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ILLINOIS CRIMINAL JUSTICE INFORMATION AUTHORITY

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Is Crime Predictable?

A Test of Methodology for Forecasting Criminal Offenses

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*Uncertainty is much more comfortable
when one is certain of it.*

-- Gerry Homan
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Acknowledgments

The Predictability of Crime Project involved the participation of a number of people at the Authority over several years. Roy Jung, an intern in the Statistical Analysis Center (SAC), organized the data and carried out the initial analysis and tentative model identification for each time series. Kenneth Grant, a SAC analyst, was responsible for the analysis that is summarized in Appendix 2. The final report benefits from the comments and suggestions of many Authority staff members, especially Christine A. Devitt and Louise S. Miller. The report was edited by Margaret J. Poethig.

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Executive Summary

Although law enforcement jurisdictions have numerous functions, one of the most important is to respond to crimes that become known to them through citizen reports or through their own investigation. Because these "offenses known to the police" constitute a demand for law enforcement resources, it would be useful to predict the degree of this demand in the future. There have been studies that attempted to model and predict the number of criminal offenses in the nation or by region, but when the Predictability of Crime Project began there was no systematic analysis of the degree to which crime is predictable for specific crime types and specific jurisdictions, nor an analysis of the best methods to use to predict crime. The Predictability Project was designed to address these questions.

The Predictability Project was composed of two parts. In the first part, the question "Is crime predictable?" for individual jurisdictions and for four types of crime was explored. In the second part of the study, the results of the first part were used to analyze the effect of a 1983 change in the administration of recordkeeping in Chicago on the number of officially recorded robberies and aggravated assaults.

Is Crime Predictable?

The primary purpose of the first part of the study was to discover whether it is possible to predict, one month ahead or one year ahead, the number of Index robberies, aggravated assaults, burglaries, or larceny/thefts known to the police in specific law enforcement jurisdictions in Illinois. Since the same statistical methods that generate accurate forecasts for other kinds of data may not generate as accurate predictions for crime data, a second purpose was to determine whether or not a standard method of forecasting (called ARIMA) could be successfully applied to local-level criminal justice data.

To test the effectiveness of ARIMA projection methods with crime data, the project analyzed the statistical adequacy of the models and the degree to which each model accurately predicted the number of crimes in each jurisdiction. This was done over a three-year period, from 1981 through 1983. ARIMA was used to model the pattern of monthly Index robberies, aggravated assaults, burglaries, and larceny/thefts known to the police in each of 14 selected Illinois jurisdictions. With these models, the project predicted the number of crimes known to the police in each month of 1982 and 1983,[1] and compared these predictions with the crime figures reported by the jurisdictions during those months. This way, the degree of accuracy of the predictions from jurisdiction to jurisdiction and crime type to crime type could be analyzed.

Thus, the first part of the project was designed to answer two questions, the substantive question, "Is crime predictable?" and the methodological question, "What is the best method to use to predict crimes known to the police? In addition, three goals of the project were:

1) to determine if the quality of available data is sufficient to conduct monthly time series analysis for the selected jurisdictions and crimes,

[1] In cases where a serendipitous intervention, an unpredicted sharp change in the level of crime, was suspected, predictions were calculated for 1981, and sometimes for 1980 as well.

2) to determine whether the types of statistical models commonly used for other kinds of data can be used for crime data, and

3) to evaluate the resources required for accurate predictions of local-level offenses and to weigh the costs against the benefits of such predictions to local law enforcement agencies.

The most important results of this part of the Predictability Project were the following:

- Using a standard time series analysis methodology, it was possible to predict the number of criminal offenses in some jurisdictions, and for some crime types. However, crime was much more predictable in certain jurisdictions than in others, regardless of the type of crime.

- The analysis required for accurate predictions is difficult and time-consuming. The identification of a statistical model that will generate accurate predictions for a particular set of data is neither an automatic nor a particularly objective process, but requires an expert who has had extensive experience in model identification.

- Serendipitous interventions, or unexpected sharp increases or decreases in the level of crime, occurred repeatedly. In a few jurisdictions, such an intervention occurred for every type of crime analyzed; in burglary, the majority of jurisdictions had a serendipitous intervention. The presence of serendipitous interventions challenges the assumption that officially recorded crime patterns can be analyzed over time within a jurisdiction. Analysis should not assume that an increase or decrease in offenses known to the police always reflect a change in the actual number of crimes.

- The analysis indicated that the degree of predictability may be related to the quality of data collection and recordkeeping. In certain jurisdictions, predictive accuracy was usually good for every type of crime, while in other jurisdictions, predictive accuracy was usually poor for every type of crime. Moreover, some jurisdictions experienced a sudden improvement in predictive accuracy that coincided with a serendipitous intervention.

- Index larceny/theft was, by far, the most predictable type of crime examined. The number of offenses was predicted within 10 percent for at least one year in 11 cities, and in four cities both 1982 and 1983 were predicted within 10 percent. For example, the model for Arlington Heights larceny/theft (see Figure 1) predicted 1982 within 1 percent and 1983 within 3 percent, using the intervention prediction method.[2]

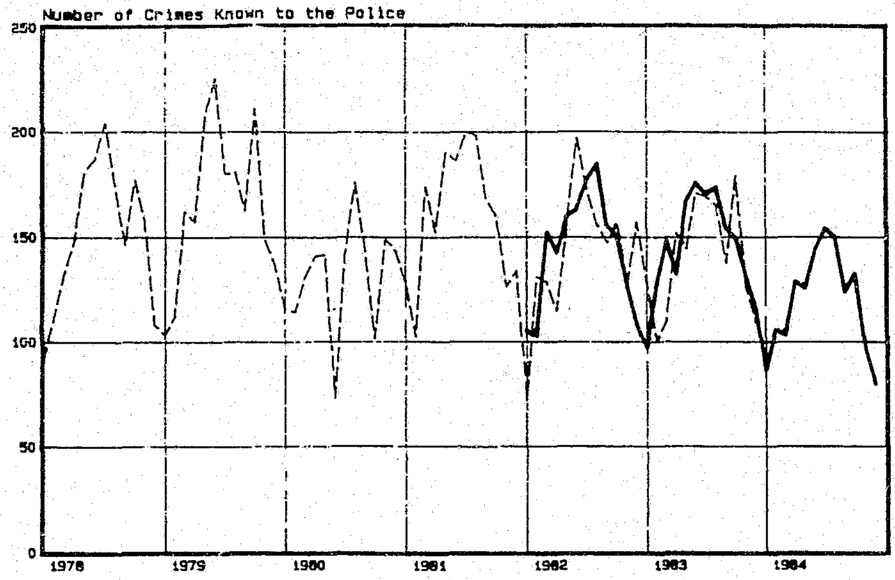
- Of the 14 cities in which Index burglary was analyzed, only three models generated successful predictions, two jurisdictions could not be successfully modeled at all, and in the remaining nine the analysis discovered a serendipitous intervention. In Elgin (see Figure 2), predictions for Index burglary were relatively accurate for both the total year (within 1 percent) and the average month (within 15 percent) in 1982, but the 1983 prediction was 10 percent too high, using the intervention prediction method.

[2]Two prediction methods were used in this study: the year-ahead method and the intervention method. The purpose of each of these methods is described in this report.

Figure 1. Predictions for Arlington Heights Index Larceny/Theft, 1978-1984

Actual Versus Predicted Monthly Totals

Predicted Monthly Totals ——— Actual Monthly Totals - - - -



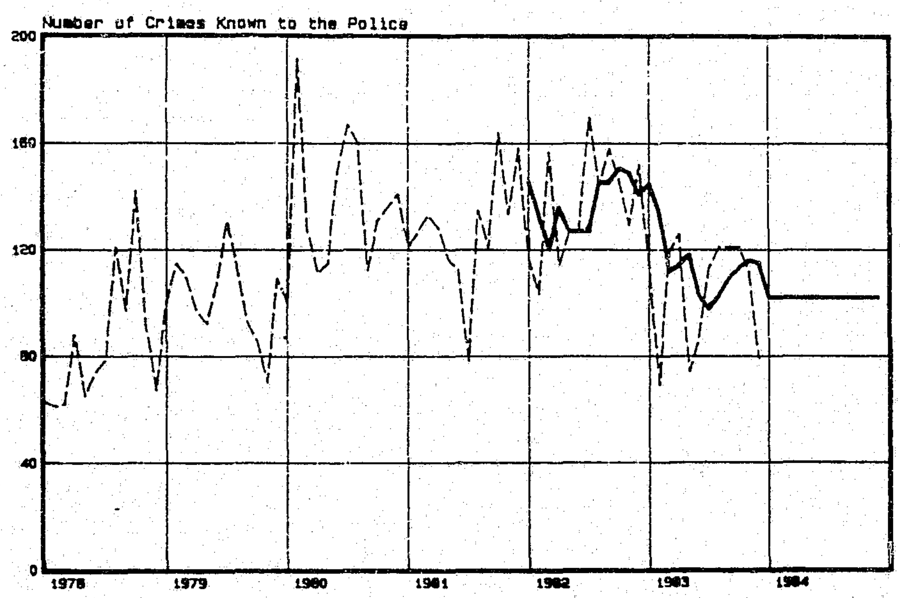
Months, January 1978 through December 1984

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 2. Predictions for Elgin Index Burglary, 1978-1984

Actual Versus Predicted Monthly Totals

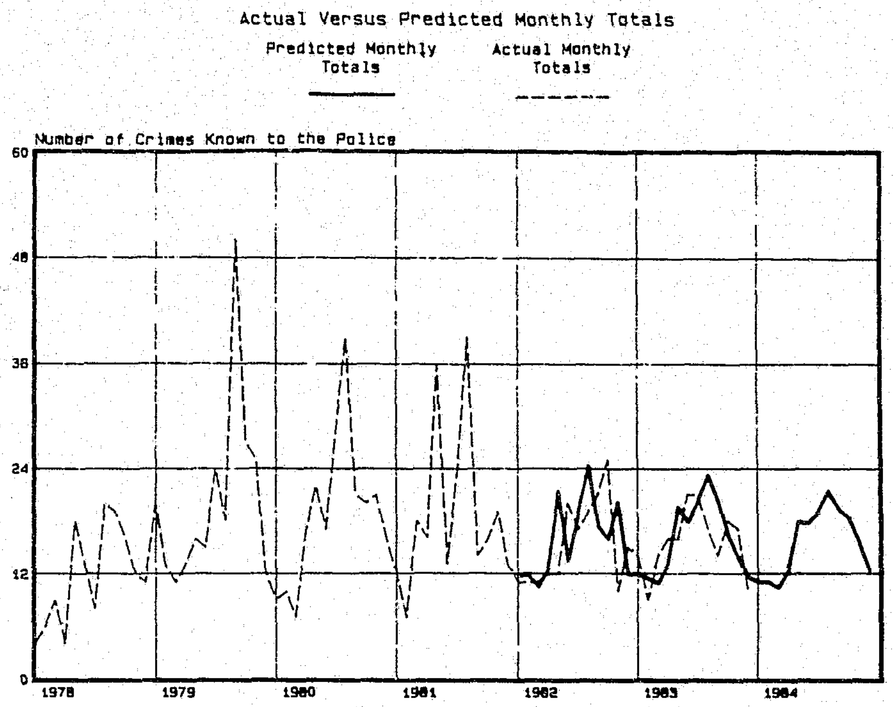
Predicted Monthly Totals ——— Actual Monthly Totals - - - -



