Evaluating the Quality of Cities' Geometric Design Standards

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Are cities employing state-of-the-practice street design standards? An evaluation of the street design standards used by medium-size and large cities in Oklahoma is presented. The researchers asked city staff in 19 cities to send their various geometric design and subdivision standards, and staff in 12 of those cities responded. The researchers evaluated stopping sight distance, horizontal curvature, gradient, street section width, and intersection radius standards. The standards evaluated were those intended for new developments or streets. The researchers established "recommended" design practices by referring to nationally recognized publications. The standards of each city were compared with the recommended practices to determine the adequacy of the city design standards, and the city standards were evaluated on the basis of a system devised by the researchers. The evaluation results indicated that the 12 cities had good gradient standards. Turning radius standards were generally adequate, and the adequacy of stopping sight distance standards was mixed. The standards for centerline radius and for arterial street section widths were often inadequate. The need to improve the quality of street design standards at the local level was also discussed by the researchers. The 1991 federal transportation bill (Intermodal Surface Transportation Efficiency Act) mandates a review of state standards for highways that receive federal aid; it is suggested that an outside review of city design standards may be needed.

The general public has become more aware of quality in everything from consumer products to medical services. When a profession or an industry fails to mandate quality (i.e., high standards), the public reacts negatively. Current public attitudes toward lawyers and politicians are cases in point.

Transportation engineers define quality in a number of ways, including the adequacy of roadway design criteria. Much effort has gone into preparing *A Policy on Geometric Design of Highways and Streets*, or the Green Book (*1*), and other publications so engineers can follow state-of-the-practice design criteria. State departments of transportation attempt to employ adequate design practices, and FHWA requires projects to be designed to comply with good practices. On the other hand, city streets are designed under the auspices of local governments, which have neither the federal oversight nor the vast resources of a state agency to effect adherence to accepted good practices. Do the cities have state-of-the-practice standards, or are city street design standards inadequate?

To evaluate the quality or adequacy of the geometric design criteria used by the cities in one state, the researchers evaluated the street design standards used by large and medium-size cities in Oklahoma. Staff in 12 of the 19 cities contacted sent their various geometric design and subdivision standards to the researchers. The researchers evaluated stopping sight distance, horizontal curvature, gradient, section width, and intersection radius standards. The standards evaluated were those intended for new streets. The researchers established "recommended" design practices after referring to nationally recognized publications. The standards of each city were compared with the recommended practices to determine the quality of the city design standards, and the city standards were evaluated on the basis of a system devised by the researchers.

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BACKGROUND

The street system forms the framework for community development and permits the circulation of people and goods throughout the community. A city needs good design criteria to develop a functionally efficient and safe street system. Progressive design criteria permit citizens to get quality streets from their tax dollars. A poorly designed road gives an inferior level of service to the traveling public and can create conditions conducive to accidents and tort lawsuits.

To establish a set of geometric design standards that is both adequate and comprehensive, the engineer must have a good understanding of underlying design fundamentals. These fundamentals include an appreciation of interactions between the driver, the vehicle, and the roadway. The engineer must also appreciate the limitations of the driver and the vehicle and recognize that the roadway should accommodate the limitations of prudent drivers and vehicles that are not defective.

State and national agencies have the size and funding to employ civil engineers specializing in transportation engineering. These transportation engineers can draw from their own and others' experiences, continuing education opportunities, and other resources to maintain a knowledge of current street design issues.

In contrast many local governments employ only a few civil engineers. These engineers may be responsible for water, wastewater, solid waste, storm water and waterways, public structures, as well as street design and traffic control devices. It is difficult for an engineer to be an expert in all of these areas; many cities employ no engineers with transportation expertise. The local engineer may be subject to direct pressure from city councilmembers (who neither know nor appreciate fundamental geometric design concepts) to accommodate developers, emotional citizens, or other pressure groups. Local politicians and engineers may feel pressure to stretch the funds used for street paving past the limits of accepted design practices. Any of these factors may create an environment that is not conducive to the development and enforcement of state-of-the-practice geometric design standards at the local level.

RESEARCH STEPS

To evaluate city street standards, the researchers collected city design standards and reviewed them. The researchers created procedures to evaluate the adequacy of the standards.

