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**UNREPORTED COLLISIONS WITH POST-AND-BEAM
GUARDRAILS IN CONNECTICUT, IOWA AND NORTH CAROLINA**

Malcolm H. Ray, Associate Professor
Jennifer A. Weir, Associate Research Engineer

Department of Civil and Environmental Engineering
Worcester Polytechnic Institute
100 Institute Road, Worcester, MA 01609-2280
508-831-5340; 508-831-5808 (Fax)
mhray@wpi.edu

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ABSTRACT

This paper presents results of an in-service performance evaluation of four guardrail systems: the G1 cable guardrail, G2 weak-post W-beam guardrail and the G4(1S) and G4(1W) strong-post W-beam guardrails. The study was focused particularly on estimating the number of unreported collisions with and the true distribution of vehicle occupant injuries. The data were collected in portions of Connecticut, Iowa and North Carolina during a 24-month data collection effort in 1997 to 1999. The collision performance was measured in terms of collision characteristics, occupant injury and barrier damage. Unreported collisions were counted in all three areas by periodically inspecting guardrails in a specific control section. Ninety percent of the guardrail collisions on these control sections were unreported or were reported as property-damage-only. Only 41 percent of the guardrail collisions on the control sections were reported to the police. By counting unreported collisions, collisions reported only to maintenance personnel, and police-reported collisions, a more complete assessment of the risk of injury and performance of the barriers was obtained. Within the sample size limitations of the data collected to date, there was no statistically significant difference between the performance of the guardrails in the three states, and there was no difference between the performance of the G1 and G2 or the G1 and G4(1W).

KEYWORDS

Roadside safety, in-service performance evaluation, guardrails, unreported collisions.

INTRODUCTION

Guardrails are a fundamental component of the roadside safety system on roadways in the United States. Many types of guardrails have been developed and used over the past five decades but the number of different types of guardrails commonly used has decreased in recent decades as States have chosen the systems with the most design flexibility. Guardrails can be categorized into three broad types: weak-post guardrails, strong-post guardrails and rigid barriers. Weak-post systems, which are intended to experience large lateral deflections that slowly bring the vehicle to rest, require lateral clear areas behind the barrier as large as four or five meters. Strong-post barriers usually require less than a meter of lateral clear space but redirect vehicles more sharply. Rigid barriers, which are designed to experience no lateral deflection, redirect vehicles even more abruptly. Choosing the appropriate barrier for a particular site involves matching the site conditions to the performance characteristics of the barrier.

A number of studies have attempted to evaluate the in-service performance of guardrails but they have not adequately accounted for unreported collisions.(1,2,3,4,5) The purpose of this paper is to examine the in-service performance of the G1, G2, G4(1S), and G4(1W) guardrails in portions of Connecticut, Iowa and North Carolina, focusing on the issue of reported and unreported collisions. All reported collisions involving these guardrail types were investigated in one-half of Hartford County in Connecticut, a four-county area of Iowa and a three-county area in North Carolina. Unreported collisions were counted on specific segments of roadways in all three areas by periodically inspecting each guardrail and noting all damage including minor paint scraps, tire rubs and dents. These segments are referred to as “control sections” in this paper. The data collection began on 1 July 1997 and continued until 30 June 1999. Bullnose median barrier installations in Iowa, which incorporate the G4(1W) guardrail system, were excluded from this analysis although they are examined elsewhere.(6) Guardrail-bridge transitions were also excluded from this analysis.

Figure 1 shows examples of the guardrail types. The G1 cable guardrail, SGR01a in the AASHTO-ARTBA-AGC *Hardware Guide*, is used in all three states.(7) It consists of S75x8.5 steel posts with 5000-mm spacing and three 19-mm diameter steel cables.(7) The 3-cable guardrail has been used for at least 30 years. Today cable guardrails are used extensively in upper mid-western states like Nebraska, North Dakota, South Dakota and Minnesota and are also common in the northeastern states like New York and Connecticut and mid-Atlantic States like Virginia and North Carolina.(8) The standard G1 three-cable guardrail has successfully passed the NCHRP

Report 350 crash tests for test level three.(7)

The G2, or SGR02, is a weak-post W-beam guardrail used in Connecticut. It also uses S75x8.5 steel posts spaced at 3810 mm and a 2.67-mm thick steel “W” section.(7) While weak-post w-beam guardrails were once very common, they are now used almost exclusively in east-coast states like Connecticut, New York, Pennsylvania, Virginia and North Carolina.(8) The system has not passed the crash test requirements of NCHRP Report 350 although a modified version has recently been tested and accepted for use on federal-aid highways.(9)