Months, January 1978 through December 1984

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

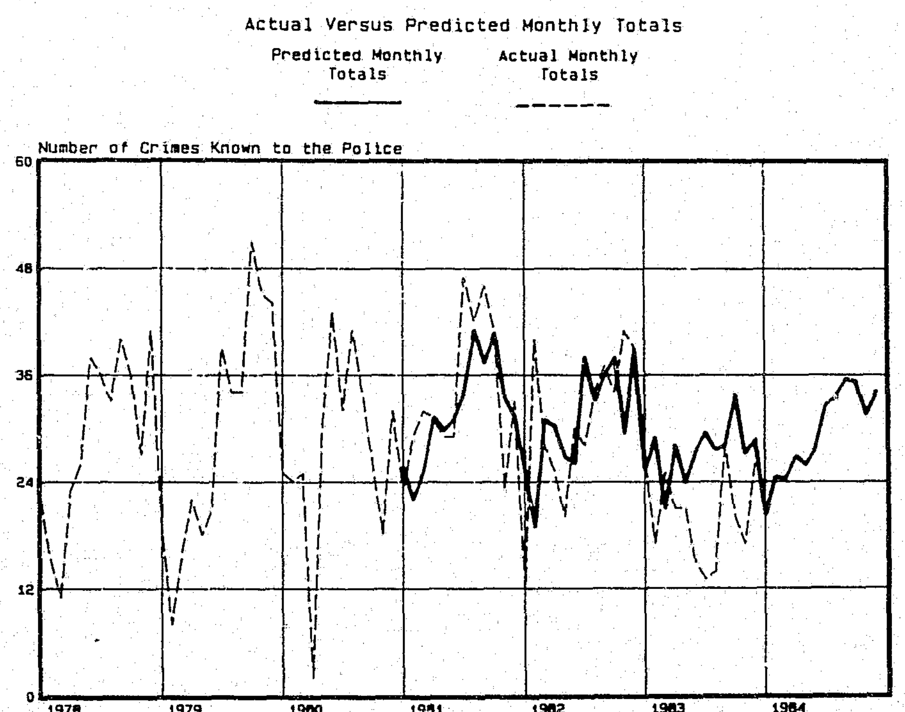
Figure 3. Predictions for Evanston Index Aggravated Assault, 1978–1984



Months, January 1978 through December 1984

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 4. Predictions for Peoria Index Robbery, 1978–1984



Months, January 1978 through December 1984

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

- The predictive accuracy for Index aggravated assault ranged from very accurate to completely unpredictable, depending on the jurisdiction. In Evanston (see Figure 3), the predictions for 1982 and 1983 were within 2 percent (intervention method). The average monthly predictions were 27 percent and 21 percent inaccurate.

- Overall, predictability for Index robbery was more successful in jurisdictions with more robberies per month. However, jurisdictions with fewer than 30 but more than 10 robberies per month could often meet the total year predictability criterion, if not the criterion for the average month.[3] Peoria (see Figure 4), for example, had more robbery offenses per month than any other jurisdiction, and it was the only jurisdiction in which both the monthly and yearly accuracy criteria were met for two years for Index robbery. Robbery offenses in Peoria dropped in 1983, relative to previous years. 1982 was predicted within 1 percent and 1981 within 10 percent. Because the 1983 prediction was 56 percent too high, and the prediction for the average 1983 month was 69 percent wrong, we suspected a serendipitous intervention had occurred in Peoria in 1983.

- In all 14 jurisdictions, there was some consistency from jurisdiction to jurisdiction in the best-fitting type of ARIMA model for a certain type of crime. This information may make model identification in the future somewhat easier than it was in this project.

- Similarly, the seasonal patterns identified by the project showed some consistency. For example, in Index robbery, the degree of seasonality seemed to be related to the number of offenses in the average month. Index larceny/theft was strongly seasonal in every jurisdiction analyzed.

An Application: The Chicago Intervention Analysis

The primary purpose of the second part of the Predictability Project, the Chicago Intervention Analysis, was to demonstrate the utility of the prediction methods that had been explored in the first part of the project. One of the most important practical applications of time series analysis is to determine whether or not a change occurred in a time series. For example, a police department might want to know if a burglary prevention program had any effect on the number of burglaries. An intervention analysis of the number of burglaries known to the police before and after the program began might give some indication of its success. The Chicago Intervention Analysis was conducted for Chicago Index robbery and aggravated assault, by weapon type.

In addition to demonstrating time series methods with the Chicago Intervention Analysis, we attempted to answer two practical questions:

1) Did the change in data collection and recording practices in Chicago in 1983 affect the number of crimes officially recorded, or were the changes in the number of crimes due to actual increases in crimes known to the police? and

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[3]The criteria used to determine predictive accuracy in this project were accuracy within 30 percent for the average month predictions, and accuracy within 20 percent for the total year predictions (year-ahead method). If an ARIMA model did not meet these criteria for at least two years, it was rejected and the analysis continued to test other alternative ARIMA models. In some cases, however, no model could meet these generous criteria. For details, see "Project Design and Methods."

2) How much of the increase in the number of each type of recorded crime was due to recordkeeping, and how much to actual changes in crime occurrences?

The most important results of this part of the Predictability Project were the following:

- The amount of increase in Index robbery, due to the changes in data recording, depended on the seriousness of the offense. The number of firearm robberies did not change at all, the number of knife robberies increased about 10 percent, the number of other-weapon robberies increased about 20 percent, and the number of strongarm robberies increased about 40 percent.

- Since firearm robbery is a serious crime, it always had been accurately and completely recorded, even before the administrative changes in recording practices. As can be seen in Figure 5, the number of Chicago firearm robberies did not change in 1983. The predictive accuracy of firearm robbery in Chicago in 1983 was better than the accuracy in 1981 or 1982. Also, the predictive accuracy in Chicago in 1983 was better than the accuracy in total Illinois (non-Chicago) in 1983.[4] Thus, the reform in Chicago data recording practices had no effect on the number of firearm robbery offenses in official records.

- There were indications that the level of Chicago knife robbery offenses changed in 1983 (see Figure 6). The prediction for every month from May through December 1983 was too low, by an average of 26 percent. In contrast, there was no change in the number of knife robberies in total Illinois (non-Chicago) in 1983. Therefore, the number of officially recorded Index knife robbery offenses in 1983 in Chicago was apparently affected by the change in recording practices.

- The number of Index aggravated assaults in Chicago generally increased more, due to the change in recording practices, than the number of Index robberies. Firearm assaults increased about 20 percent, knife assaults increased about 40 percent, and other-weapon assaults increased about 30 percent.

- There is some indication that the number of Index assaults with the body as a weapon (for example, a karate attack) was underrecorded both before and after the change in recording practices.

- There was a serendipitous intervention--a precipitous decline--in the number of knife assaults and other-weapon assaults in Chicago that occurred early in 1981, and this unusually low level continued through most of 1982.

- The time series experiment design of the Chicago Intervention Analysis produced estimates of the amount of 1982-1983 change in officially recorded Chicago robbery and aggravated assault that was due to the changes in crime recording practices. From this, we can estimate the amount of change, for each type of crime, that was due to an actual change in crime, as reflected in crimes known to the police. The analysis estimated that, while some types of crime (firearm robbery, knife robbery, and other-weapon assault) did increase, some (other-weapon robbery and body-as-weapon assault) stayed the same, and others (strongarm robbery, firearm assault, and knife assault) actually declined.

[4]The aggregate total of offenses in Illinois, excluding Chicago, was used as a control group for the analysis of change in the level of offenses in Chicago.

Figure 5. Predictions for Chicago Index Firearm Robbery, 1980-1983

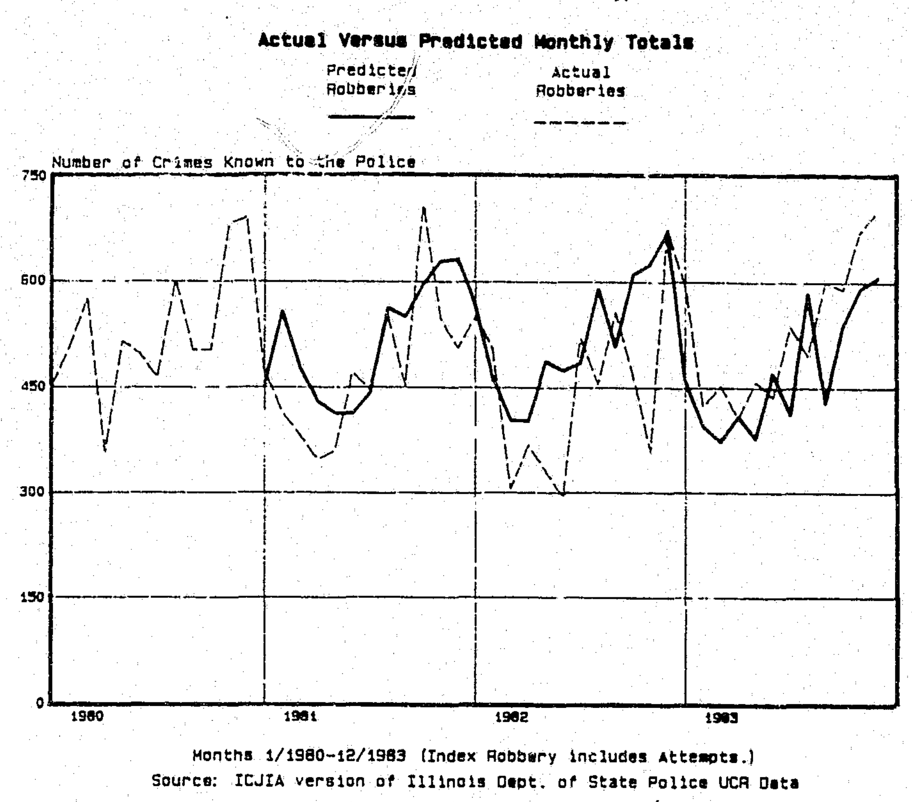
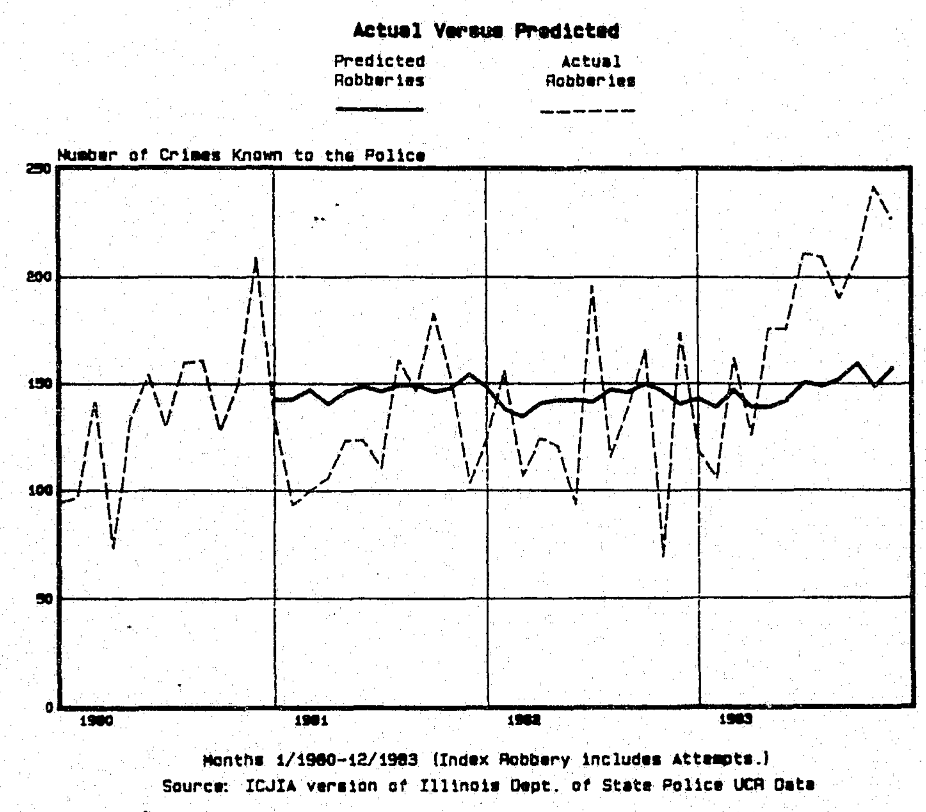


Figure 6. Predictions for Chicago Index Knife Robbery, 1980-1983



- The FBI, which also estimated the amount of change in actual offenses from 1982 to 1983, concluded that total Index robbery offenses decreased about 8 percent, and total Index aggravated assault offenses declined by about 2 percent. Thus, the more painstaking and detailed methods of the Chicago Intervention Analysis produce very different conclusions from the imputation methods of the FBI.

