The Use of a Priority Formula in Urban Street Programming

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There is a need for a simple formula that would aid in developing major arterial street improvement programs in urban areas. The need for careful capital programming is emphasized by the general lack of local government funds for such purposes.

Research from three cities (San Diego, Phoenix, and Nashville) covering a span of about six years is presented. As these studies proceeded, three basic test formulas were developed and evaluated. Further variations of the most recent formula were intensively evaluated, and a test formula is presented. The results of the work in the three cities indicate that an urban street construction priority formula should not be too complex, certainly minimize the judgment elements that go into it, and be based on facts. The formula makes possible the presentation of various projects in a relative priority list. At this point, administration, coordination, and budget considerations and judgment can most properly be applied to develop a capital program that will provide maximum benefit to the public.

•WITH THE DEMAND for governmental services constantly increasing at all levels of government, there is a noticeable and growing trend for the public to resist increased taxes and turn down bond programs. Nowhere is this paradox more acutely felt than at the local level of government. Our urban areas are faced with ever-increasing numbers of people and their desire to move in individual vehicles.

Urban streets are costly—a mile of modern 4-lane major street will cost nearly $500,000 for engineering, right-of-way and construction—and urban street funds are difficult to find. The problem of the city of Phoenix, Ariz., (Table 1) illustrates the point. The 1963 lesgislature increased the state motor fuel taxes 1 cent—to 6 cents per gallon, providing Phoenix with an additional $1.6 million per year. These funds were secured only after three years of increasingly intense, well-organized effort by a large number of organizations and citizens. The need for these new funds was glaringly apparent and was well-recognized by the general public.

The adopted 6-year major street and highway capital improvement program anticipates constructing nearly 28 miles of major arterial street and two railroad grade separation structures at a cost in excess of $20.5 million by 1969. This is about four miles of major arterial street a year.

Phoenix is used merely to emphasize that the limited funds for the improvement of major arterial streets in urban areas must be carefully programmed to insure the maximum return to the motorist for his investment. Such programs must be based on factual priorities that can be understood by the public.

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TABLE 1

City of Phoenix, Arizona

Street & Freeway Financing—Next 20 Years

THE PROBLEM

		Millions	
		Total	Per Year
Total Deficiencies & Needs – *1962*		$333.8	
LESS: Freeways Financed by Other Agencies	$90.5		
Local & Collector Streets Financed by Property Owners	106.7		
Total Financed by Other than City		-197.2	
CITY OF PHOENIX RESPONSIBILITY		$136.6	$6.8
Revenue for Construction—Existing Sources		-24.3	-1.2
SHORT – *1962*		$112.3	$5.6
New Funds From 1963 Legislature			-$1.6
Still **SHORT**			$4.0

BACKGROUND

The need for a simple formula to aid in establishing the priority for streets to be constructed in urban areas has long been recognized. Certainly such a formula would not replace judgment but would be a device to list urban projects as to their relative importance.

Recognizing the need for urban program priority procedures has led to significant contributions in this direction. Among the most notable are the carefully detailed program of Milwaukee, Wis., the Kentucky Urban Program Priority Procedures developed in 1957, the Tennessee Priority Method, and the recent work done by the Automotive Safety Foundation in cooperation with the Washington State Highway Commission.

Possibly urban street priorities must be based on the individual characteristics of each urban area as available data, the recognition of the need, and available funds vary from city to city and state to state. However, there would be considerable merit in a simple, easily applied urban street construction priority formula susceptible to certain types of national summary and analysis. Perhaps this would be a means of developing a clear and more factual evaluation of the critical needs for additional funds to provide necessary urban transportation systems.

There are several areas where priority formulas will prove useful—resurfacing programs, freeway construction, traffic signal installations, and arterial street construction. This paper is confined to the development and testing of an urban major arterial street construction priority formula which may have wider application.

A list of major street construction projects based on a priority formula could be a significant aid to the development of a recommended capital improvement program for urban areas. A major concept in the development of a formula is to reduce judgment in the formula to the absolute minimum, thus making the formula as factual as possible. Judgment and budgetary elements would be brought into the final selection of the actual projects for the recommended program.

In September 1960, the Highway Research Board sponsored a workshop conference on formulating highway construction programs; the results were published (HRB Special Report 62, 1961) and are an important contribution by the Department of Economics, Finance and Administration. A similar conference directed primarily at problems of formulating major street and freeway construction programs in urban areas would also be a significant contribution to this field. The American Public Works Association Transportation Committee is now studying major street construction priorities for urban areas. This committee hopes it will develop a useful publication. One objective is to include several priority formulas developed for use in urban areas. In the background is also the work of the National Committee on Urban Transportation. The subcommittee on Developing Project Priorities for Transportation Improvement summarized their work in Procedure Manual 10-A of the National Committee series. This procedure manual developed a suggested technique and form for the complete evaluation of a

TABLE 2

PROPOSED GUIDING PRIORITY RATING METHOD[1]
(San Diego Metropolitan Area Transportation Study)

$$\text{Priority Index} = \frac{\text{Project Cost per Vehicle-Mile}}{\text{Project Benefit Index}}$$

		Relative Weight	
Project Benefit Index			
Community service:			
Pattern and continuity		15	
Coordinating and timing		15	
Roadbed condition		5	
Present capacity ratio		15	
Long-range future service		10	
Subtotal			60
User benefits:			
Time saving-delay rate:			
Present	5		
5-yr future	5		
Subtotal		10	
Duration of deficiency		5	
Distance saving of improvement, 5-yr avg.		5	
Accident rate, 2 year		15	
Time to amortize investment		5	
Subtotal			40
Total			100
Project Cost			
Right-of-way plus construction per vehicle-mile (10 yr)			

[1]Priority rating index should be based on the expected improvement in deficient conditions.

project, including street classification, when the project is needed, administrative and budgetary considerations, and service considerations. This paper is concerned with formulating a simple factual analysis of the service considerations, a continuation of the programs undertaken by San Diego, Phoenix, and Nashville.

SAN DIEGO EFFORT

The city of San Diego, Calif., has been publishing an annual 6-yr capital improvement program for many years. As a part of the pilot city program of the National Committee on Urban Transportation, efforts were made to develop a capital improvement program priority formula for major street construction. Two of the earliest formulas were based primarily on traffic data. In one of these, priority was determined by the percent capacity overload, a second combined volume, speed and delay, and accident rates into a priority formula. Both these efforts were helpful but were not the sought-for formula.

Table 2 gives a guiding priority rating method developed in 1958. The basic philosophy of the formula was to weight community service 60 percent and user benefits 40 percent. The final priority index brought cost into the picture by dividing the cost per vehicle mile by the project benefit index. In an effort to test this formula, 25 projects were selected. Eleven people having knowledge and responsibilities in administration, planning or engineering, who participated in the capital improvement program project selection, were asked to rank the 25 projects. As this test proceeded, it became obvious that the formula itself included judgment in all of the community service benefits as well as some of the user benefits. At least 70 points out of 100 in this formula were basically judgment ratings. Thus, the proposed priority rating formula simply provided a judgment ordering of the projects, essentially no different from the results obtained by the capital improvement committee using the same basic factual data. In short, the formula was too complicated and included entirely too much judgment to be of real use.

San Diego has continued its work in this area and is currently testing the same formula discussed in this paper. They are also developing and testing several variations as part of a "three city" research project.

PHOENIX FORMULA AND TEST

The city of Phoenix completed a street deficiency study in December 1961, which found that approximately 152 miles out of 260 miles of major arterial streets were deficient. The limitation of funds makes it essential that the priority of projects be carefully determined to insure the maximum benefit to the motoring public.

From the San Diego effort, Formula B was developed (Table 3). Again it is clear that there is a considerable amount of judgment in the elements to be rated. For this reason Formula C (Table 4) was developed for test purposes.

Formula C reduces judgment to a minimum and contains four basic elements: delay rate, safety record, structural condition, and traffic service. Delay rate is assigned a relative weight of 50 percent. Delay during the peak hour is an excellent direct and indirect measure of the service provided by a street. Indirectly it measures side friction, capacity, congestion, psychological impact on driver and, in a sense, the accident rate. In an urban area the time a driver takes to go from A to B is a most important yardstick of the quality of traffic service of the transportation system. The collision index recognizes the safety record of the facility, which although important, is difficult to measure truly.

Structural condition is important; however, in an urban area it is felt to be of relatively much less importance than the delay or traffic service element. The structural condition element is broken into surface and drainage portions. In some areas the drainage may assume relatively more importance than the surface and subsurface condition, or vice versa. It is important that structural condition itself is 15 percent of the total relative weight.

