Fall 1999

Toward the Development of a Pursuit Decision Calculus: Pursuit Benefits Versus Pursuit Cost

Thomas J. Madden

Geoffrey P. Alpert
University of South Carolina - Columbia, geoffa@mailbox.sc.edu

Publication Info

Published in *Justice Research and Policy*, Volume 1, Issue 2, Fall 1999, pages 23-41.
Madden, T.J. and Alpert, G.P. (1999). Toward the Development of a Pursuit Decision Calculus: Pursuit Benefits Versus Pursuit Cost. *Justice Research and Policy*, 1(2), 23-41.

TOWARD THE DEVELOPMENT OF A PURSUIT DECISION CALCULUS: PURSUIT BENEFITS VERSUS PURSUIT COST

Thomas J. Madden
Geoffrey P. Alpert

Abstract

To make unbiased decisions about whether to pursue a fleeing vehicle, officers must understand both the costs and the potential benefits of a pursuit. This manuscript describes an approach that identifies and assesses the impact of pursuit characteristics on pursuit costs. Data from official pursuit forms generated by officers in the Miami-Dade police department were used as a basis of the study. Log-linear models were used to identify direct and interactive effects of the pursuit characteristics. Upon finding significant effects, odds ratios were calculated. The findings indicate that there are certain pursuit characteristics, including number of units and speed, that significantly increase the likelihood of pursuits resulting in a cost to society including personal injury or property damage.

Support for this research has been provided, in part, by the National Institute of Justice Grant #93-IJ-CX-0061. Opinions stated in this paper are those of the authors and do not necessarily represent the official position of the National Institute of Justice.

JUSTICE RESEARCH AND POLICY, Vol. 1, No. 2, Fall 1999.

Police officers have the discretion to stop drivers for traffic and other violations. In the majority of cases, the driver will obey the police officer's order. Unfortunately, not all suspects stop when signaled. Therefore, whether to pursue a fleeing suspect is a decision many, if not all, officers must eventually face. Police pursuits generate a benefit to society when they result in an arrest, but at what cost? The cost of a pursuit can be exorbitant. The generally accepted estimate is that 40% of all pursuits result in a crash, 20% involve personal injury, and 1% result in a death. Strong supporters of pursuits believe pursuits are justified for any offense, including traffic violations (California Highway Patrol, 1983; Hannigan, 1992). These supporters argue that unless suspects are aggressively chased, they and others will likely flee the police, which will result in havoc on the roadways. Further, they believe the decision to engage in the pursuit and the ongoing decision of whether to continue the pursuit should be made by the officer in the field.

Alternatively, some police departments have created more restrictive pursuit policies (Kenney & Alpert, 1997), limiting pursuits to those of a known or suspected violent felon who will pose a serious threat to the public if not apprehended immediately (Alpert, 1997). In some cases, family members of people injured in a pursuit have suggested a total ban on pursuits, and the city of Baltimore has had a no-chase policy for more than 20 years.[1]

The most prudent pursuit decision is not dichotomous, chase versus no chase, but one that weighs the benefits of a pursuit against the costs. The goal of this manuscript is to contribute to the development of a "pursuit calculus"; that is, given certain pursuit characteristics, what are the odds that the pursuit will result in damage or injury? These odds must be weighed against the benefits of apprehension.

Development of a Decision Calculus

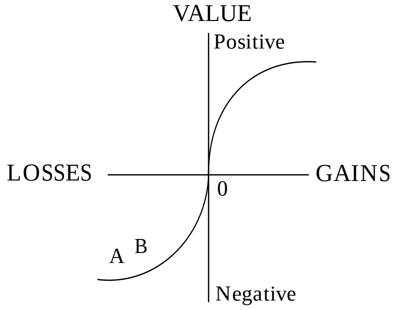
As long as there are police officers who are determined to catch fleeing suspects, pursuits are inevitable. The goal of police administration with respect to pursuits is to maximize the benefit (apprehension of serious criminals) while

---

[1] In a report in the *Boston Herald* (May 18, 1998), the grandmother of a young man killed as a result of a high-speed chase in Falmouth, MA, said she planned to petition the state legislature to ban all pursuits. Officers involved in the pursuit stated that they terminated the pursuit minutes after beginning the chase. However, members of the community reported that they heard on police scanners that the pursuit lasted 45 minutes.

minimizing the cost (damage or injury). Individual departments, either formally or informally, need to develop a procedure that can identify when pursuits should be initiated, continued, or terminated. These decisions must be based on both the benefits and the costs. Without incorporating the element of cost, the decision of whether or not to pursue will be based only on the potential benefit, which may induce an error in judgement. Arkes (1991) describes three categories of judgmental biases: strategy-based errors, association-based errors, and psychophysically based errors. Figure 1 depicts the value function of Prospect Theory, a theory concerned with the process of making decisions under risk (Kahneman & Tversky, 1979), used by Arkes to describe the sunk cost effect. This is one example of a psychophysically based judgment error.

