SECTION V
Analysis of Motor Vehicle Theft Using Survival Model

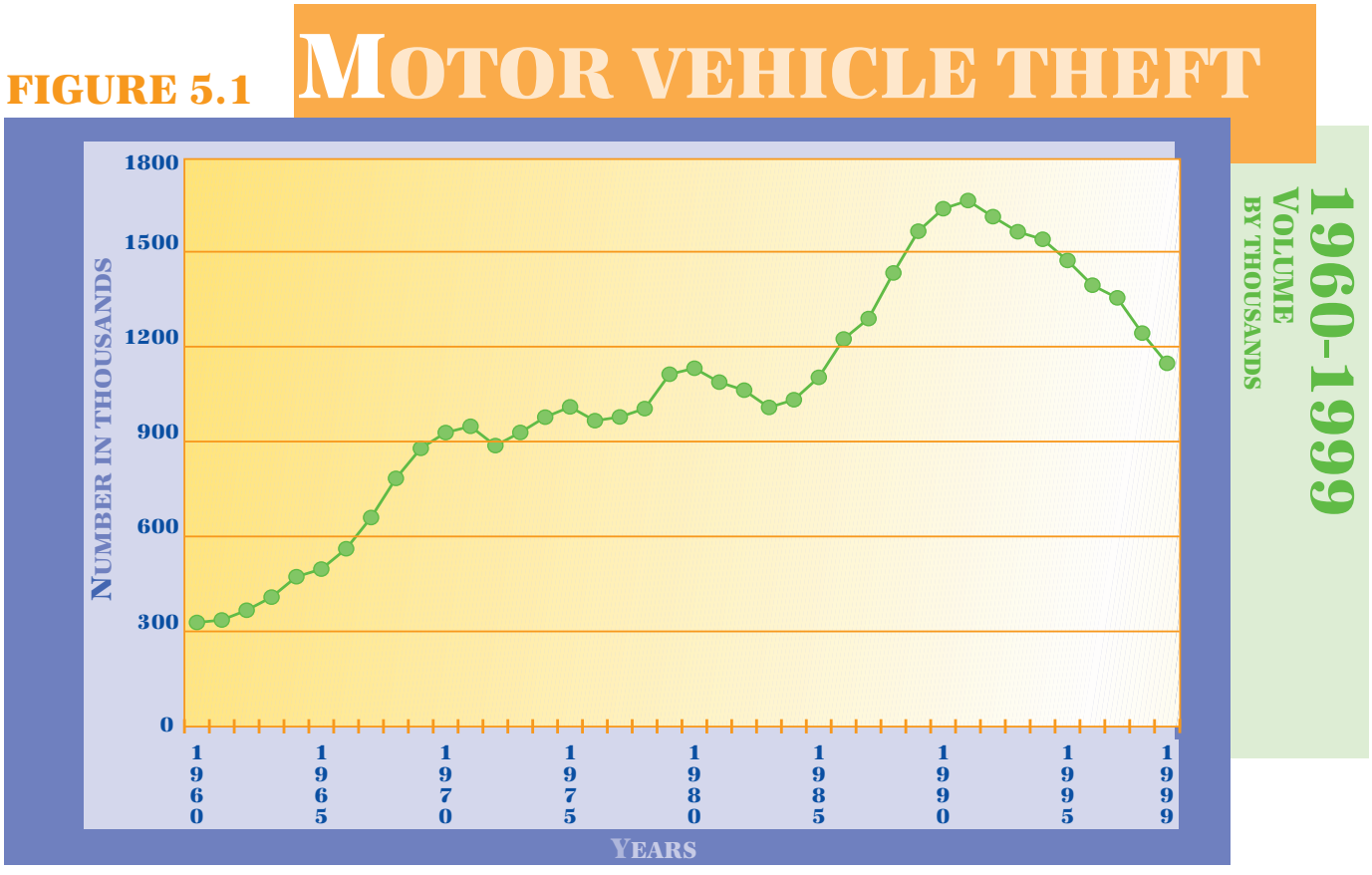
Introduction

Motor vehicle theft, as defined by the Uniform Crime Reporting (UCR) Program, is the theft or attempted theft of a motor vehicle including automobiles, trucks, buses, motorcycles, motor scooters, and snowmobiles. The definition also includes the temporary possession of a motor vehicle by those persons not having lawful access and joy riding. Farm equipment, bulldozers, airplanes, construction equipment, or motorboats are not included in this definition. (*UCR Handbook*, 1984, p. 28).

