A Sufficiency Rating Method for Urban Intersections

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INTRODUCTION

Clearly, by any measurement, highways are "big business" and are becoming more important as time passes. Consequently, it is of utmost importance that those persons in authority in the highway field recognize a duty to utilize the funds at their disposal to promote the public interest in the best possible manner—the most good for the most people —on a non-partisan basis.

As one method of implementing such a policy, a Highway Sufficiency Rating System was established as a joint effort of the Arizona Highway Department and the Bureau of Public Roads in 1946. Since that time, many states have adopted the basic idea while altering the details of application to suit their individual needs. The basic concept is that every road section is evaluated in accordance with its ability to meet the demands placed upon it, utilizing certain arbitrary standards for comparison purposes. In general, all rating systems attempt to give an evaluation of the ability of each road section to carry traffic safely, rapidly and economically (1, 10).*

The original rating systems were devised for application on the rural primary highway system, and most present variations are also thus used. If a state uses a rating system at all, it is certain to be for its rural primary roads. A sufficiency rating technique for rural state highways is currently being used in Indiana.

Ratings of urban facilities, however, are relatively uncommon. Here the procedure is usually an adaptation of the method used to rate the rural primary roads; only those facilities are rated which are urban extensions of state roads (4, 12, 13). To quote Curtis J. Hooper, formerly with the Connecticut Highway Department:

> "Across the nation the state highway departments have always devoted the major part of their effort toward the rural sections of

* Numbers in parentheses refer to references at the end of the report.

the state. Only in the recent past have their obligations been broadened to include the problems found on arterial streets in the incorporated communities.

"Having devoted a great number of years to the elimination of 'rural mud,' we are now faced with the obligation to do something about the 'urban muddle' " (9).

The rating of urban highways is much more complex than the rating of rural roads. The factors which effect the adequacy of the street are more numerous and more different of evaluation than those on rural highways. The major source of trouble and delay on urban streets is the urban intersection; the adequacy of a major street is almost always determined by the adequacy of its intersections and the operational characteristics of such intersections. As a result, any evaluation of a major urban street must of necessity include an evaluation of the intersections on that street. This paper briefly describes the development of a sufficiency rating method for such intersections based on logical, engineering procedures.

Factors which were considered to influence the ability of an intersection to serve traffic are divided into two categories and are called physical factors and traffic factors. The Physical Rating of the intersection considers the physical factors of surface condition, ridability and skid resistance, as is conventional; also rated are intersection geometrics, curb radius for right-turning vehicles, visual restrictions, and lighting. The complete Physical Rating is a function of the intersection as a unit.

The Traffic Rating uses average delay per vehicle as a measure of user satisfaction with the service provided. A Traffic Rating is determined for each approach to the particular intersection being investigated.

THE PHYSICAL RATING

The factors included in the Physical Rating are those concerned with the structural quality of the pavement or with the geometric layout of the intersection. These factors, with maximum ratings as developed for this study, are shown in Table 1.

Structural Factors

The first factor of the Physical Rating which is listed is Surface Condition. The procedure utilized to rate this factor assumes that the surface condition of the pavement is indicative of the condition of the entire pavement structure on the basis that failure of any portion of the structure will be reflected or indicated by corresponding surface distress. Pavement evaluation was thus on a performance basis.

TABLE 1

PHYSICAL RATING FACTORS

FACTOR	POINTS
Surface Condition	20
Ridability	5
Skid Resistance	5
Intersection Geometrics	20
Curb Radius for Right Turn	5
Visual Restriction	5
Lighting	5
Other Characteristics	5
	70

The rating is based on field evaluation of the "maintenance requirement" of the intersection pavement In making the evaluation all evidence of existing or impending failure is considered, including pumping, faulting, warping, map cracking, raveling, creeping, spalling, scaling, frost heave, failure of bituminous patching and resurfacing, wash-boarding, chuckholes, extruded joint filler, etc. Separate rating scales were developed for Portland cement concrete and bituminous surfaces. These scales cover maintenance measures appropriate to the respective surface types, and provide for a reduction in the rating as the maintenance measures found necessary increase in scope and severity. Table 2 lists the possible maintenance measures associated with Portland cement concrete surfaces along with rating ranges considered appropriate for surfaces with these maintenance requirements. Table 3 lists the same information for bituminous surfaces. The appropriate maintenance measures vary in some respects between the two surface types, recogniz-

TABLE 2

SURFACE CONDITION RATINGS FOR PORTLAND CEMENT CONCRETE SURFACES

MAINTENANCE REQUIREMENTS	RATING RANGE
No Maintenance Required	18-20
Joint Sealing Only	14-17
Patching	7-13
Resurfacing and/or Undersealing	3-6
Complete Reconstruction	0-2

TABLE 3
SURFACE CONDITION RATINGS FOR BITUMINOUS SURFACES

MAINTENANCE REQUIREMENTS	RATING RANGE
No Maintenance Required	19-20
Minor Patching and/or Overlay Joint Maintenance	15-18
Moderate Patching	11-14
Extensive Patching and/or Sealing	7-10
Resurfacing	3-6
Complete Reconstruction	0-2

ing the fundamental structural difference which exists between rigid and flexible pavements.

To promote uniformity of rating, more detailed descriptions of maintenance requirements have been prepared. The maintenance requirements range from "No Maintenance Required" to "Complete Reconstruction" and the defects which must exist to justify each kind of maintenance are detailed in Tables 4 and 5 for Portland cement and bituminous concrete pavement, respectively.

Table 6 presents the developed Ridability Rating, which is based on surface roughness in inches per mile. If actual measurement is not feasible or desirable (and present equipment is not adaptable to intersection areas) the indicated average roughnesses for various pavement types and conditions of pavements or estimates of pavement roughness may be used. The descriptive ratings—best, average, worst—and the roughness ranges in the table are based on previous research of the Joint Highway Research Project which included an investigation of the roughness of various kinds of pavement surfaces as built in conformance with Indiana State Highway Commission specifications (8).

Table 7 presents the skid resistance rating. Stopping distances shown are based on stopping from 30 miles per hour on a wet surface. Indications of likely distance and rating categories for various surface types as built in Indiana are taken from previous research performed at Purdue (7). Again, if field tests are not feasible, use of a table of this type which permits estimation of skid resistance is indicated.