Traffic volume itself is the final element in a street improvement formula. Traffic volumes are included in the delay rate, but they are also included in the formula because

TABLE 3

PHOENIX MAJOR STREET IMPROVEMENT PRIORITY, FORMULA B
(Jan. 12, 1961)

Element		Relative Weight (points)	
Community Service			
Master plan-continuity of route development		10	
Coordination and timing in relation to other projects and jurisdictions		10	
Structural condition		15	
Surface	2		
Subsurface	8		
Drainage	5		
Ratio of $\frac{\text{future (design)}}{\text{present}}$ traffic volumes		10	
Present capacity ratio		10	
Subtotal			55
User Service			
2-yr accident rate/mile + accident/mile		10	
Duration of deficiency		10	
Time saving			
Delay rate "after" less delay rate "before"		15	
Time to amortize investment		10	
Subtotal			45
Possible points			100

Highest point value = most needed facility

TABLE 4

PHOENIX MAJOR STREET IMPROVEMENT PRIORITY, FORMULA C

Element		Relative Weight (points)
Delay rate per mile during peak hour		50
Collision index—2-yr accidents/mile plus accident rate/mile		15
Structural condition		15
Surface and subsurface	5	
Drainage	10	
Traffic - $\frac{\text{present ADT}}{2{,}000} + \frac{\text{future (5-yr forecast) ADT}}{\text{present ADT}}$		20
Possible points		100

Highest point value = most needed facility

of their importance. The aim was to give an important weight within the traffic element to the present traffic and yet recognize the future traffic needs. Toward this end, a 5-yr forecast is suggested. At first glance this may appear to be too short a time; however, the traffic element in the formula indicates that present traffic needs generally outweigh future needs. The formula gives heavy weight to future traffic volumes where a very rapid growth in traffic is envisioned. The 5-yr forecast period acknowledges the limitations that apply to 20-yr forecasts on specific major arterial streets, whereas normally, capital programs are for 5- or 6-yr periods.

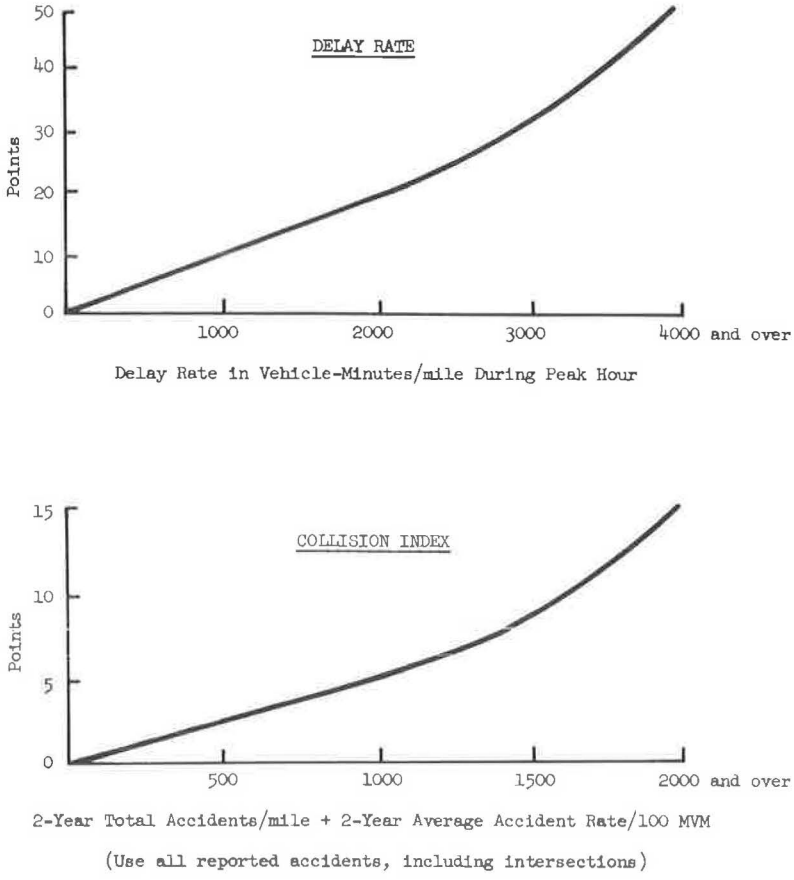


Figure 1. Major street improvement priority, Formula C, rating scales.

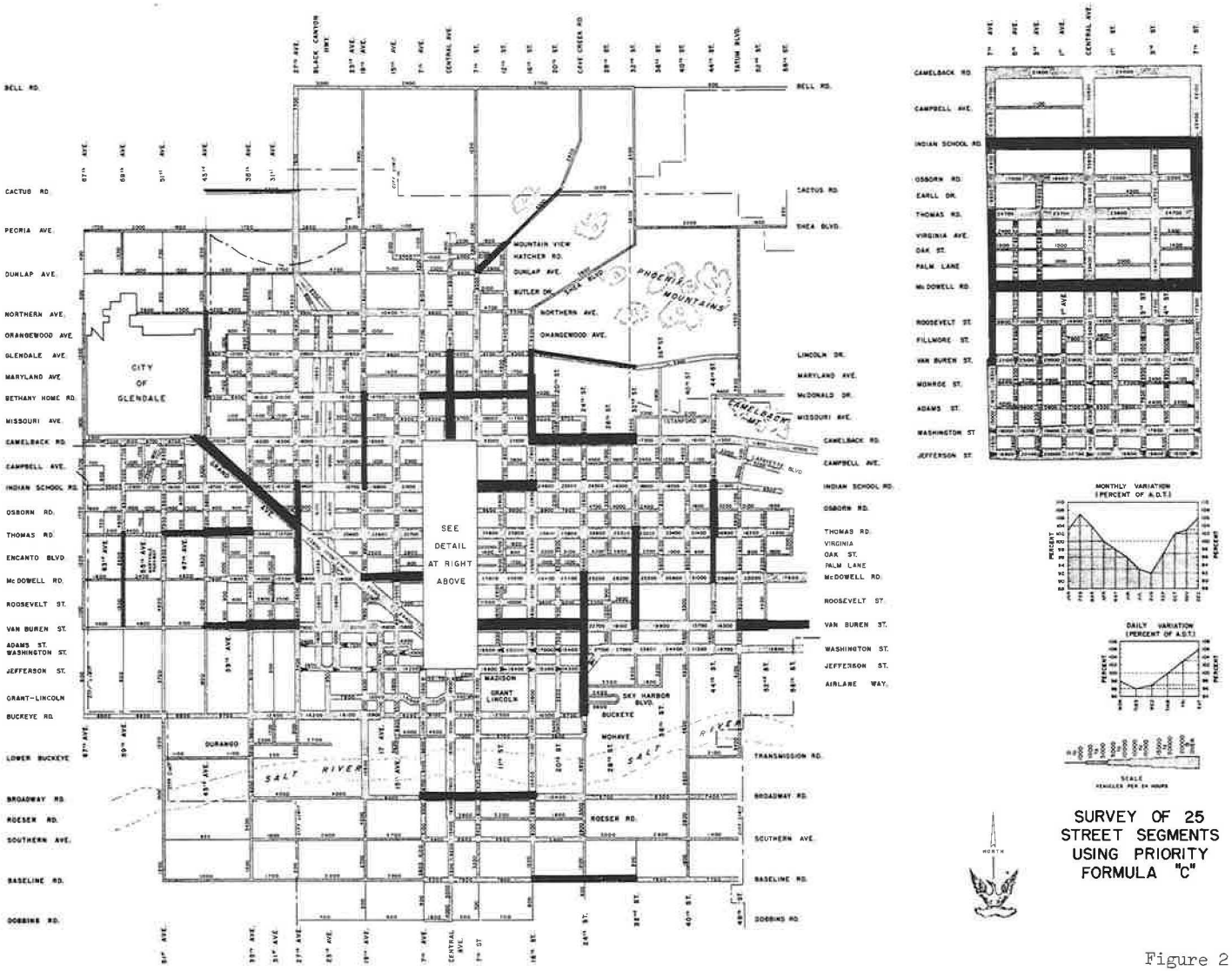
In conjunction with Formula C, two rating scales were developed to determine the points for the delay rate and collision index. These curves (Fig. 1) were developed using existing data from Phoenix and San Diego combined with the following points of view:

1. The delay rate should give relatively few points in the lower scale of delay but the number of points should increase more rapidly as greater delay rates are experienced.
2. Accident rates should be used but tempered with the total number of accidents. Otherwise, erroneous conclusions can be drawn from either the accident rate or the use of total accidents.

Twenty-five street segments (a total of 51.5 miles) (Fig. 2) were selected to test the formula. The selection of these segments was carefully done to insure a range of projects from those recently completed through projects obviously extremely low on the priority scale. The completed projects were rated as they existed prior to their recent improvement. Asked to participate in the judgment ratings were nineteen individuals having responsibility in the areas of administration, planning, public works, traffic engineering, engineering, and street maintenance.

TEST RESULTS

Table 5 gives the result of the judgment ratings and demonstrates the widespread dispersion of the judgment of individual raters, all experienced people in positions of



SURVEY OF 25 STREET SEGMENTS USING PRIORITY FORMULA "C"

Figure 2.