Figure 1
The Value Function of Prospect Theory



Sunk Cost Effect

Decisions should be based on the anticipated benefits and costs that will result from a particular choice. Future costs or benefits are relevant; prior (sunk) costs are not. When sunk costs are used in making a decision, an error in judgment is made. In Figure 1, people who have already invested substantial amounts and have not yet realized compensatory returns would be located at point B.

People in this situation are not very sensitive to future losses. They will take more risk than they normally would to recoup their sunk costs. For example, a person who started with $150 at the racetrack and lost $140 may consider the $140 a sunk cost. This person may consider betting $10 on a 15:1 long shot in the last race. There are two ways to frame the decision: status quo and sunk cost. For the status quo frame, only future benefits and losses are considered. Weighing the possible gain of $140 against the possible loss of $10, the person would be located at Point 0 in Figure 1, the intersection of the axes. The sunk cost framing context views the present state as a loss of $140 (point B) and the decision is between returning to the reference point 0 or increasing the loss to $150 (Point A). Prospect Theory predicts that the sunk cost framing context would produce more risk-seeking behavior than the status quo framing context. Individuals who do not modify their point of reference as they lose are likely to make bets they would not make under normal circumstances.

Consider the police officer who has been involved in a pursuit for a period of time. What is influencing the decision to continue the pursuit, the future benefits versus future costs, or the sunk costs of pursuing for a length of time without the satisfaction of apprehending the driver? Would an officer without the sunk cost make the same decision to continue the pursuit as an officer experiencing sunk cost? It must be remembered that police pursuits are not static events. They may start in a noncongested area and travel into a congested area, they increase in speed, road conditions change, etc. Police officers need to update the pursuit conditions in terms of both benefits and costs to make an unbiased decision about whether to continue a pursuit.

The contribution of Prospect Theory is that unlike the expected utility model (see Tversky & Kahneman, 1983), it accounts for context effects on individual choice under risk. The simple framing of a decision in terms of gains or losses can affect choice, which raises an interesting question for police pursuits: would the choice to pursue be different if the decision were framed in terms of gains (no injury) versus losses (no apprehension)? The research underlying the development of Prospect Theory indicates that people are risk averse when the decision is framed in terms of gains, and risk takers when the decision is framed in terms of losses.

Costs of Police Pursuits

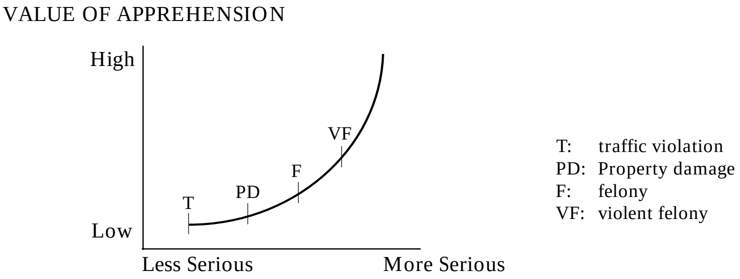
Alpert and Fridell (1992) report the generally accepted figure that approximately 40% of all pursuits result in damage. The question that needs an answer is whether there are certain environmental characteristics of a pursuit, such as high speed, number of units, time of day, area of pursuit, etc., that increase the odds of a pursuit resulting in damage or injury.