Geometric Factors

The concern for safety and freedom of movement through proper geometric design are the main factors of interest. One way such operation is promoted is by restricting vehicles to desirable paths. Commonly in urban areas the intersection is so small that no great opportunity for erratic driving exists. In some cases, however, the

TABLE 4
MAINTENANCE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE SURFACES

Maintenance Requirements	Deficiences
No Maintenance Required	No evidence of displacement: no pumping, faulting, vertical alinement problems, etc. Slabs comparable to new in riding quality, but may show evidence of cracking on up to 5 per cent of surface area. All edges of cracks are sharp and no evidence of spalling, scaling, or raveling of aggregates can be found.
Joint Maintenance Patching	No marked evidence of joint displacement and faulting. Only slight vertical alinement problems noticeable in some sections. Usual joint maintenance and sealing procedures are adequate. Slight spalling at cracks. Very minor subgrade support problems. Surface rough, in some sections. Joint and cracks spalled and/or faulted, needing localized patching.
Resurfacing and/or Undersealing	Subgrade support problems, pumping and faulting. Rough surface over all of the section. Aggregate exposed and raveled out in some sections. 50-75 percent of slabs show severe cracking.
Reconstruction	Extremely poor riding quality. Evidence of extreme slab movement on passage of vehicles. Surface pitted and aggregate raveled out from scaled sections. 75-100 per cent of slabs show severe cracking.

TABLE 5

MAINTENANCE REQUIREMENTS FOR BITUMINOUS SURFACES

Maintenance Requirements	Deficiences
No Maintenance Required	No evidence of deformation or cracking. Smooth surface except for normal shrinkage cracking.
Minor Patching and/or Overlay Joint Maintenance	Very slight deformation and cracking. Less than 10 percent of surface area needs patching.
Moderate Patching	Slight deformation and cracking. Between 10-50 percent of surface is in need of patching.
Extensive Patching and/or Sealing	Slight deformation and moderate map cracking. About 50 percent of surface in section is breaking up in various stages.
Resurfacing Reconstruction	Considerable deformation and severe map cracking with most of the surface showing evidence of some break-up. Clear evidence of base and/or subgrade failure. Extremely distorted and broken surface.

TABLE 6
RIDABILITY RATING

		Pavement Surface Types					
Ridability Description	Roughness Inches Per Mile	Rock Asphalt	Portland Cement Concrete	Bituminous Concrete	Bituminous Coated Aggregate	Bituminous Surface Treatment	Ridability Rating
Excellent	Below 60	Best		Best			5
Good	60-75	Avg	Best	Avg+	Best		4
Fair	75-90	Worst	Avg	Avg—	Avg+	Best	3
Poor	90-150		Worst	Worst	Avg—	Avg	2
Very Poor	Above 150				Worst	Worst	1

TABLE 7

SKID RESISTANCE RATING

Stopping Distance Feet	Skid Resistance Rating	Rock Asphalt	Surface Type and Kind of Coarse Aggregate: Portland Cem. Conc.		Bituminous Concrete		Bituminous Surface	
			Stone	Gravel	Stone	Gravel	Stone	Gravel
60								
	5	Avg					Best	
70								
	4		Best Avg+	Best Avg+			Avg+	Best
80								
	3		Avg— Worst	Avg— Worst	Best Avg	Best	Avg—	Avg+
90								
	2				Worst	Avg Worst	Worst	Avg—
100	0							
								Worst
110+								

gross intersection area is excessively large because of the number of approach streets, angles of intersection, offset centerlines, or other reasons. Channelization improves such situations by minimizing "broken field running."

The technique developed for the rating of intersection geometrics in this study requires an exact definition of the intersection area. Then, for any actual intersection, the area is simply calculated.

Fig. 1 shows typical "actual areas" as defined. Notice that the

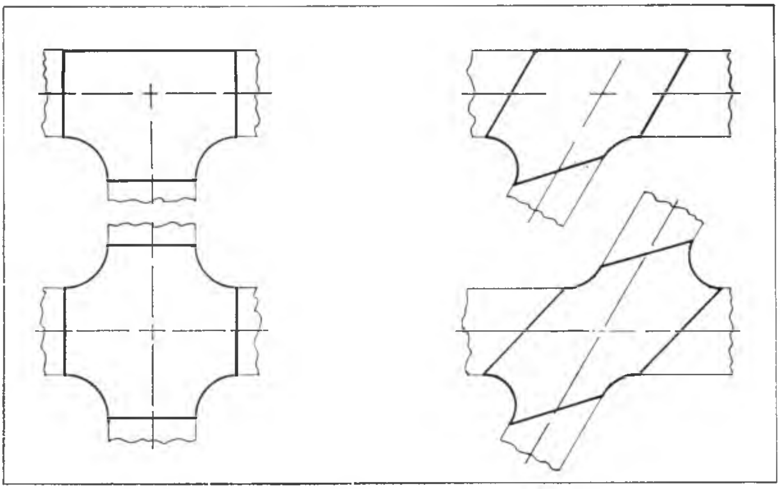

Fig. 1. Typical "actual areas."

points of tangency of the curved curb sections with tangent sections of curb are the critical points. Lines connecting such points, along with the curb areas, define the actual area. Where the intersection is three-way, boundary lines cross the through street parallel to the centerline of the side street.

The actual area of an intersection is compared to a "standard area." Fig. 2 illustrates the characteristics of a standard area, which may be summarized as follows:

> The angle of intersection is 90 degrees; street widths used are average values, in case opposite approaches are not the same width; the corner radius R is the average of all the radii of the actual intersection, with no individual radius permitted to exceed eighty feet.

The standard area cannot be calculated until certain dimensions of the actual intersection are known. The "standard area" in each case is tailor-made to the characteristics of the actual intersection under study, and its significance lies in the fact that with given street widths and curb radii the standard area is the smallest area the intersection could have.

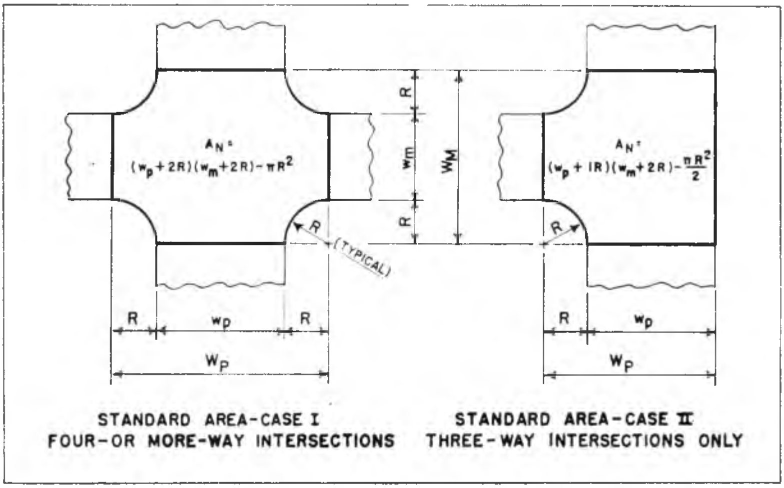

Fig. 2. Standard areas.