The G4(1W) in Iowa and the G4(1S) in North Carolina are two versions of a blocked-out strong-post W-beam guardrail using a 2.67-mm thick steel “W” section and posts spaced at 1905 mm.(7) The strong-post W-beam guardrails are by far the most common type of guardrails in use today.(8) While there are a number of varieties of this system using different combinations of posts and blockouts, every state uses some type of strong post w-beam guardrail.(8) The G4(1W), a modified SGR04b shown in Iowa DOT’s Standard Road Plan as RE-12A, uses 200x200mm wood posts with wood blocks, whereas the G4(1S), or SGR04a, uses W150x13 steel posts with steel blocks.(7)(10)

Figure 1: Typical installations of G1, G2, G4(1W), and G4(1S) guardrails (top to bottom)



DATA COLLECTION

Data Collection Areas

Data concerning reported and unreported collisions were collected over a two-year period in Iowa and North Carolina (e.g., from 1 July 1997 until 30 June 1999) and one year period in Connecticut (e.g., 1 July 1997 until 30 June 1998). The data collection area in Connecticut was composed of the interstate network in the northern half of Connecticut Department of Transportation (DOT) District 1, which contains the Hartford metropolitan area, including Bradley Airport, several smaller municipalities and four interstate highways. The Iowa data collection area was composed primarily of Cedar, Johnson, Linn and Scott Counties in southeastern Iowa, containing three metropolitan areas, four interstate highways, and roadways in a variety of functional classes. The data collection area in North Carolina was comprised of Durham, Orange, and Wake Counties in the 5th and 7th Divisions of the North Carolina DOT (NC-DOT), including three major interstate routes (I-40, I-85 and I-440), two large cities (Durham and Raleigh) and three counties with a mixture of urban and rural land uses. All collisions reported to the police or highway maintenance agencies in these areas were investigated by data collection teams. The teams collected information about the hardware damage and site characteristics as well as the conventional police-reported data.

Control Sections

Portions of interstate highways within the three data collection areas were closely monitored during the data collection for evidence of unreported collisions. These segments were called “control sections.” The Connecticut control section was approximately 31 kilometers of I-91 (both directions) containing 3.6 kilometers of G1 installations and 25.2 kilometers of G2 installations. It experienced average daily traffic (ADT) volumes of about 42,000 vehicles per day each direction. The Iowa control section was a 35.8 kilometer segment of I-80 eastbound containing 1.5 kilometers of G1 installations and 0.4 kilometers of G4(1W) installations. It experienced average daily traffic (ADT) volumes of about 16,000 vehicles per day one way.⁽¹¹⁾ The North Carolina control section was approximately 14.5 kilometers of I-40 (both directions) containing 1.4 kilometers of G1 installations and 2.9 kilometers of G4(1S) installations. It experienced average daily traffic (ADT) volumes of about 50,000 vehicles per day each direction past the G1 median installations and 45,000 vehicles per day each direction past the

G4(1S) roadside and median installations.

The control sections were generally representative of their data collection areas in terms of guardrail types and quality of installation. One installation characteristic that is of particular concern is the rail mounting height of the guardrails. Rail mounting height has been shown to affect the performance of guardrails, particularly cable guardrails, in terms of vehicle containment and occupant injury.(5)(12) Table 1 summarizes the height of guardrails in the control section installations and in collision cases in the data collection areas. The collision cases include reported collisions in the control sections. Average undamaged rail heights were measured for each guardrail installation in the control sections and for many of the collision cases.

Table 1. Height of undamaged rail in guardrail control section installations and collision cases, by state.

Connecticut	<u>G1 (cable)</u>		<u>G2 (weak-post W-beam)</u>	
	CT control section	CT collisions	CT control section	CT collisions
No. of installations/cases	8	10	42	55
Design height (mm)	685	685	836	836
Mean height	795	739	818	828
Minimum height	635	635	680	680
Maximum height	820	945	945	975
No. acceptable (± 75 mm)	6 (75%)	7 (70%)	27 (64%)	37 (67%)
No. too high	2 (25%)	3 (30%)	6 (14%)	9 (16%)
No. too low	0 (0%)	0 (0%)	9 (21%)	9 (16%)

Iowa	<u>G1 (cable)</u>		<u>G4(1W) (strong-post W-beam)</u>	
	IA control section	IA collisions	IA control section	IA collisions
No. of installations/cases	12	25	14	48
Design height (mm)	685	685	706	706
Mean height	774	766	704	702
Minimum height	685	500	640	560
Maximum height	865	970	790	860
No. acceptable (± 75 mm)	5 (42%)	9 (36%)	12 (86%)	36 (75%)
No. too high	7 (58%)	13 (52%)	2 (14%)	5 (10%)
No. too low	0 (0%)	3 (12%)	0 (0%)	7 (15%)

North Carolina	<u>G1 (cable)</u>		<u>G4(1W) (strong-post W-beam)</u>	
	NC control section	NC collisions	NC control section	NC collisions
No. of installations/cases	11	76	5	200
Design height (mm)	685	685	706	706
Mean height	897	743	704	678
Minimum height	820	230	660	120
Maximum height	1300	1300	740	1010
No. acceptable (± 75 mm)	0 (0%)	51 (67%)	5 (100%)	153 (76%)
No. too high	11 (100%)	24 (32%)	0 (0%)	7 (4%)

