Abridgment

Analysis of the Problem of Urban Utility-Pole Accidents

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An investigation of the problem of urban utility-pole accidents was undertaken by using 1975 data from utility-pole accidents and a sample of other urban run-off-road accidents. These data were obtained by visiting and inventorying each accident site identified in a search of police accident files in 20 urban-suburban areas included in the study.

To put the problem in perspective, the table below gives the distribution of first object struck in all single-vehicle run-off-road accidents:

First Object Struck	Number of Accidents	Percentage of Total
Utility pole	1291	21.1
Fence, guardrail	825	13.5
Sign, mailbox, parking meter, guy wire	728	11.9
Culvert, ditch, embankment	714	11.7
Tree	682	11.1
Light, signal pole	466	7.6
Fire hydrant	223	3.6
Building	215	3.5
Ground (generally rollover)	187	3.1
Wall	175	2.9
Shrubbery	120	2.0
Bridge	116	1.9
None	79	1.3
Other	303	4.9
Total	6124	100.0

Utility poles were by far the most frequent source of impact, accounting for 21.1 percent of all objects struck. Combining this figure with the fact that single-vehicle accidents accounted for 10.4 percent of all urban accidents (1) suggested that 2.2 percent of all accidents in urban areas involve impacts with utility poles.

Although it is clear that utility poles were the most frequent object struck in urban single-vehicle accidents, this is of little consequence unless the severity of such accidents relative to other fixed-object accidents is known. Distributions of injury for different objects struck in single-vehicle accidents are given below (total accidents excludes those where injury was unknown):

Object	Total Accidents	Injury Accidents		Percentage of Total Injury Accidents
		Number	Percent	
Utility pole	1166	589	50.5	31.4
Fence, guardrail	740	171	23.1	9.1
Sign, parking meter, mailbox, guy wire	668	133	19.9	7.1
Culvert, ditch, embankment	674	300	44.5	16.0
Tree	598	257	43.0	13.7
Light, signal pole	365	77	21.1	4.1
Fire hydrant	179	32	17.9	1.7
Building	163	33	21.2	1.8
Ground (generally rollover)	175	92	52.6	4.9
Wall	147	53	36.1	2.8
Shrubbery	100	7	7.0	0.4
Bridge	115	47	40.9	2.5
None	79	12	15.2	0.6
Other	202	72	35.6	3.8
Total	5371	1875	34.9	100.0

Except for vehicles striking the ground (52.6 percent), which were generally rollover accidents, utility-pole accidents had the highest percentage of injury (50.5 percent). To illustrate the overall effect of frequency and severity, this table also gives the probability of injury associated with each type of object, i.e., the likelihood of being injured by that particular object in a single-vehicle accident. It can be seen that utility poles were by far the most frequent source of injury.

The second table also shows that, in general, the proportion of injury accidents decreases as the rigidity of the object decreases. Exceptions are the categories of ground and culverts, ditches, and embankments—objects one would not necessarily associate with severe injury. However, these obstacles had a high incidence of rollover (96.3 and 20.2 percent respectively), which most likely caused the injury. Collisions that involve culverts, ditches, or embankments also had a high probability (23.6 percent) of contacting a second obstacle, which contributed to their above-average severity. The same was true for collisions with signs, mailboxes, parking meters, and guy wires; 53.8 percent of these accidents involved a second impact.

After it was established that utility poles were the most frequently struck and one of the most aggressive roadside objects, factors that differentiated utility-pole accidents from other single-vehicle accidents were examined. Few differences were noted in the variables that describe the vehicle, the driver, or environmental conditions; however, differences were detected in the variables that describe road characteristics, vehicle departure attitude, and characteristics of pole placement.