- The detailed Chicago Intervention Analysis concluded that, overall, the actual number of Index robberies known to the police in Chicago did not change from 1982 to 1983, and that firearm and knife robbery increased at least 8 percent, other-weapon robbery did not change, and strongarm robbery declined about 7 percent. For Index aggravated assault, the analysis concluded that the actual number, overall, decreased slightly, just as the FBI estimate concluded. However, firearm assault and knife assault declined about 12 percent, other-weapon assault increased at least 18 percent, and body-as-weapon assault probably did not change.

Introduction

The intelligent allocation of resources in the administration of justice depends upon the ability of criminal justice officials to anticipate, with some degree of accuracy, the demand for those resources. Although law enforcement jurisdictions (police departments and sheriffs' offices) have numerous functions, one of the most important is to respond to crimes that become known to them through citizen reports or through their own investigation. These "offenses known to the police" thus constitute a demand for law enforcement resources, and it would be useful to predict the degree of this demand in the future.

The primary purpose of the Predictability of Crime Project was, therefore, to discover whether it is possible to predict, one month ahead or one year ahead, the number of Index robberies, aggravated assaults, burglaries, or larceny/thefts known to the police in specific Illinois law enforcement jurisdictions.[5] Since the same statistical methods that generate accurate forecasts for other kinds of data may not be as successful for crime data, the second purpose of the project was to determine whether or not a standard method of forecasting called ARIMA could be successfully applied to local-level criminal justice data.[6]

Predictive Accuracy, by Crime Type and Jurisdiction

The Predictability Project was designed to model and forecast criminal offenses in specific Illinois jurisdictions, because most law enforcement decisions are made at the local level. This design had two advantages: 1) local predictions could provide useful information for local decisions, and 2) local predictions would allow the analysis to take into account jurisdictional differences in crime patterns or crime recording practices. Such jurisdictional differences are likely, because reported offenses not only vary with the nature of criminal activity, but also vary with the way in which crime is recorded (McCleary, *et al.*, 1982). However, it is only recently that sufficient data have existed to permit the statistical forecasting of offenses. Only since 1972 has jurisdiction-level time series data on offenses known to the police been available in Illinois.[7] With these data, it is now possible to determine whether or not the number of offenses follow some predictable pattern over time, or whether they occur randomly.

The degree to which crime is predictable may vary not only by jurisdiction but also by crime. For example, the best model to describe and predict the number of robbery offenses may not be the same as the best model for assault offenses. Both may differ from the best model for burglary offenses. If robbery and assault follow different patterns over time, a model of the two kinds of offenses added together, as in total Index violent crime, is likely to produce misleading results or incorrect forecasts. Because it may be misleading to attempt to model

[5] The Crime Index is a group of eight serious crimes that together give some indication of the level of criminal activity in a jurisdiction. The FBI created the Crime Index in the 1930s. The bureau selected the crimes (murder, rape, robbery, aggravated assault, burglary, theft, motor vehicle theft, and arson) to be included in the Index on the basis of their seriousness, frequency of occurrence, consistency of definition across jurisdictions, pervasiveness in all geographical parts of the country, and likelihood of being reported to the police. See Miller and Block (1985).

[6] For a definition of ARIMA, see "Predictive Modeling Methods," page 11.

[7] The number of offenses known to the police equals the total number of reported offenses minus those that were unfounded or referred to another jurisdiction.

total Index crime or even total violent or total property Index crime, the Predictability Project was designed to model and forecast individual Index crimes--robbery, aggravated assault, burglary and larceny/theft.[8] Thus, the results of the study are not only specific to jurisdictions, but are also specific to types of crime

Models of individual crimes are not only more accurate than models of total aggregate crime categories, but they are also more useful to law enforcement managers. For example, the best managerial response to an increase in larceny is not necessarily the same as the best response to an increase in robbery.

In addition, models of offenses known to the police could be useful to prosecutorial, court, or correctional managers and administrators. The progression of criminal justice through arrest, court case filing, conviction, and prison commitment begins with the offense. Thus, the law enforcement statistic--offenses known to the police-- could be considered to be the starting point from which all other criminal justice system statistics flow. As a result, the successful prediction of offense data could be useful for law enforcement resource management decisions and could also serve as input for models to project court caseload or prison population.

In summary, the Predictability Project was designed to answer the question, "Is crime predictable?" for each of four types of crime and for individual Illinois jurisdictions. The project modeled the pattern of monthly crimes known to the police in each selected jurisdiction for the period 1972-1981, using a standard forecasting technique called ARIMA. With these models, the project then predicted the number of crimes known to the police in each month of 1982 and 1983, adjusted the prediction models when necessary, and then predicted the number of crimes in each month of 1984. Finally, the project compared the degree of accuracy of these predictions from jurisdiction to jurisdiction and crime type to crime type.

Methodological Goals of the Predictability Project

The Predicability Project attempted to answer not only the substantive question, "Is crime predictable?" but also the methodological question, "What is the best ARIMA model to use to predict crimes known to the police?" Specifically, the project had the following four methodological goals:

1) to determine if the quality of available data is sufficient to conduct monthly time series analysis for the selected jurisdictions and crimes,

2) to determine whether the types of statistical models commonly used for other kinds of data will successfully model crime data,

3) to evaluate the resources required for accurate predictions of local-level offenses and to weigh the costs against the benefits of such predictions to local law enforcement agencies, and

4) to demonstrate the usefulness of these prediction methods in a practical situation, an analysis of the effect of a 1983 change in recordkeeping practices in Chicago.

[8] Note that each of these Index crimes includes attempts. See Miller and Block (1985). For a discussion of the choice of these particular Index crimes for analysis, see "Sample," page 15.

Time Series Data Quality Assessment

While the latter three of the methodological goals listed above address the applicability of various statistical methods for conducting time series analysis with crime data, the first methodological goal addresses the availability of data that are appropriate for these statistical methods to be used.

In the initial stages of the Predictability Project, it became clear that an unexpected methodological goal would be accomplished--the determination of the quality and availability of Illinois offense data at the jurisdictional and crime-specific level for conducting time series analysis. Even though relatively long monthly time series, beginning in 1972 in most cases, were available on the books for almost every Index crime and jurisdiction, when the actual monthly series were first examined for this project, a surprisingly high proportion contained at least one missing or obviously erroneous monthly offense total. This situation had not been noticed earlier, because previous analysis had used aggregate groups of months, jurisdictions, and crime types. It is difficult to detect errors in aggregate data (Coldren, 1980).

In addition, by comparing the degree of predictability in one data set against another, the Predictability Project examined the extent to which aspects of the data other than completeness or accuracy might affect time series analysis. Three aspects were particularly important: the length of the series, the average number of offenses per month, and whether or not the series contained extreme values or a large discontinuous increase or decrease.

Predictive Modeling Methods

The self-projecting approach to time series forecasting is based on an examination of the historical behavior of the phenomenon to be predicted--in this case selected types of Index offenses known to the police each month in selected jurisdictions. It is called self-projecting because it derives projections solely on the basis of past crime trends, without including other types of data. The self-projecting method used in this study was ARIMA. ARIMA stands for AutoRegressive, Integrated, Moving Average. The ARIMA method will not be explained in detail here, because previous reports from the Statistical Analysis Center of the Illinois Criminal Justice Information Authority (see Block, 1984b) and other references (e.g., Hoff, 1983) offer simple but adequate explanations. However, the section "Method of Choosing the Best ARIMA Model" (page 22) and Appendix 1 do provide a quick overview of ARIMA concepts and the statistical tests used in the Predictability Project.

An ARIMA model describes change over time in a variable by describing the relationship between each occurrence and the occurrence one, two, or more time periods previously. The particular type of ARIMA model makes an assumption about these relationships from one time period to the next. To choose the appropriate ARIMA model type, it is necessary to diagnose the relationships from month to month in the time series.

ARIMA was developed for use with economic data. Whether or not it works with crime data is a relatively unexplored question. Therefore, the project was designed to examine the particular categories of ARIMA model that work best with crime data. There are many possible types of ARIMA model. The wrong choice of ARIMA model type for a series of data will probably generate inaccurate forecasts. Moreover, previous Authority analysis suggests that types of ARIMA model that commonly fit economic data do not necessarily fit crime data. For example, the X-11/ARIMA computer package (see Appendix 1) attempts to fit three standard types of ARIMA model--types that fit a high percentage of economic series. Out of nearly 100 crime series for which the X-11/ARIMA program has been used at the Authority, these standard ARIMA types succeeded in fitting only one or two series.

Thus, the methodological goal of the Predictability Project was twofold:

1) to determine whether *any* type of ARIMA model would successfully fit crime series, and

2) to determine whether *certain* types of model would tend to fit certain kinds of crime, or crime in certain jurisdictions.

Resources Necessary for Prediction

Two universal concerns of any governmental agency, including law enforcement agencies, are the degree to which timely answers are important and the degree to which resources to obtain these answers are limited. While it may be useful for a law enforcement agency to be able to predict offenses known to the police if the predictions are available in a few days and with a small expenditure of resources, it may not be useful if the answer is not timely and the cost is great.

In the Predictability Project, therefore, we attempted to determine the degree of difficulty in producing accurate (or the best possible) predictions of four crime types in 14 Illinois jurisdictions. The question was this: In order to produce accurate predictions, is it necessary for an expert in time series analysis to spend days in the effort, or can accurate predictions of offenses be calculated by knowledgeable crime analysts in a relatively short time?