Collecting the Data

The researchers solicited various geometric design and subdivision standards from 19 cities listed in the Oklahoma Municipal League directory (*2*) as having populations of 20,000 or more. Officials in 12 cities responded by providing design manuals, subdivision regulations, or detailed drawings of their street designs. The materials received were researched thoroughly, and a data base in which to store quantitative information was set up.

After analyzing the data, the researchers made field visits to each of the responding cities and administered a questionnaire to city staff. This helped the researchers understand city practices.

Analyzing the Data

The researchers established ''recommended'' design criteria by consulting publications such as the Green Book (*1*) and *Traffic Engineering Handbook* (*3*). The researchers also referred to *Residential Streets* (*4*) by ASCE, *Residential Street Design and Traffic Control* (*5*) by ITE, and *NCHRP Report 330* (*6*).

The standards of each city were compared with the recommended practices to determine the quality of various city design standards. To make a quantitative comparison, the researchers devised methods to evaluate how close each city came to following the recommended practices. The method assigned a rank of 1 to a particular city's standard if it appeared to meet or exceed recommended practices, a rank of 3 if the city's standard was less than recommended and somewhat marginal, and a rank of 5 if the city's standard was deficient. For some of the design topics, the 3 rank was further divided into ranks 2 and 4 to differentiate among degrees of adequacy. The details of the evaluation method are described in the following sections.

Central Concepts

The concepts of functional design and design speed were central to the analyses.

The functional design concept defines and differentiates among streets, depending on the degree to which a street provides property access or provides movement for higher volumes at higher speeds. There are three main functional classes of urban streets: arterials, collectors, and locals. For a given city a separate evaluation was made of the standards used for each functional class. If a city had both major arterial and minor arterial classes, then standards for the two classes were analyzed separately.

Design speed is an important roadway design control. The chosen design speed must be high enough to accommodate the expectations of most drivers who will use the road. The design speed for most facilities is the one at which 85 to 90 percent of the users drive (*1*). Good practice dictates that various roadway elements —alignment, sign placement, and intersection spacing—must accommodate drivers traveling at the design speed. One basis for the evaluations was how well various design elements accommodated vehicles traveling at design speed.

DATA ANALYSIS

When cataloging and analyzing data, the researchers kept the identities of the cities confidential by using letters in place of the city names. The 12 cities were referred to as A, B, C, D, E, F, G, H, J, K, L, and M.

The researchers evaluated stopping sight distance, horizontal curvature, gradient, section width, and intersection radius standards. These standards were chosen for evaluation because most of the cities furnished information with which to evaluate these items and because relatively objective criteria exist for these items.

Stopping Sight Distance

There should be enough sight distance available on the roadway so that a driver in a vehicle traveling at the design speed can stop before reaching a stationary object ahead (*1*). Stopping sight distance (SSD) in feet is calculated from the formula

$$\mathrm{SSD} = 1.467Vt + V^2/[30\,(f + g)] \qquad (1)$$

where

V = initial speed, mph,
f = coefficient of friction,
t = 2.5 sec, and
g = decimal grade.

The adequacy of each city's SSD standards was evaluated by comparing, for each functional class, the city's design speed with the speed for which the city's SSD was adequate. The researchers developed a statistical methodology to evaluate the adequacy of the city standard. The analysis incorporated the following assumptions:

- Vehicle speeds follow a normal distribution;
- Ninety percent of drivers will travel at or less than the design speed; and
- Standard deviation (σ) of the speed distribution was 5 mph.

For those cities that listed no design speeds in the documents sent to the researchers, the following design speeds were assumed:

- Arterial or major arterial, 40 mph;
- Minor arterial, 35 mph;
- Collector, 30 mph; and
- Local residential, 25 mph.

With the stated assumptions, 90 percent of drivers traveled at or less than the design speed, and the median speed was approximated to be 6.41 mph less (i.e., $1.282 * \sigma = 6.41$) than the design speed.

For each city and functional class, the researchers calculated the maximum speed for which the city standard for SSD was safe. The maximum safe speed (i.e., the speed accommodated by the city standard for SSD) was then compared with the design speed.