ROAD CHARACTERISTICS

It is not surprising that there was a strong cross correlation among road type, road width, speed limit, and average daily traffic (ADT). By using the combined sample of utility-pole plus run-off-road accidents, mean speed limit, mean road width, and mean ADT were calculated for each road type as given below (1 km/h = 0.62 mph and 1 m = 3.3 ft):

Item	Arterial	Collector	Local
Mean speed limit (km/h)	68.7	59.2	51.5
Mean road width (m)	9.4	9.5	7.9
Mean ADT (000s)	13.4	6.9	5.2

It is clear that road type can be characterized by using road width, speed limit, or ADT. In pursuing this further, it was also shown that ADT can be predicted from road width and speed limit so that road width and speed limit are sufficient to characterize the road system.

Figure 1. Proportion of single-vehicle accidents involving utility poles by road width and speed limit.

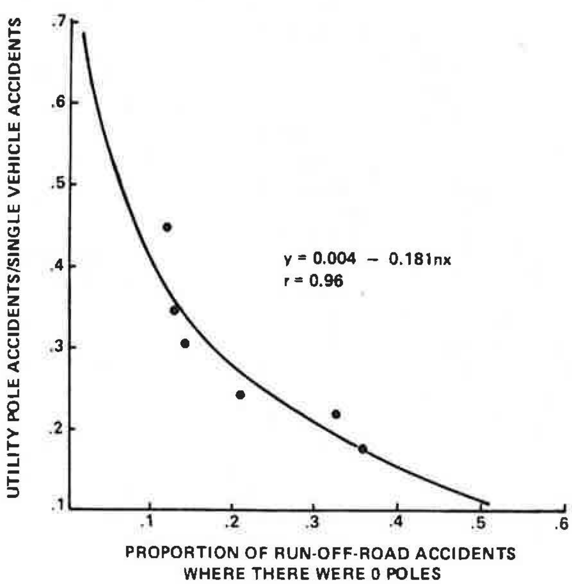
Road Width (m)	Speed Limit (km/h) 24	32	40	48	56	65	73	81	89	Overall
0 - 5.9	.200	.105	.105	.206	.104	.214	.120	.074	.211	.179
6.0 - 8.9	.286	.261	.208	.236	.320	.252	.168	.205	.172	.230
9.0 - 12.0	--	--	.217	.362	.491	.467	.227	.200	.143	.339
12.1 - 15.0	--	--	.175	.328	.352	.607	.318	.632	.263	.334
15.1 - 18.0	--	--	.158	.194	.333	.542	.095	.125	.030	.210
16.1 - 21.1	--	--	.286	.129	.360	.313	.219	--	.143	.214
21.2 - 24.1	--	--	--	.267	.135	.043	--	.083	.091	.122
≥24.2	--	--	--	.500	.120	.230	.330	.077	--	.066
Overall	.236	.209	.180	.270	.280	.314	.186	.185	.146	.239

[box] Utility pole accidents overrepresented within speed limit

[circle] Utility pole accidents overrepresented within road width

Note: 1 km = 0.62 mile; 1 m = 3.3 ft.

Figure 2. Proportion of single-vehicle accidents involving utility poles versus proportion of run-off-road accidents where there were no poles.



To show the effect of these two parameters on the frequency of utility-pole accidents, Figure 1 shows data for utility-pole accidents as a proportion of single-vehicle accidents jointly for road width and speed limit. The figures that are circled are cells in which utility-pole accidents are overrepresented compared with the overall speed-limit figure, and the figures that are boxed are cells in which utility-pole accidents are overrepresented compared with the overall road-width figure. For example, for roads that have a speed limit of 56 km/h (35 mph) and a width of 6 to 9 m (20 to 29 ft), the figure 0.320 shows that utility-pole accidents were overrepresented compared with the overall road-width figure of 0.230 and the overall speed-limit figure of 0.280. This suggests that, although there is a correlation between speed limit and road width, both variables contribute to the overrepresentation. The interaction is clear in that overrepresentation of utility poles occurs for roads with speed limits of 48 to 64 km/h (30 to 40 mph) and widths of 9 to 15 m (30 to 50 ft). This was shown to be the result of higher than average pole densities; also, roads of <9-m (<30-ft) width had high pole densities but did not have high frequencies of pole accidents, possibly because of lower travel speeds.