A second concern was to try to quantify the expert skills and experience necessary to produce accurate predictions of crime data. As part of this effort, we attempted to discover whether or not certain types of model were so common with particular types of crime that an analyst might try these model types as a standard shortcut to the involved process of model identification. In addition, because prediction is an art, not a science, a record of the necessary steps and decisions required to identify a well-fitting and accurate model was kept and included in this report. By identifying these steps, we hoped to make crime prediction less of an art and more of a science, less subjective and more objective, and less the purview of the statistical expert and more accessible to those who are expert in local-level conditions.

Time Series Intervention Analysis

In practical situations, one of the most important applications of time series analysis is to determine whether or not a change occurred in the series. For example, a police department might want to know if a burglary prevention program had any effect on the number of burglaries. Such an analysis is called an *intervention analysis* of the number of burglaries known to the police before and after the program, or intervention, began, and is intended to give some indication of the program's success. Another intervention analysis might be designed to determine the extent to which a change in early release policy made a difference in the prison population. Any new law, change in policy or practice, or new crime prevention program might constitute an intervention.

Although the results of time series intervention analyses have obvious practical uses, such studies must be carefully conducted. The effect of an intervention can take many forms (McCleary and Hay, 1980). A change may occur gradually or suddenly after the intervention. In fact, it can even occur before the intervention, in anticipation of a law, for example. These and other problems make the design of a good time series intervention analysis difficult. One solution to this problem is the time series experiment (Campbell and Stanley, 1966). The Predictability Project included such a formally designed time series experiment of an intervention occurring in Chicago. This intervention involved the improvement of the administration of data collection and the maintenance of criminal offense data. Following investigation by a local television station, which accused the Chicago Police Department of "killing crime" by failing to make an official record of some crimes reported to the department, and following an internal audit supervised by the FBI (Chicago Police Department, 1983), the Chicago Police Department instituted mechanisms to improve the accuracy and completeness of crime recording.

The purpose of these administrative mechanisms was to ensure that those crimes that previously had been underrecorded would now be recorded completely and accurately. After the department began to react to the investigation and audit early in 1983, the total number of officially recorded offenses did, in fact, increase. However, this increase may not have been due to the change in administrative practices, but due instead (or in addition) to a real increase in crime. In the first place, it cannot be assumed that an across-the-board increase occurred in the recording of every type of crime. The greatest increase probably occurred in those kinds of crime that had previously been underrecorded the most. Also, the publicity surrounding the investigation may have changed the tendency of victims to report particular kinds of crime to the police. Thus, how can it be determined whether actual Chicago crime occurrences increased, decreased, or stayed at the same level before and after the investigation and audit?

Intervention analysis for a particular crime type permits analysts to estimate the number of offenses that would have been recorded in 1983 if the previous recording practices had been in effect. If the numbers actually recorded in 1983 were higher (or lower) than this estimated range, or if the form of the ARIMA model changed in 1983, we would suspect that the new administrative mechanisms accounted for the change. On the other hand, if the number of crimes actually recorded in 1983 was within the estimated range and if the ARIMA model for previous years still appeared to fit 1983, we would suspect that the new mechanisms did not affect the recording of that type of crime. We hypothesized, for example, that no change would occur in those types of crime, in particular serious offenses such as firearm robbery, that had not been undercounted prior to the 1983 changes.[9] (For the detailed design of the time series experiment, see "Chicago Intervention Analysis Methods," page 24.)

In summary, the final methodological goal of the Predictability Project was to conduct a field test of descriptive time series intervention analysis methods. The prediction methods that had been systematically tested in the first part of the project were used in a formally designed time series experiment--the Chicago Intervention Analysis--in order to answer a practical question about a change in the recording practices of Chicago crime data.

[9]This hypothesis is based on the findings of Block and Block (1980, 1984), which show that more serious victimizations, specifically robbery with a firearm, are more likely to be reported to the police by the victim and, when reported, are more likely to become official statistics.

Project Design and Methods

Sample

The jurisdictions and crimes selected for this study were not chosen randomly. The Predictability Project was designed to see how well a method of analysis (ARIMA modeling) worked in a variety of situations involving different jurisdictions and different crimes. The purpose of the Predictability Project was make accurate predictions for as many types of jurisdictions and crimes as possible, not to generalize findings to a universe of all jurisdictions and all crime types.

The four crimes used in this study--Index robbery, aggravated assault, burglary, and larceny/theft--were chosen because data collection for Index crimes may be more uniform across jurisdictions than for non-Index crimes (FBI, 1983:1). Two other Index crimes, murder and forcible rape, were not analyzed, because too few of these crimes occur in most jurisdictions to permit time series analysis (fewer than five per month). Index arson was not analyzed, because statewide data are available only since 1983. Index motor vehicle theft was not analyzed due to time constraints in the project.

The goal of the Predictability Project was to analyze crime patterns in as many Illinois jurisdictions outside of Chicago as possible, within the limits of our time and resources. The sample included 15 Illinois jurisdictions other than Chicago (see Table A). Seven of the jurisdictions in the sample are in the Chicago metropolitan area, and the others are scattered throughout the state. Berwyn was later eliminated because of data quality problems.[10] Quincy was included in the analysis because the Authority had done a previous study of crime prediction with Quincy data; thus the Predictability Project was a basis for comparison with past analyses (Cooprider, 1984). Although Chicago was not part of the main study, Chicago aggravated assault and robbery, as well as total Illinois (non-Chicago) aggravated assault and robbery, were analyzed in the Chicago Intervention Analysis.

In each jurisdiction except Chicago, all four Index crimes were analyzed if enough crimes occurred monthly to permit ARIMA analysis. The criterion for "enough crimes" was a mean of five occurrences per month over the entire 1972-1983 time period (see Table B). All of the jurisdictions had enough larceny/thefts and burglaries to permit analysis. However, four jurisdictions did not have enough robberies and three did not have enough aggravated assaults.[11]

As might be expected in a group of jurisdictions that vary in population, the crime rate per 100,000 population and the number of crimes in a typical month also vary widely (see Table B). The highest crime rates and crime numbers generally occur in the most populous jurisdictions, but this is not always true. As Miller, Block, and Dykstra (1982) pointed out in their analysis of

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[10]Data for June 1979 are missing, and figures for September, October, and November 1978 are extremely high (twice as high as any other month in the 1972-1983 time period).

[11]Des Plaines and Skokie had an average of more than five aggravated assaults per month over the entire 1972-1983 period, but had five or fewer per month, on the average in recent years. Therefore, they were not analyzed.

Table A. Population Characteristics of Jurisdictions in the Sample, 1980

Jurisdiction	1980[a] Population	County	SMSA[b] Central City
Quincy	42,554	Adams	Not in an SMSA
Berwyn[c]	46,849	Cook	Chicago
Rock Island	47,036	Rock Island	Davenport, Iowa
Des Plaines	53,568	Cook	Chicago
Skokie	60,278	Cook	Chicago
Cicero	61,232	Cook	Chicago
Elgin	63,798	Kane	Chicago
Arlington Heights	66,116	Cook	Chicago
Evanston	73,706	Cook	Chicago
Joliet	77,956	Will	Chicago
Aurora	81,293	Kane	Chicago
Decatur	94,081	Macon	Decatur
Springfield	99,637	Sangamon	Springfield
Peoria	124,160	Peoria	Peoria
Rockford	139,712	Winnebago	Rockford
Chicago	3,005,072	Cook	Chicago

[a]Source: ***General Population Characteristics--Illinois: 1980 Census of Population***, Part 15, Table 14 (August 1982). Bureau of the Census.

[b]"The general concept of a 'Standard Metropolitan Statistical Area' (SMSA) is one of a large population nucleus, together with adjacent communities which have a high degree of economic and social integration with that nucleus." ***General Population Characteristics--Illinois: 1980 Census of Population***, Appendix A (August 1982). Bureau of the Census.

[c]Berwyn was not analyzed due to data quality problems. For each Index crime, the figures for September, October, and November 1978 are extremely high, and the June 1979 figure is zero. Because the original police data files are no longer available, the problem could not be resolved.

Illinois county data, crime rates are not necessarily higher for larger jurisdictions or lower for smaller jurisdictions. They are low in some jurisdictions (Arlington Heights) and high elsewhere (Rock Island, Cicero robbery) compared to other jurisdictions of similar population.[12]

It would be a mistake to conclude that differences in crime rates from jurisdiction to jurisdiction reflect only differences in the actual incidence of these crimes (see Miller and Block, 1985; Block and Block, 1984). Official rates of crimes known to the police reflect not only the occurrence of crime, but also the decisions made by both citizens and the police that affect whether an incident is defined as a crime and also whether a crime ever becomes an official statistic. Therefore, we would expect differences from jurisdiction to jurisdiction, even if the actual likelihood of crime occurrence were the same. On the other hand, if data recording in each jurisdiction did not change over time, then differences over time would be attributed to real differences in crime occurrence within that jurisdiction.

[12]Note that the jurisdictions in Table B are arranged in order of population size.

However, administrative practices regarding the collection and maintenance of crime data were known to have changed in Chicago. This is the subject of the Chicago Intervention Analysis part of the Predictability Study. In addition, the analysis of other jurisdictions frequently discovered sharp changes in the number of offenses, which this report calls *serendipitous interventions*. These changes may have been due to administrative changes in crime recording. Thus, the Predictability Project tests the assumption that crime patterns can be analyzed over time in a jurisdiction because recording practices seldom change within one jurisdiction over time.

Table B. Index Crime Characteristics of Jurisdictions in the Sample[a]

Jurisdiction in order of Population	Robbery		Aggravated Assault		Burglary		Larceny/Theft	
	1980 Rate	# per Month	1980 Rate	# per Month	1980 Rate	# per Month	1980 Rate	# per Month
Quincy	42	3*	202	6	1,643	51	4,096	134
Berwyn	83	b	45	b	1,244	b	1,528	b
Rock Island	330	12	527	15	2,979	99	5,341	185
Des Plaines	78	3*	119	7**	1,092	46	2,978	126
Skokie	63	3*	154	6**	1,279	55	2,963	161
Cicero	286	12	263	11	1,594	60	2,059	88
Elgin	160	7	252	12	2,389	97	3,874	183
Arlington Heights	27	1*	74	4*	982	54	2,367	150
Evanston	260	16	308	16	2,614	118	4,814	291
Joliet	394	22	670	46	2,666	145	5,157	292
Aurora	214	15	419	23	1,837	114	4,417	267
Decatur	168	10	231	17	1,780	109	4,686	310
Springfield	343	23	513	30	3,169	218	5,112	371
Peoria	284	30	812	89	2,785	253	5,509	506
Rockford	352	28	522	42	2,997	265	4,845	502
Chicago[c]	541	1,536	340	896	1,141	3,092	3,423	8,178

[a]Index offenses known to the police in 1980 per 100,000 population in 1980 (see Table A). Source: *Crime in Illinois* (1980). Springfield, Illinois: Illinois Department of Law Enforcement. Mean number per month, 1972 through 1983.

[b]Not calculated because of data quality problems (see Table A).

[c]For robbery and aggravated assault, mean number per month, 1974 through 1983. The mean number for each weapon type was firearm robbery (613), knife robbery (151), other-weapon robbery (184), strongarm robbery (588), firearm assault (248), knife assault (341), other-weapon assault (242), body-as-weapon assault (65). For burglary and larceny/theft, mean number per month, 1981 through 1983.

*Not analyzed because mean number of crimes per month was less than five.