Varying any condition results in a larger area. By comparing actual area to standard area a measure of the excess area present, if any, can be obtained. The "area ratio" is defined as standard area divided by actual area (instead of possibly vice versa) because it was desired that the ratio values fall between zero and unity limits. Intersections with area ratios greater than .98 are given a rating of 18 points and decrease in rating value to zero points for all ratings below .64 as shown in Fig. 3.

Note that the top score on the basis of area ratio alone is 18 out of

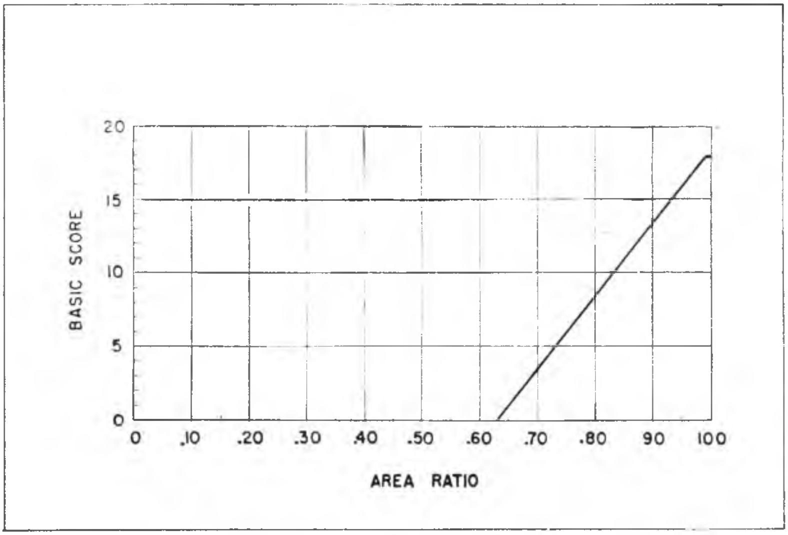

Fig. 3. Intersection geometrics basic score.

a possible 20 points. This was established because it was believed that every intersection could benefit to some extent with some channelization. Those intersections with excess area as indicated by low area ratios and low basic scores can benefit considerably by channelization.

If channelization exists, therefore, a correction factor "C" is added to the basic score, with the stipulation that the sum (or corrected score) may not exceed the maximum 20 points. The correction is calculated by measuring the lengths of all possible paths through the intersection, and obtaining the total of these distances. Only one path is used for each directional movement through the intersection, and that path most commonly used for each movement is chosen. Then each such path is examined again and the length of the path which is laterally restricted, or channelized, is measured. The total of these channelized distances is obtained and the correction is computed by the equation

$$C = 20 \times \frac{\text{Total of channelized lengths}}{\text{Total length of all intersection paths}}$$

In determining channelized path lengths, a path is considered channelized if all of the following conditions are met:

1. The path has the same number of lanes as at the intersection entry, or fewer;
2. The lane width on curved sections increases no more than 5 feet above the width of the lane on tangent alignment; and
3. Side restrictions as defined below exist along both sides of the path.

The following physical conditions are considered to produce "restriction" within the meaning established above:

1. Pavement edges,
2. Curbs of all kinds,
3. "Jiggle bars,"
4. Traffic buttons,
5. Islands,
6. Painted island extensions,
7. Lane lines setting off separate turning lanes, and
8. Any other physical dividers or separators.

The following conditions are considered as producing *no* side restriction:

1. Painted lane and centerlines,
2. Painted islands,

3. Signs, and
4. Painted legends and arrows on pavement.

Where channelized paths cross, obviously side restrictions must be interrupted for short distances. In determining restricted lengths, such short distances (say 40 to 50 feet) are ignored and the channelized length measurements carried through such gaps continuously. Use of judgment is required in this connection.

Thus far, no rating element has been introduced to discriminate with regard to the quality of the channelization. Obviously, no channelized intersection should get top rating because of the magnitude of channelization provided, irrespective of quality. Consequently, from the adjusted score (maximum value of 20, as noted above) certain deductions are then made if conditions are found to exist which are contrary to best available expert opinion. Each deduction is made only once for an interesection, even if the fault occurs more than once. Conditions which commonly exist and which are of poor quality are as follows with suggested values to be deducted from the geometrics score:

Fault	*Deduction*
Undue distortion of a major flow path	2
Undue distortion of a minor flow path (over and above the usual rule of "bend the minor flow")	1
Islands not offset at least 2 feet from the edge of a traffic lane	1
Crossing movements not near 90° angles	2
Merging movements not at flat (10°-15°) angles	2
Funneling not used where feasible	1
Shadowing not used to protect waiting or crossing vehicles where feasible	1

The basic score plus the channelization corrections, if any, (sum not to exceed 20 points) is the geometric rating. Skewed or offset unchannelized intersections are penalized by this system; so are intersections with five or more approaches because they are compared to standard areas with only four approaches. Unchannelized intersections with excess area may have their ratings improved by channelizing, and good design does this. A well-channelized intersection will receive the maximum rating of 20 points, or close to it, even if it has a large actual intersectional area.

A second geometric factor evaluated was curb radius. This factor recognizes that vehicles desiring to execute a turn should be able to do so without unduly interfering with other traffic. Truck turns are the essence of this problem, and it was arbitrarily decided that if an average of 12 or more vehicles of any design classification (average for several days) make the turn in any hour the curb design should accommodate these vehicles. Right turns are in general more critical than left turns, so the analysis was confined to the suitability of the geometry for right-turning trucks. The problem is further complicated by the effect of the angle of intersection on the vehicle path, and by the various maneuvers that are possible, such as from curb lane on the approach to curb lane on the exit, inside lane to curb lane, etc.