The researchers assumed a level gradient, which yields a less rigorous criterion than that which could have been applied. With the assumed median speed and standard deviation, the researchers calculated the percentage of the drivers who were afforded adequate SSD as they traveled streets designed to meet the city standard.

If the city standard for SSD accommodated the speeds of 90 percent or more of the drivers, the city standard got 1 as its rank. If the city standard accommodated between 89.9 and 80.0 percent, the city standard got a rank of 2. A percentage of between 79.9 and 70.0 got a rank of 3, and a rank of 4 was given if the percent accommodated fell between 69.9 and 60.0. Anything less than 60.0 percent fetched the lowest rank, 5, for the city standard. Table 1 gives this ranking system.

To illustrate the method City D had local residential street design speed (30 mph) and stopping sight distance (175 ft) standards. The 30-mph design speed was also the assumed 90th percentile speed, and the standard deviation was 5 mph. For an SSD of 175 ft the maximum safe speed was 28.0 mph.

$$\Delta = v - v_{\mathrm{MED}} = v - (v_{\mathrm{DES}} - 1.28\,\sigma)$$

$$= 28.0 - (30 - 6.41) = 4.41 \text{ mph} \qquad (2)$$

$$\Delta/\sigma = 4.41/5.0 = 0.882 \qquad (3)$$

For $Z = 0.882$ the area under the normal curve is 0.31 (two-tail) or 0.81 (one-tail). With the design speed as the 90th percentile benchmark, 81 percent of the drivers' speeds were accommodated by City D's SSD design standard, and City D received a 2 as the adequacy of its SSD design standard for local streets.

Although these evaluation assumptions were arbitrary, they were not unreasonable. The assumptions helped measure how close the cities came to following the recommended practices that were based on state-of-the-practice criteria. The ranking method caused any design element that was not even adequate for speeds 5.2 mph less than the design speed to get the lowest ranking. Table III-1 (wet pavement SSD) in the Green Book (*1*) lists a range of assumed speeds for each design speed; this range has 5-mph spread for the 45-mph design speed and a smaller spread for lower speeds. So for design speeds under 50 mph, the city standard would have to be below that needed to meet the lower SSD design values in Table III-1 of the Green Book (*1*) before the city would get a 5 rank.

This analysis was not performed on those cities that did not list sight distance standards. Table 2 lists the city standard design speed, the city standard for SSD, and the calculated speed for which the standard SSD was safe.

Horizontal Centerline Radius

Good horizontal alignment of a roadway requires that the road be laid out so that its curves are in a harmonious relationship with design speed, superelevation, and side friction. The equation to find a radius (R) suitable for a given combination of speed, cross fall (cross slope), and side friction is (*1*)

$$R_{\min} = \frac{V^2}{15(e + f)} \qquad (4)$$

where

R = curve radius (ft),
V = vehicle speed (mph),
e = rate of superelevation (ft/ft), and
f = side friction factor.

For low-speed urban streets, the "urban" side friction values (*1*) were used.

In addition, there must be adequate SSD to "see around the curve up ahead." The needed sight line is a chord to the curve of the inside lane centerline, and the sight distance is measured along the inside lane centerline. This sight distance is found from the equation

$$\text{SSD} = \arccos(1 - M/R) * R/28.648 \qquad (5)$$

where M is the offset distance in feet from the curve to the line of sight.

The maximum safe speed for a given radius is the least of the following three cases:

1. Maximum safe speed when the roadway has a positive cross fall,
2. Maximum safe speed when the roadway has a negative cross fall, or
3. Maximum safe speed for the available SSD around a curve.

Sometimes a city street is divided by a median and both roadways are superelevated with the curve, or sometimes an undivided city street will be superelevated across the entire cross section. More often, the outside of the curve will have a negative or an adverse cross fall, so in most cases the lesser of Case 2 or Case 3 is the critical situation.