**Des Plaines and Skokie had an average of more than five aggravated assaults over the entire time period 1972-1983, but an average of five or less per month in recent years. Therefore, they were not analyzed.

Analysis Method for Each Series

The following is a concise description of the standard method followed for the analysis of each time series. For a more detailed technical discussion of each step in the analysis, see Appendix 1

Time Series Pattern Description

Because basic description is a necessary prelude to time series analysis, the first step in the Predictability Project was to describe the pattern of change over time in each series. This was done by searching for the best ***time series pattern description***. A time series pattern description is a graph showing the original data with a superimposed ***line segment fit*** (see Figure 7).

A line segment fit is a series of straight line segments connected to each other; it is calculated by spline regression (Block, 1983). The best line segment fit chosen for a time series could be one straight line, a two-segment line, a three-segment line (as in the Rock Island burglary example, Figure 7), or a four-or-more-segment line. A computer program calculates a package of line segment fit alternatives, and the user chooses a fit that is simple yet accurate.[13] For more detail about time series pattern description, see Appendix 1, Grant (1985), and Block (1983).

For some series, pattern description analysis revealed possible data quality problems. These problems were resolved or corrected at this early stage of analysis.

Description of Seasonality

A complete description of patterns over time includes an answer to the question, "Is this series seasonal?" This question is not easily answered with a simple yes or no, but depends upon the working definition of seasonality.[14] At this descriptive stage of analysis, Kallek's (1978:15) simple and straightforward definition of seasonality was used:

> Seasonality refers to regular periodic fluctuations which recur every year with about the same timing and with the same intensity and which, most importantly, can be measured and removed from the time series under review.

To determine whether a series was seasonal according to this definition, the project used the diagnostic tests available in a standard seasonal adjustment computer package, the X-11 (see Appendix 1 and Block, 1984b). This analysis not only told us whether or not the series contained seasonal fluctuation by the above definition, but also provided, in cases in which the series was seasonal, estimates of the pattern of seasonal fluctuation--which months were high or low and the degree to which they were high or low.

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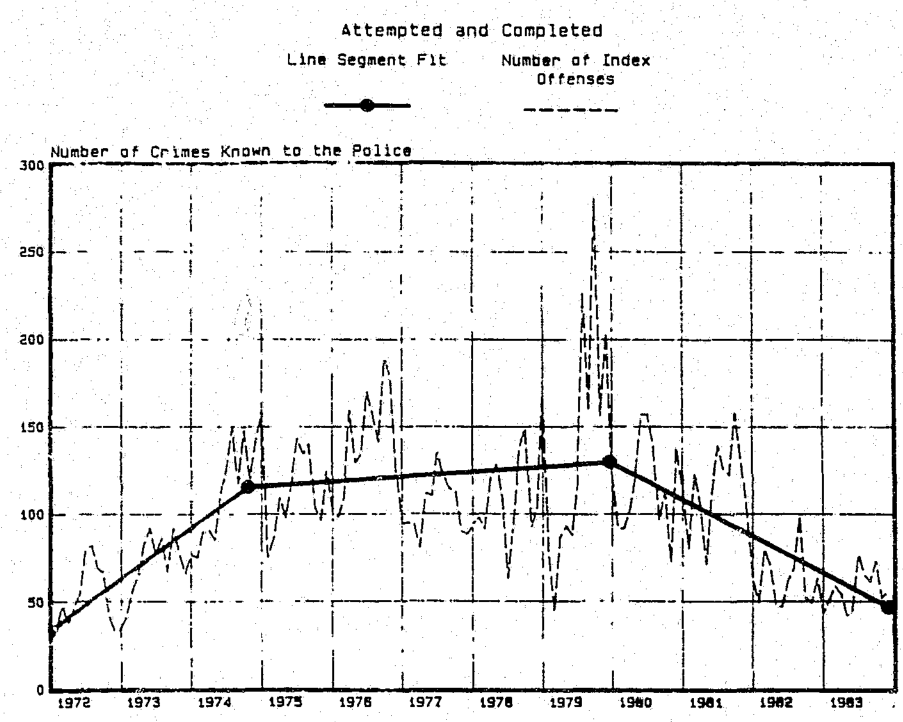
[13] The criterion for accuracy in the spline regression (line segment fit) program that is used at the Authority, like the criterion generally used in regression, is a minimum sum of squared residuals. See Block (1983) for more detail.

[14] For a complete discussion of alternative conceptual and operational definitions of seasonality, see Block (1984b).

Figure 7. Patterns of Change Over Time in Rock Island Index Burglary, 1972-1983



Months, January 1972 through December 1983

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Model Identification

An ARIMA model describes change over time in a variable by describing the relationship between each occurrence and the occurrence one, two, or more time periods previously. This is known as a description of the ***stochastic*** relationships in a time series. Each type of ARIMA model makes a different assumption about the stochastic relationships from one time period to the next.

Identifying the most appropriate ARIMA model to calculate future predictions of crime involves several stages of analysis. First, a series of tests are used to diagnose the relationships from month to month in a time series. Given the results of this diagnosis, the stochastic patterns in the time series are further explored with the Durbin-ARIMA method of analysis. Next, a model that seems appropriate according to the diagnostic tests and the Durbin-ARIMA analysis is fit to the data, or ***estimated***, using the Box and Jenkins method. If the model is not an adequate fit, the analyses are repeated. (See "Method of Choosing the Best ARIMA Model," page 22, and Appendix 1 for the specific tests used to diagnose the relationships from month to month in a time series.)

Durbin-ARIMA Analysis

Given an ARIMA model type, the mathematical calculation of the best fit is relatively straightforward (see Appendix 2). However, two or more ARIMA models that seem appropriate according to the initial diagnostic tests may produce entirely different projections (Pierce, 1980:130; Block, 1984b), and it is difficult to distinguish between the models. Therefore, in this analysis, we added a second diagnostic step: the Durbin-ARIMA analysis. As suggested by Roberts (1984), Durbin-ARIMA analysis is a method for exploring the stochastic patterns in a time series so that the most appropriate type of ARIMA model can be chosen.

Model Estimation: Box/Jenkins Fits

The most appropriate ARIMA model, given the model identification process and the Durbin-ARIMA analysis, was estimated using an iterative method developed by Box and Jenkins (1970). After the model is estimated, it is subjected to statistical tests of adequacy. The residuals of each model (the difference between the modeled estimates and the actual figures) are also subjected to statistical tests. (For details of these tests, see Appendix 1.) Those models that passed the statistical tests were used to calculate future predictions.

Analysis of Predictive Accuracy

Each model was developed with data through 1981, and was used to calculate predictions for each month of 1982. Actual 1982 figures were then compared to the predicted figures for each month, and two summary statistics were calculated--the percent error for the average month and the percent error for the year 1982 (the sum of all 1982 predictions compared to the total number actually occurring in 1982). If the model failed to predict within 30 percent for the average month or within 20 percent for the total year, the model was rejected and a search for a better one was conducted.

The 20 percent and 30 percent criteria were chosen as the maximum amount of error for which any definition of accuracy seems reasonable. The purpose was to eliminate those predictions that were the most inaccurate. Although predictive accuracy studies with economic data (for example, Dagum, 1979) usually use much stricter criteria for accuracy, previous Authority analyses indicate that accuracy with crime data may not be as great. In order to explore the variation of predictive accuracy from crime type to crime type and from jurisdiction to jurisdiction, a high maximum criterion for accuracy was chosen.

If the model predicted 1982 adequately, the model was then recalculated using data through 1982, and the months of 1983 were predicted. Again, these predictions were compared to the real figures, and the same criteria were used for accuracy--30 percent for the average month and 20 percent for the total year. If this prediction was not adequate, the search for a better model for the total series was conducted again, through 1983. Even though the model had been adequate for predicting 1982, the success of the model may have been a coincidence. In several cases, by reanalyzing the series at this point, not only was 1983 predicted more accurately with the revised model, but 1982 was also predicted more accurately. The reasons for this are twofold: 1) the identification of the best ARIMA model is not an entirely objective process (see Appendix 2); and 2) the series through 1982 was shorter than the series through 1983.

If the ARIMA model predicted 1982 successfully, but not 1983, the possibility that an intervention had occurred in 1983 was considered. In other words, there may have been some change in 1983, such as a crime prevention program, a sudden crime wave, or a change in recordkeeping, that resulted in a sharp increase or decrease in the number of offenses known to the police. Such an intervention is called a ***serendipitous intervention***, because it was not hypothesized at the beginning of the Predictability Project, but was discovered in the process of analysis. The analysis of each serendipitous intervention situation was a unique problem, and each is discussed in detail in the results. In these situations, the criteria for identifying the best model were that the model must meet statistical and predictive accuracy standards in at least two years. If, for example, a serendipitous intervention apparently occurred in 1983, and the criteria were therefore not met for 1983, then criteria had to be met for 1981 and 1982. In a number of time series, 1980 and other years were also analyzed.

1984 Predictions

Finally, if the ARIMA model through 1981 successfully predicted 1982 and the model through 1982 successfully predicted 1983, the model was then calculated using all data through 1983. This model was again subjected to the tests of model adequacy (see Appendix 1). If the model was not adequate, the entire process started again. At this point, any changes that were made were slight. If the model through 1983 was accurate, however, it was used to predict each month of 1984.[15] (At the completion of the analysis, actual 1984 data were not yet available to check the accuracy of 1984 predictions.)

Method of Measuring Predictive Accuracy

Two alternative methods were used to measure degree of predictive accuracy--the *year-ahead* method and the *intervention* method. Both are equally sound, but they answer different questions about predictive accuracy. The year-ahead method, as its name implies, predicts each month one year ahead. For example, a model based on the time period 1972-1982 might be used to predict each month of 1983. The year-ahead method would be used in most ordinary prediction situations, because usually we are interested in predictions that are farther in the future than the next month. The intervention method predicts only one month ahead and therefore would not be used to answer the question, "Is crime predictable?" The intervention method is useful as a diagnostic tool in the analysis of prediction error. Therefore, in research such as this, in which we are looking for the causes of error in predictions, the intervention method and the year-ahead method both provide necessary, though different, information.

The year-ahead method assumes that the underlying month-to-month pattern of the series, the ARIMA model, does not change, and that the analyst does not know the actual number of offenses that occurred in any month of the year being predicted. For example, using actual monthly data through December, a model was identified and used to predict crimes that would occur each month for the next 12 months. Thus, a year-ahead prediction for January, based on a model estimated on data through the previous December, benefits from knowledge of the number of offenses that actually occurred in December. However, in calculating a prediction for February, the year-ahead method uses the estimated, not the actual, January observation. By the time the following December is predicted, information on actual offenses is 12 months old.[16]

The intervention method (Roberts, 1984) is the same as the year- ahead method in that the monthly data in the year being predicted are not used to estimate the ARIMA model. However, the two methods differ in that the intervention method prediction uses actual data, not estimated data. For example, each month of 1983 is predicted with a model (an ARIMA equation) that was estimated on the time period 1972-1982. The ARIMA equation stays the same for each prediction, but the observation used with the ARIMA equation to predict each month is the actual observation, not an estimate. In a prediction of October, the intervention method assumes that the number of actual offenses in each month through September is known. However, the ARIMA equation, describing the relationship between each month and the preceeding months, is the same for the October prediction as it was for the January prediction.

