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Estimation Procedures for Crimes in the United States Based on NIBRS Data

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This report describes the estimation process for crime statistics that will be published by the FBI based solely on data submitted by state and local law enforcement agencies to the National Incident-Based Reporting System (NIBRS). It provides a basic background on general estimation and the use of confidence intervals around the estimates. *Estimation* refers to the statistical process that allows inferences to be made about an outcome of interest (e.g., the number of murders in the United States) in a population, even if information about the outcome is only known for part of the population.

Additionally, the report describes why estimation is needed to generate national statistics on reported crime based on NIBRS data, discusses how the new estimation process will differ from the previous process, and details how the new procedures account for the challenges faced when estimating crime based solely on NIBRS. This information will enable the public to interpret the new crime estimates and to understand that the estimates will continue to serve as a reliable and accurate source of information about crime known to law enforcement, regardless of changes to the statistical methodology or the underlying data source.

Introduction

Since 1930, the FBI has gathered and published annual crime statistics based on data voluntarily submitted by law enforcement to the Summary Reporting System (SRS) of the FBI's Uniform Crime Reporting (UCR) Program, providing an authoritative perspective on the scope of crime reported to law enforcement in the nation. The SRS data collection was voluntary and not all law enforcement agencies provided data each year. To account for agencies that did not submit data, the FBI began estimating crime in the 1960s, using the reports of participating agencies to produce national

and state crime estimates. The aggregate crime counts and estimates from the SRS served data users well over the years, but the growing need for more detailed information on crime known to law enforcement led to the development of NIBRS in the mid-1980s. After NIBRS was established, state crime reporting programs and local agencies could decide if they would report data using SRS or NIBRS. To accommodate that choice, the FBI's UCR Program collected crime and arrest data through both SRS and NIBRS, and annual national estimates of reported crime were based on the aggregation of both sources of data.

In 2016, with support from [prominent law enforcement organizations](#), the FBI announced that the UCR Program would retire the SRS on January 1, 2021. Following that decision, the UCR Program modernized its data collection system and increased the frequency of crime data releases. The FBI, working closely with the Bureau of Justice Statistics (BJS), also encouraged its law enforcement partners to transition to NIBRS, with BJS and the FBI providing support through training and grant funding.

The FBI moved to a NIBRS-only data collection on January 1, 2021. The transition to NIBRS offers several significant improvements compared to the SRS:

1. *Counting all offenses in an incident*—When crime incident information is collected, each offense in an incident is counted. Comparatively, SRS imposed the hierarchy rule, where only the most serious offense in an incident was counted.¹

¹The hierarchy rule in the SRS states when more than one offense occurs within an incident, only the most serious crime contributes to the agency's monthly crime totals. For example, an incident involving murder, robbery, and motor vehicle theft only counts the homicide for the monthly totals, as homicide is the highest offense on the hierarchy. <https://ucr.fbi.gov/nibrs/2012/resources/effects-of-nibrs-on-crime-statistics>

2. *Providing a more complete picture of crime known to law enforcement*—NIBRS enables law enforcement agencies to report information on 58 different offense types, covering a wider variety of crimes than the 10 offenses formerly recorded in the SRS. NIBRS data provide a much more in-depth profile of reported crime occurring in a community.
3. *Capturing information about the characteristics of each crime incident*—NIBRS vastly expands the information collected on reported crime, to include demographic characteristics of crime victims, offenders, and persons arrested; details of the incident type and location; the types of weapons used; and important relationships between victims and offenders. SRS did not collect all of these specific details.

The transition to NIBRS means that the FBI's UCR Program will generate crime statistics based solely on data submitted to NIBRS. In 2021, approximately 66 percent of law enforcement agencies in the United States submitted data to NIBRS. To calculate a national crime rate based on NIBRS data, the FBI, in partnership with BJS and with statistical and technical support from RTI International, established a new set of statistical procedures to estimate crime using data provided by NIBRS-contributing agencies. Relying solely on NIBRS data for this new estimation process required addressing several challenges:

1. *Producing national and state-level crime estimates as law enforcement agencies continue to transition to NIBRS*—The number of agencies transitioning to NIBRS has increased annually since 2016, when the FBI announced their intention to retire the SRS as of January 1, 2021. In addition, in 2021, the first year for which estimates will be produced, the overall number of law enforcement agencies submitting data to NIBRS is smaller than the number of agencies for which SRS data were available in prior years. The estimation methodology must account for the reduced number of agencies reporting in 2021, as well as be flexible to accommodate the fluctuation in the number of reporting agencies in future years.
2. *Developing estimation techniques that can run effectively and efficiently on very large amounts of data*—The NIBRS data structure is much larger than SRS, as each NIBRS record contains a rich set of information on each crime incident, the victims affected, and the offenders and arrested persons involved. The SRS data generally consisted of

aggregate offense counts with limited supplemental information for each law enforcement agency. Conversely, NIBRS reporting agencies provide incident-specific records for all the recorded crime incidents in their jurisdiction. The ability to connect the details within each incident—for instance, victim data with the criminal offenses they experienced—provides context about crime that was previously unavailable. This means that one agency could potentially report thousands of individual crime incidents through NIBRS, whereas they would have reported only summarized offense totals to SRS. The increased size and detail of the NIBRS database requires, therefore, a more complex estimation process.