The same assumptions, statistical analysis method, and ranking system used for the SSD analysis were used for analyzing the

TABLE 1 Ranges for Ranking City Standards

Number of standard deviations above median	Speed (mph) above assumed median	Speed (mph) below the design speed	Percent % accommodated by the design element	Rank
> 1.282	> 6.41	0	≥ 90.0	1
1.282 - 0.842	6.41 - 4.21	0.1 - 2.2	89.9 - 80.0	2
0.842 - 0.524	4.21 - 2.62	2.2 - 3.8	79.9 - 70.0	3
0.524 - 0.253	2.62 - 1.27	3.8 - 5.1	69.9 - 60.0	4
< 0.253	< 1.27	< 5.1	< 60.0	5

TABLE 2 Evaluation of SSD Standards

	CITY DESIGN SPEEDS				CITY STOP SIGHT DIST				MAXIMUM SAFE SPEED, GIVEN CITY SSD			
CITY	Maj. Art. mph	Min. Art. mph	Col. mph	Loc. Res. mph	Maj. Art. ft.	Min. Art. ft.	Col. ft.	Loc. Res. ft.	Maj. Art. mph	Min. Art. mph	Col. mph	Loc. Res. mph
A					300		250	200	39.0		35.2	30.5
B												
C												
D	60	30	35	30	350	200	250	175	42.7	30.5	35.1	28.0
E	40	30	30	25	350	200	200	200	42.7	30.5	30.5	30.5
F	40	30	30	25	350	200	200	200	42.7	30.5	30.5	30.5
G	55	45	35	35	350	200	200	200	42.7	30.5	30.5	30.5
H					200	200	200	200	30.5	30.5	30.5	30.5
J					550	400	250	175	55.7	46.2	35.2	28.0
K	50	na	35	30	450	na	250	200	49.3	na	35.2	30.5
L	40	30	30	25	350	200	200	200	42.7	30.5	30.5	30.5
M					500	300	200	200	52.6	39.0	30.5	30.5

NOTE: City H SSD from vertical curve sight distance criteria

City J SSD from sight triangle requirement

na - not applicable, city does not have this class

adequacy of horizontal radius standards. Additional assumptions included:

- Cross fall along the outside of the curve was adverse or negative, and
- Maximum safe speed for sight distance could be calculated on the basis of an available horizontal line of sight extending to the edge of the right-of-way line.

Again the assumption of level gradient makes the SSD criterion less rigorous.

To illustrate the method, City K had local residential design speed (30 mph) and radius (430 ft) standards. A 430-ft radius, with the city standard for a 0.0347 ft/ft cross fall, was suitable for 33.6-mph speeds along the outside of the curve with negative cross fall. With the given city street and right-of-way widths, the driver would have a line-of-sight offset (M) of 20 ft. This value of M was measured from the center of the inside lane to the right-of-way line, and it provided a SSD safe for 36.4 mph. The lesser of the two speeds, 33.6 mph, was critical.

$$\Delta = x - x_{MED} = 33.6 - (30 - 6.41) = 10.0 \text{ mph} \quad (6)$$

$$\Delta/\sigma = 10.0/5.0 = 2.0 \quad (7)$$

For $Z = 2.0$ the area under the one-tail normal curve is greater than 0.90. With City K's design speed as the benchmark, the horizontal radius design standard accommodated more than 90 percent of the drivers, for a rank of 1.

Some cities did not report a value of centerline radius to be analyzed. For those cities that did report a centerline radius standard but that did not report design speed, the researchers used the assumed design speeds mentioned above. Table 3 shows the data used for the evaluation.

Grades

When grades are too flat, drainage problems may occur. When grades are too steep, uniform traffic operation is disrupted, heavy

TABLE 3 Evaluation of Horizontal Radius Standards

	CITY DESIGN SPEEDS				CITY MINIMUM RADIUS				MAXIMUM SAFE SPEED, GIVEN CITY RADIUS, CROSSFALL AND BORDER			
CITY	Maj. Art. mph	Min. Art. mph	Col. mph	Loc. Res. mph	Maj. Art. ft.	Min. Art. ft.	Col. ft.	Loc. Res. ft.	Maj. Art. mph	Min. Art. mph	Col. mph	Loc. Res. mph
A												
B												
C					uk	300	100	50	uk	30.4	20.5	14.3
D	60	30	35	30	1412	300	350	100	50.2	30.0	31.5	20.5
E	40	30	30	25								
F	40	30	30	25	400	300	100	100	32.9	30.3	20.7	20.6
G	55	45	35	35								
H					500	250	200	140	35.7	uk	26.1	24.4
J					500	300	100	100	35.3	29.2	20.1	20.1
K	50	na	35	30	1400	na	610	430	50.7	na	38.3	33.6
L	40	30	30	25	400	300	100	100	32.7	29.2	20.1	20.1
M					500	300	100	100	36.0	30.3	uk	20.5

NOTES: City K allows smaller radius when superelevation employed

na - not applicable, city does not have this class

uk - unknown, data missing

vehicles slow too much, and driving on icy streets is complicated. (*1*) Table 4 lists the gradient controls suggested by the Green Book.