[15]These 1984 predictions are too voluminous to include here, but are available on request from the Authority.

[16]This example assumes, of course, that the model in question describes each observation as related to the preceeding observation--these models are called ***first order*** models. In other types of ARIMA model, called ***second order*** models, the information to predict January would be taken from November (two months ago). For details, see Appendix 1, and "Method of Choosing the Best ARIMA Model," page 22.

Thus, like the year-ahead method, the intervention method assumes that the ARIMA model does not change. But in contrast to the year-ahead method, the intervention method assumes that the analyst knows the actual number of offenses that occurred in the previous month.

With the year-ahead method, a large prediction error could have at least two causes. The ARIMA model (description of the relationship between each observation and the next) could have changed or the level of the series (the number of crimes in a typical month) could have changed. The best ARIMA model could change without an actual change in crime level. Conversely the relationships from month to month in 1983 could be the same as the pattern of relationships in previous years, but the numbers could be all higher or lower in 1983. If 1983 observations are much higher than all previous observations, for example, the level of the series has increased, and predictions based on a 1972-1982 model probably would be too low. The intervention method helps determine whether the prediction error found with the year-ahead method was due to a change in model, a change in the level of the series, or both.

The cause of a large prediction error with the intervention method is likely to be a change in ARIMA model, not a change in the level of the series. If the level of offenses increased in 1983 but the ARIMA model did not change, for example, the 1972-1982 model would be too low in predicting January 1983. However, the February intervention-method prediction would be estimated using actual January data (but the same 1972-1982 equation). Since the ARIMA model relates each month to the next month, the February prediction will be corrected for the actual level of January.[17] Therefore, errors in prediction with the intervention method can be assumed to indicate a change in the model, not a change in the level.

Method of Choosing the Best ARIMA Model

The Predictability Study found the best possible ARIMA model for the following crime types and jurisdictions:[18]

1) each of four types of Index crime in 14 Illinois law enforcement jurisdictions,

2) each of four weapon types of Index robbery in Chicago and in total Illinois (non-Chicago), and

3) each of four weapon types of Index aggravated assault in Chicago and in total Illinois (non-Chicago).

To understand ARIMA models as they are discussed in this report, the following section provides a quick overview of ARIMA modeling and definitions of a few important terms. There are other sources available for a complete treatment of ARIMA models,[19] and more detailed information can also be found in Appendix 1.

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[17] Again, this assumes a first order model, but the same logic could apply to a second order or 12th order model.

[18] For some types of crime in some jurisdictions, the identification of an ARIMA model was not possible because the number of offenses in a typical month was five or fewer (see Table B). For Index robbery, these jurisdictions were Arlington Heights, Des Plaines, Quincy, and Skokie. For Index aggravated assault, only Arlington Heights had fewer than five offenses per month over all years, but Des Plaines and Skokie had fewer than five offenses per month in the final years of the series.

[19] For an elementary review of the ARIMA method, see Hoff (1983) or Block (1984b).

An Overview of ARIMA

ARIMA models are classified as (p,d,q)(Sp,Sd,Sq), where each term specifies the number of serial (month-to-month) or seasonal (every 12 months) autoregressive orders, degrees of differencing, or moving average orders. Most models contain zero, one, or two orders of autoregression (p) and zero, one, or two orders of moving average (q), and may require zero, one, or two degrees of differencing (d). In addition, an ARIMA model may or may not be seasonal, requiring one or two orders of seasonal autoregression (Sp), one or two orders of seasonal moving average (Sq), or one or two degrees of seasonal differencing (Sd) in the model. Therefore, to understand what an ARIMA model means, it is necessary to understand the concepts of autoregressive processes, moving average processes, and differencing.

In an *autoregressive* (AR) process, the current observation is a function of a past observation. An AR(1) autoregressive process means that the current observation is affected by the previous observation. An AR(2) autoregressive process means that the current observation is affected by the second previous observation. A seasonal autoregressive process, AR(12), means that the current observation is affected by the observation one year ago.

In a *moving average* (MA) process, the current observation is a function of a past *error*, not of the total observation. An error is a statistical term for the part of an observation that is unpredictable and unmeasurable. An MA(1) moving average process means that the current observation is affected by the error of the previous observation. An MA(2) moving average process means that the current observation is affected by the error of the second previous observation. A seasonal moving average process, MA(12), means that the current observation is affected by the error of the observation one year ago.

Before it is possible to identify an ARIMA model, it may be necessary to transform a time series by *differencing* (see Appendix 1 for detail). ARIMA models cannot be calculated unless there is no change over time in the level or the variance of the series. This condition is called *stationarity*. Most actual time series violate this condition. However, if they are transformed by differencing, the transformed data often can be modeled. In first differencing, each observation is subtracted from the neighboring observation. In 12th differencing, each observation is subtracted from the observation 12 months away.

Thus, the letters (p,d,q) and (Sp,Sd,Sq) summarize the autoregressive, differencing, and moving average components of an ARIMA model; p and Sp refer to serial and seasonal autoregressive processes, d and Sd refer to serial and seasonal degrees of differencing, and q and Sq refer to serial and seasonal moving average processes. For example, an ARIMA (2,1,0)(1,0,0) model contains AR(1), AR(2), and AR(12) processes, and required first (serial) differencing but not 12th (seasonal) differencing.

In effect, the terms (p,d,q)(Sp,Sd,Sq) describe the class of ARIMA model type. If two time series can be described by the same class of ARIMA model, they follow the same statistical patterns over time. They are similar in the relationship each observation in the series has to previous observations and later observations.

Criteria for ARIMA Model Identification

In the Predictability Project, the decision as to the best ARIMA model type was based on the following criteria:

1) Residuals of the model had to fluctuate randomly over time.

Residuals are the difference between the modeled figures and the actual figures. Thus, they are the month-to-month variation that the ARIMA model does not explain. See Appendix 1 for specific tests for random fluctuation.

2) The final model had to be simpler than alternative models (known as parsimony).

Of two ARIMA models, the model with any of the following characteristics was considered to be the simpler:

a) the model was autoregressive or moving average, but not both, and

b) the model contained fewer AR or MA terms (for example, an AR(1) model would be simpler than an AR(2) model).

3) The final model had to have better predictive accuracy for 1981, 1982, and 1983, year-ahead method, than alternative models. For the Chicago Intervention Analysis, the model had to have better predictive accuracy for 1981 and 1982.

Note that each model chosen as best was a better predictor for that series than alternative models, but not necessarily an adequate predictor according to the 20 percent yearly and 30 percent monthly criteria.

In some cases that are discussed in detail below, a model would predict several years accurately, but not one year. For example, a model might predict 1980, 1981, and 1983 accurately, but not 1982. In such a situation, we considered the possibility that a serendipitous intervention had taken place in the given year. In other words, some unexpected event may have occurred (a change in crime prevention or enforcement or a change in recordkeeping) that caused a rapid increase or decrease in the number of offenses. The identification of the best ARIMA model (or models) was complex in such situations, and the analysis is discussed for each case as it arises. However, the general rule in identifying the best model in such a series was that the model should predict within the 20 percent yearly and 30 percent monthly criteria in at least two years.

Chicago Intervention Analysis Method

The purpose of the Chicago Intervention Analysis was to use the time series analysis methods of the first part of the Predictability Project to answer a practical question: What was the effect of the change in crime recording practices in Chicago in 1983 on the number of offenses known to the police? Two methods of analysis were used to answer this question, both of them essentially descriptive--time series pattern description (see page 18 and Appendix 1), and an analysis of predictive accuracy over several years, as measured by the year-ahead method and the intervention method.[20] These analysis methods were part of a research design called an interrupted time series quasi-experiment with a nonequivalent no-treatment control group (Cook and Campbell, 1979:214) that is intended to measure the effect of a change, or intervention. This was done for eight types of crime: Index robbery and Index aggravated assault, by four weapon types.

[20]This project was limited to descriptive methods for analyzing an intervention because, at the time of the analysis, the exact specification of an ARIMA model to include the effect of an intervention (a transfer function) was very difficult to do with available Authority computer packages.

Because the reform in data collection and recording practices in Chicago in 1983 was intended to reduce the undercounting of crimes in official statistics, then it is reasonable to assume that the degree of change in the number of officially recorded crimes is related to the degree to which each crime had been previously undercounted. The degree of undercounting was hypothesized to be related to the seriousness of the crime. In order to control for the possible effect of crime seriousness on the likelihood that a crime would become officially recorded, each Index crime was divided into the smallest categories for which data are available in Chicago, that is, four weapon categories for each Index crime: firearm, knife, other weapon, and body-as-weapon (strongarm robbery and assault with hands, feet, etc.).

Thus, the Chicago intervention analysis used eight types of crime: firearm robbery, knife robbery, robbery with another weapon, strongarm robbery, firearm aggravated assault, knife aggravated assault, aggravated assault with another weapon, and aggravated assault with hands or feet as a weapon (for example, a karate attack). Note that these are Index crimes. Therefore, each category of robbery includes attempted robbery, and each category of aggravated assault includes aggravated assault (threat), aggravated battery, and attempted murder.[21]

The first step of the analysis was to find the best ARIMA model for the period 1974-1982.[22] To do this, the same analysis method was used for each series as in the first part of the Predictability Project. A model was identified for the period 1974-1980, and 1981 was predicted. If the 1981 prediction was accurate, the same type of ARIMA model was identified for the period 1974-1981, and 1982 was predicted. If the 1982 prediction was accurate, the same type of ARIMA model was identified for the period 1974-1982, and 1983 was predicted.[23]

The analysis then compared the predicted values to the actual values for 1983. All things being equal, if the change in Chicago's recordkeeping practices did not affect the number of crimes, then the 1983 prediction should be at least as accurate as the 1981 and 1982 predictions. Although it is never possible to be sure that all things are equal, the design of the Chicago Intervention Analysis used a control group to ensure that most things were equal. Specifically, to control for the possibility that some statewide change could have affected the number of offenses, the analysis used total Illinois (non-Chicago)[24] as a control group. If the change in the number of recorded offenses in Chicago was due to the change in the administration of recordkeeping that occurred at that time only in Chicago, then predictions for the total year and the average 1983 month in Chicago (year-ahead method) would be less accurate than predictions for 1983 for Illinois (non-Chicago) for the same crime. Thus, the Chicago Intervention Analysis had the usual design of a time series experiment (Cook and Campbell, 1979).

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[21] It is impossible to differentiate between completed and attempted Index robberies, or between the three types of Index aggravated assault (attempted murder, aggravated battery, and aggravated assault/threat) in Chicago during the time period of the study.

[22] Weapon-specific robbery data are not available before 1974 in Chicago, or before 1975 in the rest of the state. Weapon-specific assault data are not available in Chicago or the rest of the state before 1974. In addition, for some types of robbery or assault, the analysis had to begin with 1975 or 1976, because pattern description analysis and model-building analysis showed that the initial year or two of the series was different from the later years.

[23] In some cases, a serendipitous intervention was found in 1981. In these cases, a model for the period 1974-1979 was also identified. Each of these analyses is discussed in detail later in the paper.

[24] Total Illinois (non-Chicago) refers to the aggregate total of all crimes known to the police in Illinois outside of Chicago.