VEHICLE DEPARTURE ATTITUDE

The percentages of single-vehicle accidents that are utility-pole accidents are given below by travel speed (1 km/h = 0.62 mph):

Range of Travel Speed (km/h)	Utility-Pole Accidents (%)	Range of Travel Speed (km/h)	Utility-Pole Accidents (%)
0-15	13.9	64-80	15.3
16-31	16.2	81-96	22.6
32-48	23.6	97-112	26.2
49-64	24.9	113-119	41.7

The data suggest that as travel speed increases the proportion of pole accidents increases. This can be explained by a decreasing departure angle with increasing speed, which, correspondingly, increases the probability of pole contact; i.e., a vehicle exiting at a very shallow angle will have a trajectory that will expose it to more utility poles than the trajectory of a vehicle that exited at a much greater angle. A further indication of this effect is in the side-of-road-exited and road-path variables. Utility-pole accidents compared with run-off-road accidents in general had more departures to the right side of the road and a higher proportion of vehicles exiting from a straight road—situations in which one would expect a lower than average departure angle.

CHARACTERISTICS OF POLE PLACEMENT

The percentages of single-vehicle accidents that are utility-pole accidents are given below for each data collection area:

Collection Area	Utility-Pole Accidents (%)
Macon, Georgia	44.8
Knoxville, Tennessee	34.8
Columbus, Ohio	30.9
Nashville, Tennessee	24.4
Erie and Niagara counties, New York	21.9
San Diego, California	17.5

It can be seen that there is a significant variation between areas that, if one assumes that the characteristics of the driving population are approximately the same, must result from different roadway and pole-placement characteristics. Characteristics of pole placement include pole spacing, pole offset, and the number of poles within 183 m (600 ft) of either side of the struck pole or position of final rest. The latter parameter is particularly useful in that it can describe areas that have one or fewer poles.

One would expect the overall frequency of utility-pole accidents for a given area to be a function of the relative density of utility poles in that area. To test this, Figure 2 shows the proportion of utility-pole accidents in single-vehicle accidents plotted against the percentage of run-off-road accidents that occurred where there were no utility poles. Fitting a logarithmic curve through the data points shows a very strong correlation (r = 0.96) and suggests that the majority of the between-area variation is explained by the relative density of poles in each area.

Figure 3 shows the proportion of utility-pole accidents in run-off-road accidents plotted as a function of pole spacing. Fitting a regression line through the data points shows that there is a high degree of correlation (r = 0.96); i.e., as pole spacing increases, the frequency of utility-pole accidents decreases. This result complements that of Figure 2 because, from the evidence on pole spacing, sites where there were less than two utility poles had to be excluded.

Pole offset completed the definition of pole placement. Figure 4 shows the proportion of utility-pole accidents in single-vehicle accidents plotted against lateral offset at the final rest position of the pole. It can be seen that the proportion of utility-pole accidents is high at low offsets, which is where the utility poles are located. Once the mean pole offset [1.7 m (5.5 ft)] is reached, the frequency of utility-pole accidents starts to flatten out although there is still a downward trend.

REGRESSION ANALYSIS

After the factors that affect the frequency of utility-pole contact have been identified, the next step is to assess the relative importance of these parameters. This was done by using stepwise multiple regression (Table 1). At each step of the regression, the constant and coefficients of the regression equation are given together with the 95 percent confidence interval; the square of the multiple correlation coefficient is also

Figure 3. Proportion of single-vehicle accidents involving utility poles versus pole spacing.