The researchers developed a set of desirable and absolute gradients for evaluating the adequacy of each city's gradient standards. They took into consideration that the terrain in most Oklahoma cities is rolling or flat and that land prices are inexpensive in comparison with land prices in other parts of the country. Table 5 lists the recommended maximum and minimum grades in percentages for different functional categories.

The 12 cities furnished standards for grades, but not all cities had values for all categories. Table 6 gives these values.

The researchers evaluated the adequacy of each city's grade standards by comparing them with the desirable and the absolute

TABLE 4 Maximum and Minimum Grades Suggested by the Green Book (*1*)

Functional Class and	Maximum		Minimum	
Green Book reference pages	Desirable %	Absolute %	Desirable %	Absolute %
Arterial 40 mph (p. 525, 235)	7	10	0.50	0.30
Arterial 30 mph (p. 525, 235)	8	11	0.50	0.30
Collector 30 mph (p. 472, 480)	9	12	0.50	0.30
Local res. (p. 435)		15	0.30	0.20

TABLE 5 Recommended Maximum and Minimum Grades

Functional class	Maximum		Minimum	
	Desirable %	Absolute %	Desirable %	Absolute %
Major Arterial	7	10	0.40	0.30
Minor Arterial	8	11	0.40	0.30
Collector	9	12	0.40	0.30
Local Res.	10	15	0.30	0.20

standards. If the city standard maximum grade was equal to or less than the desirable maximum value, the city standard got a rank of 1. If the city grade fell between the desirable and the absolute maximum values, the city standard got a rank of 3. If the city standard grade exceeded the absolute maximum value, it got a rank of 5.

If the city standard minimum grade was equal to or greater than the recommended desirable minimum value, the city standard got a rank of 1. If the grade was between the desirable and the absolute minimum values, the city standard got a rank of 3. If the city standard minimum grade was less than the absolute minimum, it got the lowest rank of 5.

Section Width

The researchers evaluated the section width standards of the cities. The principles considered included the following:

1. It is desirable that the gutters on higher-speed, higher-volume streets be offset from the lane edge, so drivers will have a greater sense of freedom and so depressions in front of inlets will not be in the path of moving vehicles;
2. It is desirable that arterial streets have separate lanes for left-turning vehicles; for the design passenger vehicle to make a me-

TABLE 6 Evaluation of Gradient Standards

City	MAXIMUM GRADE				MINIMUM GRADE			
	Maj. Art.	Min. Art.	Col.	Loc. Res.	Maj. Art.	Min. Art.	Col.	Loc. Res.
A	4.0		4.0	6.0	0.4		0.4	0.4
B	10.0		10.0	10.0	0.5		0.5	0.5
C	6.0		6.0	10.0	0.5		0.5	0.5
D	4.0		6.0	8.0	0.4		0.4	0.4
E	5.0	7.0	10.0	10.0	0.5	0.5	0.5	0.5
F	7.0	7.0	10.0	15.0	0.5	0.5	0.5	0.5
G	5.0	5.0	8.0	8.0	0.5	0.5	0.5	0.5
H	5.0	5.0	8.0	8.0	0.3		0.3	0.3
J	6.0	6.0	6.0	8.0				
K	5.0		8.0	8.0	0.5		0.5	0.5
L	7.0	7.0	10.0	15.0	0.5	0.5	0.5	0.5
M	5.0	7.0					0.4	0.4