The staggering cost to the public in terms of lost property has been a real concern for the victims of motor vehicle theft, policy makers, and law enforcement. Understandably, the law enforcement community has attempted to better understand, prevent, and solve this crime for years. In an effort to assist law enforcement and all individuals and organizations concerned with crime, staff members of the Federal Bureau of Investigation (FBI) collect, compile, and disseminate crime data. In addition, they conduct detailed studies and analyses to inform the public about the dynamics of crime and the preventive measures that can be taken against the loss of property. In that regard, this study has been prepared to take a closer look at a crime that affects millions of the Nation's citizens.

Americans consider their automobiles a primary means of transportation, and the loss of a vehicle creates a great deal of temporary inconvenience both in terms of lifestyle and cost. In many cases, stolen cars have also been used in the commission of other serious crimes. According to the UCR Program, nearly 43 million motor vehicles were stolen from 1960 to 1999 (see Figure 5.1). Although it was not a steady increase, the trend shows that motor vehicle theft increased significantly during those four decades. Declines in the 1990s, however, show major

FIGURE 5.1



reductions in motor vehicle thefts both in terms of volume and declining marginal rates.

Obviously, some cars that are stolen are later recovered. The rate by which stolen vehicles are recovered in terms of days or weeks, and information pertaining to the frequency of incidents based on the day of the week, the month of the year, and the location type are vital in understanding motor vehicle theft. Such information is crucial in designing preventive measures both by the general public and law enforcement agencies. In 1982, an FBI study titled "Recovery Analysis of Stolen Vehicles Based Upon the National Crime Information Center (NCIC) Records" was conducted by Dr. Yoshio Akiyama. Using 1977 data from the National Crime Information Center (NCIC), the study pointed out that 77 percent of all stolen vehicles are recovered. This study also determined that 50 percent of the stolen vehicles are recovered within 3 days after the incident. It is clear that the more time that elapses, the smaller the probability of recovering the vehicle becomes. The whole phenomena of motor vehicle theft is influenced by a variety of factors including seasonality, geographic location, population, day of the week, unemployment, and income. It may be difficult to answer all questions related to motor vehicle theft in one or two studies, as the problem must be examined from different angles using different research methodologies and data.

This study will address the issues itemized in the section titled Objectives. The methodology and the data used in this research are specified and detailed in the sections bearing the titles Methodology and Data. The results of the estimations, including related discussions and analysis, are also presented in this text. Finally, the conclusion of the study and its implications are addressed in the Summary and Conclusion.

Objectives

The objective of this study is to learn more about motor vehicle theft and convey the UCR Program's research findings on the topic. The specific objectives of the study are to:

1. Estimate and analyze the recovery and survival rates of stolen motor vehicles.
2. Examine the pattern of motor vehicle thefts and recoveries by day of the week and by month of the year.
3. Tabulate and analyze incidents by location of the incident.
4. Analyze clearances in comparison to recoveries.
5. Compare the results obtained using data from the UCR Program's National Incident-Based Reporting System (NIBRS) and NCIC. (Incidentally, this approach seems to indirectly validate NIBRS as a reliable source of information.)
6. Interpret the results and articulate some of the factors and attributes affecting the outcomes of the study.

Methodology

The continuation of the stolen (and lost) status of a motor vehicle is viewed in this study as the state of "survival" in concert with statistical methodology. A survival function will be specified, and the Kaplan-Meier estimator of the survivorship function (Kaplan and Meier, 1958) will be applied in order to estimate the survival rate of a vehicle. In this case, the status change in survival implies recovery of the vehicle based on the amount of time that elapsed since the incident date. Survival analysis is a type of statistical method for studying the change of a certain status in time as in clinical studies that measure the occurrence of death, equipment failures, job terminations, earthquakes, retirements, recidivism, automobile accidents, divorce, etc. Since the same methodology is applicable to many situations, it is customary to adopt the term "survival" in various fields of discipline. In this study we used the Kaplan-Meier estimator to estimate the rate of survival of a stolen vehicle. The specifications and description of the survival model are shown in Appendix A.