3. *Identifying the set of key indicators for which estimates will be produced*—The expanded level of detail in NIBRS could hypothetically result in the production of several million more estimates compared to SRS. The new estimation methodology needs to target a set of priority indicators of crime and arrest to ensure the procedures generate valid and reliable estimates on these key metrics based on complete and high-quality data.

Estimation Basics

Estimation enables the conversion of statistical sample data into estimates of population characteristics. It is the statistical process which allows inferences to be made about an outcome of interest in a population (e.g., the number of murders in the United States), even if information about the outcome is only known for part of the population. Regarding data submitted to the UCR Program, *inferences* are made about crimes known to law enforcement in the United States. Not all law enforcement agencies submit all their crime data; some provide only partial data, or no data at all, on crimes and arrests. Estimation is used to generate statistics about crime known to law enforcement that are still representative of the entire population, including the population covered by the agencies that did not provide complete information.

Estimation is a statistical process based on data from a subset of the population, which means that any estimated statistic has some amount of uncertainty associated with it. Uncertainty is a combination of the natural, random variation in an indicator plus any variation resulting from specific, identifiable, or systematic causes that over- or under-measure that indicator. Both types of variation are often used to

describe the *confidence* in an estimate. It is a way to quantify how far the estimated value of an indicator might be from the *population value* (i.e., the value that would be generated if all data were reported and nothing was missing).

For instance, if 75 percent of the law enforcement agencies that have traditionally submitted crime data in the past now submit NIBRS data, then there would be 25 percent of law enforcement agencies whose data were not reported. The resulting estimate made for the 25 percent of agencies that did not report would need to have an associated statistical measure of confidence to fully understand the result. This measure is expressed as a range, often called a *confidence interval*. When the *coverage rate*—the proportion of the population represented in the subset of agencies used for the estimation process—approaches 100 percent, the corresponding level of uncertainty approaches zero. In other words, if the value of the outcome is known for all or nearly all the population then the level of certainty in the estimate is very high and, as a result, no confidence intervals are needed.

Historically, no confidence intervals have been needed for SRS-based crime data. When the converted data of agencies that submitted to NIBRS was combined with the data of agencies that submitted to SRS, approximately 95 percent of the population was covered. Therefore, even though estimation was used to account for the small portion of missing crime reports, no confidence intervals were needed because the change to the estimates would be negligible if the values for agencies covering the remaining 5 percent of the population were known.

One key assumption of estimation is that the sample data represent a *random subset* of the population. A sample is random if the probability of selecting data from the underlying population is known, such that the sample data appear to be in no apparent or predictable order. Random selection minimizes the risk of conscious or unconscious bias that could impact estimates resulting from the sample data. If the subset of the population is not random—for instance, if all the units in the population cannot be specified or if the probability of selection is not known, it is possible the calculated estimate will be *biased*. A *biased estimate* means the estimate is shifted either higher or lower than the population value because the subset of the population upon which estimates are based does not accurately represent the population.

Regarding NIBRS reporting, determining which agencies have or have not transitioned to NIBRS is not random. As such, the set of agencies who have completed their transition cannot be considered a random subset of all law enforcement agencies. Therefore, the numbers and types of crime reported by agencies that have transitioned to NIBRS may not be the same as those reported by agencies that have not yet transitioned.

In addition to the randomness of the subset of population, the issue of coverage of the population is also critical to NIBRS estimation. While coverage does not directly measure bias, it is a measure that can give a quick indication of the likelihood of whether bias in the estimates exists or not. There is an inverse relationship between coverage and *estimation bias*: as coverage increases, the impact on estimation bias decreases. If agency coverage in NIBRS remains markedly lower than 100 percent, the impact of estimation bias may be significant and should be reflected by the measure of uncertainty calculated for each estimated indicator (i.e., confidence intervals).

How NIBRS Estimation Differs from SRS Estimation

Estimation has long been used to produce the official annual reported crime statistics generated by the FBI, based on data from the SRS.² As mentioned above, the transition to a NIBRS-only crime incident data collection system offers significant benefits when compared to SRS. When it comes to the production of crime estimates, these benefits are accompanied by a unique set of considerations — namely, differences between the SRS and NIBRS collection methodologies—that must be addressed through modifications to the estimation process.