In Connecticut, 75 percent of the G1 guardrails and 64 percent of the G2 guardrails on the control section were at an acceptable height, compared to 70 percent of all G1 and 67 percent of all G2 guardrail collision cases in the data collection area. In Iowa, 42 percent of the G1 guardrails and 86 percent of the G4(1W) guardrails on the control section were at an acceptable height, compared to 36 percent of all G1 and 75 percent of all G4(1W) guardrail collision cases in the data collection area. In North Carolina, none of the G1 guardrails and all of the G4(1S) guardrails on the control section were at an acceptable height, compared to 67 percent of all G1 and 77 percent of all G4(1S) guardrail collision cases in the data collection area. The Connecticut and Iowa control sections resembled their data collection areas closely in terms of rail height, while the G1 guardrails in the North Carolina control section did not match those in the data collection area as closely.

While the Iowa and North Carolina data collection areas contained roads in several functional classes, 79 percent of the guardrail collision cases in Iowa occurred on interstates and the rest occurred on U.S. routes. Seventy-two percent of the guardrail collision cases in North Carolina occurred on interstates and 13 percent occurred on U.S. routes. All of the collision cases in Connecticut and all of the installations in the three control sections were on interstate highways.

Data Collection Methods

One data collection team was formed for each of the data collection areas. The teams were provided with a set of forms for recording data about collisions. The data collection teams were notified about collisions by police and highway maintenance agencies, and information from police accident reports and maintenance cost-recovery reports were collected for each case where available. In addition to these official sources of information, the collision sites were visited and the damage to the guardrail was measured and documented with photographs.

The data collection teams also surveyed every guardrail installation on the control segments approximately once each month and recorded any minor damage. This procedure was not standardized as well as the procedure for collecting reported-collision data. In theory, a data collector would walk the length of each guardrail installation and examine it for any damage, recording the type and location of damage and the survey date. In reality, the survey methods varied by team. For example, the Iowa team inspected the guardrails meticulously on foot and recorded even the slightest signs of damage, while the North Carolina team initially conducted drive-by surveys, which only

captured moderate guardrail damage. The teams also stored the collision data differently. In order to standardize the data somewhat, presumed collision events resulting in very minor damage were removed from the Iowa unreported collision data for the purpose of this analysis. Thus, the estimates of unreported collisions include those that caused minor to moderate damage, such as dents in the guardrail, collapsed end sections, or slightly bent posts. In essence, the teams independently arrived at criteria that noted damage involved some type of permanent deformation of the guardrail system (e.g., bent posts, dented rails, etc.) and ignored very minor markings like paint scraps and tire rub marks. In the context of this paper, whenever metal components of the barriers were either dented or deformed, a possible collision event was recorded by the data collectors. Possible collisions leaving only scuffs, paint scraps, scratches, and other very minor damage were eliminated from further consideration. Figure 2 shows examples of minor and very minor damage.

Another difficulty that was encountered is that different types of barriers have different thresholds for damage. For example, it is very difficult to contact a strong-post w-beam guardrail without leaving some type of mark on the guardrail system. On the other hand, it is very difficult to determine when cable guardrails have been struck if the collision was very minor. Likewise, some maintenance activities like snow plowing can bend guardrail posts in a weak-post system making it difficult to distinguish between maintenance-induced damage and collision-induced damage. Estimating the number of collisions based on very minor damage and markings of the guardrail, therefore, does present some potential difficulties.

Figure 2a. Very minor damage.



Figure 2b. Minor damage.



REPORTED COLLISIONS

Frequency

Data from a total of 471 guardrail collisions were collected in the Connecticut study area for 12 months and in the Iowa and North Carolina study areas during the entire 24-month data collection period, including 127 G1 collisions, 126 G2 collisions, 201 G4(1S) collisions, and 15 G4(1W) collisions. Of these, 401 were reported to the police. The proportions of police-reported collisions and maintenance-only reported collisions are very different among the States, as shown in Table 2.

Table 2. Police-reported and maintenance-only-reported guardrail collisions.

	G1				G2		G4				Total					
	CT		IA		NC		All		CT			IA G4(1W)		NC G4(1S)		
	No.	%	No.	%	No.	%	No.	%	No.	%		No.	%	No.	%	
Police-reported	14	100	18	78	59	77	91	81	96	99	12	86	201	100	400	94
Maintenance-reported	0	0	5	22	17	23	22	19	1	1	2	14	0	0	25	6
Total	14	100	23	100	76	100	113	100	97	100	14	100	201	100	425	100

The reason for the difference in maintenance versus police-reported rates in the three states is that State DOTs use different procedures to repair barriers. In Iowa, State DOT workers perform repairs to guardrails and are therefore notified by the police whenever a barrier is struck. In North Carolina, repair and maintenance are generally contracted out such that the DOT is not notified unless the damage itself poses a hazard to traffic. The DOT issues periodic contracts to repair all the damaged barrier on a segment of the roadway for normal repair situations. In Connecticut, the police reports are not released to the public, including the DOT, for a period of time after they are completed, so it is difficult to match collision data to repair data.