The rating method established is as follows. A selected design vehicle is assumed to approach in the curb lane and for adequate curb radii to encroach on no other approach lane. Fig. 4 shows the minimum

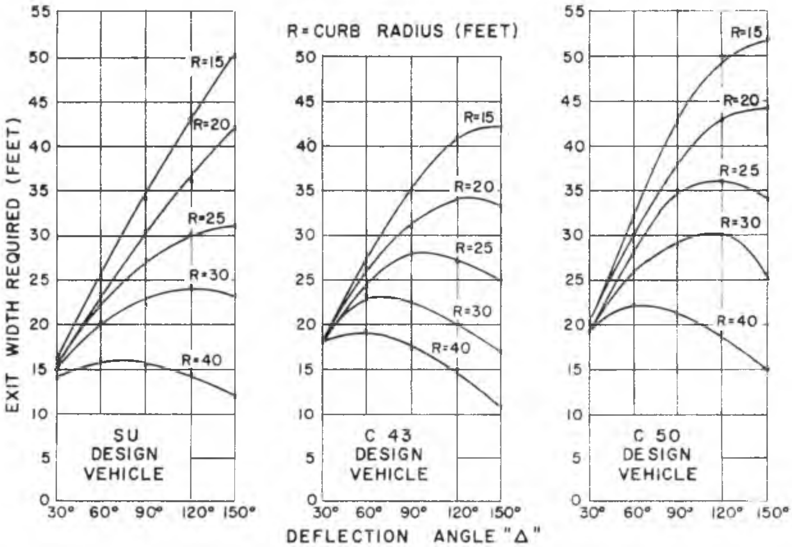

Fig. 4. Required exit widths.

exit widths required for the standard AASHO design vehicles making such an approach, given the curb radius and the angle of intersection. Exit width required is then compared with exit width available. For every foot of encroachment of the vehicle across the centerline of the exit roadway, one point of the rating for this factor is deducted. For example, a C-43 design vehicle turning a 90° corner where the curb radius is 25 feet requires about 28 feet of exit width. If the exit width available is 26 feet, there is a two-foot encroachment across the centerline and the rating is 5-2, or 3 points for this approach. The lowest approach rating is used as the Curb Radius rating for the intersection.

In considering the geometric factors a need was felt for evaluating visibility, or the lack of it. At controlled intersections, the driver (theoretically at least) doesn't need to worry about what the "competition" is doing. Nevertheless, it seems certain that inability to observe potential interference and danger leads to a sense of restriction, and as this is a geometric restriction, this effect is included in the Physical Rating factors.

The Visual Restriction evaluation method chosen is based on the American Automobile Association's graphical method of determining safe approach speeds at intersections (15). AAA's original procedure determined safe approach speed on the cross street, given major street speed, obstruction location and vehicles in the worst possible legal position.

The modification adopted stated that if visibility on the approach is such that safe cross-street speed is as high as 25 miles per hour there is no restriction, and the full five-point rating is awarded. For lower safe cross-street speeds the rating is less. A graphical method of determining the rating was developed and is given in Figs. 5 and 6.

Detailed instructions and procedures for using Figs. 5 and 6 are as follows:

1. Determine the values of a′ and b′. For most dangerous legal position, the value for a′ is either 12 feet (with parking) or 6 feet (without parking); the value for b′ is either one-half the street width plus 3 feet, or the street width minus 12 feet, whichever is smaller.
2. Measure distances from view obstructions to curb lines (a″ and b″).

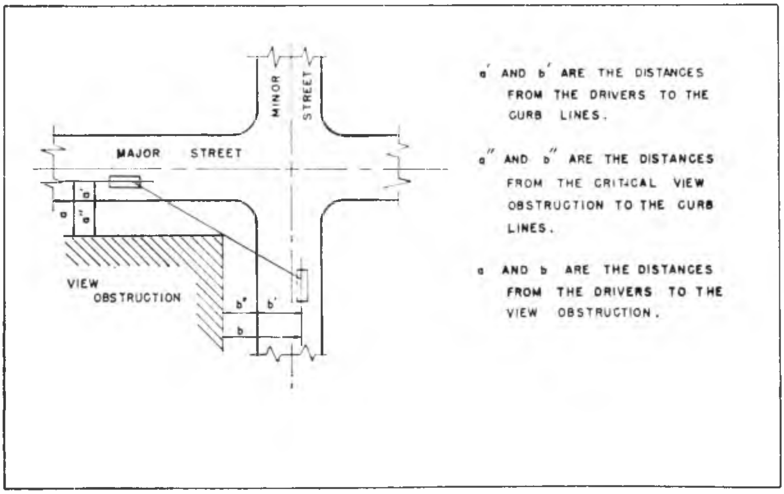

Fig. 5. Critical view obstruction location.

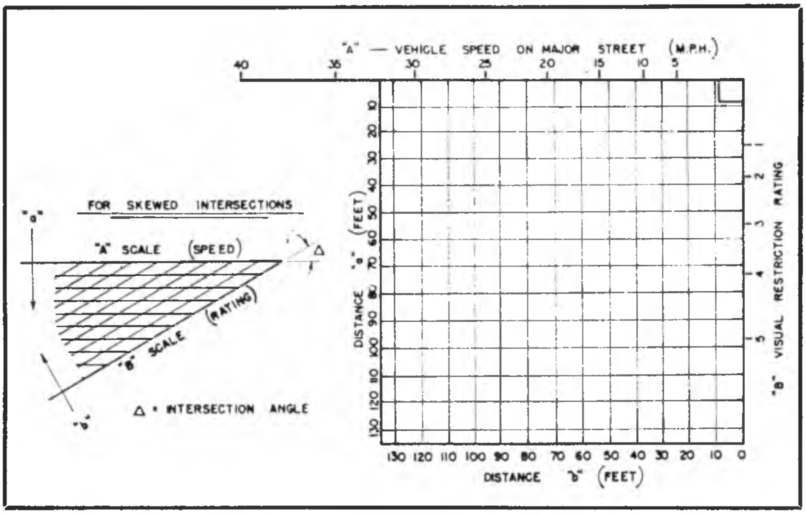

Fig. 6. Visual restriction rating chart.

3. Determine the critical distances a and b ($a = a' + a''$; $b = b' + b''$).
4. Locate the most restrictive view obstruction at the intersection on the chart, Fig. 6, by using the values of a and b obtained above.
5. Determine the speed value for the major street by using the value of the speed limit.
6. Draw a straight line through the speed value in miles per hour for the major street (on the "A" scale) and the point of the view obstruction as located in item 4 above.
7. The intersection of this line with the "B" scale is the Visual Restriction rating relative to the view obstruction.
8. The rating for the most restrictive obstruction is used as the intersection rating for this factor.

