the demand actually exceeds the possible capaci of the bridges with their present approaches. The condition will be relieved materially by the completion of the two four-lane one-way bridg now under construction.

Highway System Planning

In harmony with the premise that roads must be designed on a basi of driver behavior, is the relatively new technique of planning the syste of arterial roads to serve the heavy flow lines of metropolitan areas on the basis of origin and destination surveys. These surveys disclose the desire lines of major travel. The pattern which emerges is that of a wheel, usually somewhat distorted in shape, but essentially providing radial lines from the urban center which are joined by concentric circles at spaced distances from the center. The concept has the two major objec tives of providing free flowing arterial routes in and out of the center, and of separating through, longer-distance traffic from local vehicle and pedestrian interferences. Also, such a plan will keep a high percentage of the total traffic out of the more congested center of the city. Drive behavior can be relied upon to exercise a high selectivity of route if th facilities provide a choice. Under such circumstances the driver will choose the route that will give him the most direct access to his destination, but at the same time will give him the shortest distance of travel through the more congested downtown streets. The Pentagon system serves three bridges across the Potomac River into the downtown streets of Washington. These bridges are interconnected by the system, and the driver from the Virginia suburban districts had, until the bridges became so congested as they are today, a choice among the bridges of that route which would require him to travel the least distance on, or would keep him off, the downtown, congested city streets. The degree to which he accomplished this purpose without any imposed controls is amazing, and is shown by the following record:

Comparison of a distribution of the traffic between the three Potomac River, Washington, bridges calculated on an assumed usage of the shortest route between origin and destination of trips with actual distributions observed on August 16, 1944, and throughout the year September 1, 1943, to August 31, 1944.

Bridge	Actual distribution on August 16, 1944	Actual distribution September 1, 1943 to August 31, 1944	Calculated distribution if shortest routes were used
	Percent	Percent	Percent
Highway Bridge	41.8	42.6	40.2
Memorial Bridge	33.0	31.5	32.7
Key Bridge	25.2	25.9	27.1
Total	100.0	100.0	100.0

The above table shows the actual distribution is representative of the free choice of traffic between origins and destinations during a period when the traffic volumes were relatively low and there was not sufficient congestion on the bridges to alter the desired usage.

A study of the origins and destinations of traffic using the three bridges indicates that the slight percentage differences between the shortest routes and the actual routes used, probably resulted from traffic dividing itself in its use of the three bridges to the one that would permit the shortest travel distance on the Washington central city streets.

Finally, this discussion is directed to the essentials of today's program of highway improvement. Since 1934, - nearly one and one-half decades, - the State-wide planning surveys have been accumulating the facts of the amount and characteristics of the traffic use of our highways. State by State, undoubtedly more is known about the highways, their use and their needs, than about any other major public undertaking. Until recently this wealth of material had not been generally analyzed and organized to serve its most important purpose as conceived when the surveys were started. In 1945 the California Legislature, recognizing the need for a long-range highway improvement plan, established a study committee to organize the available material and to secure new data necessary to bring together a complete engineering and economic report. The completion of the report, the legislative recommendations, the legislative debate and the adoption of the major recommendations, are now a part of the State's highway history. California has a well-rounded, long-term modern highway improvement program. With this successful guide many other States have now in active operation legislative study committees, which, with the competent technical assistance of the Automotive Safety Foundation, are maturing long-range programs of comparable caliber. The planning is designed to serve both economic needs and safety of use. Since the future reduction in the highway fatality toll, as has been shown, will depend so largely upon safer roads, no effort by the Foundation can result in a greater contribution to highway safety.

There are also implications of vehicle design that can be well heeded. For example, it is certain the driver needs to have a better sight of the right-hand edge of the road. Also, that protective bumpers, front and rear, capable of absorbing shock, be installed in place of expensive grillage which is going to suffer more in the future than in the past. Roads cannot be designed to prevent this type of accident, which is likely to involve a series of cars. Also, is it not time to forget the emphasis on minor over-speeds of the decent driver and concentrate on the driver who by his behavior creates accident hazards? The driver who passes in a no-passing zone, who parks his vehicle on the pavement and who crowds the other fellow's lane is a killer. Why not take him off the road?

The purely routine speed checking is as futile and wasteful of enforcement officers' time and ability as is their detail to check on overtime parking, both of which only result in congestion in the traffic courts on matters having a minimum relation to real traffic safety. We need the time of the traffic officers and of the courts to take the dangerous driver off the roads. Only a very small percentage of drivers habitually disregard the rules of safe driving.