Occupant Injury

The most important measure of roadside hardware performance is the amount of human trauma resulting from roadside hardware impacts. The reason for installing the hardware in the first place is to minimize the risk to vehicle occupants by shielding them from even more serious collisions with more hazardous roadside objects like poles, trees and steep side slopes. The severity of injuries to the vehicle occupants was assessed using the occupant injury codes listed on the police report (e.g., the KABCO scale). Each case was assigned the code for its most

severe injury. Since the occupant injury information comes from the police report, the information was limited to the 401 police-reported collisions.

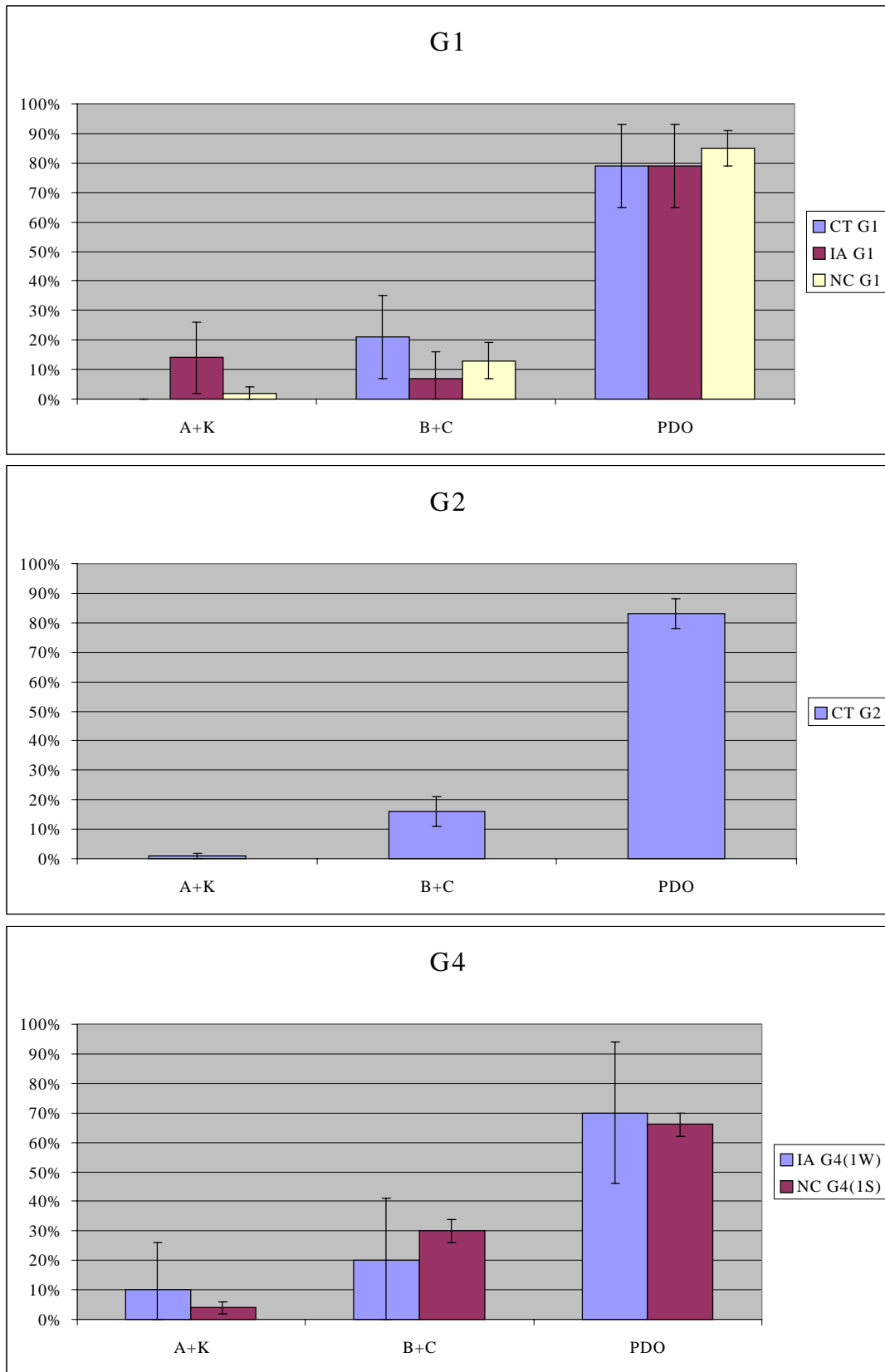
Table 3 summarizes the occupant injury severities of the police-reported collisions. In Connecticut, about 80 percent of collisions with either the G1 or the G2 involved only property damage, and only one collision involved a fatality or severe injury (e.g., A+K severity). In Iowa, about 80 percent of collisions with the G1 and 70 percent of collisions with the G4(1W) resulted in only property damage, and 13 percent of both involved fatalities or severe injuries (e.g., three cases). In North Carolina, 85 percent of collisions with the G1 and 65 percent of collisions with the G4(1S) resulted in only property damage, and about three percent of both involved fatalities or severe injuries (e.g., ten cases).