Table 1 summarizes the estimation considerations and how they are addressed in the SRS and NIBRS estimation processes. Five specific considerations are addressed in the new NIBRS-only-based estimation process:

1. *Addressing missing information within a reported incident (or item-level missingness)*. Item missingness

²For decades, SRS statistics have been used as the basis for the estimates of crime volume, rate, and trends published by the FBI. As states became NIBRS-certified, some proportion of law enforcement agencies in those states began reporting data via NIBRS. Because timeseries estimates were based on summary data, those NIBRS data were converted to the SRS format. The conversion of NIBRS to SRS format maximized the number of agencies included in the SRS statistical estimates.

refers to instances in which a valid value has not been reported for a critical field within a reported incident needed for estimation, either because the information is missing or because the reporting agency submitted a value of unknown.

2. *Accounting for partial reporting agencies.* Partial reporting agencies are agencies who report some crime incidents through NIBRS but not for all 12 months.
3. *Estimating for nonreporting agencies.* Nonreporting agencies are law enforcement agencies that do not report any crime incident data to NIBRS. Because the data of NIBRS agencies could be converted for the SRS database, estimation for nonreporting agencies was minor. However, the nonparticipation rate for NIBRS is higher because it includes not only those agencies who did not submit any crime or arrest data, but also those SRS agencies whose data could not be converted to NIBRS. The FBI and BJS anticipate that the number of nonreporting agencies will decrease annually, as additional law enforcement agencies complete their transitions to NIBRS reporting.
4. *Expressing statistical measures of confidence in each estimate.* A statistical measure of confidence in an estimate is the quantification, usually expressed as a range, of how well the estimated value of an indicator represents the population value. Estimates based on NIBRS-only crime data will initially have a lower degree of statistical confidence compared to SRS-based estimates because—
 - a. The overall population coverage rate is lower—65 percent of the population is covered by agencies that submitted NIBRS for the 2021 transition year compared with 95 percent of the population whose data for previous years were represented in SRS format (which was achieved by converting NIBRS agencies' data).
 - b. The agencies reporting to NIBRS are not a random subset of all potential reporting agencies.
5. *Developing methods to determine the reliability of estimates.* Determining the reliability of each estimate generated from the NIBRS-based estimation process is critical for ensuring that the FBI's annual crime statistics are representative based on scientifically sound data and can be trusted. Several factors can impact the reliability of NIBRS-based crime estimates, including low agency coverage rates and the rareness of the event or phenomenon

being measured, e.g., bias (hate) crime, among other factors.

Addressing item-level missingness. For some NIBRS data elements, law enforcement agencies may submit a value of *unknown* or may simply not provide a value when they submit a crime incident record. These *unknown* or missing values impact estimation procedures for key indicators. For instance, when estimating the attribute of a critical incident like demographic characteristics (e.g., age, race, sex at birth) of a crime victim, there must be a known value to produce rates by those demographic characteristics. To fill in the unknown or missing values, a statistical process called *imputation* is used.

Imputation is the general term for a type of procedure which fills in missing information based on the information that is known for a record. For item missingness, *hot deck imputation*³ is used to fill in the missing or unknown values based on three factors: (1) known agency-level characteristics (e.g., agency type and size), (2) the offense type from the reported data, and (3) the known information about the segment being imputed (e.g., if only victim age is missing, use the known victim sex and race to inform imputation). However, imputation is only conducted when the underlying assumption in the imputation process (i.e., that the donor agency is similar to the imputed agency) is met. The complete set of NIBRS data elements that are imputed include victim age, sex, and race; age, sex, and race of persons arrested; offender age, sex, and race among cleared cases; and victim-offender relationship among cleared cases.

Accounting for partial reporting agencies. For partial reporting agencies, the estimation process must first assess the amount of data submitted by each participating law enforcement agency. This is measured by determining how many months of data were provided. For agencies reporting crime incident information for at least three, but fewer than twelve months of the calendar year, *imputation* is conducted.

With SRS data, only offense counts were imputed. This allowed the FBI's UCR Program to use a straightforward ratio imputation approach (i.e., *extrapolation*) in which the number of crimes reported are inflated to account for the number of missing months. For example, if six months of data were

³See page 17 of [Violent Victimization Known to Law Enforcement in the Bakken Oil-Producing Region of Montana and North Dakota, 2006-2012 \(ojp.gov\)](#) for a description of hot deck imputation.

provided, the six-month count was doubled to equal the 12-month imputed count.