Data Sources

NIBRS and NCIC are the two main sources of data used in this study. NIBRS is an incident-based reporting system for which data are collected on each single episode, called an incident. NIBRS data are a product of local, state, and federal automated record systems. Data are collected on each single incident and arrests within 22 offense categories made up of 46 specific crimes called Group A offenses. In addition to the Group A offenses, there are 11 Group B offense categories for which arrests are reported (*NIBRS Handbook*, 1992, p. 1-2). On the other hand, NCIC is a computerized data filing system that provides documented criminal justice information "concerning crimes and criminals of nationwide interest" to all local, state, and federal law enforcement agencies (*NCIC 2000 Operating Manual*, 1999, p. 1). The system serves criminal justice agencies in the 50 states, the District of Columbia, U.S. Territories, and Canada. Both databases are managed by the FBI.

Motor vehicle theft data for 1999, including the incident, clearance, and recovery dates, and the characteristics of the property (such as type, value, make, model, and color) are derived from the above data sources for this study. A major difference between these two databases is the extent of their representation. NIBRS data are collected from only 18 states, but NCIC contains information from every jurisdiction in the Nation. In this study, only

single-offense NIBRS incidents related to a single stolen motor vehicle are considered for the ease of analysis.

Results and Analysis

This section presents the analysis of motor vehicle theft. It is organized into four parts: incident, recovery, clearance, and survival analysis. In some of the sections, estimates from NCIC data are presented for comparison and confirmation purposes against the results obtained from the NIBRS data.

Motor Vehicle Theft Incident

According to the *Uniform Crime Reporting Handbook*, NIBRS Edition, an incident is defined as "one or more offenses committed by the same offender, or group of offenders acting in concert, at the same time and place" (p. 25). These incidents can take place at different locations, geographic areas, days of the week, months of the year, etc., as illustrated in the following tables.

Table 5.1 presents the percent of incidents as recorded by NIBRS and NCIC by the day of the week. NIBRS data are based on 70,196 incidents, and NCIC data represent the national total of 599,857 cases for the calendar year 1999. In both systems, Monday, Friday, and Saturday show higher frequencies of incidents. Higher frequency during the weekend is in concert with the general pattern of criminal activities as supported by additional NIBRS statistics from 1998.

Table 5.1

Percent Distribution of Motor Vehicle Theft Incidents by Day of the Week

Day	NIBRS	NCIC
Sunday	13.55	13.31
Monday	14.14	14.85
Tuesday	13.43	14.21
Wednesday	13.40	14.28
Thursday	13.66	14.14
Friday	15.69	14.97
Saturday	16.13	14.24
Total	100.00	100.00

The close similarity of results drawn from both NIBRS and NCIC data has great implications in validating NIBRS as a reasonable and representative source of national crime data. This information not only confirms the quality of NIBRS data, but also assures law enforcement agencies, researchers, and other users that NIBRS data are reliable.

Table 5.2 shows monthly variations (in percent) of the motor vehicle thefts based on NIBRS data where the date of the incident is known. Because the data represent only one year, no statistical seasonality pattern can be observed.

Table 5.2

Percent Distribution of Motor Vehicle Theft Incidents by Month

Month	Percent
January	7.93
February	6.62
March	7.14
April	7.88
May	8.20
June	8.11
July	9.15
August	9.22
September	8.64
October	9.33
November	8.58
December	9.20
Total	100.00

Table 5.3 relates to the location of motor vehicle thefts. It is seen that more than three out of four autos are stolen at residences, parking lots, or streets. These locations represent places where autos are most commonly parked. Over one half of the incidents take place where autos are parked in areas without attendants (residences and streets).

Table 5.3

Percent Distribution of Motor Vehicle Theft Incidents by Location

Location	Percent
Residence/Home	35.31
Parking Lot/Garage	22.75
Highway/Road/Alley	17.96
Unknown Location	6.96
Commercial/Office Building	4.87
Bar/Night Club	2.53
Speciality Store	1.65
Service/Gas Stations	1.27
Hotel/Motel	1.18
Convenience Store	0.94
All Others	4.58
Total	100.00

Recovery of Stolen Motor Vehicles

In NIBRS, motor vehicle recoveries are reported. Since motor vehicles are frequently recovered without identifying or apprehending the offenders, the recovery has to be distinguished from clearance or arrest. Also, a recovery does not imply that the autos are returned to the owner in their original shape prior to the theft.