Patterns of Change Over Time

Before any attempt to forecast the future, it is necessary to describe the past. Therefore, the analysis of each time series began with two descriptive analyses: time series pattern description and descriptive seasonal analysis. The line segment graph, or spline regression line, produced by time series pattern description describes the overall patterns in the past, answering the questions:

- Did the number of offenses generally increase, decrease, or stay at the same level over the time period?

- Did the number of offenses change direction, for example, from increasing to decreasing?

- If the number of offenses did change direction, roughly when did that happen?

A descriptive seasonal analysis answers the question:

- Did the number of offenses fluctuate with the seasons, and if so, what was the pattern of this fluctuation?

Time Series Pattern Description

Time series pattern description served three purposes--a check for data quality, an exploration of possible discontinuous breaks or extremes in the series, and an exploration of stationarity in the series.[25] Although space does not permit a discussion of every pattern description here, this section will review the more interesting findings.

The line segment fits of a number of crimes analyzed in the Predictability Project showed a discontinuity between the first two years and the rest of the series. For some crimes, the number of offenses in the first year or two was much higher, and for other crimes the number was much lower, than in succeeding years. This was the case, for example, in Chicago Index firearm robbery (see Figure 8) and in Cicero Index burglary (see Figure 9). In both cases, the initial pattern description indicated that the first year or two of the time series might not follow the same ARIMA pattern as the other years. It is common knowledge among time series analysts that a new time series may produce different information in the first year or two following initial data collection than after data collection procedures become more familiar. A possible reason for this is that data definitions may become clearer after they have been used in the field for a year or two. In Illinois, 1972 was the first year the Department of Law Enforcement (now the Department of State Police) collected statewide Uniform Crime Report data, and 1974 was the first year in which Index robbery and assault data were collected by weapon type.

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[25] Stationarity, a term used in ARIMA modeling, refers to the requirement of constant level and constant variance. For details, see Appendix 1.

Figure 8. Patterns of Change Over Time in Chicago Index Firearm Robbery, 1974-1983

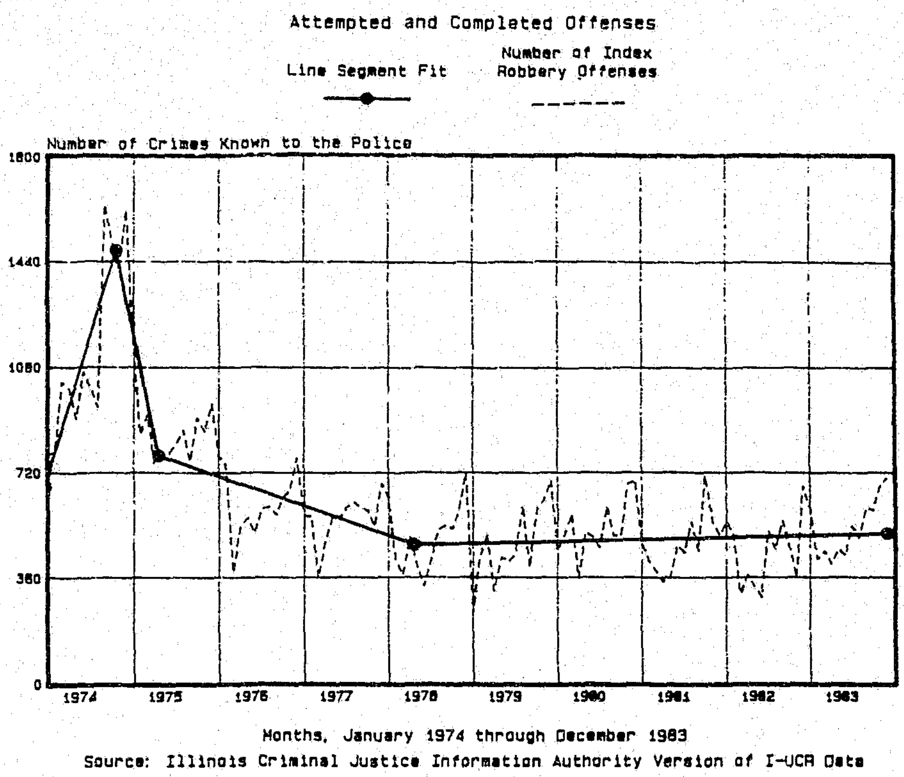
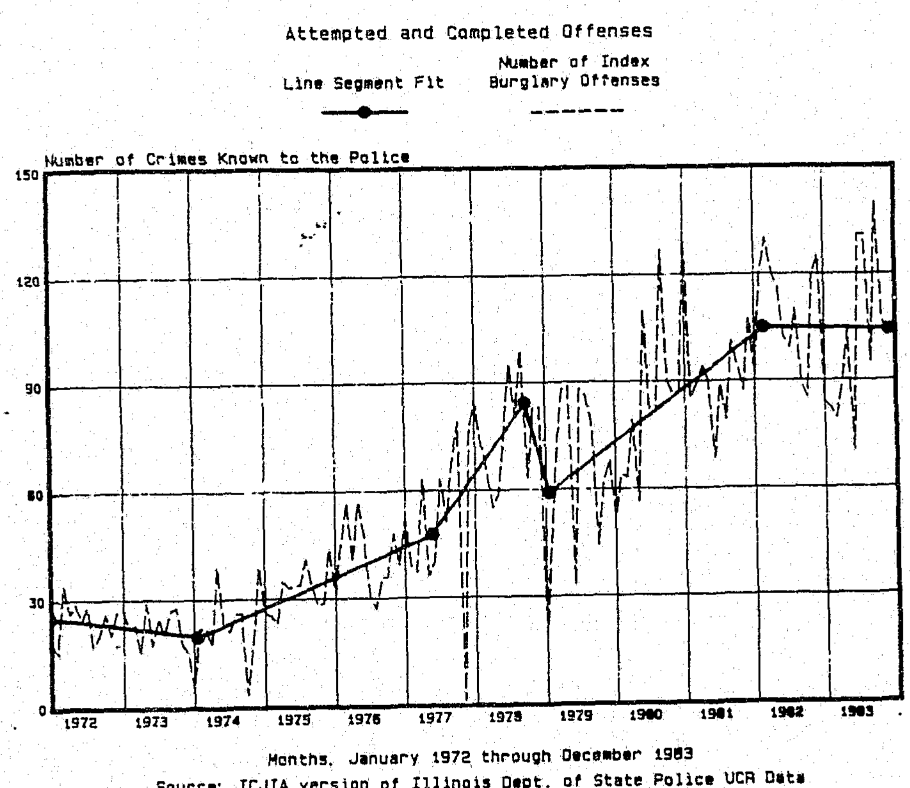


Figure 9. Patterns of Change Over Time in Cicero Index Burglary, 1972-1983



Exploratory time series pattern description also can help to identify apparent changes in data definition, either in a single month or between an earlier and a later time period. The existence of an outlier (an extremely high or low value) may be the first indication of a data definition problem that must be resolved before other analysis is possible. For example, in November 1977, the number of Index burglary offenses in Cicero (see Figure 9) dropped to zero--a situation highly unlikely considering previous monthly figures in Cicero. The pattern description of Cicero burglary also suggests a discontinuity (a sharp change) between the high number of offenses in 1978 and the relatively low number in 1979. Both the extremely low number of offenses in November 1977 and an apparent change or discontinuity in 1978-1979 are seen in every crime type analyzed in Cicero.

In Elgin Index robbery (see Figure 10), there were several extreme values in 1974.[26] This made it difficult to identify a good ARIMA model for the entire 1972-1983 period, but the period 1975-1983 was successfully modeled.

One of the decisions necessary for ARIMA modeling is whether the series is stationary (has a constant level and constant variance). If the series is not stationary, an ARIMA model is impossible to calculate unless the series is transformed in some way, such as first or 12th differencing (see Appendix 1). A graph helps to determine whether such a transformation is necessary. Figure 9 is an example of a series that is not stationary.

A graph with a superimposed line segment fit may also focus the analyst's eye on variations from the general fit, such as seasonal fluctuations or other cycles. It sometimes happens that a time series will fluctuate with the seasons during certain years, but not during other years. In the Cicero Index larceny/theft series for example (see Figure 11), a practiced eye might notice a cyclical pattern in 1978, 1979, and 1980 that is not apparent in earlier years. In fact, the ARIMA analysis for Cicero Index larceny/theft found two separate models, one for the period 1972-1977 and a second (with much more seasonality) for the period 1978-1983. Such cases of changing seasonality indicate that something basic about the time series, perhaps the way in which the data were collected, has changed.

As another example, a change in seasonal fluctuation in the time periods before and after 1979, which is suggested in the line segment fit of Evanston Index burglary (see Figure 12) and was also apparent in the descriptive seasonal analysis results, was the first indication that two different ARIMA models would be needed to describe the time series. Eventually, after considerable analysis, it was concluded that Evanston Index burglary followed one ARIMA pattern from 1972 to 1978 and another from 1979 to 1983 (see "Is Crime Predictable?-- Index Burglary," page 63).

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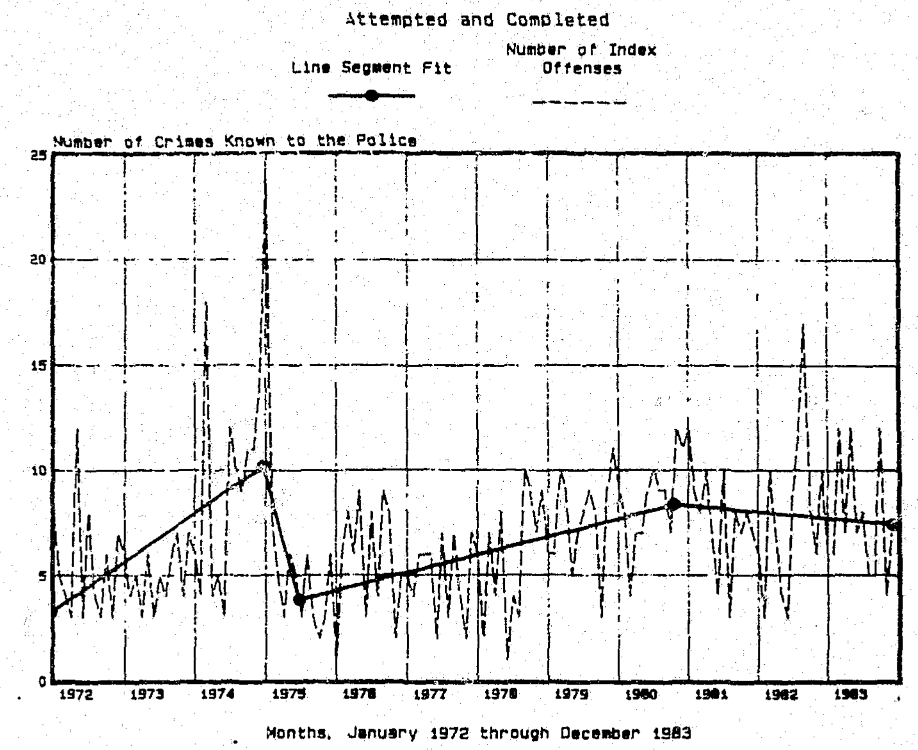
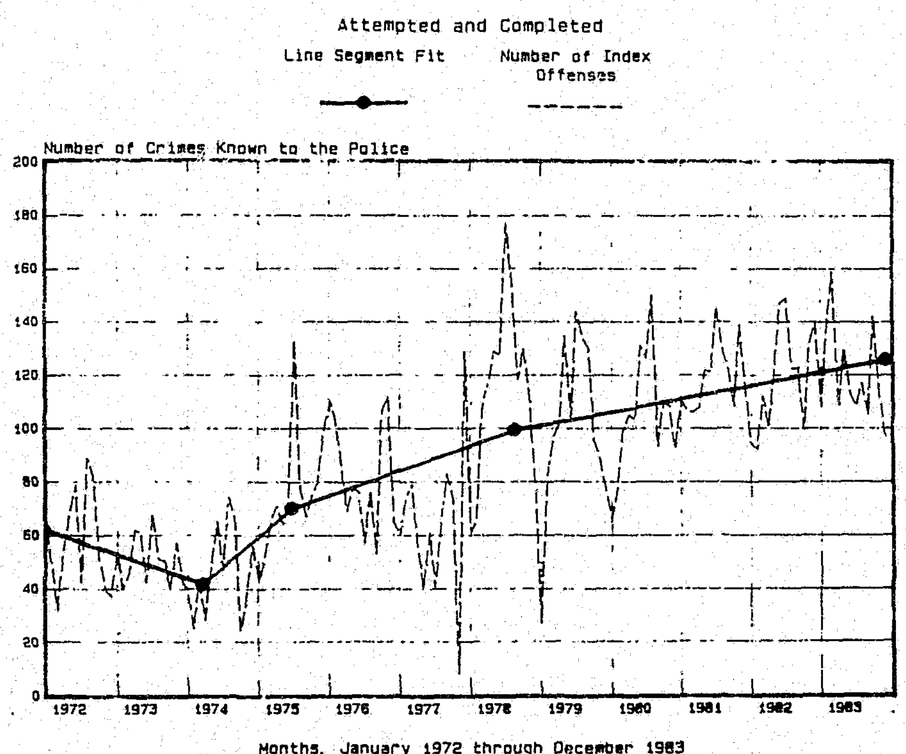
[26]The line segment fit for Elgin robbery (see Figure 10) is an exception to the general rule (see Appendix 1) that no line segment should be shorter than 12 months. The extreme values in 1974 created a discontinuity between 1974 and 1975, and the line segment fit in the graph was chosen so that this discontinuity would be described. The same thing happened in the line segment fit for Cicero burglary (see Figure 9).