Miscellaneous Factors

Another considered factor in the Physical Rating was lighting. It appears that a number of factors operate to increase the accident rate during hours of darkness, but the only one the engineer can currently do much about is visibility. Improved street lighting is the obvious approach, and where ever the lighting system has been upgraded, accident experience has often improved (2, 5). Minimum illumination levels recommended by the Illumination Engineering Society and adopted by the American Standards Association for various levels of vehicular traffic, pedestrian volume and pavement reflectance are used as the basis for this rating (11, 16). Table 8 presents the recommended average horizontal

TABLE 8
CURRENT RECOMMENDED AVERAGE HORIZONTAL FOOTCANDLES
(Lumens Per Square Foot)

	Vehicular Traffic Classification*											
	Very Light Under 150			Light (150-500)			Medium (500-1200)			Heavy to Heaviest (1200 up)		
Reflectance	Poor 3%	Normal 10%	High 20%	Poor 3%	Normal 10%	High 20%	Poor 3%	Normal 10%	High 28%	Poor 3%	Normal 10%	High 20%
Pedestrian Traffic: Heavy (Main Bus. Sts.)	0.9	0.6	0.45	1.2	0.8	0.60	1.5	1.0	0.75	1.8	1.2	0.90
Medium (Intermediate)	0.6	0.4	0.30	0.9	0.6	0.45	1.2	0.8	0.60	1.5	1.0	0.75
Light (Residential)	0.3	0.2	0.15	0.6	0.4	0.30	0.9	0.6	0.45	1.2	0.8	0.60

*Numbers in parentheses are maximum vehicles per hour at night, total of all directions.

Based on:
American Standard for Street and Highway Lighting
D 12.1—1953

foot candles of illumination for various volumes of vehicles and pedestrians and pavement reflectance. The rating is computed by the following relation:

$$\text{Rating} = 10\left(\frac{\text{existing illumination level}}{\text{recommended illumination level}} - .5\right)$$

The rating adopted gives zero points for an illumination intensity equal to or less than half of the recommended level and, increases to the full five point rating if the recommended level is met.

Two other minor factors conclude the Physical Rating. The existence or non-existence of curbs was considered a matter of consistency for the area and is scored on an all-or-nothing basis (see Table 9). Similarly, intersection drainage is of some importance (see Table 10). These two factors are rated a maximum of five points if both factors are adequately handled and a lower number of points, dependent on the seriousness of the inadequacy, if either factor is deficient.

The sum of the ratings given to the several factors just discussed is the Physical Rating of the intersection. A perfect rating would be 70 points.

TABLE 9

CURB RATING

Existing Condition	Points
1. Intersection curbs exist where consistency and/or good design indicate a need for curbs.	3
2. Intersection curbs do not exist where there is considered to be no need for them from the standpoint of either good design or area consistency.	3
3. Intersection curbs do not exist where consistency and/or good design indicate a need for them.	0

TABLE 10

DRAINAGE RATING

Flooding History	Points
1. There exists no record of the intersection having been flooded by a "ten-year storm".	2
2. The intersection floods occasionally.	1
3. The intersection floods chronically.	0

THE TRAFFIC RATING

The physical rating for an intersection has been established on the basis of the visible and/or structural characteristics which affect traffic flow. Correspondingly a traffic rating was desired which would evaluate "customer satisfaction" with intersection conditions as influenced by interference from traffic control devices, other vehicles and/or pedestrians. These traffic influences are, in the main, variable over wide ranges during short time periods, in contrast to the stability of physical factors.

When a driver passes through an intersection with little or no delay, he is pleased; if he is delayed more than a token amount his ire rises with the length of the delay until a point of frustration and resignation is reached. Beckman, *et al,* stated it briefly:

> "Conditions are good if delay is small; they are bad if delay is large . . . we shall suppose that 'traffic conditions are fully described by an assessment of the delays that occur" (3).

"Average-travel-time delay" was selected as a factor descriptive of user satisfaction; the intersection traffic rating used in this evaluation is based on such average delay.

The delay for any given vehicle was defined as the difference between the time at which the vehicle was expected to arrive in the intersection if not interfered with by traffic control devices, other vehicles and/or pedestrians, and the actual time of entry after being subjected to any or all of the above influences. In equation form this may be stated:

Delay = Actual Entry Time—Expected Entry Time, or briefly:

Delay = Time In—Time Due In.

Traffic ratings based on such an average delay criterion are applicable to all intersection approaches and a rating scale was adopted which awards a full 100 point Traffic Rating to any intersection approach where average delay per vehicle on that approach for vehicles during the peak hour is ten seconds or less. The rating then decreases linearly at the rate of two points for every additional second of delay, becoming zero at an average delay of 60 seconds.

A Traffic Rating is determined for each approach to an intersection, and the Intersection Traffic Rating is found by calculating the weighted average of all the approach ratings. That is, each approach rating is multiplied by the volume on that approach; the sum of all of these products is divided by the total intersection volume to give the Intersection Traffic Rating.

This is glibly stated, and easily done—but the average delays for each approach must be evaluated. The evening peak hour usually poses the worst congestion problems. Delays at that time will most often be used. The delays may be field measured using appropriate procedures, or in some cases, they may be closely approximated and rated directly from theoretical curves developed as a part of this research. These curves for fixed-time signalized intersections are shown in Figs. 7-15.

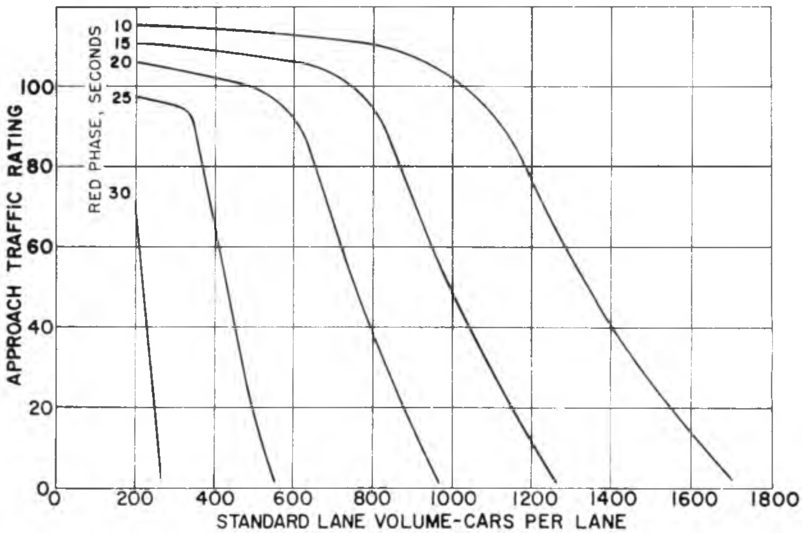

Fig. 7. Intersection approach traffic rating, 40-second cycle and various red phase lengths.