Research on pursuit driving has progressed from descriptive studies (Fennessy, Hamilton, Joscelyn & Merrit, 1970) to statistical models designed to assess the impact of the pursuit environment on the decision to pursue (Alpert, 1997; Alpert & Madden, 1996; Crew & Fridell, 1994). The most comprehensive literature review on police pursuits is provided by Alpert and Fridell (1992). Only a limited number of studies provide information on specific costs and benefits of pursuits. Auten (1994a) estimates the average cost of a pursuit which ends in a crash at

$28,500 (Auten, 1994a; Auten, 1994b, p. 76).[2] Crew, Fridell and Pursell (1995) report that 38% of the pursuits initiated for a traffic violation result in a crash. The pursuits that have the greatest likelihood of resulting in personal injury or death are pursuits of suspected felons and DUI (17% and 14%, respectively). The policing community and the research literature have frequently based the costs of a pursuit on the broad measures of an accident, injury, or death (Alpert & Fridell, 1992).

Figure 2 presents a hypothetical value function for four possible offenses: traffic violation (T), property damage (PD), felony (F), and violent felony (VF). The hypothetical value function is specified as nonlinear. The marginal value increases for the apprehension of more serious violations. On the one hand, all apprehensions have a positive value, and all pursuits would be authorized if only benefits were influencing the decision. On the other hand, pursuits also have costs. The higher the risk factors, the greater the chance of injury. In the present example, there are three pursuit profiles in which the likelihood of injury is a function of the pursuit risk factors. These are labeled as Profiles A, B, and C in Figure 3. Profile A has the lowest risk of injury, whereas profile C has the highest risk of injury. If the risk of injury were characterized by profile A, all pursuits would be authorized. If the risk of personal injury were at level B in Figure 3, then only pursuits for a felon or violent felon would be authorized. The potential

Figure 2
Pursuit Value Function

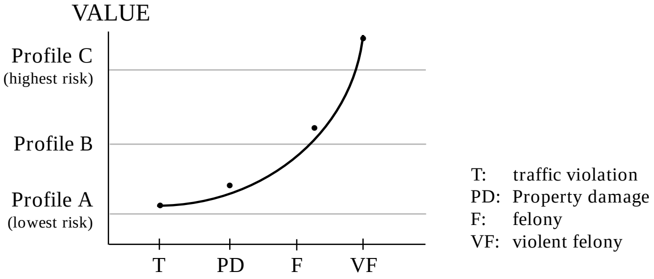


---

[2] This estimate did not include legal costs, costs of agency time spent investigating the accident or possible policy violations, overtime, or time off for injuries.

risks of the pursuit, however, outweigh the potential benefits of stopping a driver for a traffic violation or a property damage violation. The pursuit of a violent felon would be authorized for any of the risk factors present in Figure 3. The potential benefits are greater than the potential costs for any of the pursuit profiles.

Figure 3
Value and Costs of Pursuit



If pursuits have no costs, then all suspects should be pursued. Without costs the aggressive supporters of pursuits (California Highway Patrol, 1983; Hannigan, 1992) are correct. However, there are costs, and in some cases very severe costs, including the loss of life. A pursuit decision calculus may accentuate the circumstances under which these strong pursuit supporters should modify their philosophy in the interest of public safety.

To quantify the costs and benefits of a pursuit, Crew et al. (1995) created a "pursuit trade-off ratio." The ratio compares the odds of apprehension to the odds of a pursuit resulting in injury or death. While the pursuit trade-off ratio relates benefits to costs, it does not identify specific factors contributing to the likelihood of damage or injury. The first step in the development of a pursuit decision calculus is to identify the characteristics most associated with damage or injury, and then estimate the impact or change in the likelihood of damage or injury when the factors are present.

The Pursuit Decision Calculus

Data used in this study represent the aggregated official pursuit reports from the Miami-Dade Police Department (Florida) between the years of 1990 and 1994. This agency has been concerned about the problems associated with pursuits and has instituted exemplary policies, training, supervision, and accountability systems. Therefore, these data may not be generalizable to other agencies, but they do show how a pursuit calculus can assist law enforcement.