NOTE: City H sets 0.5% minimum grade for asphalt streets

TABLE 7 Section Widths for Ranking Criteria

CLASS	MINIMUM FACE-TO-FACE OF CURB WIDTHS TO GET RANK RANK 1	RANK 3	RANK 5
Arterial or Major Arterial	width for 4 through lanes, center median, offset curbs: 48+18+4=70 ft	width for 4 through lanes, center flush median, offset curbs: 44+12+2=58 ft	less than 58 ft.
Minor Arterial	width for 4 through lanes, center flush median, offset curbs: 44+12+2=58 ft	width for 4 through lanes and offset curbs: 44+2=46 ft	less than 46 ft.
Collector	width for 2 through lanes plus parking on both sides: 22+8+8=38 ft	width for 2 through lanes plus parking on one side: 24+8=30 ft	less than 30 ft.
Local	width for one through lane plus parking on both sides: 12+8+8=28 ft.	width for one through lane plus parking on both sides: 10+8+8=26 ft.	less than 26 ft.

dian U-turn from the inside lane to the outside lane, the Green Book (*1*) calls for 24 ft for two lanes plus an 18-ft median;

3. It is desirable that collector streets have at least two moving lanes unimpeded by parked vehicles; and

4. So long as the street's length is limited, it is acceptable for local residential streets to have width for one lane of moving traffic, with parking available on both sides.

Both safety and convenience dictate that urban arterial streets have medians. Getting the left-turning vehicles out of the through lane allows through traffic to maintain speed, allows progressive movement between traffic signals to be maintained, and reduces the potential for rear-end collisions. In a number of passages the Green Book (*1*) suggests that arterial streets have separate lanes for left-turning vehicles in the form of either flush continuous left-turn lane medians or medians with left-turn bays. A 1990 report (*6*) noted that four-lane undivided streets generally have higher accident rates than streets with a median. The report also stated that raised medians were the best technique for preserving the function of through traffic movement and controlling access on an arterial.

The standards for Oklahoma cities were set with consideration of the relatively low price of land. Most parts of Oklahoma were opened to development as late as 1889 to 1900, and a grid of through streets at 1-mi intervals exists in most cities. Present land development is characterized by low densities, and there is usually plenty of open space for wide streets. Table 7 lists the criteria used by the researchers. Table 8 lists the street section widths called for by the city standards. The section standards proposed in various authoritative publications do not fully agree. The criteria used by the researchers are not as rigorous as some; in some categories the researchers' criteria listed narrower lanes, flush me-

TABLE 8 City Street Section Standards

City	Arterial or Major Arterial ft	Minor Arterial ft	Collector ft	Local ft
A	64	44	40	27
B	47	47	37	26
C	?	44	32	26
D	87	50	36	26
E	48	44	32	26
F	50	50	32	26
G	52	52	32	26
H	50	na	34	26
J	48	48	32	26
K	48	na	32	26
L	50	50	32	26
M	62	48	32	28

dians, and curb offsets in comparison with the recommendations of many others.

Intersection Radius

The curbs of two intersecting streets are joined not at a right angle but with a short curve. If this short curve has an unnecessarily large intersection radius, the distance required for the pedestrian crossing movement is lengthened (*4*). A larger radius may also increase the frequency of "rolling stops" or encourage higher turning speeds (*4*). On the other hand, inadequate radii result in vehicles bumping the curb. From the driver's point of view, the intersection radius needs to be large enough for most vehicles to turn without having to turn at a crawl speed or without bumping into the curb while turning (*7*).

The researchers evaluated the adequacy of city radius standards for arterial-arterial, arterial-collector, and collector-collector intersections. The adequacy of a radius is a function of the width of the lane turned from, the width of the lane turned into, and the design vehicle. The researchers used the design vehicles listed in Table 9 for evaluating adequacy.

The researchers used city street lane widths in combination with the standard values for intersection radius to make scaled drawings of typical intersections. Each intersection radius was evaluated by overlaying vehicle turning templates onto the scaled intersection drawings. The design vehicle began the right rurn entirely within the right lane and completed the turn without striking the curb. A ranking was then given on the following basis:

Rank 1, vehicle made a 90-degree turn without entering the lane for opposing flow on the street turned into (i.e., did not cross the centerline);

Rank 3, vehicle made the turn but jutted out less than 1 ft into the oncoming lane; or

Rank 5, vehicle made the 90-degree turn but jutted out more than 1 ft into the oncoming lane.

For example, a city might specify a 50-ft-wide arterial section with four lanes and a 30 ft radius. If the WB-50 vehicle template made a 90-degree turn at the intersection of two arterials, from a 12-ft lane into a street half-width of 25 ft without crossing the centerline, then the rank given was 1.