Table 5.4 reflects the percent distribution of recoveries of stolen motor vehicles by the day of the week that they are recovered. The total number of recovered motor vehicles is 37,271 according to the NIBRS data, representing

a 53.1-percent recovery. The corresponding number for NCIC, 308,535, represents a 51.4-percent recovery rate. The striking similarity between the two sources of crime data is another important and confirmatory finding, which is consistent with the earlier finding in Table 5.1

A higher percentage of autos are stolen during the weekend and recovered during the earlier part of the week (see Tables 5.1 and 5.4).

Table 5.4

Recovery of Stolen Motor Vehicles by Day of the Week

Day	NIBRS	NCIC
Sunday	13.06	11.14
Monday	15.92	16.08
Tuesday	15.74	16.42
Wednesday	14.27	15.80
Thursday	14.09	15.13
Friday	13.94	14.16
Saturday	12.98	11.27
Total Recovered	100.00	100.00

Table 5.5 shows the percent of autos recovered by month. Because most stolen vehicles that are recovered are found within a few days, this table is consistent with the figures found in Table 5.2.

Table 5.5

Recovery of Stolen Motor Vehicles by Month

Month	Percent Recovered
January	9.55
February	7.22
March	8.00
April	7.80
May	7.89
June	7.96
July	8.87
August	9.16
September	8.58
October	8.68
November	8.03
December	8.26
Total	100.00

Clearance of Motor Vehicle Thefts

In UCR, a crime is cleared "either by arrest or exceptional means" (*UCR Handbook*, p. 41). When elements beyond a law enforcement agency's control preclude the agency from clearing an offense by arrest, the agency can clear the offense by exceptional means. For an offense to be cleared by exceptional means, several criteria must be met. The agency must have 1) identified the offender; 2) enough evidence to support an arrest; 3) identified the offender's exact location; and 4) a reason outside the agency's control that does not allow the agency to arrest, charge, and prosecute an offender. Examples of exceptional clearances include the death of the offender (suicide, justifiably killed by police or private citizens, etc.); the victim's refusal to cooperate with the prosecution after the identification of the offender; or the denial of extradition because the offender committed a crime in a another jurisdiction and is being prosecuted. (Additional details regarding exceptional clearances can be found on page 42 of the *UCR Handbook* and page 34 of the *NIBRS Handbook*.) The tables below are based on all 1999 NIBRS single-offense incidents that involved the theft of one motor vehicle, so that the numbers of incidents, offenses, and autos stolen are identical.

Table 5.6 reflects the relationship between the clearance and recovery rates of stolen motor vehicles. Generally, clearance and recovery rates are not directly related to each other. The table indicates that for incidents where autos are recovered, NIBRS data show that there was a 17.15 percent clearance rate, i.e., the remaining 82.85 percent of the incidents are not cleared (although the autos are recovered). For incidents with no recovery, there was a lesser rate of clearance, 7.75 percent. For motor vehicle theft, the recovery rate (53.10 percent) is much higher than the clearance rate (12.95 percent).

Table 5.6

Percent of Clearances for Motor Vehicle Thefts by Recovery Status

	Cleared	Not Cleared	Total
Recovered	17.15	82.85	100.00
Not Recovered	7.75	92.25	100.00
Total	12.95	87.05	100.00

Motor vehicle theft clearances generally result from arrests (and to a limited degree from exceptional clearances). Therefore, the following arrest statistics were compiled to examine the age, sex, and race composition of the persons arrested. According to the NIBRS data, the total number of arrestees in 1999 for motor vehicle incidents where only one vehicle was stolen was 9,291.

Table 5.7 shows that the age group, "12 to 17" years old, has the largest number of arrests for both sexes and for any race. The next highest group is "18 to 24" years old.