Table 3. Occupant injury severity in 400 police-reported guardrail collisions.

Scenario	G1				G2		G4				Total					
	CT		IA		NC		All		CT		IA G4(1W)		NC G4(1S)		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Severe or Fatal (A+K)	0	0	2	14	1	2	3	3	1	1	1	10	8	4	13	3
Moderate Injury (B+C)	3	21	1	7	8	13	12	23	16	16	2	20	61	30	91	23
Property damage only	11	79	11	79	50	85	72	74	85	83	7	70	132	66	296	74
Total	14	100	14	100	59	100	87	100	102	100	10	100	201	100	400	100

The aggregate level of occupant injury is summarized at the end of Table 3 for all guardrail collisions in the three data collection areas. In general, guardrail collisions resulted in severe and fatal occupant injuries in approximately three percent of the police-reported collisions. Some level of occupant injury occurred in about 26 percent of police-reported collisions. Figure 3 represents the injury severity rates for only the police-reported collisions. The 90th percentile precision ranges of the error rates were calculated where possible and are shown as error bars in Figure 3. For example, since there were 14 G1 collisions in Iowa and 11 of these resulted in property damage only, there is a 90 percent probability that the true percentage of property-damage-only collisions was between 61 and 97 percent. The range cannot be calculated for a category if there were no observations in that category.

Figure 3: Distribution of occupant injury severities in police-reported guardrail collisions.



For example, the probability that the true proportion of property-damage-only G1 collisions in Connecticut is 79 percent \pm 14 percent (e.g., between 65 and 93) is at least 0.90 (e.g., 90 percent confidence). The proportion of property-damage-only G1 collisions in Iowa is the same as in Connecticut, and the proportion in North Carolina is 85 percent \pm 6 percent (e.g., between 79 and 91 percent) at the 90 percent confidence level. While the range of the estimates is relatively wide (e.g., 14 percent for Connecticut and Iowa and six percent for North Carolina), the estimates for all three data collection areas overlap, indicating that the G1 data are consistent with each other. The ranges for G1 performance in the three states overlap at all severity levels where a range could be calculated, indicating that there is no statistically significant difference among the performance of the G1 in the three states.

Similarly, there is no statistically significant difference between the performance of the G4(1S) in North Carolina and the G4(1W) in Iowa. There is also no statistically significant difference between the performance of the G1 and G2 in Connecticut or between the performance of the G1 and G4(1W) in Iowa. There is, however, a statistically significant difference between the performance of the G1 and G4(1S) in North Carolina, showing that in general in North Carolina, a collision with a G1 results in less severe damage to vehicle occupants than does a collision with a G4(1S).

UNREPORTED COLLISIONS

The “control sections” in each data collection area were relatively small sections of roadway where very detailed information about collisions could be obtained. The guardrails in the control section were inspected frequently and the location and type of damage observed was noted. When a formerly undamaged section of guardrail was observed to be damaged, a collision was presumed to have taken place.

There was evidence of about 31 collision events per year with G1 installations and 144 collision events per year with all guardrail installations on the control segments as shown in Table 4 (Iowa and North Carolina data are averaged over two years whereas the Connecticut total represents the number actually collected in one year). Of these presumed collision events, about 17 (54 percent) of the G1 events and 75 (53 percent) of all events were reported to police or maintenance agencies. As discussed earlier, slight differences in data collection methods among the States probably caused much of the variation among unreported collision frequencies. On average, the

data suggest that about 50 percent of the collisions with guardrails in the States of Connecticut, Iowa, and North Carolina are not reported to the police or DOT. Presumably, if no one was injured and the vehicle was still operable after the collision, the driver left the scene without a police report being filed or maintenance personnel being notified. These collisions represent guardrail successes, since they shielded an errant vehicle from some more hazardous roadside feature without causing occupant injuries or serious property damage.

Table 4. Reported and unreported guardrail collisions per year on control segments in data collection areas.