RESULTS

The researchers evaluated the adequacy of city design standards intended for new developments or streets. Table 10 gives the results in the form of rankings of the quality of various city geometric design standards. The gaps in Table 10 reflect the absence of a functional class in a particular city, the absence of a standard for a particular design issue, or a missing standard for a particular functional class.

It is noteworthy that a number of cities had incongruous standards, in the sense that the speed for which the sight distance was suitable differed greatly from the city's design speed. Some of the city design speeds are rather high and probably could be decreased. On the other hand the 30-mph design speed that a number of the cities had adopted for minor arterials is probably too low for Oklahoma conditions. The present study indicated that despite the availability of published state-of-the-practice design criteria, some of the fundamental geometric standards at the local level were substandard. Standards for major arterials were most in need of improvement.

In general, the cities had SSD standards that were adequate for the design speed. However, half the cities needed to revise their SSD standards for their major arterials. Standards for SSD should consider the effects of downgrades on stopping distances.

The city standards for horizontal centerline radii did not accommodate the drivers' needs (i.e., the design speed) in many instances. Only City K had consistently adequate minimum radius standards. The assumption that the line of sight was clear up to the right-of-way line may have been overly generous; it may be that city standards for horizontal curvature are actually worse than the evaluation indicated.

In almost every instance city standards for gradient met or exceeded those recommended by the Green Book (*1*). The cities' gradient standards scored better than the other design issues evaluated.

In most instances, the cities' standards for street section width were marginally adequate (Rank 3), but could improve. Arterials were an exception; most cities needed to call for wider major arterial sections.

The cities had adequate to good intersection turning operations, as measured by the lane widths and radii. There were data to evaluate only 8 of the 12 cities' intersection standards.

The researchers had to interpret some of the standards and could have made a mistake in so doing. In a few cases the various design documents for a particular city did not agree with each other.

Some of the cities contacted did not have standards for such fundamental design criteria as minimum SSDs, and during the interviews some city engineers did not understand such concepts as a "design vehicle" for geometric layout controls. A city staffer from one of the cities that did not respond to the survey said that that city had no geometric design standards.

The widespread horizontal radius deficiencies cause one to wonder whether some local staff appreciate fundamental design issues. The need to remove left-turning vehicles from the traffic stream to preserve the functional demands of major arterial traffic often seemed to be ignored.

TABLE 9 Recommended Intersection Design Vehicles

	Collector	Arterial
Collector	Bus	WB-50
Arterial	WB-50	WB-50

RECOMMENDATIONS

Many of the suggested design criteria contained in the Green Book (*1*) and other recognized publications are based on the scientific studies of the limitations and capabilities of drivers, vehicles, and roadways. It is doubtful that the engineer at the local level can rationally justify design standards that vary greatly from those suggested by the experts. If the recommended practices constitute a valid yardstick, then some city street design standards do

TABLE 10 Ranking of City Standards

	A	B	C	D	E	F	G	H	J	K	L	M
ARTERIALS AND MAJOR ARTERIALS												
SSD	2			5	1	1	5	5	1	2	1	1
Centerline radius			uk	5		5		4	4	1	5	4
Grade - maximum	1	3	1	1	1	1	1	1	1	1	1	1
Grade - minimum	1	1	1	1	1	1	1	3	uk	1	1	uk
Section width	3	5		1	5	5	5	5	5	5	5	3
MINOR ARTERIALS												
SSD				1	1	1	5	4	1		1	1
Centerline radius			4	1		1		uk	5		2	4
Grade - maximum					1	1	1	1	1		1	1
Grade - minimum					1	1	1	uk	uk		1	1
Section width	5	3	5	3	5	3	3		3	na	3	3
COLLECTORS												
SSD	1			1	1	1	4	1	1	1	1	1
Centerline radius			5	4		5		4	5	1	5	uk
Grade - maximum	1	3	1	1	3	3	1	1	1	1	3	uk
Grade - minimum	1	1	1	1	1	1	1	3	uk	1	1	1
Section width	1	3	3	3	3	3	3	3	3	3	3	3
RESIDENTIAL LOCALS												
SSD	1			2	1	1	4	1	1	1	1	1
Centerline radius			5	5		4		2	4	1	4	4
Grade - maximum	1	1	1	1	1	3	1	1	1	1	3	uk
Grade - minimum	1	1	1	1	1	1	1	1	uk	1	1	1
Section width	3	3	3	3	3	3	3	3	3	3	3	3
INTERSECTION RADIUS												
Arterial w/ arterial	1		3	1		3	3	1		1	3	
Arterial w/ collector	3		5	1		3	3	1		1	3	
Collector w/ collector	1		1	1		1	1	1		1	1	