TABLE 5

PHOENIX FORMULA C JUDGMENT RATINGS

Segment	Location	Relative Order by Individual Raters																			Priority (avg.)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
A	59th Ave. Van Buren—Thomas	22	25	23	24	24	25	25	23	22	25	20	24	25	18	19	19	24	25	25	25
B	43rd Ave. Bethany—Northern	18	20	24	20	23	24	20	18	21	17	19	23	23	24	9	22	21	21	17	22
C	27th Ave. McDowell—Ind. Sch.	17	14	8	19	14	17	13	10	16	13	10	16	15	17	4	16	16	15	9	14
D	19th Ave. Ind. Sch.—Bethany	6	5	5	7	12	12	10	7	6	21	18	15	13	13	8	3	6	13	16	8
E	7th Ave. Van Buren—Thomas	4	2	3	4	4	5	4	2	15	6	3	2	4	8	3	2	3	1	3	3
F	Central Camelback—Glendale	10	16	22	8	11	6	16	14	17	1	1	17	7	11	21	5	11	23	23	12
G	7th St. McDowell—Ind. Sch.	1	1	1	2	1	3	2	3	2	4	7	3	2	1	25	1	4	2	2	1
H	16th St. Camelback—Glendale	9	6	16	9	13	11	7	9	14	7	17	12	11	7	14	14	12	9	10	10
I	24th St. Buckeye—McDowell	7	4	4	3	5	4	5	5	3	2	2	5	3	5	2	17	5	5	5	4
J	32nd St. Van Buren—Thomas	12	15	19	5	6	18	8	11	7	5	8	7	6	6	12	13	17	8	8	7
K	44th St. McDowell—Ind. Sch.	14	9	11	18	15	19	15	12	20	9	9	21	8	12	11	12	18	11	12	13
L	Baseline 16th St.—32nd St.	24	24	21	12	22	16	23	24	13	24	21	22	21	22	13	20	25	19	22	23
M	Broadway 7th Ave.—16th St.	21	10	13	17	17	9	12	20	19	16	14	10	12	20	10	10	23	10	15	16
N	Van Buren 43rd Ave.—27th Ave.	13	11	6	14	7	7	6	15	12	19	4	8	5	14	5	11	14	7	6	6
O	Van Buren 7th St.—24th St.	23	22	20	23	20	20	18	6	4	8	13	11	17	4	24	9	19	17	20	19
P	Van Buren 48th St.—60th St.	19	19	18	22	21	8	22	17	23	18	23	20	20	23	22	21	8	16	21	20
Q	McDowell 19th Ave.—7th St.	2	3	2	1	2	1	3	1	1	3	6	4	1	3	23	7	1	4	1	2
R	Thomas 51st Ave.—35th Ave.	11	13	9	15	10	10	14	16	18	15	22	18	18	16	17	15	20	14	11	18
S	Ind. Sch. 7th Ave.—16th St.	5	17	15	21	16	21	1	4	10	12	12	6	22	2	20	6	2	6	7	9
T	Camelback 16th St.—32nd St.	25	18	10	10	9	15	19	8	11	11	11	14	9	21	16	18	10	18	19	15
U	Bethany 7th Ave.—16th St.	20	8	14	11	8	13	17	13	8	10	15	9	14	9	7	8	15	12	13	11
V	Glendale 16th St.—32nd St.	15	21	17	13	19	23	24	22	24	22	16	19	19	19	15	23	7	22	24	21
W	Cave Creek 7th St.—20th St.	8	12	12	16	18	14	9	21	9	23	24	13	16	10	1	25	13	20	14	17
X	"Q" Ave. 43rd Ave.—Black Canyon	16	23	25	25	25	22	21	25	25	20	25	20	24	25	18	24	22	24	18	24
Y	Grand Ave. Thomas—Camelback	3	7	7	6	3	2	11	19	5	14	5	2	10	15	6	4	9	3	4	5

responsibility in the street program of a major city. Usually one or two raters were rather far off the mean. Alternate efforts were made to reduce the spread of judgment ratings. For example, the highest and lowest rater were eliminated; then the two high and two low. These efforts produced no significant difference in the order of the judgment ratings. Table 5 also demonstrates that any one project may receive a spread in judgment rating from nearly the highest to the lowest. Because judgment is not infallible, it is difficult to determine whether the formula or the combined judgment of the raters is correct. Perhaps these factors emphasize best the need for a major street improvement priority formula.

Table 6 compares these judgment ratings to the order of priority developed by the formula. The difference in positions between the judgment and formula ratings for each street segment is given in the final column. The individual segments with a difference of position of five or more are indicated.

The largest deviation of 16 positions occurred on Segment O, obviously in need of improvement. However, this 4-lane facility is presently in an intensively developed area and is fully improved. As a practical matter, significant relief will come from a nearby parallel freeway included in the adopted major street and highway plan. Here is a situation where the priority formula gave a high rating but judgment would remove it from the construction program. This demonstrates the judgment and funding considerations that must be applied in the development of a capital improvement program.

Table 7 gives the specific points for each element of the formula for the 25 projects. Review of this table gives insight into the other projects where there is a significant deviation between the formula and the judgment ratings as follows:

TABLE 6

PHOENIX COMPARISON OF JUDGMENT AND FORMULA C RATINGS

Segment	Location	Judgment Priority	Formula Priority	Position Difference
A	59th Ave. Van Buren—Thomas	25	21	4
B	43rd Ave. Bethany Home—Northern	22	19	3
C	27th Ave. McDowell—Indian School	14	8	6*
D	19th Ave. Indian School—Bethany Home	8	17	9*
E	7th Ave. Van Buren—Thomas	3	6	3
F	Central Camelback—Glendale	12	12	0
G	7th St. McDowell—Indian School	1	5	4
H	16th St. Camelback—Glendale	10	15	5*
I	24th St. Buckeye—McDowell	4	7	3
J	32nd St. Van Buren—Thomas	7	9	2
K	44th St. McDowell—Indian School	13	10	3
L	Baseline 16th St.—32nd St.	23	25	2
M	Broadway 7th Ave.—16th St.	16	18	2
N	Van Buren 43rd Ave.—27th Ave.	6	11	5*
O	Van Buren 7th St.—24th St.	19	3	16*
P	Van Buren 48th St.—60th St.	20	23	3
Q	McDowell 19th Ave.—7th St.	2	1	1
R	Thomas 51st Ave.—35th Ave.	18	22	4
S	Indian School 7th Ave.—16th St.	9	4	5*
T	Camelback 16th St.—32nd St.	15	13	2
U	Bethany Home 7th Ave.—16th St.	11	14	3
V	Glendale 16th St.—32nd St.	21	24	3
W	Cave Creek 7th St.—20th St.	17	16	1
X	"Q" Ave. 43rd Ave.—Black Canyon	24	20	4
Y	Grand Ave. Thomas—Camelback	5	2	3

*Difference of 5 or more between judgment and formula order of priority.

TABLE 7

PHOENIX FORMULA C

Segment	Location	Relative Weight (points)				Total Points (100 max.)	Formula Rank
		Delay Rate (50 max.)	Collision Index (15 max.)	Structural Condition (15 max.)	Traffic (20 max.)		
A	59th Ave. Van Buren—Thomas	0	3	12	4	19	21
B	43rd Ave. Bethany—Northern	½	2	15	4½	22	19
C	27th Ave. McDowell—Ind. School	6	5	15	5	31	8
D	19th Ave. Ind. School—Bethany	1½	6	9	6	22½	17
E	7th Ave. Van Buren—Thomas	7	6	13	8	34	6
F	Central Ave. Camelback—Glendale	3½	6	7	8½	25	12
G	7th St. McDowell—Ind. School (as it was)	7½	6	13	9½	36	5
H	16th St. Camelback—Glendale	1½	6	9	7	23½	15
I	24th St. Buckeye—McDowell	7½	12	14	8½	32	7
J	32nd St. Van Buren—Thomas	2½	7	12	8	29½	9
K	44th St. McDowell—Ind. School	4	5	12	6½	27½	10
L	Baseline 16th St.—32nd St.	0	2	1	5½	8½	25
M	Broadway 7th Ave.—16th St	1	7	7	7	22	18
N	Van Buren 43rd Ave.—27th Ave.	0	6	13	7½	26½	11
O	Van Buren 7th St.—24th St.	9½	15	3	12½	40	3
P	Van Buren 48th St.—60th St.	0	2	3	9	14	23
Q	McDowell 19th Ave.—7th St. (as it was)	32	15	13	13	73	1
R	Thomas 51st Ave.—35th Ave.	0	4	8	6½	18½	22
S	Ind. School 7th Ave.—16th St.	11	8	4	15	38	4
T	Camelback 16th St.—32nd St.	3½	4	5	12	24½	13
U	Bethany 7th Ave.—16th St.	1	6	12	5½	24½	14
V	Glendale 16th St.—32nd St.	0	2	7	5	14	24
W	Cave Creek 7th St.—20th St.	½	4	15	4	23½	16
X	"Q" Ave. 43rd Ave.—Black Canyon	0	2	15	3½	20½	20
Y	Grand Ave. Thomas—Camelback	7½	15	13	9½	45	2

1. Segment C project is one-fourth mile away from a completed urban freeway and the poor structural condition of the facility combined with some delay produced a higher priority by the formula. As on Segment O, judgment would tend to weigh the existence of the freeway and thus lower the final priority.
2. Segment D has a low delay but a considerably higher rating on structural condition. The various raters had a wide spread of opinion on the relative priority of this particular project. This may well be due to its being parallel to and approximately three-fourths mile away from a completed freeway.
3. Segment H received a low number of delay and traffic points but a number of structural condition points; thus, the priority formula produced a somewhat lower rating than judgment.
4. Segment N, which judgment said should be among the very earliest, received zero points on the delay rate and relatively few points on traffic but a high number of points on structural condition. As in Segment H, judgment assigned a higher position than did the formula.
5. Segment S rated high by the priority formula due to the relatively high delay rate and traffic points received. Judgment lowered the priority because this segment had been improved to modern 4-lane standards within the last seven years.