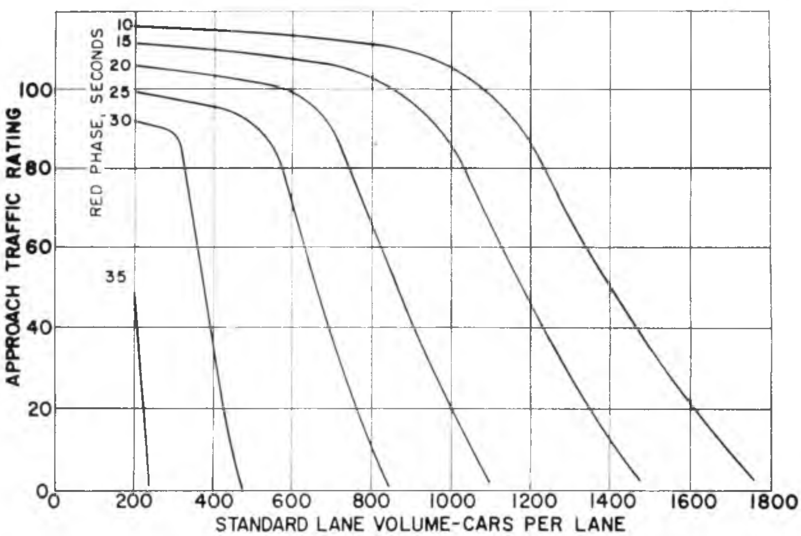

Fig. 8. Intersection approach traffic rating, 45-second cycle and various red phase lengths.

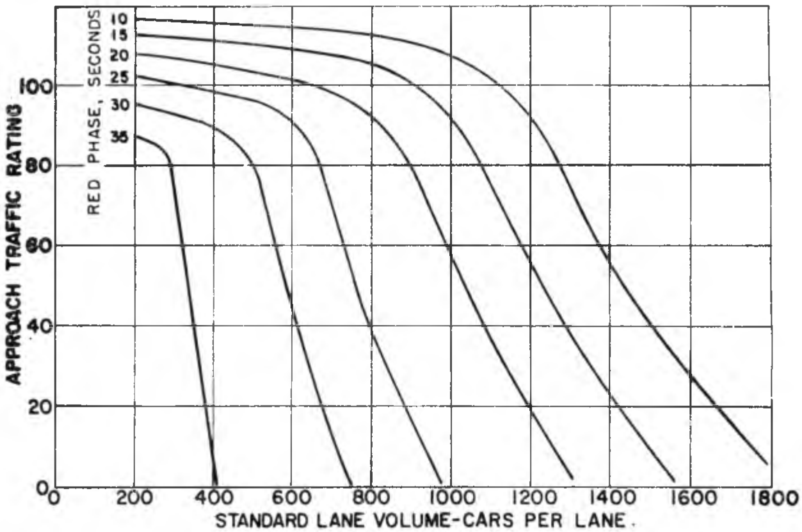

Fig. 9. Intersection approach traffic rating, 50-second cycle and various red phase lengths.

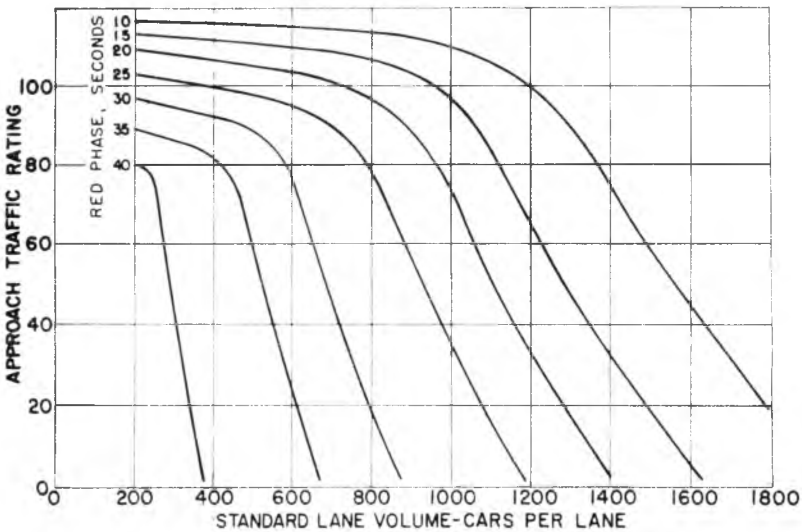

Fig. 10. Intersection approach traffic rating, 55-second cycle and various red phase lengths.

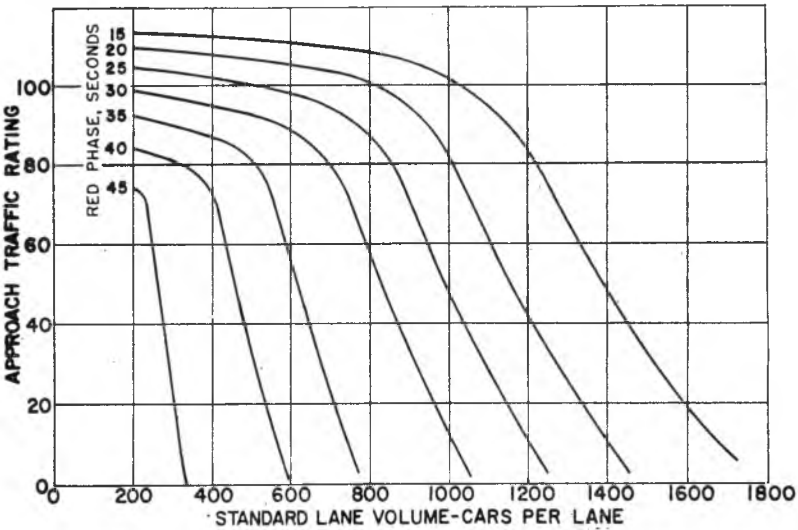

Fig. 11. Intersection approach traffic rating, 60-second cycle and various red phase lengths.