not measure up. Although the standards from only one state were studied, it would be odd if the problem of substandard standards were confined to one state. It is more likely that local design standards in other states also need improvement.

If local design standards do in fact need improvement, there are a number of possible ways to proceed, including

1. Do nothing,
2. Conduct education and extension programs, or
3. Invoke federal or state involvement and regulation.

To choose the "do nothing" option, it appears that one would have to conclude that no significant problems were being caused by cities having standards below the state of the practice. A rebuttal to this position is that, to accept less than the state of the practice, one must be unaware of the research-based principles on which state of the practice is founded.

A common prescription in U.S. society for curing a deficiency or problem is more education. One possible remedy for inadequate city design standards is more education for city officials. A rebuttal to this argument is that the inhibiting factors mentioned earlier plus time constraints sometimes stifle change at the local level. Also the record shows that local government officials are not always receptive to or able to implement improved and progressive engineering practices. If city officials were overwhelmingly proactive, how can one explain the need to have outside pressures (e.g., lawsuits and legislative mandates) to make cities take action? A case in point was that cities did not improve wastewater treatment systems until they were forced to do so by the federal government.

In recent years another common approach to addressing problems has been federal or state intervention. A disadvantage to federal or state standards would be the creation of more regula-

tions and bureaucracy; some will oppose intervention on the basis of their philosophical biases, regardless of the facts or needs. The principle of the federal government setting minimum environmental (wastewater, storm water, etc.) requirements that local governments must meet could be applied to transportation; the federal or state governments may need to mandate local government street standards for a few design topics. The following factors suggest this need:

1. Local governments may lack the funds to hire personnel with the expertise to establish a comprehensive, up-to-date set of street design standards;
2. Some local government officials and staff do not always appreciate the need to implement progressive geometric design controls; and
3. Local political environments may not be conducive to establishing adequate, modern street design standards, especially when such standards would impose more stringent requirements than those currently in effect.

A set of uniform minimum standards would benefit the engineering design community if the result were a reduction in differences among city standards, which would in turn reduce the number of different practices with which engineers would have to cope. More important, the general public would benefit, because a higher level of safety and convenience would be built into the street network if inadequate standards were overridden by mandated practices. Perhaps future exposure to tort lawsuits would be reduced, saving the taxpayers' money.

CLOSING

Transportation is not a local issue now any more than the wastewater issue was in recent years. In the typical U.S. metropolitan area one city merges into the next. Travel and commerce move from city to city and state to state; travel does not recognize the city limit. Like wastewater traffic congestion and accidents affect people downstream of a city. If the engineering design criteria recommended by the experts are reasonable and if it is important that the public be afforded a minimum level of quality, then engineering leaders need to devise methods that actually bring quality to the public. If the current method if ensuring quality is not working, another method should be considered.

An analysis of one state's data does not prove a widespread need, but it suggests further investigation. Section 1049 of the 1991 federal transportation bill (Intermodal Surface Transportation Efficiency Act) mandates a review of state standards relating to design. Although research often emphasizes state highway issues, local government needs should not be overlooked: there should be more evaluations of the quality or adequacy of city design practices. It may be that city design standards are adequate in some regions but not in others. There will be legitimate reasons for differences among cities' standards, but at some point differences can cross the line into the realm of inferior practice. If standards are mandated, it will take effort to build standards that control practices that do not measure up to the criteria that are based on engineering science without interfering with legitimate differences. Mandating a few fundamental city street design standards should not have a significant impact on the affairs of those cities that have adequate transportation design standards. Only those with inadequate standards, the ones not delivering a certain level of quality to the public, would feel a significant impact.

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