TABLE 8

FORMULA C—ANALYSIS OF TRAFFIC ELEMENT

Segment	Location	1962 ADT	1967 ADT	Traffic Points		
				A[1]	B[2]	C[3]
A	59th Ave. Van Buren-Thomas	2,000	6,000	4.0	2.7	2.8
B	43rd Ave. Bethany-Northern	2,500	8,000	4.5	3.0	3.3
C	27th Ave. McDowell-Ind. School	6,500	10,000	5.0	4.5	5.1
D	19th Ave. Ind. School-Bethany	9.200	14,000	6.0	6.0	6.9
E	7th Ave. Van Buren-Thomas	12,200	20,000	8.0	7.8	9.0
F	Central Camelback-Glendale	12,700	24,000	8.5	8.3	9.5
G	7th St. McDowell-Ind. School (as it was)	15,600	26,000	9.5	9.7	11.2
H	16th St. Camelback-Glendale	11,600	16,000	7.0	7.4	8.5
I	24th St. Backeye-McDowell	14,000	20,000	8.5	8.7	10.3
J	32nd St. Van Buren-Thomas	13,000	17,000	8.0	8.2	9.4
K	44th St. McDowell-Ind. School	10,200	14,000	6.5	6.6	7.5
L	Baseline 16th St.-32nd St.	7,800	11,000	5.5	5.2	5.9
M	Broadway 7th Ave.-16th St.	11,500	16,000	7.0	7.3	8.4
N	Van Buren 43rd Ave.-27th Ave.	12,700	17,000	7.5	8.0	9.2
O	Van Buren 7th St.-24th St.	22,700	26,000	12.5	13.6	15.7
P	Van Buren 48th St.-60th St.	14,800	20,000	9.0	9.2	10.6
Q	McDowell 19th Ave.-7th St. (as it was)	23,100	28,000	1.30	13.8	16.0
R	Thomas 51st Ave.-35th Ave.	10,200	14,000	6.5	6.5	7.5
S	Ind. School 7th Ave.-16th St.	27,400	31,000	15.0	16.3	18.7
T	Camelback 16th St.-32nd St.	21,300	26,000	12.0	12.8	14.8
U	Bethany 7th Ave.-16th St.	7,700	14,000	5.5	5.3	6.1
V	Glendale 16th St.-32nd St.	6,300	12,000	5.0	4.6	5.2
W	Cave Creek 7th St.-20th St.	3,800	8,000	4.0	3.3	3.6
X	"Q" Ave. 43rd Ave.-Blk. Canyon	1,500	4,000	3.5	2.2	2.3
Y	Grand Ave. Thomas-Camelback	16,200	24,000	9.5	10.0	11.5

[1] Present volume ÷ 2,000 + 5-yr forecast ÷ present volume.
[2] Present volume ÷ 1,750 + 5-yr forecast ÷ 2 × present volume.
[3] Present volume ÷ 1,500 + 5-yr forecast ÷ 2 × present volume.

It is interesting that few of the street segments received a high number of points for delay rate. The cause of this is not fully understood. Certainly, the delay rate curve shown in Figure 1 could possibly be adjusted; however, it is based on the point of view that the relative points should increase more rapidly as the delay increases. If the shape of the curve were varied a relatively large number of points for a relatively small amount of delay might well be found. This is not considered proper rating. The second possible cause is that congestion in Phoenix has not yet reached the point where maximum delays are the norm rather than the exception. The shape of the curve deserves further research. Perhaps a family of curves for different urban characteristics is needed.

Table 7 shows good spread was obtained by collision index and structural condition ratings. However, the spread of traffic volume rating was not as broad as expected. The highest rating was 15 out of 20 points; the lowest, 3½. The traffic volume component in Formula C places heavy value on present volumes and adds the 5-yr forecast growth ratio, which attempts to reach a balance between present and future needs in capital programming.

In view of the lack of spread in the original traffic elements of the formula, a study was made of the effect of changing the constants in the formula (Table 8). The final formula (C in Table 8), present volume divided by 1,500 plus a 5-yr traffic forecast divided by 2 times the present average daily traffic volume, appeared to give the best results from the standpoint of differentiating between the various projects.

The overall results obtained from the first test of Formula C were encouraging. The inconsistencies developed by the formula were explainable and no worse than the inconsistencies demonstrated by the spread in the individual judgment of the several raters. The lack of spread in the delay rate points (Table 7) is cause for concern, but this can possibly be explained as previously indicated.

BROADER TEST OF FORMULA C

Following the original test, 48 miles of major arterial streets which were being considered for a tentative 6-yr capital program were rated by the original test Formula C. These streets were combined with the 25 sections included in the first test and then all were rated by Formula C. Table 9 demonstrates a very good spread in the total points being rated. However, in the middle ranges there was only a slight variation from project to project. Either all of the projects are about the same or the formula needs further refinement in order to give better separation.

Table 10 was prepared to indicate how the major street improvement priority formula could be used in the preparation of a 6-yr program. In the development of a program it is necessary to consider available funds, the continuity of particular projects, and the disruptions of traffic in various parts of the community. Table 10 demonstrates the results of the application of these several considerations to a priority listing.

The results of the broader test continued to be encouraging. This broader test included 88.9 miles of major arterial street.

TEST USING CAPITAL PROGRAM

The tentative 6-yr capital program that was tested, was based on anticipation that a 2 cent per gallon city gasoline tax would produce about $3.2 million per year in new revenue for the city. Inasmuch as the city gasoline tax was invalidated by the Supreme Court of Arizona, and subsequently the state legislature increased the state gasoline tax 1 cent with 80 percent of the revenue going to cities and towns, a new 6-yr capital improvement program had to be developed.

The program under way is based on the estimate of an additional $1.6 million per year for construction of major arterial streets by the city. The traffic element of Formula C was modified as previously suggested to develop Formula D (Table 11). Table 12 is a summary of the application of Formula D to the projects in the adopted program plus the original 25 test segments. This test included 75.3 miles of major arterial street.