This matter of driver behavior goes very deep. It involves a psychology that may well be inherent in a people who have been, and are capable of, building and running the outstanding democracy of the world. It is the essence of the spirit of freedom which revolts against unfair or unreasonable restrictions but which is tempered in the large majority to support of the public welfare. So it seems reasonable to accept the pattern established by the behavior of the decent majority and deny the freedom of the road to the violator of this pattern. Safety of the highways is, as democracy is, a matter of cooperation and coordination.

Schedule I

R e g i s t r a t i o n s

Years	Automobiles	Trucks and Busses	Ratio Trucks and Busses to Automobiles	Total
1904	54,590	700	1/78.0	55,290
1910	458,377	10,123	1/45.3	468,500
1920	8,131,522	1,107,639	1/ 7.3	9,239,161
1930	22,972,745	3,559,254	1/ 6.5	26,531,999
1940	27,372,397	4,663,027	1/ 5.9	32,035,424
1947	30,718,852	6,641,611	1/ 4.6	37,360,463
1/ 1948	33,225,000	7,332,000	1/ 4.5	40,557,000

1/ Estimated

Schedule II

Speed Zones vs. Uniform Legal Limit for State
Relation between Curvature and Safe Speeds

Degree of Curvature	Radius of Curvature	Suggested Zone Speed*
	Feet	mph
3	1910	60
4	1433	53
5	1146	48
6	955	43
7	819	40
8	717	37
9	637	35
10	574	33
11	522	32
12	478	31
13	442	30
14	410	29

* Before zoning speeds are posted the curves should be tested by competent observers to determine the safe speed for the particular conditions.

Schedule III

Efficient Operating Grades for Trucks

Distance from bottom of grade where trucks would be reduced to 30 miles per hour.

This schedule assumes an approach speed of 40 mph. Bad alignment, weak or narrow bridges, or other hazardous conditions at the bottom of the hill would make these speeds unsafe.

Light-powered trucks with gross loads of 30,000 pounds

Grade	Distance from bottom of grade	Vertical climb from bottom of grade
Percent	Feet	Feet
2	2000	40
3	1090	33
4	760	30
5	570	29
6	470	28
7	400	28
8	325	26

Medium-powered trucks with gross loads of 40,000 pounds

2	1780	36
3	1035	31
4	740	30
5	550	28
6	450	27
7	390	27
8	320	26

Schedule IV

Hourly Design Capacities for Express Highways1/

Type of highway	Rural areas 2/		Urban areas 3/	
	Flat Terrain 4/	Rolling Terrain 5/	Flat Terrain	Rolling Terrain
2-lane	600	500	-	-
4-lane	2800	2500	4550	3850

1/ Based on 10 percent commercial vehicles during the peak hours.
2/ Based on 2/3 of traffic in one direction and an operating speed of 50 mph.
3/ Based on 60 percent of traffic in one direction and an operating speed of 35 to 40 miles per hour.
4/ Based on sight distance of at least 1500 feet on 80 percent of the 2-lane highways.
5/ Based on sight distance of at least 1500 feet on 60 percent of the 2-lane highways.

Schedule V

Annual Average 24-hour Design Capacities for Express Highways
(For average conditions)1/

Type of highway	Rural areas 2/		Urban areas 3/	
	Flat Terrain	Rolling Terrain	Flat Terrain	Rolling Terrain
2-lane	4000	3300	-	-
4-lane	18,700	16,700	38,000	32,000

1/ Based on the conditions shown in Schedule 4.
2/ Based on a 30th highest hour of 15 percent of the annual average traffic.
3/ Based on a 30th highest hour of 12 percent of the annual average traffic.

Schedule VI

Average spacing between vehicles following other vehicles closely in the same lane at the same speed

(Spacing measured from the rear bumper of one car to the front bumper of the following car)

Speed		2-lane highway		4-lane divided highway			
				Left lane		Right lane	
mph	ft/sec.	feet	seconds	feet	seconds	feet	seconds
10	14.7	30	2.04	–	–	–	–
20	29.3	42	1.43	–	–	–	–
30	44.0	62	1.41	60	1.36	80	1.82
40	58.7	90	1.53	77	1.31	105	1.79
50	73.4	122	1.66	107	1.46	130	1.77
60	88.0	162	1.84	139	1.58	156	1.77