The database contains 1,049 recorded pursuits. The pursuit reports indicate, among other things, whether the pursuit resulted in property damage or personal injury. In this database, 25.5% of the pursuits resulted in property damage and 20.4% resulted in personal injury. These two pursuit outcomes, damage and injury, served as the criterion variables for the analyses. The environmental factors chosen to model the costs are: the geographical area where the pursuit took place (area); the reason the pursuit was initiated (reason); number of units in the pursuit (units); time of day the pursuit was initiated (time); and the top speed of the pursuit (speed). Weather and road conditions were not included in the analysis because of very small variance; less than 5% of the pursuits took place on wet roads or in poor weather conditions. The elapsed time of the pursuit was also not included in the analyses because the majority of the forms were missing that information. The frequencies for these pursuit characteristics are reported in Table 1.[3]

Table 1

Frequency Distributions for Pursuit Costs and Pursuit Characteristics

Variable	Level	Count	Percent
Damage	Yes	240	25.5
	No	701	74.5
Injury	Yes	192	20.4
	No	749	79.6
Units	One	620	65.9
	Two[a]	321	34.1
Daylight	Yes	297	31.6
	No	644	68.4
Reason	Traffic	427	45.4
	Other[b]	514	54.6
Area	Commercial	289	30.7
	Residential	652	69.3
Speed	<65	721	76.6
	66+	220	23.4

[a] Two or more units
[b] All offenses (e.g., DUI, car theft, assault) other than a simple traffic violation

---

[3] These are not the only factors that should be considered when estimating the costs of a pursuit Other variables, if available, could be included in the model.

Analytical Approach

Since the criterion variables, personal injury and property damage, are categorical, as are many of the exogenous variables, log-linear models were selected to assess and statistically test the relationships between an endogenous variable and the exogenous variables. As a brief review of the use of log-linear models, consider the case in which the effects of two exogenous variables, B_j and C_k, on an endogenous variable A_i, where i=j=k=1,2, are assessed. One analytical alternative is to cross-tabulate each of the exogenous variables, B_j and C_k, with the endogenous A_i. For example, cross-tabulation of the variables units and speed on outcome would test for the main effects of B_j and C_k on A_i; however, the technique ignores any effect of the interaction of BC_{jk} on A_i.

To assess the statistical significance of main effects and higher order effects of the exogenous variables upon a criterion variable, the partial association test, which is based on the likelihood ratio statistic, is used. The likelihood ratio statistic, which is similar to the traditional c^2 square statistic, can be used to test how well a hypothesized model fits observed data. And, in addition, the likelihood ratio statistic can be used to test differences between nested models. For the case of the three variables A_i, B_j, and C_k, the saturated model–the model including all main effects and higher order interactions–would be:

$$(1)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk}$$

The saturated model will always perfectly fit the data; there are no degrees of freedom. To test for specific effects, hierarchical models nested within the saturated model are specified. For this example with three variables, the set of hierarchical models for the interactive effects would be:

$$(2)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk}$$
$$(3)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk}$$
$$(4)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + AC_{ik}$$
$$(5)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + BC_{jk}$$
$$(6)\quad Y_{ijk} = A_i + B_j + C_k + AC_{ik} + BC_{jk}$$

If, for example, interest centered on testing the significance of the interaction between A_i and C_k, the following models could be fit:

$$(7)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk,} \text{ and}$$
$$(8)\quad Y_{ijk} = A_i + B_j + C_k + AB_{ij} + BC_{jk}$$

These two models form a nested hierarchy; model 8 is nested within model 7. Notice the only difference between the two models is whether the interaction of interest, $AC_{ik,}$ is included. For each model, the likelihood ratio statistic, denoted as L^2, is calculated as a measure of how well the model fits the data. Therefore L^2 (7) is the likelihood ratio statistic for model 7 and L^2 (8) is the likelihood ratio statistic for model 8. It can be shown (Dillon & Goldstein, 1984) that L^2 (8) and L^2 (7) are asymptotically c^2 with V_8 and V_7 degrees of freedom, respectively. It can also be shown that L^2 (8) – L^2 (7) is asymptotically c^2 with V_8 – V_7 degrees of freedom. The difference in the likelihood ratio statistics can be used to test the hypothesis HO: $AC_{ik} = 0$. If the interaction between A_i and C_k is significant, then there will be a significant difference between the fit of the model containing the AC_{ik} effect and the model that does not contain the effect. The next section of the paper shows the results of using log-linear models to calculate the partial association between the characteristics of a pursuit and the cost of the pursuit.

Results

The partial chi-square tests for the effects containing the criterion variable personal injury and one or more of the pursuit background characteristics are provided in Table 2. Table 3 contains the partial association tests for property damage.