TABLE 9

FORMULA C APPLIED TO TENTATIVE 6-YEAR PROGRAM AND 25 TEST SEGMENTS

	Major Arterial Street	Relative Weight (points)				Total Points (100 max.)	Rank
		Delay Rate (50 max.)	Collision Index (15 max.)	Structural Condition (15 max.)	Traffic (20 max.)		
	Thomas Rd. Black Canyon to 19th Ave.	50	15	10	11½	86½	1
*	McDowell Rd. 19th Ave. to 7th St. (as it was)**	32	15	13	13	73	2
	Indian School Rd. 35th Ave. to Black Canyon	18	15	8	10	51	3
	7th St. Maricopa Freeway to Van Buren	17	15	11	7½	50½	4
*	Grand Ave. Thomas to Camelback	7½	15	13	9½	45	5
	19th Ave. Buckeye to Van Buren	14½	15	8	5	42½	6
*	24th St. Buckeye to McDowell	7½	12	14	8½	42	7
	16th St. Buckeye to Van Buren	11	15	8	8	42	8
*	Van Buren 7th St. to 24th St.	9½	15	3	12½	40	9
	7th Ave. Osborn to Camelback	9½	11	8	10½	39	10
	Indian School Rd. Grand Canal to 24th St.	2½	15	8	13	38½	11
*	Indian School Rd. 7th Ave. to 16th St.	11	8	4	15	38	12
*	7th St. McDowell to Indian School (as it was)**	7½	6	13	9½	36	13
*	7th Ave. Van Buren to Thomas	7	6	13	8	34	14
	Camelback Rd. 7th Ave. to 16th St.	4	12	4	13	33	15
	44th St. Thomas to Camelback	2½	15	9	6½	33	16
	Camelback Rd. Black Canyon to 7th Ave.	4	7	10	11½	32½	17
	McDowell Rd. 44th St. to 52nd St.	0	15	6	11½	32½	18
	Van Buren 39th Ave. to Black Canyon	4½	6½	11	9	31	19
	24th St. Maricopa Freeway to Buckeye	0	15	11	5	31	20
*	27th Ave. McDowell to Indian School	6	5	15	5	31	21
	Washington & Adams 9th Ave. to 12th Ave.	0	15	12	4	31	22
	Papago Park Rd. Van Buren to McDowell	0	0	15	15	30	23
*	32nd St. Van Buren to Thomas	2½	7	12	8	29½	24
	McDowell Rd. 28th St. to 44th St.	3½	7½	6	12½	29½	25
	Broadway Rd. 19th Ave. to 7th St.	½	15	7	6½	29	26
	7th St. Camelback to Glendale	2	6	12	9	29	27
	24th St. Indian School to Lincoln	½	8	13	6	27½	28
*	44th St. McDowell to Indian School	4	5	12	6½	27½	29
*	Van Buren 43rd Ave. to 27th Ave.	0	6	13	7½	26½	30
*	Central Ave. Camelback to Glendale	3½	6	7	8½	25	31
*	Camelback 16th St. to 32nd St.	½	8	6	10	24½	32
	Indian School 51st Ave. to 35th Ave.	½	8	6	10	24½	33
*	Bethany Home 7th Ave. to 16th St.	1	6	12	5½	24½	34
	16th St. Grand Canal to Bethany Home	1	6	8	9	24	35
*	16th St. Camelback to Glendale	1½	6	9	7	23½	36
*	Cave Creek 7th St. to 20th St.	½	4	15	4	23½	37
	16th St. Broadway to Buckeye	5	6½	5	7	23½	38
	7th St. Glendale to Dunlap	1½	4	10	7	22½	39
*	19th Ave. Indian School to Bethany Home	1½	6	9	6	22½	40
*	Broadway 7th Ave. to 16th St.	1	7	7	7	22	41
*	43rd Ave. Bethany Home to Northern	½	2	15	4½	22	42
	Thomas Rd. 43rd Ave. to 27th Ave.	1	6	7	8	22	43
	44th St. Washington to McDowell	½	5½	9	5½	20½	44
*	"Q" Ave. 43rd Ave. to Black Canyon	0	2	15	3½	20½	45
*	59th Ave. Van Buren to Thomas	0	3	12	4	19	46
*	Thomas Rd. 51st Ave. to 35th Ave.	0	4	8	6½	18½	47
	Bethany Home 43rd Ave. to 35th Ave.	0	4	8	5	17	48
	16th St. Bethany Home to Northern	0	3½	7	5½	16	49
	Indian School 67th Ave. to 51st Ave.	0	3	5	7	15	50
*	Van Buren 48th St. to 60th St.	0	2	3	9	14	51
*	Glendale Ave. 16th St. to 32nd St.	0	2	7	5	14	52
*	Baseline Rd. 16th St. to 32nd St.	0	2	1	5½	8½	53

* 25 test segments.
** Construction completed.
Note: 88.9 miles of major arterial street rated.

TABLE 10

FORMULA C APPLIED TO TENTATIVE 6-YEAR PROGRAM AND 25 TEST SEGMENTS

	Major Arterial Street	Total Points (100 max.)	Year Scheduled (6-yr program)
	Thomas Rd. Black Canyon to 19th Ave.	86½	1
*	McDowell Rd. 19th Ave. to 7th St. (as it was)	73	**
	Indian School Rd. 35th Ave. to Black Canyon	51	3
	7th St. Maricopa Freeway to Van Buren	50½	2
*	Grand Ave. Thomas to Camelback	45	Budgeted
	19th Ave. Buckeye to Van Buren	42½	3
*	24th St. Buckeye to McDowell	42	Budgeted
	16th St. Buckeye to Van Buren	42	3
*	Van Buren 7th St. to 24th St.	40	
	7th Ave. Osborn to Camelback	39	4
	Indian School Rd. Grand Canal to 24th St.	38½	6
*	Indian School Rd. 7th Ave. to 16th St.	38	
*	7th St. McDowell to Indian School (as it was)	36	**
*	7th Ave. Van Buren to Thomas	34	Budgeted
	Camelback Rd. 7th Ave. to 16th St.	33	4
	44th St. Thomas to Camelback	33	5
	Camelback Rd. Black Canyon to 7th Ave.	32½	6
	McDowell Rd. 44th St. to 52nd St.	32½	5
	Van Buren 39th Ave. to Black Canyon	31	1
	24th St. Maricopa Freeway to Buckeye	31	4
*	27th Ave. McDowell to Indian School	31	
	Washington & Adams 9th Ave. to 12th Ave.	31	3
	Papago Park Rd. Van Buren to McDowell	30	5
*	32nd St. Van Buren to Thomas	29½	
	McDowell Rd. 28th St. to 44th St.	29½	5
	Broadway Rd. 19th Ave. to 7th St.	29	5
	7th St. Camelback to Glendale	29	1
	24th St. Indian School to Lincoln	27½	1 & 4
*	44th St. McDowell to Indian School	27½	
*	Van Buren 43rd Ave. to 27th Ave.	26½	
*	Central Ave. Camelback to Glendale	25	
*	Camelback 16th St. to 32nd St.	24½	
	Indian School Rd. 51st Ave. to 35th Ave.	24½	3
*	Bethany Home Rd. 7th Ave. to 16th St.	24½	2
	16th St. Grand Canal to Bethany Home	24	3 & 6
*	16th St. Camelback to Glendale	23½	
*	Cave Creek 7th St. to 20th St.	23½	
	16th St. Broadway to Buckeye	23½	4
	7th St. Glendale to Dunlap	22½	2
*	19th Ave. Indian School to Bethany Home	22½	1 Mile Budgeted
*	Broadway Road 7th Ave. to 16th St.	22	
*	43rd Ave. Bethany Home to Northern	22	
	Thomas Road 43rd Ave. to 27th Ave.	22	4
	44th St. Washington to McDowell	20½	5
*	"Q" Ave. 43rd Ave. to Black Canyon	20½	
*	59th Ave. Van Buren to Thomas	19	
*	Thomas 51st Ave. to 35th Ave.	18½	
	Bethany Home Rd. 43rd Ave. to 35th Ave.	17	6
	16th St. Bethany Home to Northern	16	6
	Indian School Rd. 67th Ave. to 51st Ave.	15	5
*	Van Buren 48th St. to 60th St.	14	
*	Glendale Ave. 16th St. to 32nd St.	14	
*	Baseline Rd. 16th St. to 32nd St.	8½	

* 25 test segments.
** Construction completed.
Note: 88.9 miles of major arterial street rated.

TABLE 11

MAJOR STREET IMPROVEMENT PRIORITY, FORMULA D[1]

Element		Relative Weight (points)
Delay rate per mile during peak hour		50
Collision index: 2-yr accidents/mile plus accident rate/mile		15
Structural condition		15
Surface and base	5	
Drainage	10	
Traffic: $\frac{\text{present ADT}}{1500} + \frac{\text{5-yr future forecast ADT}}{2\ (\text{present ADT})}$		20
Max. possible points		100
List projects in order of highest point value		

[1] Program developed from list of projects and evaluation of budgetary and administrative considerations.

TABLE 12

FORMULA D APPLIED TO ADOPTED 6-YEAR PROGRAM AND 25 TEST SEGMENTS

Major Arterial Street	Relative Weight (points)				Total Points (100 max.)	Rank
	Delay Rate (50 max.)	Collision Index (15 max.)	Structural Condition (15 max.)	Traffic (20 max.)		
Thomas Rd. Black Canyon to 19th Ave.	50	15	10	14.3	89.3	1
7th Ave. RR Structure/Jefferson to Grant-Lincoln	50	15	7	8.9	80.9	2
* McDowell Rd. 19th Ave. to 7th St. (as it was)**	32	15	13	16	76.0	3
Indian School Rd. 35th Ave. to Black Canyon	18	15	8	12.1	53.1	4
7th St. Maricopa Freeway to Grant-Lincoln	17	15	11	9.3	52.3	5
* Grand Ave. Thomas to Camelback (as it was)**	7.5	15	13	11.5	47.0	6
* 24th St. Buckeye to McDowell (as it was)**	7.5	12	14	10.3	43.8	7
19th Ave. Buckeye to Van Buren	14.5	15	8	6.3	43.8	8
16th St. Buckeye to Van Buren	11	15	8	9.8	43.8	9
* Van Buren 7th St. to 24th St.	9.5	15	3	15.7	43.2	10
* Indian School Rd. 7th Ave. to 16th St.	11	8	4	18.7	41.7	11
7th Ave. Osborn to Bethany Home	9.5	11	8	13.0	41.5	12
* 7th St. McDowell to Indian School (as it was)**	7.5	6	13	11.2	37.7	13
* 7th Ave. Van Buren to Thomas	7	6	13	9.0	35.0	14
44th St. Thomas to Camelback	2.5	15	9	7.7	34.2	15
Van Buren 39th Ave. to Black Canyon	4.5	6.5	11	10.7	32.7	16
* 27th Ave. McDowell to Indian School	6	5	15	5.1	31.1	17
24th St. Maricopa Freeway to Buckeye	0	15	11	5.0	31.0	18
Washington & Adams Tie-in	0	15	12	3.9	30.9	19
* 32nd St. Van Buren to Thomas	2.5	7	12	9.4	30.9	20
7th St. Camelback to Glendale	2	6	12	10.8	30.8	21
* Camelback 16th St. to 32nd St.	0.5	8	6	14.8	29.3	22
Dunlap 7th Ave. to Central	4	6	13	6.2	29.2	23
* 44th St. McDowell to Indian School	4	5	12	7.5	28.5	24
* Van Buren 43rd Ave. to 27th Ave.	0	6	13	9.2	28.2	25
24th St. Missouri to Lincoln Drive	0.5	8	13	6.5	28.0	26
Indian School 51st Ave. to 35th Ave.	0.5	8	6	12.0	26.5	27
* Central Ave. Camelback to Glendale	3.5	6	7	9.5	26.0	28
16th St. Grand Canal to Camelback	1	6	8	11.0	26.0	29
* 16th St. Camelback to Glendale	1.5	6	9	8.5	25.0	30
16th St. Broadway to Buckeye	5	6.5	5	8.4	24.9	31
* Bethany 7th Ave. to 16th St.	1	6	12	5.2	24.2	32
7th St. Glendale to Dunlap	1.5	4	10	8.1	23.6	33
Thomas Rd. 43rd Ave. to 27th Ave.	1	6	7	9.4	23.4	34
* Broadway 7th Ave. to 16th St.	1	7	7	8.4	23.4	35
* 19th Ave. Indian School to Bethany Home	1.5	6	9	6.9	23.4	36
* Cave Creek 7th St. to 20th St.	0.5	4	15	3.6	23.1	37
Papago Park Road Van Buren to McDowell**	0	0	15	7.8	22.8	38
44th St. Washington to McDowell	0.5	5.5	9	6.1	21.1	39
* 43rd Ave. Bethany Home to Northern	0.5	2	15	3.3	20.8	40
* Thomas Rd. 51st Ave. to 35th Ave.	0	4	8	7.5	19.5	41
* "Q" Ave. 43rd Ave. to Black Canyon	0	2	15	2.3	19.3	42
* 59th Ave. Van Buren to Thomas	0	3	12	2.8	17.8	43
* Van Buren 48th St. to 60th St.	0	2	3	10.6	15.6	44
* Glendale Ave. 16th St. to 32nd St.	0	2	7	5.2	14.2	45
* Baseline Rd. 16th St. to 32nd St.	0	2	1	5.9	8.9	46