Collision Type	G1				G2	G4				Total No.
	CT No.	IA No.	NC No.	All No.	CT No.	IA G4(1W) No.	NC G4(1S) No.	All No.		
Unreported	4	5	5	14	13	0.5	40	40.5	67.5	
Maintenance-only-reported	0	0	0	0	1	0	0	0	1	
Police-reported	10	1	5.5	16.5	54	1.5	3	4.5	75	
Total	14	6	10.5	30.5	68	2	43	45	143.5	

Where both inventory and collision information are available, it is possible to calculate expected average collision rates based on the number of vehicles passing guardrail installations. The control sections were inventoried and the locations and lengths of guardrail systems were recorded. Over 500 million vehicle-kilometers are traveled past a guardrail installation each year on these three segments of interstate highways combined, as shown in Table 5.

Table 5. Collision rates for guardrails on the control segments.

Characteristics	G1				G2	G4				Total
	CT	IA	NC	All	CT	IA G4(1W)	NC G4(1S)	All		
No. of installations	18	13	3	34	106	8	20	28	168	
Total length of installations (km)	3.59	1.48	1.37	6.44	25.28	0.37	2.94	3.31	35.03	
One-way segment AADT	42,000	16,000	50,024		42,000	16,000	43,344			
Million vehicle-km per year	53.7	8.4	48.7	110.8	378.0	2.1	45.4	47.5	536.3	
Collision events in one year										
Unreported collisions	4	5	5	14	13	0.5	40	40.5	67.5	
All reported collisions [§]	10	1	5.5	16.5	55	1.5	3	4.5	75	
All collisions	14	6	10.5	30.5	68	2	43	45	143.5	
Collisions per million vehicle-km past guardrail										
Unreported collisions	0.075	0.592	0.103	0.126	0.034	0.235	0.882	0.853	0.126	
All reported collisions [§]	0.186	0.118	0.113	0.149	0.146	0.704	0.066	0.095	0.142	
All collisions	0.261	0.710	0.216	0.275	0.180	0.939	0.948	0.948	0.268	

§ Reported collisions are those that are reported to either a police agency or a maintenance agency.

The collision rates shown in Table 5 were calculated using the data in Table 4. The location of the guardrail (e.g., roadside or median) was taken into account when calculating the vehicle-kilometers traveled per year. On average, 0.268 collisions (e.g., reported and unreported) occurred per million vehicle-kilometers traveled past a guardrail, or in other words, one collision event occurred for every 3.7 million vehicle-kilometers traveled past a guardrail. As shown earlier, 50 percent of these can be expected to be minor collisions that result in no occupant injury and so little property damage that they are not reported to the police. Collisions serious enough to be reported to the police will occur at an average rate of 0.142 events per million vehicle-kilometers traveled past a guardrail. This analysis, of course, is based on the average occurrence of guardrail collisions and may not provide accurate predictions of the collision frequency at a specific site. Some sites will experience higher or lower rates because of traffic conditions or site characteristics at that specific location, and differing attention to detail in data collection will result in different estimates of unreported collision events.

Unreported collision rates varied among the guardrail systems studied and among the same systems used in different states. As discussed earlier, this is likely due primarily to procedural differences among data collectors. Other factors affecting unreported collision rates may include differences between the property-damage threshold for reporting collisions in each state and differences between guardrail systems in terms of the visible evidence of collisions.

While the unreported collision rates vary, the reported collision rates are reasonably consistent with each other. The data collection procedures were much more standardized and reliable for the police-reported cases and the inventory and traffic data were reliable. Reported collisions with the G1 in all three states occurred at an average rate of 0.149 collisions per vehicle-km past a guardrail. The G2 in Connecticut had a similar reported collision rate. The G4 systems in Iowa and North Carolina appear to have very different rates, but this is likely due to the small sample in Iowa. Only 2.1 vehicle-km were traveled past a G4 on the Iowa control section in a year, compared to 45.4 vehicle-km past a G4 on the North Carolina control section.

Occupant Injury

Table 6 summarizes the severity of occupant injuries for guardrail collisions on the control sections, with and without the presumed unreported collision events. Unreported collisions were assumed to have resulted in

minor property damage only (i.e., presumed property damage only). In Connecticut, occupants suffered some level of injury in 20 percent of police-reported G1 collisions (14 percent of all G1 collisions) and 21 percent of police-reported G2 collisions (16 percent of all G2 collisions). In Iowa, occupants suffered only property damage in all G1 collisions but suffered some level of injury in 67 percent of police-reported G4(1W) collisions (50 percent of all G4(1W) collisions). In North Carolina, occupants suffered some level of injury in 18 percent of police-reported G1 collisions (10 percent of all G1 collisions) and 50 percent of police-reported G4(1S) collisions (3 percent of all G4(1S) collisions). Severe and fatal injuries occurred in about one percent of all guardrail collisions, and some level of occupant injury occurred in about ten percent of all collisions.

Table 6. Occupant injury severity and rates in 210 control section guardrail collisions.