Personal Injury

The four-way interaction among number of units, reason for pursuit, area of pursuit and speed was statistically significant ($p = .04$), as was the two-way interaction between units and time ($p = .04$). Three of the pursuit characteristics–units, area and speed–had a statistically significant direct effect on the likelihood of personal injury. The odds ratios for the direct effects are shown in Table 4. When more than one unit is involved, the odds of personal injury are 2.03 to 1 compared to a pursuit with only one police unit. The odds of personal injury are 1.75 more likely in a commercial area versus a residential area, and 1.78 times more likely when the speed of the pursuit exceeds 65 miles per hour. Whenever a pursuit involves more than one unit, is in a commercial area, or has speeds in excess of 65 mph, the likelihood of the pursuit resulting in personal injury increases.

To assess the odds of personal injury for statistically significant interactions between or among two or more of the pursuit characteristics, a multiway table composed of the pursuit characteristics was formed. The odds ratios are then calculated for each cell of the multiway table. Table 5 presents the odds of injury for the interaction between the number of units and the light conditions. When more than one unit is involved in a pursuit, the odds of personal injury are 2.03 to 1 (see Table 4). The data in Table 5 show that the lighting conditions of the

Table 2

Partial Association Tests for Personal Injury

Effect				Df	χ^2	*p*-value
Units	Time	Reason	Area	1	0.159	.69
Units	Time	Reason	Speed	1	1.652	.12
Units	Time	Area	Speed	1	0.000	.98
Units	Reason	Area	Speed	1	4.180	.04
Time	Reason	Area	Speed	1	0.092	.76
Units	Time	Reason		1	0.272	.60
Units	Time	Area		1	0.028	.87
Units	Reason	Area		1	0.131	.72
Time	Reason	Area		1	0.244	.62
Units	Time	Speed		1	0.070	.79
Units	Reason	Speed		1	0.140	.71
Time	Reason	Speed		1	0.000	.99
Units	Area	Speed		1	2.593	.11
Time	Area	Speed		1	0.082	.77
Reason	Area	Speed		1	0.163	.69
Units	Time			1	4.296	.04
Units	Reason			1	0.144	.70
Time	Reason			1	0.410	.52
Units	Area			1	0.019	.89
Time	Area			1	2.378	.12
Reason	Area			1	3.140	.08
Units	Speed			1	1.359	.24
Time	Speed			1	1.930	.16
Reason	Speed			1	0.098	.75
Area	Speed			1	0.029	.87
Units				1	15.706	.00
Time				1	0.057	.81
Reason				1	0.189	.66
Area				1	6.245	.01
Speed				1	5.238	.02

Table 3

Partial Association Tests for Property Damage

Effect				Df	χ^2	*p*-value
Units	Time	Reason	Area	1	1.371	.24
Units	Time	Reason	Speed	1	0.250	.62
Units	Time	Area	Speed	1	2.449	.12
Units	Reason	Area	Speed	1	0.261	.61
Time	Reason	Area	Speed	1	0.088	.77
Units	Time	Reason		1	0.799	.37
Units	Time	Area		1	0.206	.65
Units	Reason	Area		1	1.404	.24
Time	Reason	Area		1	4.595	.03
Units	Time	Speed		1	0.049	.82
Units	Reason	Speed		1	0.373	.54
Time	Reason	Speed		1	6.781	.0
Units	Area	Speed		1	0.878	.35
Time	Area	Speed		1	0.281	.60
Reason	Area	Speed		1	0.288	.59
Units	Time			1	0.064	.80
Units	Reason			1	9.536	.00
Time	Reason			1	3.156	.08
Units	Area			1	0.011	.92
Time	Area			1	0.285	.59
Reason	Area			1	0.825	.36
Units	Speed			1	1.666	.20
Time	Speed			1	0.937	.33
Reason	Speed			1	1.410	.24
Area	Speed			1	1.853	.17
Units				1	0.031	.86
Time				1	0.273	.60
Reason				1	0.755	.38
Area				1	3.193	.07
Speed				1	0.222	.64

pursuit moderate the direct effect of the number of units. During daylight conditions, when more than one unit is involved, the odds of injury are 3.88 to 1. At night the odds of injury are 1.55 to 1. Consistent results are found when number of units is specified as the moderating variable. The odds of injury for day rather than night conditions is greatest when more than one unit is involved in the pursuit.

Table 6 provides estimates for the likelihood of personal injury for the four-way interactions among speed, area, reason, and units involved in a pursuit.