* Test segments.
** Construction completed.
Note: 75.3 miles of major arterial street rated.

Table 13 lists the projects in the adopted 6-yr capital program and the 25 test segments and compares the total points for each project to the year scheduled in the 6-yr program. In the adopted program we specifically identify the projects only in the first three years. In order to retain flexibility, the projects for the second 3-yr period are simply listed as high-priority projects without being identified by specific year. Thus, in Table 13 years 4 through 6 for any project appear in the second half of the program. Each year the program will move forward one year and certain projects will be identified as specific projects in year 3; thus, the engineering and right-of-way acquisition can begin.

Again the usefulness of the priority formula is illustrated. The formula was used as a guide and a means of summarizing the factual elements that go into the final determination of priority. The availability of funds, right-of-way acquisition problem, continuity of program, traffic disruption, and the need to connect to completed or programmed urban freeways being built by the State Highway Department, are all important considerations that weigh in the final determination of a major street construction program.

TABLE 13

FORMULA D APPLIED TO ADOPTED 6-YEAR PROGRAM AND 25 TEST SEGMENTS

	Major Arterial Street	Total Points (100 max.)	Year Scheduled (6-yr program)
	Thomas Rd. Black Canyon to 19th Ave.	89.3	3
	7th Ave. RR Structure/Jefferson to Grant Lincoln	80.9	1
*	McDowell Rd. 19th Ave. to 7th St. (as it was)	76.0	**
	Indian School Rd. 35th Ave. to Black Canyon	53.1	4-6
	7th St. Maricopa Freeway to Grant-Lincoln	52.3	2
*	Grand Ave. Thomas to Camelback (as it was)	47.0	**
*	24th St. Buckeye to McDowell (as it was)	43.8	**
	19th Ave. Buckeye to Van Buren	43.8	2
	16th St. Buckeye to Van Buren	43.8	3
*	Van Buren 7th St. to 24th St.	43.2	
*	Indian School Rd. 7th Ave. to 16th St.	41.7	
	7th Ave. Osborn to Bethany Home	41.5	4-6
*	7th St. McDowell to Indian School (as it was)	37.7	**
*	7th Ave. Van Buren to Thomas	35.0	**
	44th St. Thomas to Camelback	34.2	4-6
	Van Buren 39th Ave. to Black Canyon	32.7	2
*	27th Ave. McDowell to Indian School	31.1	
	24th St. Maricopa Freeway to Buckeye	31.0	4-6
	Washington & Adams Tie-in	30.9	1
*	32nd St. Van Buren to Thomas	30.9	
	7th St. Camelback to Glendale	30.8	2
*	Camelback 16th St. to 32nd St.	29.3	
	Dunlap 7th Ave. to Central	29.2	1
*	44th St. McDowell to Indian School	28.5	
*	Van Buren 43rd Ave. to 27th Ave.	28.2	
	24th St. Missouri to Lincoln Drive	28.0	4-6
	Indian School 51st Ave. to 35th Ave.	26.5	4-6
*	Central Ave. Camelback to Glendale	26.0	
	16th St. Grand Canal to Camelback	26.0	
*	16th St. Camelback to Glendale	25.0	
	16th St. Broadway to Buckeye	24.9	4-6
*	Bethany Home 7th Ave. to 16th St.	24.2	3
	7th St. Glendale to Dunlap	23.6	3
	Thomas Rd. 43rd Ave. to 27th Ave.	23.4	4-6
*	Broadway 7th Ave. to 16th St.	23.4	
*	19th Ave. Indian School to Bethany Home	23.4	
*	Cave Creek 7th St. to 20th St.	23.1	**
	Papago Park Rd Van Buren to McDowell	22.8	**
	44th St. Washington to McDowell	21.1	4-6
*	43rd Ave. Bethany Home to Northern	20.8	
*	Thomas Rd. 51st Ave. to 35th Ave.	19.5	
*	"Q" Ave. 43rd Ave. to Black Canyon	19.3	
*	59th Ave. Van Buren to Thomas	17.8	
*	Van Buren 48th St. to 60th St.	15.6	
*	Glendale Ave. 16th St. to 32nd St.	14.2	
*	Baseline Rd. 16th St. to 32nd St.	8.9	

* Test segments.
** Construction completed.
Note: 75.3 miles of major arterial street rated.

NASHVILLE TEST

In spring 1962 work on a priority rating in Nashville, Tenn., began in earnest in much the same manner as in Phoenix. Responsible members of the engineering, traffic engineering, and planning staffs were asked to rate 28 street sections in the order in which improvement was needed. These sections ranged from probably not needing improvement to obviously needing it. Figure 3 shows their geographic relationship to each other and Table 14 gives the range of ratings for each section. Obviously there is considerable discrepancy between some of the ratings. Also given is the rating for each street section obtained by using Formula C. Again there is a deviation between the formula rating and the mean of the ratings by the individuals.

At this point, the Nashville test differs from that conducted in Phoenix. There having been no opportunity to put the formula to work in testing an actual capital improvement program, the efforts put into this research have been directed toward refining the test formula. In order to do this, certain assumptions had to be made. The first was that the mean of the ratings by individuals was as good a priority ranking as

Figure 3. Urban street priorities—test street sections, Nashville, Tenn.

TABLE 14

COMPARISON OF JUDGMENT AND FORMULA RATINGS, NASHVILLE

Street Section	Range of Personnel Ratings	Formula C Rating
12th Ave. Charlotte to Demonbreun	4-22	1
Charlotte L&N RR to 19th Ave.	1-3	9
Charlotte 25th Ave. to 33rd Ave.	3-15	13T
Nolensville RR Overpass to Wallace Rd.	6-20	18
Woodmont Harding Rd. to Hillsboro Rd.	7-24	19
46th Ave. No. Murphy to Charlotte	14-27	15
Centennial 39th Ave. to 51st Ave.	7-20	16
Centennial 28th Ave. to 39th Ave.	5-22	12
Jefferson 9th Ave. to 18th Ave.	5-17	5
Woodmont Granny White to Franklin Rd.	10-27	25
Gallatin Rd. Main to Cahal	2-27	7T
12th Ave. So. Demonbreun to Acklen	5-18	13T
Charlotte Lellyett to Brook Hollow	12-27	26
21st Ave. Charlotte to Grand	1-19	3
21st Ave. Grand to Blair	4-25	4
Belcourt-Acklen 21st Ave. to 12th Ave.	7-18	7T
Shelby 2nd St. to 11th St.	6-25	11
Belmont Belcourt to TC RR	22-27	24
Hillsboro Hobbs to Harding Rd.	17-26	23
Hillsboro Harding Pl. to Old Hickory	24-26	27
White Bridge Rd. Harding Rd. to Charlotte	6-18	22
Old Hickory Lanier to Robinson	11-24	17
Granny White Glenwood to Sewanee	16-25	20
Trinity Lane Gallatin to Dickerson	13-21	21
1st Ave. Public Sq. to Broad	1-24	2
Hermitage Peabody to TC RR	1-5	6
Woodland 2nd St. to 11th St.	4-20	10

NOTE: "T" by Formula C rating indicates tie.

could be achieved. With this assumption it became necessary to attempt to tailor Formula C to yield the same answers as the individual rating.