Injury Severity	G1				G2		G4				Total	
	CT No. %	IA No. %	NC No. %	All No. %	CT No. %	IA No. %	G4(1W) No. %	NC No. %	G4(1S) No. %	No. %	No. %	
Police-reported collisions												
Severe or Fatal (A+K)	0 0	0 0	1 9	1 4	1 2	0 0	0 0	0 0	0 0	2 2	2 2	
Moderate Injury (B+C)	2 20	0 0	1 9	3 13	10 19	2 67	3 50	3 50	3 50	18 21	18 21	
Property damage only	8 80	2 100	9 82	19 83	43 79	1 33	3 50	3 50	3 50	66 77	66 77	
Total	10 100	2 100	11 100	23 100	54 100	3 100	6 100	6 100	6 100	86 100	86 100	
All collisions												
Severe or Fatal (A+K)	0 0	0 0	1 5	1 2	1 1	0 0	0 0	0 0	0 0	2 1	2 1	
Moderate Injury (B+C)	2 14	0 0	1 5	3 6	10 15	2 50	3 3	3 3	3 3	18 9	18 9	
Property damage only	8 57	2 17	9 43	19 41	43 63	1 25	3 3	3 3	3 3	66 31	66 31	
Presumed PDO §	4 29	10 83	10 47	24 51	14 21	1 25	85 94	85 94	85 94	124 59	124 59	
Total	14 100	12 100	21 100	47 100	68 100	4 100	91 100	91 100	91 100	210 100	210 100	
Collisions per million vehicle-km past guardrail												
A+K	0.0000	0.0000	0.0103	0.0045	0.0013	0.0000	0.0000	0.0000	0.0000	0.0019	0.0019	
B+C	0.0373	0.0000	0.0103	0.0226	0.0132	0.4694	0.0331	0.0331	0.0331	0.0186	0.0186	
All injuries	0.0373	0.0000	0.0205	0.0271	0.0146	0.4694	0.0331	0.0331	0.0331	0.0205	0.0205	
PDO	0.1490	0.1184	0.0924	0.1218	0.0569	0.2347	0.0331	0.0331	0.0331	0.0690	0.0690	
Presumed PDO	0.0745	0.5919	0.1026	0.1263	0.0370	0.2347	0.8820	0.8820	0.8820	0.1277	0.1277	

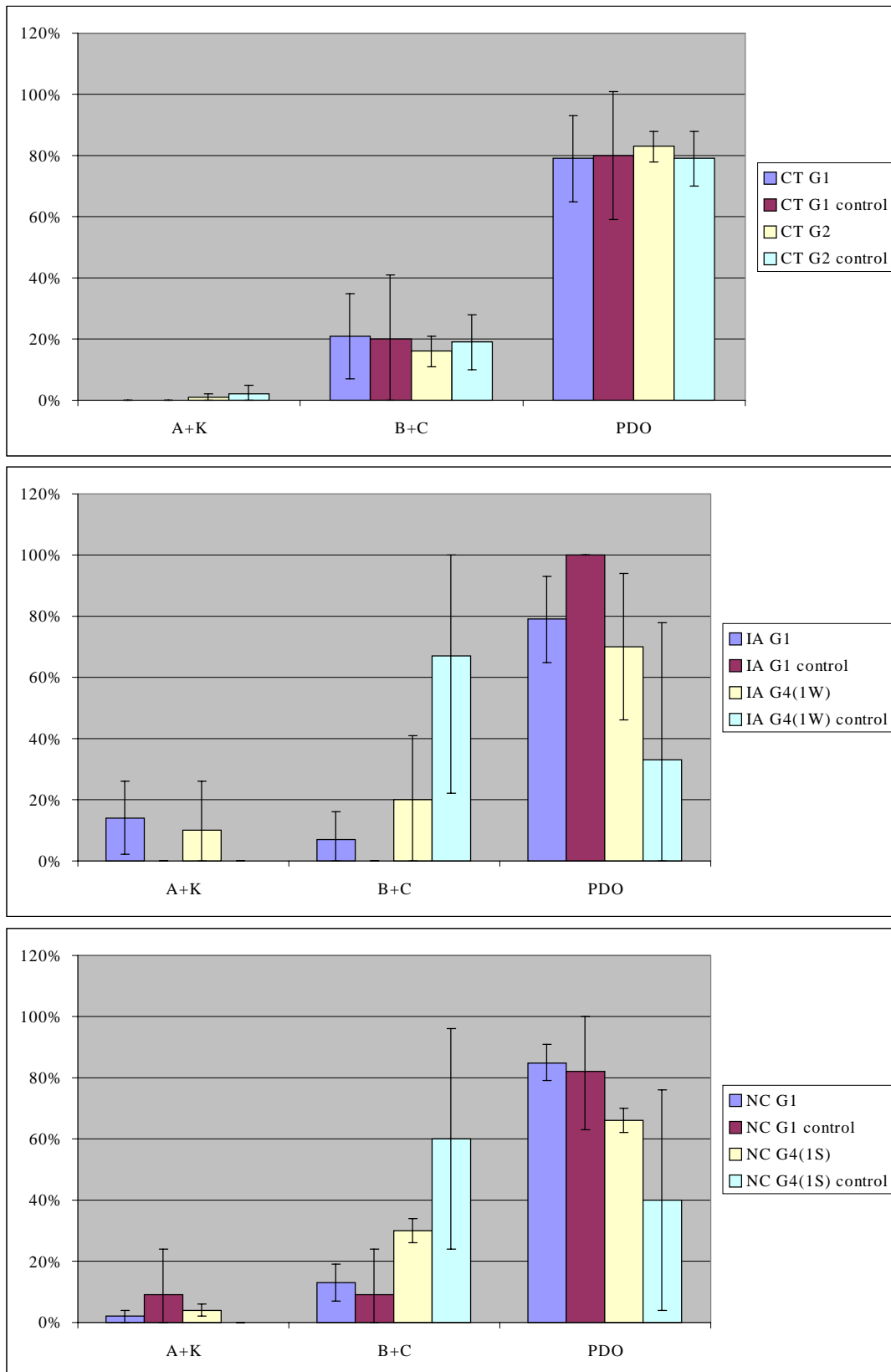
§ Unreported collisions and collisions reported only to a maintenance agency are assumed to have resulted in