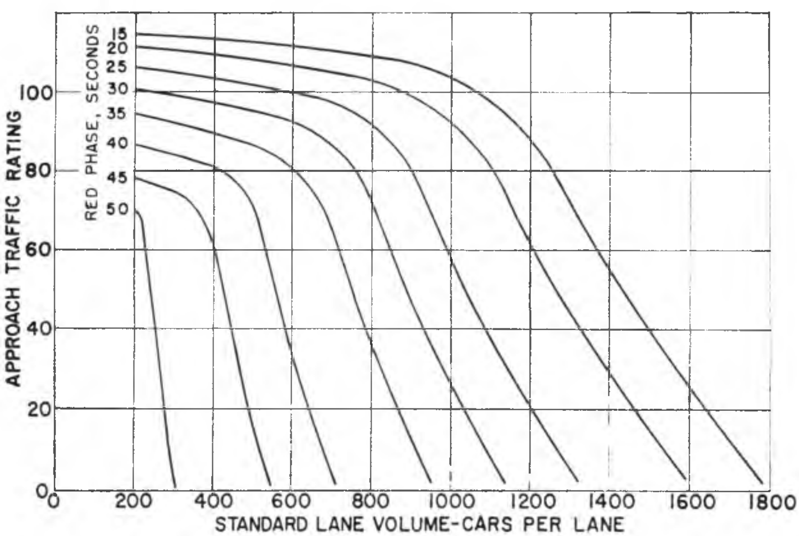

Fig. 12. Intersection approach traffic rating, 65-second cycle and various red phase lengths.

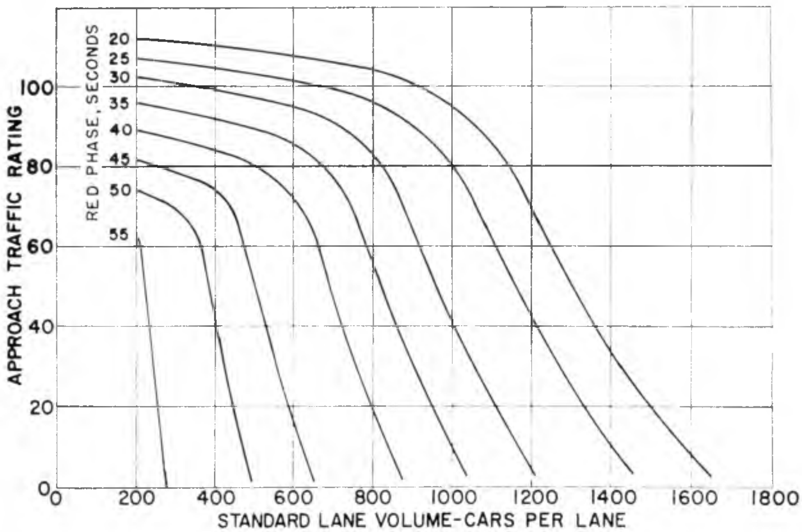

Fig. 13. Intersection approach traffic rating, 70-second cycle and various red phase lengths.

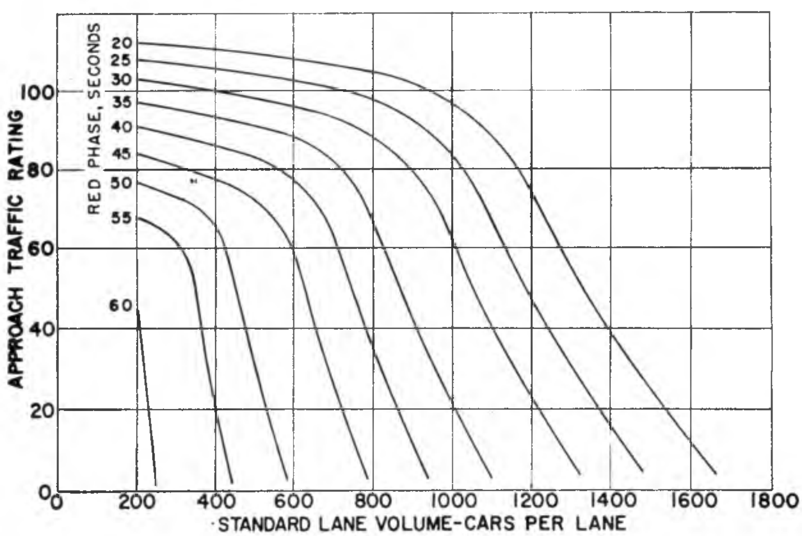

Fig. 14. Intersection approach traffic rating, 75-second cycle and various red phase lengths.

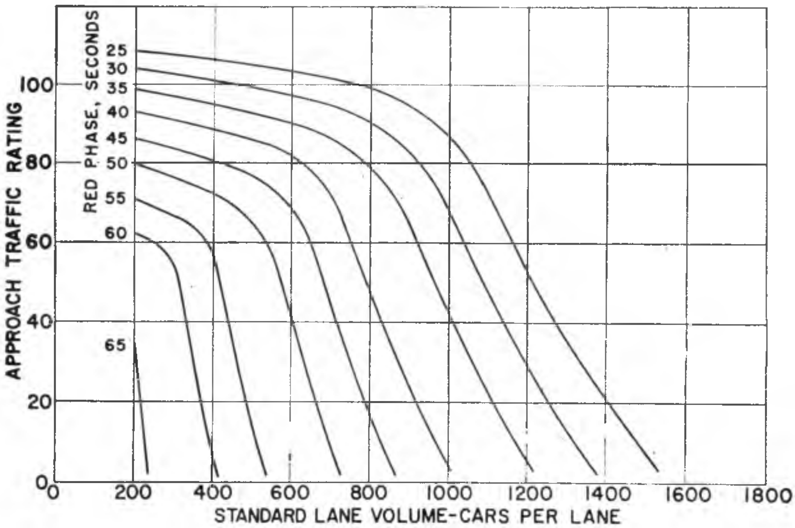

Fig. 15. Intersection approach traffic rating, 80-second cycle and various red phase lengths.

The use of these curves requires that one enter the proper figure (the one with an appropriate cycle length), select the curve corresponding to the length of the red phase on the subject approach (interpolate between two of the given curves if necessary), and obtain the approach traffic rating by use of the standard lane volume. Determination of standard lane volume is facilitated by using the chart shown in Fig. 16. The use of this chart requires that one count the highest 15-min. volume of vehicles using the approach during a typical day and converting to an hourly volume by multiplying by four. The result is the approach volume. The approach capacity is computed in the normal way using the standard *Highway Capacity Manual.* Using these two values the standard lane volume is obtained directly from Fig. 16.