Staying within the framework of delay, safety, structural condition and traffic volume and growth, the following variations were made:

1. Formula C-1 was identical in form to Formula C. However, the delay element is based on delay for both peak hours.
2. Formula C-2 varied the accident element by giving equal weight to the accident rate per mile and the accident rate per 100 million vehicle-miles. Formula C added the two together which made the accident rate per mile simply a modifying factor due to its smaller magnitude. The other elements do not change.
3. Formula C-3 used both variations.
4. Formula C-4 has been experimented with only to a small extent. It uses the logic that if a street is anticipated to have considerable traffic growth then it should receive extra points; then a street on which a decline in traffic is anticipated should lose points. The traffic formula becomes:

$$\frac{\text{Present ADT}}{6,000} + \frac{\text{1968 ADT - 1963 ADT}}{600}$$

TABLE 15

TEST RESULTS—FORMULA C VARIATIONS

	Con Sec.	Composite of Raters	Delay = 40%, Collision = 15%, Strctl. = 15%, Traffic = 30% FORMULAS				Delay = 40%, Collision = 20%, Strctl. = 15%, Traffic = 25% FORMULAS				Delay = 40%, Collision = 25%, Strctl. = 15%, Traffic = 20% FORMULAS				Delay = 45%, Collision = 15%, Strctl. = 15%, Traffic = 25% FORMULAS			
			A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Charlotte	03	1	8	7	9	7	7	8	9	7	7	8	9	9	9	8	9	8
Hermitage	03	2	6	4	8	5	6	4	8	6	6	6	8	5	6	4	8	6
1st Avenue North	01	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1
12th Avenue	74	4	2	2	2	4	2	2	2	2	2	2	1	2	2	2	1	2
Charlotte	06	5	12	11	12	12	12	13	12	12	13	13	12	12	12	13	14	13
12th Avenue South	02	6	14	13	13	13	14	12	14	13	14	11	14	13	16	12	13	12
Jefferson	03	7	5	8	6	8	5	6	6	7	5	6	5	8	5	7	5	7
Woodland Street		8	9	9	11	10	9	9	11	9	8	7	10	10	8	9	10	10
Nolensville Road	07	9	18	22	18	20	19	25	18	21	21	25	18	22	18	22	19	20
Centennial	05	10	13	14	14	14	13	14	13	14	12	16	13	14	13	14	12	14
21st Avenue	04	11	4	5	4	3	4	5	4	4	4	5	4	3	4	5	4	3
White Bridge Road	08	12	22	21	22	23	21	21	22	23	20	20	22	21	22	20	21	22
21st Avenue	73	13	3	3	3	5	3	3	[illegible]	5	3	3	3	6	3	3	3	5
Centennial	06	14	16	15	17	17	16	15	16	16	15	14	16	15	15	15	15	16
Shelby Avenue	02	15	11	10	10	9	11	10	10	10	10	10	10	10	11	10	11	11
Trinity Lane	04	16	20	19	25	24	20	19	23	23	19	19	23	22	21	27	23	24
Belcourt-Acklen	75	17	10	12	7	10	10	11	7	11	11	11	7	7	10	11	6	9
Gallatin	05	18	7	6	5	2	7	7	5	3	9	9	6	4	7	6	7	4
Woodmont	07	19	19	18	19	18	18	18	19	18	18	18	18	18	19	18	20	18
Old Hickory	04	20	17	16	16	16	17	17	17	15	17	17	17	17	17	17	17	15
Charlotte	19	21	26	26	26	26	26	26	26	26	26	26	26	26	25	25	26	26
Woodmont	05	22	25	24	23	22	25	24	25	22	25	24	25	25	27	24	25	23
Granny White	05	23	23	22	20	19	24	20	20	19	22	21	20	19	20	19	18	19
46th Avenue North	02	24	15	16	15	15	15	16	15	17	16	15	15	16	14	16	15	16
Hillsboro	08	25	20	19	21	21	22	22	21	20	23	22	21	20	22	20	21	21
Hillsboro	09	26	27	27	27	27	27	27	27	27	27	27	27	27	26	26	27	27
Belmont	03	27	24	24	24	25	23	23	23	25	23	23	23	24	24	23	23	24

	Con Sec.	Composite of Raters	Delay = 45%, Collision = 20%, Strctl. = 10%, Traffic = 25% FORMULAS				Delay = 45%, Collision = 25%, Strctl. = 15%, Traffic = 15% FORMULAS				Delay = 50%, Collision = 15%, Strctl. = 15%, Traffic = 20% FORMULAS				Delay = 30%, Collision = 30%, Strctl. = 20%, Traffic = 20% FORMULAS			
			A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Charlotte	03	1	7	9	9	7	7	8	9	8	9	9	9	10	7	6	7	7
Hermitage	03	2	6	4	8	6	6	4	8	5	6	4	8	6	6	3	8	5
1st Avenue North	01	3	1	1	1	1	1	1	2	1	2	1	2	1	1	1	1	1
12th Avenue	74	4	2	2	2	2	2	2	1	2	1	2	1	2	2	2	2	2
Charlotte	06	5	12	13	12	13	14	15	14	13	13	13	12	13	13	12	12	11
12th Avenue South	02	6	14	12	11	12	13	13	13	12	13	12	14	12	14	12	14	13
Jefferson	03	7	5	7	5	8	5	5	5	7	5	7	5	7	4	5	5	8
Woodland Street		8	9	8	11	9	9	7	10	9	10	8	11	9	8	8	10	9
Nolensville Road	07	9	18	23	17	20	21	25	19	23	18	22	18	20	25	26	22	25
Centennial	05	10	13	14	14	14	12	14	12	14	12	14	13	14	12	11	13	14
21st Avenue	04	11	4	5	4	3	4	5	4	4	4	5	4	4	5	7	4	4
White Bridge Road	08	12	21	20	21	22	21	20	21	20	22	20	22	22	21	21	20	20
21st Avenue	73	13	3	3	3	5	3	3	3	3	3	3	3	3	3	4	3	6
Centennial	06	14	16	16	16	17	15	16	15	15	16	15	16	15	15	15	15	15
Shelby Avenue	02	15	11	10	10	10	11	10	11	11	11	10	10	11	10	10	11	10
Trinity Lane	04	16	19	18	22	23	19	19	23	22	21	19	24	24	19	20	23	22
Belcourt-Acklen	75	17	10	11	7	11	10	12	6	10	7	12	6	8	11	14	9	12
Gallatin	05	18	8	6	6	4	6	9	7	6	7	6	7	5	9	9	6	3
Woodmont	07	19	20	19	19	19	18	18	20	18	19	17	20	19	18	18	19	19
Old Hickory	04	20	17	17	17	16	17	11	17	19	17	22	17	17	17	17	16	16
Charlotte	19	21	25	25	25	26	26	26	26	26	26	26	25	26	26	25	26	26
Woodmont	05	22	25	24	23	23	25	24	25	25	25	25	24	24	24	24	25	24
Granny White	05	23	26	26	25	18	20	21	18	17	20	18	19	18	20	19	18	17
46th Avenue North	02	24	15	15	15	15	16	17	15	16	15	16	15	16	16	16	17	18
Hillsboro	08	25	22	21	20	21	24	23	21	20	23	21	21	21	23	22	20	20
Hillsboro	09	26	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Belmont	03	27	23	22	23	25	23	22	23	23	24	24	23	23	22	23	24	23

	Con Sec.	Composite of Raters	Delay = 25%, Collision = 25%, Strctl. = 25%, Traffic = 25% FORMULAS				Delay = 30%, Collision = 30%, Strctl. = 10%, Traffic = 30% FORMULAS				Delay = 30%, Collision = 30%, Strctl. = 15%, Traffic = 25% FORMULAS			
			A	B	C	D	A	B	C	D	A	B	C	D
Charlotte	03	1	7	7	8	7	7	6			7	7		
Hermitage	03	2	6	2	7	4	6	3			6	3		
1st Avenue North	01	3	1	1	1	1	1	1			1	1		
12th Avenue	74	4	2	2	2	3	2	2			2	2		
Charlotte	06	5	13	11	11	11	12	11			13	11		
12th Avenue South	02	6	14	13	14	14	14	12			14	12		
Jefferson	03	7	5	5	6	8	5	7			5	5		
Woodland Street		8	9	9	12	9	8	8			8	8		
Nolensville Road	07	9	25	26	22	25	21	25			23	26		
Centennial	05	10	12	12	13	13	13	13			12	13		
21st Avenue	04	11	4	5	4	4	4	5			4	6		
White Bridge Road	08	12	21	21	21	21	20	20			20	20		
21st Avenue	73	13	3	4	3	5	3	4			3	4		
Centennial	06	14	15	15	15	15	16	16			15	15		
Shelby Avenue	02	15	10	10	10	10	10	10			10	10		
Trinity Lane	04	16	20	20	23	22	17	17			18	18		
Belcourt-Acklen	75	17	11	14	9	12	11	14			11	14		
Gallatin	05	18	8	8	5	2	9	8			9	9		
Woodmont	07	19	19	18	18	18	19	19			19	19		
Old Hickory	04	20	16	16	16	16	17	17			17	17		
Charlotte	19	21	26	25	26	26	25	24			26	25		
Woodmont	05	22	24	24	24	23	24	23			24	23		
Granny White	05	23	18	17	17	17	26	26			25	24		
46th Avenue North	02	24	17	19	19	19	15	15			16	16		
Hillsboro	08	25	22	22	20	20	21	21			21	21		
Hillsboro	09	26	27	27	27	27	27	27			27	27		
Belmont	03	27	23	23	24	24	24	22			21	22		

Next, the weights given each element were varied. The variations were quite large. The delay factor varied from a weight of 25 percent of the total to 50 percent. Accidents were weighted from 15 percent to 30 percent. Structural condition varied between 10 percent and 25 percent and the growth factor varied from 15 percent to 30 percent of the total.