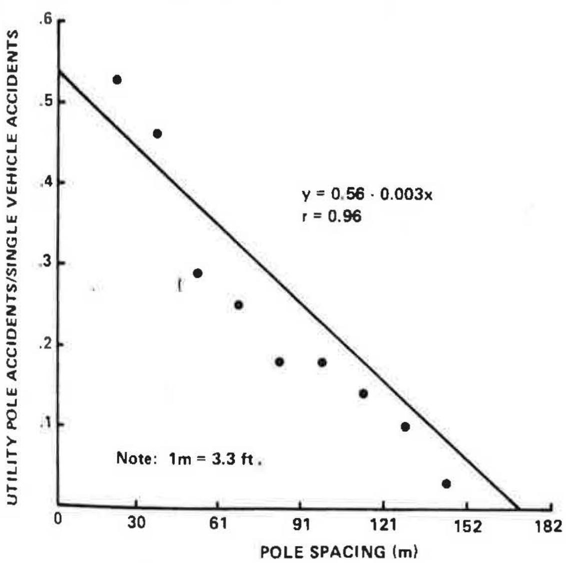


Figure 4. Proportion of single-vehicle accidents involving utility poles versus final rest position of pole.

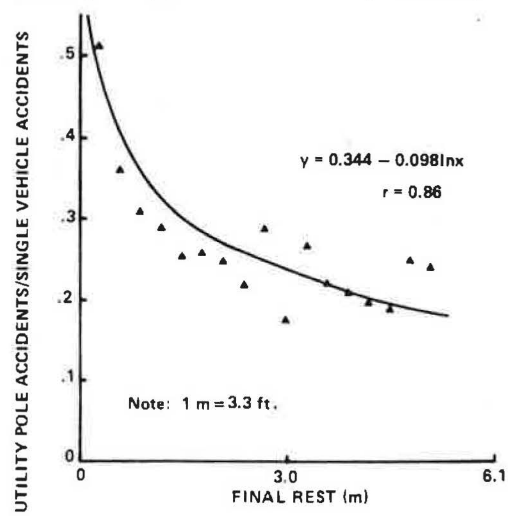


Table 1. Stepwise regression.

Step Number	Variable Entered	Constant	Number of Poles	Offset	Road Grade	Road Path	Speed Limit	Road Width	Number of Lanes	Median Width	R^2
		Coefficients of Regression Equation									
1	Number of poles	-0.055	0.0689 ± 0.002	-	-	-	-	-	-	-	0.257
2	Offset	-0.105	0.0686 ± 0.002	0.0075 ± 0.0014	-	-	-	-	-	-	0.263
3	Road grade	-0.030	0.0682 ± 0.002	0.0093 ± 0.0014	-0.059 ± 0.013	-	-	-	-	-	0.268
4	Road path	0.0093	0.0676 ± 0.002	0.0094 ± 0.0014	-0.054 ± 0.013	-0.027 ± 0.008	-	-	-	-	0.270
5	Speed limit	0.103	0.0672 ± 0.002	0.0077 ± 0.0015	-0.053 ± 0.013	-0.026 ± 0.008	-0.0022 ± 0.0007	-	-	-	0.273
6	Road width	0.088	0.0677 ± 0.002	0.0067 ± 0.0015	-0.053 ± 0.013	-0.023 ± 0.008	-0.0026 ± 0.0007	0.001 ± 0.0004	-	-	0.274
7	Number of lanes	0.107	0.0681 ± 0.002	0.0067 ± 0.0015	-0.052 ± 0.013	-0.024 ± 0.008	-0.0025 ± 0.0007	0.0023 ± 0.0007	-0.026 ± 0.012	-	0.275
8	Median width	0.075	0.0678 ± 0.002	0.0070 ± 0.0016	-0.052 ± 0.013	-0.022 ± 0.008	-0.0021 ± 0.0007	0.0045 ± 0.001	-0.045 ± 0.013	-0.005 ± 0.0015	0.277

Note Travel speed, ADT, pole spacing, and shoulder width deleted, 3371 data points.

given. The first variable entered is the number of poles, which explains 25.7 percent of the variation. Offset is then entered at step 2 and explains a further 0.6 percent of the variance. Road grade is entered at step 3, road path at step 4, and speed limit at step 5, and each explains an additional 0.5, 0.2, and 0.3 percent of the variance respectively. The remaining three steps given in the table each contributed another 0.1 percent to the total variation explained.