In this "how-to-do-it" paper, time does not permit investigating the ancestry of the traffic rating curves, but their development is fully covered in Reference 14 listed at the end of this report. The theoretical curves have been field-tested in compliance with the assumptions made in their derivation and they were found to be realistic. Many more curves, however, are needed to cover all types of intersection control. Average delay, however, provides a reasonable basis for evaluation, and it can be estimated from field studies or by the suggested theoretical means. Although it has been discussed in brief, it should be emphasized that vehicular delay is the most important factor in rating an intersection.

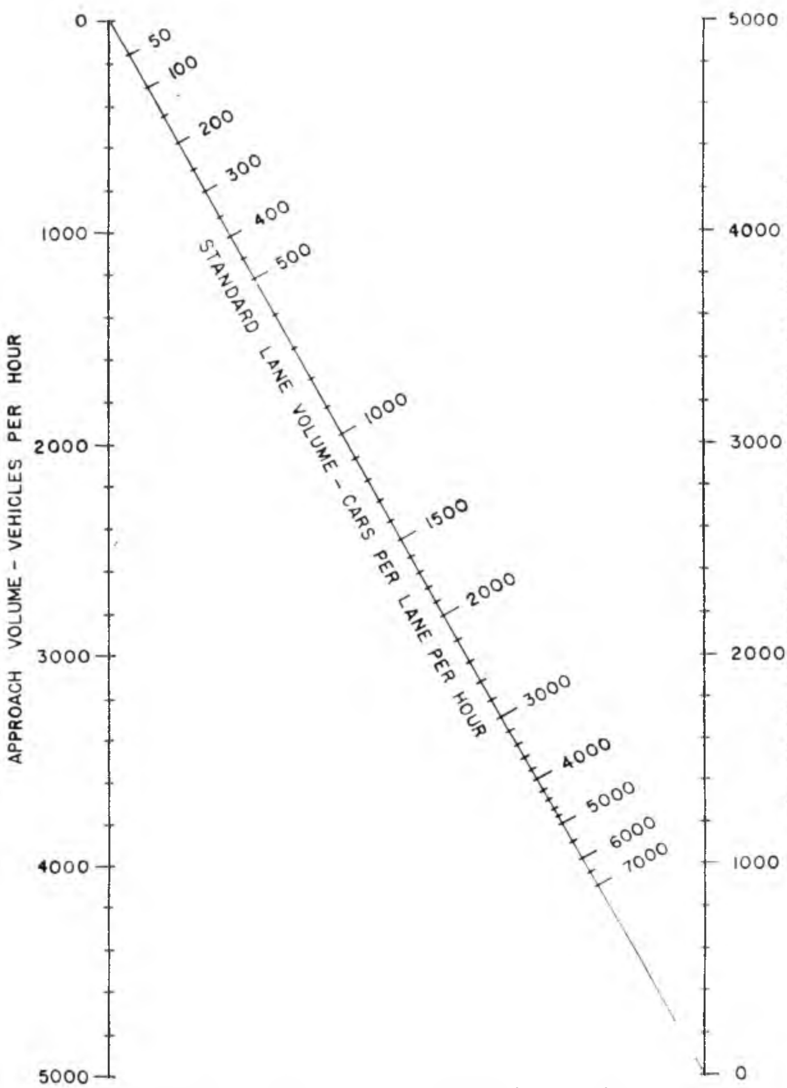

Fig. 16. Determination of standard lane volume.

THE INTERSECTION RATING

Any rating device is necessarily an attempt to evaluate how good or how poor something is—whether the thing being rated is relatively "sufficient" or "deficient." Which approach is used does not really make too much difference, but the "sufficiency" approach seems more widespread, and has been utilized here. The "fully sufficient" intersection will, therefore, be rated 100 per cent, and all others will be rated lower. The poorer the intersection, the lower the rating according to the relation to be established.

When the Traffic Rating is high (average delays are low) the Intersection Rating should be high. In general this condition will occur at low volumes where physical deficiencies are relatively unimportant, so the Physical Rating should have a limited effect on the Intersection Rating. The Intersection Rating should also reflect the increase in importance of physical deficiencies with decreasing Traffic Ratings (higher flows).

Lowest Intersection Ratings should occur when both the Physical and Traffic Ratings are low. This means high volume-to-capacity ratio plus poor physical condition equals minimum rating, indicating a need for immediate attention.

When the Physical Rating is high, approaching its maximum value of 70, the Intersection Rating should depend virtually entirely on the Traffic Rating. Hence, a good Physical Rating coupled with moderate flow at low delays should yield a high score, but the same good Physical Rating coupled with high flow with high delays should result in a low Intersection Rating.

The relation adopted for the Intersection Rating basically begins with a perfect score of 170 and deducts for deficiencies found. Traffic Rating deficiencies are at all times fully deductible. Physical Rating deficiencies, however, are multiplied by a factor before being subtracted. This factor is a function of the Traffic Rating, such that if the Traffic Rating is zero (delays are high) the Physical Rating deficiency is also fully deductible. If, however, traffic is light and the Traffic Rating is 100 per cent, then only half of the Physical Rating deficiency is deductible.

In its basic form, the relation is:

$$IR = \frac{170 - (100\text{-}TR) - (70\text{-}PR)\left(\frac{100\text{-}0.5\ TR}{100}\right)}{170} \times 100$$

What is left of the original 170 points after the fully-deductible Traffic Rating deficiency (difference between perfect and actual ratings) and the variable Physical Rating deficiency deductions are applied, is divided by 170 points and multiplied by 100 so that the Intersection Rating is in percent.

As stated above, the equation is not convenient for calculation; the form given below, obtained by multiplication and collection of terms, will be found to be much handier.

$$IR = \frac{270\ TR + 200\ PR - TR \times PR}{340}$$

SUMMARY

A general procedure has been established whereby the sufficiency of any urban intersection may be determined. The sufficiency of an intersection is evaluated by rating the physical and traffic characteristics with major emphasis placed on the ability of the intersection to handle the required traffic movements. Average delay is used as the important measure of this ability. Specific rating values are given for those intersections where control is by fixed-time signal and uniform arrival may be assumed.

Field investigation indicated that the over-all rating procedure presented produced reasonable results and that it discriminated among intersections whose characteristics were nearly the same.

The rating procedure presented in this report is recommended for evaluating the sufficiency of urban intersections. The sufficiency estimate thus obtained should be used as a tool in connection with other pertinent considerations to establish improvement priorities.

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