Ultimately there were 40 variations of Formula C. The test results of each are shown in Table 15. The ratings obtained from each set were then compared to the mean ratings of the individuals. Essentially, ratings obtained from each formula variation compared as well to the mean subjective ratings as the rating obtained from the other variations. (The average deviations ranged from 4.2 to 5.4.) The results obtained using Formula C-4, with the modified delay factor, tended to compare a little more closely to the mean subjective ratings than the others; but for the most part the changes in the formula seemed to have little effect on whether or not the resulting rating approximated the subjective rating.

The mean for each section rating was calculated from the 40 formulas. The average deviation for all sections from this mean was 0.97. One formula had an average deviation of 1.3 from this mean and at the other end an average deviation of 0.44 was encountered. In other words, the various formulas yield results that vary only slightly. This indicates that the particular formula used does not matter a great deal so long as the selected formula is consistently used.

At this point doubts were raised as to whether the formula could be tested against the subjective rating. The project proceeded to evaluate the original assumption that judgment was a valid criterion against which to test the formula.

The same group that rated the street sections originally was asked to do so again. Approximately 4½ months had elapsed since the first rating and one of the street segments had been resurfaced. The objective was to study the consistency or inconsistency of these judgment ratings. Each rater's results were compared to his earlier efforts. The comparison was expected to show differences but nothing was expected like the actual results (Table 16). The lowest average deviation from the first rating was 3.6 and the

TABLE 16

COMPARISON OF FIRST AND SECOND JUDGMENT RATINGS, NASHVILLE

Street Section	Participant's Initials							
	WL	RP	JC	OA	IH	JH	TL	AH
12th Ave. Charlotte to Demonbreun	+ 2	- 5	- 4	+11	+ 7	- 2	- 1	-17
Charlotte L&N RR to 19th Ave.	0	+ 2	+ 2	+ 9	+ 3	0	+ 1	0
Charlotte 25th Ave. to 33rd Ave.	+ 2	+10	+23	+ 2	+ 3	- 5	+ 9	+ 2
Nolensville RR Overpass to Wallace Rd.	- 5	0	+11	- 5	+ 4	+ 5	- 3	+ 2
Woodmont Harding Rd. to Hillsboro Rd.	+ 5	- 5	+ 2	+ 2	+ 6	- 4	- 6	- 2
46th Ave. No. Murphy to Charlotte	- 3	- 8	- 2	+ 5	- 1	+ 3	-10	- 4
Centennial 39th Ave. to 51st Ave.	- 6	+ 8	+ 5	+11	- 4	+ 7	+ 5	+17
Centennial 28th Ave. to 39th Ave.	+ 2	+ 6	+12	- 4	- 6	+ 7	+ 2	+19
Jefferson 9th Ave. to 18th Ave.	- 3	0	+ 8	- 4	- 8	- 1	- 1	- 1
Woodmont Granny White to Franklin Rd.	- 2	- 5	- 9	0	+ 2	+ 7	-10	- 7
Gallatin Rd. Main to Cahal	+ 7	- 6	+ 9	-10	-18	+ 5	+ 5	+ 2
12th Ave. So. Demonbreun to Acklen	- 3	- 1	+ 1	+ 1	+ 9	+ 7	+ 2	- 9
Charlotte Lellyett to Brook Hollow	- 2	- 2	- 3	+10	- 6	+ 5	+ 1	+ 3
21st Ave. Charlotte to Grand	+10	+ 2	- 3	+ 4	- 5	-13	+ 1	+ 2
21st Ave. Grand to Blair	+ 7	+10	-12	- 1	+ 5	+ 1	- 1	- 9
Belcourt-Acklen 21st Ave. to 12th Ave.	- 1	- 2	-12	- 3	+ 6	+ 4	+ 3	+ 1
Shelby 2nd St. to 11th St.	-11	+ 4	- 5	-20	-20	- 5	- 3	-17
Belmont Belcourt to TC RR	+ 1	0	-13	- 2	- 5	0	- 4	- 7
Hillsboro Hobbs to Harding Rd.	+ 7	0	0	+ 5	- 1	- 2	0	+ 2
Hillsboro Harding Pl. to Old Hickory	+ 2	+ 2	0	- 6	0	- 2	- 1	0
White Bridge Rd. Harding Rd. to Charlotte	+ 2	+ 3	+ 9	0	+11	+ 2	- 6	- 6
Old Hickory Lanier to Robinson	- 5	- 3	- 2	+ 1	+ 6	- 2	+10	+16
Granny White Glenwood to Sewanee	- 3	- 1	- 8	- 4	+ 2	- 1	+ 7	-11
Trinity Lane Gallatin to Dickerson	- 1	- 4	- 2	- 5	- 7	- 2	+ 4	0
1st Ave. Public Sq. to Broad	0	- 2	- 1	- 1	- 1	- 4	- 2	+ 1
Hermitage Peabody to TC RR	- 2	- 3	+ 5	+ 1	+ 1	- 1	0	- 1
Woodland 2nd St. to 11th St.	0	0	- 3	+ 3	- 7	- 9	- 2	+ 2

highest was 6.8. The deviation for individual sections ranged from 1.1 to 12.6. Just what this could mean on an individual street section is illustrated by this example: A 10-block long section on Shelby Avenue was rated as the fifth priority by one rater the first time. Four months later he rated it the 26th priority. At the same time another rater placed this section as 28th priority the first time but changed it to 10th on the second rating. Thus, there were two complete reversals in thought on one section but they were in the opposite direction.

A definite advantage of a formula rating had thus evolved. There is no apparent consistency to a rating which an individual might make in spite of all conscientious effort he might put forth. It became clear that judgment could best be applied to the formula ordered list of projects to arrive at a program priority.

One final experiment was tried using the data that had been assembled. It has been mentioned earlier that there is no intent to develop a formula that is a final work. The priority ratings derived from the formula are an aid to actual programming. The projects presented in the test might represent a 5- or 6-yr program of improvements. This being the case, there would be five or six projects per year.

Then, the object of a priority rating becomes, not naming a project 1st, 2nd or 3rd priority, but 1st year, 2nd year, etc. So the real problem becomes what do the various formulas do to the yearly groupings.

Of the 40 formulas used, only one of them varied a project by more than one year from where the other formulas placed it. It appears that variations of the basic formula have little effect on its overall usefulness. So long as it is applied uniformly, the results are quite similar.

CONCLUSIONS

The results of the test of an urban major arterial street construction priority formula in Nashville and Phoenix have been encouraging. Formula D incorporates the experience obtained to date in these two cities. The formula is simple and the elements that go into it are rather easily obtained.

As with any tool, it is important that it be used properly. The objective is simply to order projects under consideration in a factual way. Following this, the other important administrative, fiscal, coordination with other agencies, and area-wide considerations must be applied in the development of the capital program.

The results of the work in San Diego, Phoenix and Nashville indicate that an urban street construction priority formula should not be too complex and should certainly minimize the judgment elements that go into it. A priority formula should be based upon facts.

The studies demonstrate that one of the more difficult situations for priority formulas to recognize and evaluate is a facility that has been improved to reasonable standards, or a facility that is parallel to an existing or planned freeway. Another problem is that of the nonexisting street with zero present ADT. Here, as in the parallel freeway situation, judgment is the obvious solution. The authors do not believe that one formula can "solve" all the individual cases.

All the studies have indicated that the formula itself is not nearly as important as its consistent application. The Nashville analysis clearly demonstrates this principle.

It is difficult to evaluate a major street improvement priority formula because of the wide variances in judgment that have been obtained from the several studies. This emphasizes the need to develop a simple, easily applied, factual major street improvement priority formula for urban areas.

It is hoped that other urban areas will test Formula D and then improve it, and that these studies can be disseminated so that progress can be made in the direction of capital programming in urban areas.

A major street improvement priority formula for urban areas is needed. Such a formula can be an extremely useful tool to those responsible for developing a capital improvement program for major streets in cities. The formula makes possible the presentation of various projects in a relative priority list based on facts. At this point administrative and budgetary considerations and judgment can most properly be applied to develop the capital improvement program that will provide maximum benefits to the public.