Injury collision rates are shown in the bottom part of Table 6. Collisions resulting in some level of occupant injury occurred at comparable rates per million vehicle-km traveled past a guardrail for all the guardrail

types studied in Connecticut and North Carolina. The Iowa rates are of doubtful validity due to the small sample, as discussed previously.

Figure 4 compares the injury severity distributions of police-reported collisions on the control sections to those for the data collection areas. The 90th percentile precision ranges of the error rates were calculated where possible and are shown in Figure 4 (the range cannot be calculated for a category if there were no observations in that category). Note that in most cases there is no statistically significant difference between the control section proportions and the data collection area proportions. Where there is a significant difference, it is very small. This implies that in terms of injury severity, the control section cases were a good sample of the data collection areas.

Figure 4: Occupant injury severity of police-reported guardrail collisions on control sections and in data collection areas, with 90% confidence intervals.



CONCLUSIONS

The previous sections have described an analysis of data collected in an in-service performance evaluation of the G1, G2, G4(1W), and G4(1S) guardrails in Connecticut, Iowa and North Carolina. This analysis focused specifically on estimating the number of unreported collisions and the true distribution of vehicle occupant injuries.

The data revealed that almost 75 percent of all the police-reported guardrail collisions and 80 percent of the police-reported collisions on the control sections resulted in only property damage. On the control sections, 90 percent of the guardrail collisions were unreported or were reported as property-damage-only. Only 41 percent of the guardrail collisions on the control sections were reported to the police. Within the limits of the data collected to date, there was no statistically significant difference between the performance of the guardrails in the three states, and there was no difference between the performance of the G1 and G2 or the G1 and G4(1W). However, occupant injuries were less common in collisions with a G1 guardrail than in collisions with the G4(1S) or both G4 types combined.

The methods used to estimate unreported collisions involved a significant investment of time and resources. These methods are not feasible for every in-service evaluation, particularly those performed by state DOT forces with limited personnel. Despite attempts to standardize the data collection, differences in procedures among data collectors produced results that varied widely among the states involved in this study. Since this type of data collection is both time-consuming and sensitive to methodology and human error, the authors do not recommend its use in future in-service evaluation studies.

Instead, the authors recommend gathering data on reported injury collisions, hardware inventory, and traffic volumes. From these data, which are much less difficult to collect, rates of injury or severe-injury collisions per million vehicle-km traveled past the guardrail or other hardware can be determined. Reporting these rates for in-service evaluation projects would allow results from studies of different hardware systems in different states to be compared to each other. While the criteria for levels of property damage that must be reported varies among states, most injury collisions will be reported in all states. Since the most important measure of roadside hardware performance is the amount of human trauma resulting from roadside hardware impacts, it is appropriate to assess the performance by rates of collisions resulting in occupant injury. Comparing collision rates normalized by traffic volume should also eliminate any bias related to traffic volume.

The foregoing sections have indicated that the guardrails are performing reasonably well in Connecticut, Iowa and North Carolina. These analyses, however, are limited by a modest number of cases and the conclusions may require revision as more data are collected. It should also be noted that the quality of guardrail installation and maintenance has an important effect on the guardrail collision performance. The proportion of guardrails with the correct rail mounting height varied among the states and guardrail types. The G1 cable guardrails, in particular, had an excessively high rail mounting height in many Iowa cases and a number of North Carolina cases, likely due to frost heaves pushing the guardrail posts up out of the ground.

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