Table 5.7

Age, Sex, and Race Composition of Motor Vehicle Theft Arrestees

Age	Male					Female					Total
	W	B	I	A	U	W	B	I	A	U	
6-11	13	18	0	0	0	2	0	0	0	0	33
12-17	1,853	1,016	32	28	31	617	115	13	10	5	3,720
18-24	1,434	818	18	9	23	217	79	2	4	5	2,609
25-29	484	197	6	4	10	122	44	2	0	1	870
30-34	349	254	3	1	9	105	51	1	0	0	773
35-39	299	195	2	0	8	76	34	2	0	0	616
40-44	189	111	4	1	0	34	18	0	0	0	357
45-49	91	36	0	0	1	16	3	0	1	0	148
50-54	34	23	0	1	0	4	2	0	0	1	65
55-59	17	4	0	0	0	2	0	0	0	0	23
60-64	6	2	0	0	0	2	0	0	0	0	10
65	8	4	0	0	0	0	0	0	0	0	12
U	36	8	0	0	3	7	1	0	0	0	55
Total	4,813	2,686	65	44	85	1,204	347	20	15	12	9,291

W = White, B = Black, I = American Indian, A = Asian, U = Unknown

Survival Estimates

Since NIBRS data allow us to express recovery time in terms of days, the lapse of time for recovery was grouped into intervals (in days) as shown in Table 5.8. As illustrated in Table 5.8, Column 1 represents the time intervals. Column 2 lists the number of recovered vehicles within the specified interval given in Column 1. Column 3 indicates the number of ultimately recovered vehicles that have not yet been recovered at the beginning of the interval. The number 37,271 on the first row is the number of autos eventually recovered out of the aforementioned 70,196 stolen vehicles. Column 4 indicates the conditional probability of recovery that a car is recovered within a given interval. It is obtained by dividing Column 2 by Column 3.

Table 5.8

Recovery Pattern of Stolen Motor Vehicles

Time Interval (in Days) (1)	Number Recovered (2)	To Be Recovered (3)	Conditional Prob. of Recovery (4)
0-1	21,274	37,271	0.5708
2-6	8,329	15,997	0.5207
7-20	3,896	7,668	0.5081
21-50	1,766	3,772	0.4682
51-140	1,250	2,006	0.6231
141-320	591	756	0.7817
321-680	164	165	0.9939
over 680	1	1	1.0000

Table 5.9 describes the recovery pattern of stolen autos. Column 2 represents the percent of autos that are eventually recovered but were not recovered after a specified number of days. Column 3 is the complement of Column 2, and cumulatively represents the percent of autos recovered after a specified number of days.

Table 5.9

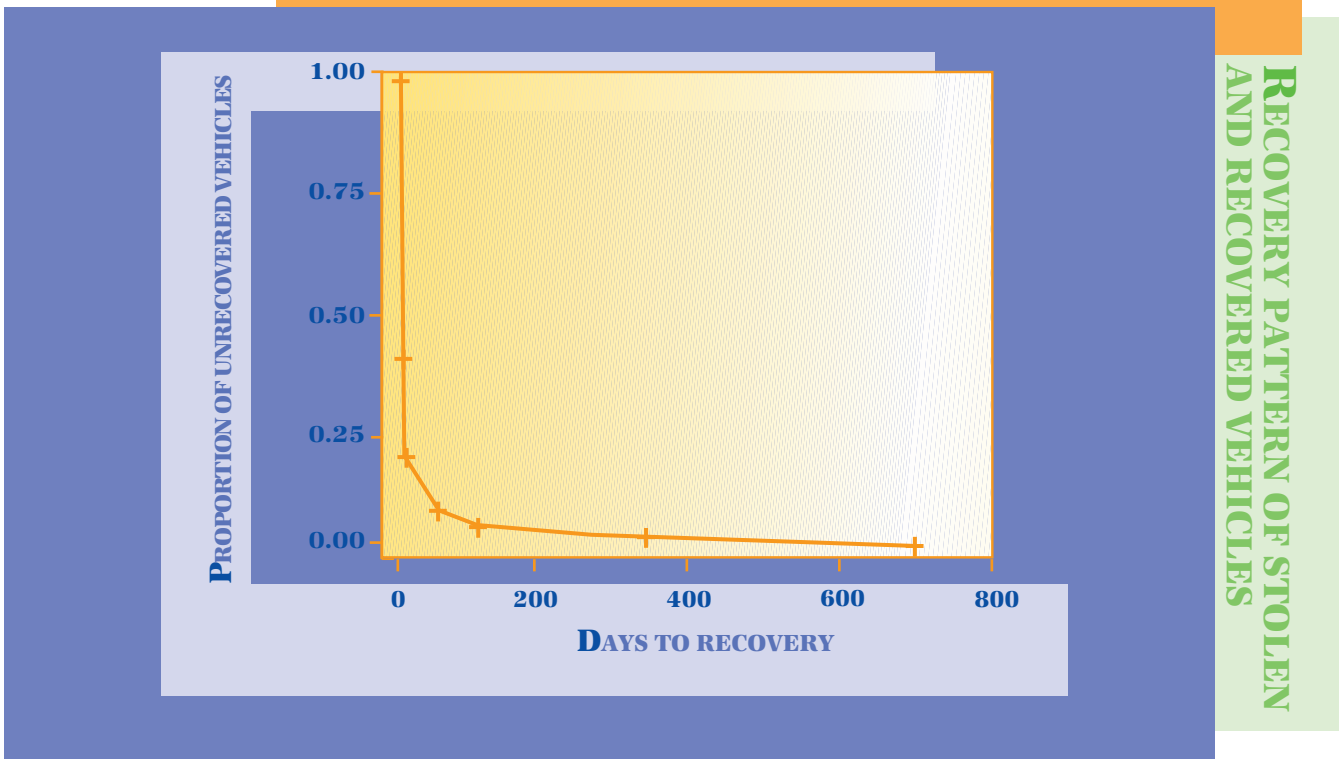
Cumulative Recovery Pattern of Recovered Vehicles