Table 4

Odds of Personal Injury for the Direct Effects of Units, Area, and Speed

Odds Ratio	Odds of Injury
Two[a] versus one unit	2.03
Commercial versus Residential area	1.75
Fast[b] versus slow speed	1.78

[a] Two or more units
[b] Speeds in excess of 65 mph

Table 5

Odds of Personal Injury for the Interaction Between Number of Units and Time of Pursuit

Odds Ratio	Moderator	Odds of Injury
	Light Conditions	
Two[a] versus one unit	Daylight	3.85
	Night	1.55
	Units	
Day versus night	One	0.60
	Two	1.45

[a] Two or more units

Table 6

Odds of Personal Injury for the Interaction Among Number of Units, Reason for the Pursuit, Area of the Pursuit, and Speed of the Pursuit

Odds Ratio	Moderators			Odds of Injury
	Units	Reason	Area	
Fast[a] versus slow	One	Traffic	Commercial	2.39
	One	Traffic	Residential	1.88
	One	Non-traffic	Commercial	0.74
	One	Non-traffic	Residential	3.50
	Two[b]	Traffic	Commercial	0.72
	Two	Traffic	Residential	1.38
	Two	Non-traffic	Commercial	2.27
	Two	Non-traffic	Residential	0.71
	Units	Reason	Speed	
Commercial versus residential	One	Traffic	Slow	1.06
	One	Traffic	Fast	1.34
	One	Non-traffic	Slow	3.50
	One	Non-traffic	Fast	0.74
	Two	Traffic	Slow	1.56
	Two	Traffic	Fast	0.82
	Two	Non-traffic	Slow	1.17
	Two	Non-traffic	Fast	3.72
	Units	Area	Speed	
Non-traffic versus traffic	One	Commercial	Slow	1.94
	One	Commercial	Fast	0.60
	One	Residential	Slow	0.58
	One	Residential	Fast	1.09
	Two	Commercial	Slow	0.82
	Two	Commercial	Fast	2.58
	Two	Residential	Slow	1.09
	Two	Residential	Fast	0.57
	Reason	Area	Speed	
Two versus one unit	Traffic	Commercial	Slow	2.78
	Traffic	Commercial	Fast	0.84
	Traffic	Residential	Slow	1.88
	Traffic	Residential	Fast	1.38
	Non-traffic	Commercial	Slow	1.17
	Non-traffic	Commercial	Fast	2.58
	Non-traffic	Residential	Slow	3.50
	Non-traffic	Residential	Fast	0.71

[a] Speeds in excess of 65 mph

[b] Two or more units

Each of the four sections of the table demonstrates the odds of injury for one factor given the eight profiles specified by the other three factors. For example, the data in the first section provide the odds of injury for pursuits that exceed 65 miles per hour for all of the possible combinations of pursuits created by the other three factors. Since the other factors each have two levels, there are eight profiles. The benefits from investigating the higher order interactions are evident in the first section of the table. The odds of injury, in general, are greater when there is more than one unit. The data in Table 4 show the odds of injury are 2.03 to 1 when more than one unit is involved in the pursuit. From Table 6 we can see that the highest odds of injury from a pursuit that exceeds 65 miles per hour occur when one unit is involved in a pursuit for a reason other than a traffic violation in a residential area.

The second section of Table 6 compares the odds of injury when the pursuit takes place in a commercial area rather than a residential area. Here the greatest odds of injury occur when more than one unit is involved at speeds in excess of 65 mph for an offense other than a traffic violation. The odds of injury for the profile created by one unit for a violation other than a traffic violation at speeds under 65 mph are also high (3.5:1). This seems counterintuitive given the results in the first section of this table. However, upon a closer examination of the data, the results are consistent. The odds of injury when the pursuit is in a residential area are .1 to 1, and .35 to 1 when in a commercial area. Therefore, the odds are 3.5 to 1 when going from a residential to commercial area. The high odds are more a result of the low likelihood of injury for pursuits under 65 mph in a residential area.

The third section of Table 6 compares the odds of injury when a pursuit results for a reason other than a traffic violation compared to pursuits for traffic violations. There is little difference in the odds ratios. Only two comparisons show odds much greater than even. The odds of injury are 2.5 to 1 for pursuits involving more than one unit at speeds in excess of 65 mph in a commercial area, and 1.94 to 1 for pursuits involving one unit in a commercial area at speeds less than 65 mph. The other six profiles are either close to 1 to 1 or less than 1 to 1. The reason for the pursuit interacts with the other pursuit characteristics, as seen in the other sections of this table, but does not have a direct effect on the likelihood of injury.