Under NIBRS estimation, the entire incident record needs to be imputed, which could include missing offense information, incident characteristics like victim demographic characteristics, location, weapon use, and characteristics of persons arrested, among other things. The more complex data structure in NIBRS requires the use of a more complex, two-step imputation process. First, a model is specified to predict the total number of incidents in a month. Second, using the estimated number of incidents from that model, hot deck imputation is used to identify an agency that matches on agency characteristics and has the closest number of total incidents among the agencies with matching characteristics. The incidents from the similar agency are used in place of the missing incidents. For agencies that reported some, but not all, months of data in a year, the reported data are eligible for use in this imputation process.

Estimating for nonreporting agencies. To account for nonreporting agencies—those agencies which have not reported any information through NIBRS during the year—a *statistical weight* is applied to the reporting agencies. A statistical weight is a number allowing the reporting agencies to represent both themselves and some portion of the nonreporting agencies. Statistical weights are designed in such a way that reporting agencies represent nonreporting agencies who have similar agency characteristics, such as agency size and agency type.

Furthermore, different statistical weights are created for different geographic levels of estimation because the distribution of nonreporting agencies throughout the United States varies by state and region. Specifically, a weight is created for estimation at each of the geographic levels for which estimates are produced: (1) national, (2) regional and (3) state. Having separate weights for different geographic areas helps ensure the weights accurately reflect the geographic area being estimated.

Expressing statistical measures of confidence in each estimate. Agencies contributing NIBRS data covered 65 percent of the United States population, compared to the 95 percent of the population covered by adding the converted data of NIBRS contributors to SRS data in prior years. A lower coverage rate reduces the amount of statistical confidence in the estimates. These measures of statistical confidence will be expressed as confidence intervals around each NIBRS-based estimate, as appropriate. The confidence intervals will present the estimated range in which the population value lies, based on a 95 percent confidence estimate. The wider the range of the confidence interval, the more statistical uncertainty there is in the estimate.

Developing methods to determine the reliability of estimates. When the level of statistical uncertainty in an estimate is too high, then an estimate is considered *statistically unreliable*. Consistent with standard principles and practices, statistically unreliable estimates are not published because they may lead to erroneous conclusions or interpretations. Estimates determined to be statistically unreliable need to be withheld from publication, and decisions on which estimates to withhold are based on a set of clear and consistent criteria developed as part of the estimation procedures.

For example, the FBI publishes estimates at the national, regional, and state levels. At the regional and state levels, NIBRS participation is not uniform. Some states have 100 percent of agencies reporting NIBRS while other states have nearly none. Similarly, some regions have high participation in all states within the region, while other regions contain states with a small number of agencies reporting NIBRS. If the level of participation in a state or region causes the estimates to be statistically unreliable, the NIBRS estimation process will flag those estimates to be withheld from publication. The indicators not published will be those assessed to have lower data quality and lower reliability. As the number of NIBRS-participating agencies increases, so too will the quantity of NIBRS data. When more data are reported, fewer estimates will be withheld from publication due to concerns over quality and reliability.

Table 1. UCR Crime Estimation and Comparison between SRS and NIBRS Estimation Processes

Considerations for Estimation	SRS Estimation Process		NIBRS Estimation Process	
	Addressed in the SRS estimation process?	Method	Addressed in the NIBRS estimation process?	Method
Item-level missingness	Not applicable	--	Yes	Hot deck imputation
Partial reporting agencies	Yes	Ratio imputation	Yes	Hot deck imputation
Nonreporting agencies	Yes	Ratio imputation	Yes	Weighting
Statistical confidence	No—unnecessary due to high coverage rate	--	Yes	Variance and bias estimation expressed as a confidence interval
Reliability of estimates	No—unnecessary due to high coverage rate	--	Yes	Application of precision suppression rules

Conclusion

Estimation has long been part of UCR crime statistics. However, because more than a simple count of crime is being estimated under NIBRS, the estimation process needs to be more complex. Furthermore, because the transition to NIBRS is not complete for all law enforcement agencies, the estimation procedure needs to include measures to accurately represent the agencies who have not yet transitioned. These challenges are accounted for in the estimation process being used for the 2021 data-year crime estimates.

The two biggest changes in the estimation process are the use of statistical weights to account for a higher number of agencies who cannot submit data through NIBRS and the creation of confidence intervals to help represent the range in which the population value for an outcome resides. As more agencies transition to NIBRS over time, the estimation procedure will be able to change accordingly. These changes will reflect a greater level of certainty in the estimates with the goal to reach the level experienced under UCR’s SRS crime estimates.

This report was prepared by BJS and the FBI’s Criminal Justice Information Services (CJIS) Division.

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