After Specified Days (1)	Percent Not Recovered (2)	Percent Recovered (3)
0	100.00	0.00
1	42.92	57.08
6	20.57	79.43
20	10.12	89.88
50	5.38	94.62
140	2.03	97.97
320	0.44	99.56
680	0.00	100.00

From Tables 5.8 and 5.9, it must be noted that the first few days are critical in recovering stolen vehicles. The longer the vehicle is in the possession of criminals, the smaller the chance of recovery. Additionally, the recovery may be difficult depending on the nature of the criminals. The law enforcement community is aware that there are those who are engaged in this business as a way to obtain expensive automobile parts that may be sold separately for lower than market prices and those who steal autos to take them abroad for their own use or for resale. Also, some criminals steal autos for use in committing other crimes.

Figure 5.2 represents the recovery pattern of stolen vehicles based on the 37,271 autos that were eventually recovered. The vertical axis represents the percent of yet-to-be-recovered autos, and the horizontal axis denotes the number of days elapsed. The behavior of the function is almost vertical in the first few days indicating a higher

FIGURE 5.2 MOTOR VEHICLE THEFT



percentage of recovery. After a few days (e.g., a week) of the incident, the graph is flat indicating that virtually no changes in recovery are expected.

Table 5.9 cumulatively depicts the recovery pattern of autos that were eventually recovered. Table 5.10 describes the recovery pattern of all stolen autos irrespective of whether they are eventually recovered. Therefore, the latter is based on the 70,196 incidents. Column 2 represents the percent of stolen autos that have been recovered after a specified number of days.

Table 5.11 describes the chance in terms of percentages of a stolen motor vehicle's recovery after a prescribed number of days. For example, if a stolen vehicle has not been recovered after six days, then there is only an 18.89 percent chance that it will every be recovered. From the table, it is clear that the chance of future recovery drastically decreases as the number of days increases.

Table 5.10

The Recovery Pattern of Stolen Vehicles, Out of 70,196 Stolen Vehicles

After Specified Days (1)	Percent Not Recovered (2)	Percent Recovered (3)
0	100.00	0.00
1	69.70	30.31
6	57.82	42.18
20	52.27	47.73
50	49.76	50.24
140	47.98	52.02
320	47.11	52.89
680	46.90	53.10

Table 5.11

The Percent Chance of Future Recovery Aft er a Specified Number of Days

Time Lapse (in Days) (1)	Commutative Number Recovered (2)	Yet To Be Recovered (3)	Not Expected to be Recovered (4)	Percent Chance of Future Recovery (5)
1	21,274	15,997	32,925	32.70
6	29,603	7,668	32,925	18.89
20	33,499	3,772	32,925	10.28
50	35,265	2,006	32,925	05.74
140	36,515	756	32,925	02.24
320	37,106	165	32,925	0.50
680	37,270	1	32,925	0.0

Summary and Conclusion

This study has made several important findings related to the patterns of motor vehicle theft, clearance, recovery, and the similarities between NIBRS and NCIC data. The tabulation of incidents by days and months could provide important information both to the law enforcement community and the general public in understanding motor vehicle theft. Both NIBRS and NCIC data indicate that the percentage of motor vehicle theft incidents are higher on weekends than weekdays.