The fourth section of Table 6 provides the odds of injury when the pursuit involves more than one unit compared to pursuits with only one unit involved. The results of the eight comparisons are consistent with the main effects shown in Table 4. In general, the odds of injury increase when more than one unit is involved. The greatest odds of injury when more than one unit is involved are for pursuits in a residential area at speeds less than 65 mph for a reason other than a traffic violation. The odds of injury are actually less for the same profile except when the speeds are greater than 65 mph. The reason for this is the same as described for the second section of Table 6: the odds in the residential area are low.

Property Damage

Pursuit characteristics have no direct effect upon the outcome of property damage. However, two of the three-way interactions were significant ($p < .05$), and one of the two-way interactions was significant (See Table 3). The odds ratios for the interaction between the reason for the pursuit and the number of units with property damage are provided in Table 7. Inspection of the odds ratios shows no pattern of property damage as a result of the reason for the pursuit or number of units in the pursuit. For example, when two or more units versus one unit are involved for a traffic violation, the odds are 1.55 to 1 that property damage will result. However, when two or more units are involved for a violation other than traffic, the odds are less than one (.62 to 1) that property damage will result. The same inconsistency holds for reason of the pursuit.

Two of the three-way interactions with property damage were statistically significant. The odds ratios for these interactions are presented in Tables 8 and 9. The odds ratios for the interaction of time, reason, and speed with property

Table 7

Odds of Property Damage for the Interaction between Number of Units and Reason for the Pursuit

Odds Ratio	Moderator	Odds of Injury
	Reason for Pursuit	
Two[a] versus one unit	Traffic	1.55
	Non-traffic	0.62
	Units	
Non-traffic versus traffic	One	1.63
	Two	0.66

[a] Two or more units

damage also show no clear pattern. In some cases, pursuits at high speeds are likely to result in property damage, whereas in other cases pursuits at high speeds are less likely to result in such damage. Inspection of the data in Table 9 also shows these inconsistencies. There are no clear patterns of property damage for the interaction of time, reason, and area with property damage. These results indicate that it is difficult to predict property damage based on the pursuit characteristics in this study. This finding is bolstered by the fact that there were no significant main effects for any of the pursuit characteristics in relation to property damage.

Table 8

Odds of Property Damage for the Interaction Among Speed of the Pursuit, Reason for the Pursuit, and Light Conditions

Odds Ratio	Moderators		Odds of Property Damage
	Reason	Light Conditions	
Fast[a] versus slow	Traffic	Day	NA
	Traffic	Night	0.72
	Non-traffic	Day	1.86
	Non-Traffic	Night	0.71
	Light Conditions	Speed	
Non-traffic versus traffic	Day	Slow	1.25
	Day	Fast	NA
	Night	Slow	0.94
	Night	Fast	0.93
	Reason	Speed	
Night versus day	Traffic	Slow	1.22
	Traffic	Fast	NA
	Non-traffic	Slow	0.91
	Non-traffic	Fast	0.35

[a] Speeds in excess of 65 mph

Discussion and Conclusions

The information generated from this research represents a case study and therefore generalizations to other law enforcement agencies must be made with caution. The factors influencing the cost of a pursuit in the Miami-Dade Police Department may be different from those in other agencies. However, the results of the research do provide important information for other agencies and researchers to consider when evaluating their pursuits. Future studies can enhance the development of a pursuit calculus by improving certain areas. First, the specification and collection of data elements must be clear and unambiguous. Our

Table 9

Odds of Property Damage for the Interaction Among Speed of the Pursuit, Reason for the Pursuit, and Area of the Pursuit

Odds Ratio	Moderators		Odds of Property Damage
	Reason	Light Conditions	
Commercial verses residential	Traffic	Day	1.34
	Traffic	Night	0.44
	Non-traffic	Day	0.76
	Non-Traffic	Night	0.92
	Area	Light Conditions	
Non-traffic versus traffic	Commercial	Day	0.87
	Commercial	Night	0.60
	Residential	Day	0.60
	Residential	Night	1.27
	Area	Reason	
Night versus day	Commercial	Traffic	0.58
	Commercial	Non-traffic	0.84
	Residential	Traffic	1.76
	Residential	Non-traffic	0.69

[a] Speeds in excess of 65 mph

measures of property damage and personal injury are dichotomous (yes or no) and do not indicate level or extent. Second, the importance of specific factors may vary according to jurisdiction. The pursuit characteristics used in the present research create a base from which other agencies can add or remove pursuit environmental factors to be studied.