It is clear from this regression analysis that the overriding factor in predicting utility-pole accidents is the number of poles. Note that this variable not only identifies that a line of poles exists but also indicates average pole spacing since poles that were within 183 m (600 ft) of either side of the struck pole (or the rest position of the vehicle in run-off-road accidents) were counted. Furthermore, it is encouraging that offset is entered as step 2 because it complements the number-of-poles parameter by providing a more complete definition of pole placement.

The remaining parameters that are entered describe the type of road—i.e., road grade—or are related to the vehicle departure angle—i.e., road path and speed limit. This suggests that, if better measures of departure attitude were available—e.g., angle and speed—a higher proportion of variation might be explained.

REFERENCE

1. Accident Facts. National Safety Council, Chicago, 1976.

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Abridgment

Mathematical Models That Describe Lateral Displacement Phenomena

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In this research, a unique technique was used to collect a reliable and permanent type of data (1). Data were collected by using two super 8-mm movie cameras to study the behavior of traffic in the right lane of freeways as it approaches a vehicle parked on the right shoulder. The general tendency of vehicles as they near a parked vehicle is to swerve away from it. The path of the average vehicle at the test location is expressed by a predictive model in terms of independent variables related to geometric parameters and traffic characteristics. By using the model, the magnitude of lateral displacement at any location can be determined as the difference between the paths of the average vehicle in the presence of a side obstruction (parked vehicle) and under normal conditions (no side obstruction).

In this research, vehicles of different sizes were used and placed on the right shoulder at various distances from the freeway edge of the pavement. Vehicles were used since they are the most common type of side obstruction. A full description of the process of data collection and methods used to extract different parameters is beyond the scope of this paper but is available elsewhere (1). A brief summary of the research methodology used is presented below.

For each experiment run, a vehicle of known width was placed on the right shoulder, and the clear distance between the most remote left point of the vehicle and the edge of the pavement was measured and recorded. Two observers, each operating a camera, were signaled by a third observer by way of portable CB units to start running approximately 7.6 m (25.0 ft) of film at a speed of 8 frames/s. Three minutes of filming were designed for each experiment (1). The camera speed of 8 frames/s permitted the running of two experiments with a 15.2-m (50.0-ft) roll of film. A digital stopwatch was placed about 15 cm (6 in) in front of each camera's objective lens; these stopwatches read to $\frac{1}{100}$ of a second and appeared in the unused portion of the frame.

The first observer was stationed on a crossover (pedestrian or crossroad) and above the center of the right lane of the freeway. The observer's line of sight during filming was parallel to the traffic flow, and the edge of the pavement was ensured to be in view. The observer was completely concealed from motorists to ensure that lateral displacement did not occur because of any outside distraction but was a normal reaction of the driver when approaching the parked vehicle at the test section. A second observer, stationed evenly with the parked vehicle and on the other side of the highway, was generally outside the right-of-way; this allowed visual coverage of about 35 to 45 m (120 to 150 ft) of the roadway with the parked (test) vehicle in the middle of the observer's view.

Both films were later advanced simultaneously through stop-action projectors, and several parameters were extracted either by visual counting or by constructing special scales that were placed on the screen to measure distances. Time was read from the photographed stopwatches.

Movies taken by the first observer were used to extract parameters such as the total volume of vehicles in the right lane, including trucks and buses, and distance between the edge of the pavement and the center of a vehicle as it passed next to the parked (test) vehicle. The speeds of individual vehicles in the right lane and in the adjacent lane, headways in the right lane, and other parameters were extracted from the movie taken by the second observer.

Data from each experiment were classified as either geometric parameters (such as degree of curvature at the test location and grades in the direction of traffic flow) or traffic characteristics (such as those parameters extracted from movie films). Data were collected from two large metropolitan areas (St. Louis and Chicago) to study whether a general model could be developed that would apply to more than one met-