Another important finding of the study is that the recovery rates of stolen motor vehicles for both NIBRS and NCIC are strikingly similar. Also, both sets of data indicate that a higher percentage of the recovery of motor vehicles takes place on the first 3 days of the week. This finding implies that if a stolen car is recovered, it will most likely be recovered within the first 3 or 4 days of the incident. The longer it takes to recover, the less chance there is of recovery. This fact is substantiated by the results obtained from the survival analysis model which is discussed in the section titled Survival Estimates. The rate of recovery, the probability of recovery within a certain number of days, and the chance of future recovery are discussed and illustrated in this section.

This study also analyzes the rate of clearances including arrests by age, gender, and race. The clearance rate appears to be much lower than the incident and recovery rates. Due to the nature of motor vehicle theft, the proportion of clearances to the number of offenses or recoveries is usually low. However, this study and further analysis based on age, sex, and race may help policy makers, law enforcement agencies, and the general community to design and implement effective measures to preempt further increases in this type of crime.

The above findings have very significant implications beyond simple similarities. Even though the operation of NIBRS is limited to few states, NIBRS is validated by NCIC as a viable and nationally representative crime data reporting system. This result may generate a sense of encouragement to expand NIBRS beyond the current 22 states that are certified and contribute incident-based data. Based on these findings, it is safe to say that the Program is heading in the right direction. Since the findings are based on only 1999 data, the interpretation must be limited to this year. Further study based on time-series data for a variety of crime categories may be needed for further comparisons and confirmations.

Appendix A

The Kaplan-Meier estimator of the survival function was used in this study. This estimator, representing time as *t*, is obtained from the equation which is generally specified as:

$$\hat{S}(t) = \prod_{t_{(i)} \le t} \left[\frac{n_i - d_i}{n_i} \right] = \prod_{t_{(i)} \le t} \left[1 - \frac{d_i}{n_i} \right]$$

$$\hat{S}(t) = 1 \ \ if \ \ t \prec t_{(1)}$$

Therefore, for each time *i*, there are n_i stolen vehicles at risk of not being recovered. The symbol d_i represents the number of cars recovered at time t_i, and *S(t)* stands for survival function. The equation shown above states that for a specified time *t*, one must take all the event times that are less than or equal to *t*. The term in the bracket is interpreted as the conditional probability of surviving time, given that one has survived at time t_i. For *t* less than t_1 (the smallest event time), the survival rate is defined to be 1. The above equation uses only the points at which the value of the estimator changes and it becomes very cumbersome to tabulate or graph the Kaplan-Meier estimator of the survivorship function when extensive data like NIBRS and NCIC are used. We solve the problem by grouping the data into intervals. The only downside to this approach is that the choice of intervals is often arbitrary, which may lead to some loss of information. Since the intervals in this study are not wide apart, however, it does not appear that there is any loss of information. Once a set of intervals has been defined, the construction of the estimator follows the same procedure as specified in the above equation.

Bibliography

Akiyama, Yoshio. "Recovery Analysis of Stolen Vehicles Based Upon the National Crime Information Center Records." Prepared for the Director of the Federal Bureau of Investigation, Washington, D.C., 1982.

Kaplan, E.L. and Meier, P. "Nonparametric Estimation from Incomplete Observations." *Journal of American Statistical Association, 53* (1958), 457-481.

U.S. Department of Justice. Federal Bureau of Investigation. *National Crime Information Center 2000 Operating Manual*, December 1999. Washington, D.C.

U.S. Department of Justice. Federal Bureau of Investigation. *Uniform Crime Reporting Handbook*, 1984 edition. Washington, D.C.

U.S. Department of Justice. Federal Bureau of Investigation. *Uniform Crime Reporting Handbook, NIBRS Edition*, 1992. Washington, D.C.