In the case of the Miami-Dade Police Department, the number of units, area of pursuits, and speeds have a direct effect on the likelihood of a pursuit resulting in a personal injury. When more than one police vehicle is involved in a pursuit, the additional units increase the likelihood of an injury. Conventional wisdom and other policy considerations suggest that more than one unit is necessary for officer protection or even survival, although there are no data that confirm this for pursuit applications.

Once a data-driven pursuit calculus is computed, the results must be translated into policy, training, and supervision directives. That is, the more management knows about its pursuits, the better it can design a plan to maximize benefits and minimize costs. The obvious response to many concerns is to train officers and supervisors about the costs and benefits of the pursuit elements. Too often, officers and supervisors are unaware of the ratio of benefits to costs or are told all pursuits are unique and must be evaluated individually.

In general, when pursuits involve more than one unit, are in a commercial rather than a residential area, and increase in speed to greater than 65 mph, the odds of injury increase dramatically. However, these main effects are moderated by the interaction of other pursuit characteristics.

When the interaction of the factors is considered, as shown in Tables 5 and 6, some pursuits should clearly be avoided. The analysis for property damage was not as conclusive. The factors had no effect on the likelihood of property damage and the interactions show no clear patterns. An outcome of property damage is certainly less predictable than an outcome of personal injury in the present study.

When suspects fail to respond to a police officer's order to stop, they create a risk to the public by acting irrationally, and illegally. The police officer must respond and maintain public safety. In some cases, when the interaction of factors increases the costs of a pursuit above its benefits, the police officer's best tool is to shut off the emergency equipment, slow down, let the suspect flee, and try to apprehend him or her through low-risk investigative techniques rather than a high-risk pursuit.

REFERENCES

Alpert, G. P. (1997, May). *Police pursuit: Policies and training* (Research in brief). Washington, DC: National Institute of Justice.

Alpert, G. P., & Fridell, L. A. (1992*). Police vehicles and firearms: Instruments of deadly force.* Prospect Heights, IL: Waveland Press.

Alpert, G. P., & Madden T. (1996). Police pursuit driving: An empirical analysis of critical decisions. *American Journal of Police, XIII (4),* 23–45.

Alpert, G., Smith W., Cosgrove, M., & Madden, T. (1996). *Police pursuit and the excessive use of force.* A final report to the National Institute of Justice.

Arkes, H. R. (1991). Costs and benefits of judgement errors: Implications for debiasing. *Psychological Bulletin, Vol. 110, No. 3,* 486–498

Auten, J. (1994a). *An analysis of police pursuit driving operations* (Vol. 1&2). Champaign, IL: Police Training Institute.

Auten, J. (1994b). Initiating events in pursuits. *Law and Order, 42,* 70–76.

California Highway Patrol. (1983). *Pursuit study*. Sacramento: State of California.

Crew, R., Fridell, L., & Pursell, K. (1995). Probabilities and odds in hot pursuit: A benefit-cost analysis. *Journal of Criminal Justice, 23,* 417–424.

Crew, R. E., Jr., & Fridell, L. (1994). Probabilities and odds in hot pursuit: A benefit-cost analysis. *Journal of Criminal Justice, 23 (5),* 417–454.

Dillon, W. R., & Goldstein, M. (1984). *Multivariate analysis*. New York: John Wiley.

Fennessy, E., Hamilton, T., Joscelyn, K., & Merritt J. (1970). *A study of the problem of hot pursuit by the police.* Washington, DC: U.S. Department of Transportation.

Hannigan, M. (1992). The viability of police pursuits. *The Police Chief, 59 (46),* 48–49.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica 47,* 263–291.

Kenney, D. & Alpert, G. P. (1997). A national survey of pursuits and the use of police force: Data from law enforcement agencies. *Journal of Criminal Justice, 25,* 315–323.

Tversky, A., & Kahneman, D. (1983). The framing of decisions and the rationality of choice. *Science 211*, 453–458.