Figure 10. Patterns of Change Over Time in Elgin Index Robbery, 1972–1983



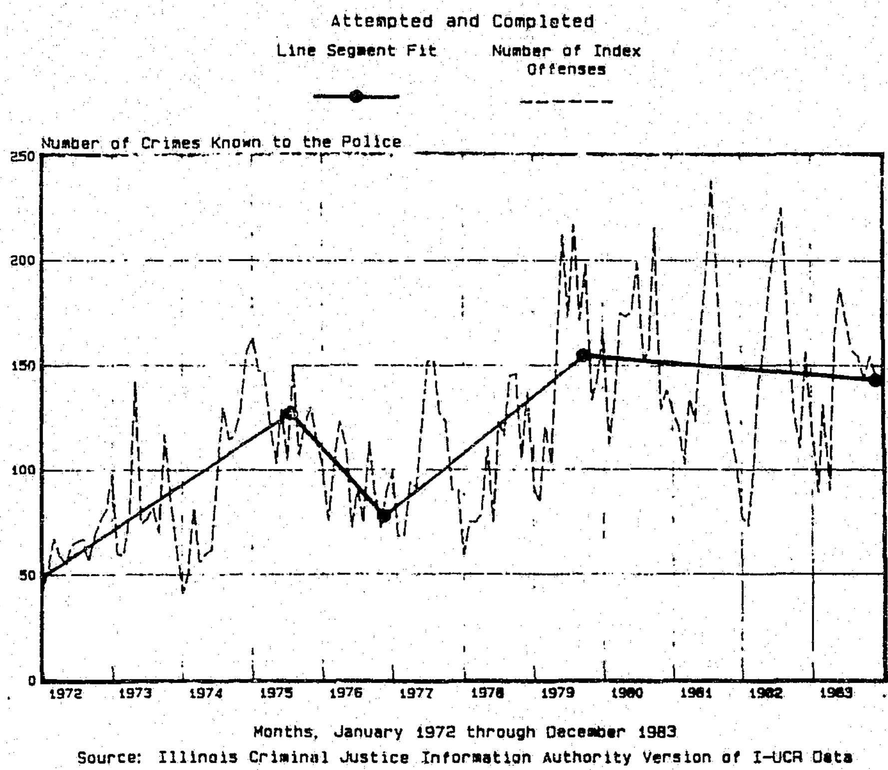
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 11. Patterns of Change Over Time in Cicero Index Larceny/Theft, 1972–1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 12. Patterns of Change Over Time in Evanston Index Burglary, 1972–1983



Descriptive Seasonal Analysis

This section presents the results of descriptive seasonal analysis using the component method. In this method, the time series data are divided into three components--the trend/cycle, the seasonal, and the irregular (error). Various statistics based on these components give the user an idea of the proportion of variation over time in the series that is due to the seasonal component, relative to the other components. Specifically, the statistics presented in the tables of this section include the contributions of the seasonal component and the irregular component to the month-to-month variation in the data (given as percents of the total month-to-month variation), and the stable seasonality F value. For details about these statistics, see Appendix 1 and Block (1984b).

As an indicator of the presence of seasonal fluctuation (at the descriptive stage of analysis), the Predictability Project used the Plewes rule of thumb (see Appendix 1), which relates the F of stable seasonality and the percent contribution of the irregular component over a one-month span.[27] The F value is analogous to a measure of significance.

In addition, the Predictability Project used the percent contribution of the seasonal component, which is analogous to a measure of association. Even if the Plewes criteria indicated no stable seasonality, when the seasonal component contributed at least 40 percent of the variance from month to month, the likelihood of seasonal fluctuation had to be seriously considered.

[27] For a more complete discussion, see Appendix 1, Block (1984b), and the studies listed in the latter's annotated bibliography.

The following summarizes the descriptive seasonal analysis results. Two criteria were used: the Plewes rule of thumb and the percent contribution of the seasonal component. Each descriptive seasonal analysis was conducted twice, once under the additive assumption of independent components, and once under the multiplicative assumption of dependent components (see Appendix 1).[28]

A final, but important, piece of information in the descriptive seasonal analysis results in tables C through F is that those analyses with a significant F of moving seasonality are starred. When a significant F of moving seasonality occurs, the results of the seasonal analysis are not trustworthy, and should be ignored. If the analysis under either the additive or multiplicative assumption, but not both, has a significant F of moving seasonality, use the results of the other analysis.

Index Robbery

None of the 10 Illinois (non-Chicago) jurisdictions for which Index robbery could be analyzed (see Table C) had significant seasonal fluctuation according to the Plewes criteria.[29] In only one jurisdiction was the contribution of the seasonal component over 40 percent; in Elgin (multiplicative assumption) it was 47 percent. However, the F value for Elgin robbery was relatively low. In contrast, firearm robbery and strongarm robbery in total Illinois (non-Chicago) showed a high seasonal contribution and a relatively high F value. However, Index robbery with a knife or another weapon showed no evidence of seasonal fluctuation, either in total Illinois (non-Chicago) or in Chicago.

Thus, robbery was not seasonal in any individual jurisdiction, according to the descriptive seasonal analysis. However, two types of robbery--firearm robbery and strongarm robbery--showed signs of seasonal fluctuation in Illinois (non-Chicago).

Index Aggravated Assault

None of the 12 Illinois (non-Chicago) jurisdictions for which Index aggravated assault could be analyzed (see Table D) contained a significant amount of seasonality according to the Plewes criteria, although Decatur, Peoria, and Springfield had seasonal contributions of at least 40 percent.[30] In the Decatur additive adjustment, the seasonal contribution was 40 percent, in the Peoria multiplicative adjustment, it was 44 percent, and in the Springfield multiplicative adjustment, it was 40 percent. In addition, the stable seasonality F values for these three jurisdictions were relatively high for aggravated assault, ranging from 8.3 in Decatur to 14.5 in Peoria.[31] This suggests that these aggravated assault series may contain some seasonal fluctuation.

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[28]Under the additive assumption, the three components are assumed to be independent; under the multiplicative assumption, they are assumed to be dependent (see Block, 1984b).

[29]The significant moving seasonality F for Rockford Index robbery and Chicago firearm robbery, additive adjustment, indicates that the results of the multiplicative adjustment (which does not have a significant moving seasonality F) should be used.

[30]The significant moving seasonality F values for Cicero and Springfield, and non-Chicago firearm, knife, and other-weapon Index aggravated assault, additive adjustment, indicate that the additive results are not trustworthy and that, therefore, the multiplicative results should be used. Elgin had significant moving seasonality F values under both the additive and the multiplicative assumption. This suggests a problem with the data (see "Is Crime Predictable?--Index Aggravated Assault," page 53).

[31]Decatur had an F of 7.3 under the multiplicative assumption, but because the F was higher under the additive assumption, we assumed that the additive assumption was correct. Thus the best F for Decatur is 8.3.

In contrast, the aggregate total of all Illinois (non-Chicago) Index aggravated assault showed a high seasonal contribution for every weapon type--from 41 percent for assault with a knife (additive adjustment), to 60 percent for other-weapon assault (additive adjustment). In fact, the total Illinois (non-Chicago) other weapon series comes close to meeting the Plewes criteria. In Chicago, the seasonal contributions are not as high, but again, the contribution for other-weapon assault is highest--52 percent in the multiplicative adjustment.

Table C. Index Robbery Seasonality Analysis: 1972-1983

	Additive Assumption			Multiplicative Assumption		
	Stable	% Contribution		Stable	% Contribution	
Jurisdiction	F value	Season.	Irreg.	F value	Season.	Irreg.
Arlington Heights[a]				Zero Observations		
Aurora	2.6	21%	75%	2.9	23%	75%
Cicero	1.4	20	80	Zero Observations		
Decatur	2.8	20	80	2.5	8	92
Des Plaines[a]				Zero Observations		
Elgin	2.9	40	59	3.1	47	53
Evanston	2.0	26	73	1.6	22	77
Joliet	1.5	19	81	1.2	12	88
Peoria	6.8	29	68	6.3	24	74
Quincy[a]				Zero Observations		
Rockford	7.5*	28*	72*	6.8	27	73
Rock Island	2.1	21	79	1.9	21	79
Skokie[a]				Zero Observations		
Springfield	6.6	32	66	7.1	32	67
Chicago**						
Firearm	9.5*	34*	64*	11.6	31	68
Knife	4.2	25	75	4.2	17	83
Other Weapon	5.0	21	79	5.1	15	85
Strongarm	6.0	21	79	6.0	19	81
Non-Chicago**						
Firearm	22.3	54	45	22.8	59	40
Knife	2.3	23	77	2.3	26	74
Other Weapon	2.9	18	81	3.0	17	83
Strongarm	15.6	40	59	17.1	42	58

[a]Not analyzed because mean number of crimes per month was less than five (see Table B).
*F value of moving seasonality greater than or equal to 2.41, indicating that this adjustment is not trustworthy.
**Years 1975-1983 analyzed.

Table D. Index Aggravated Assault Seasonality Analysis: 1972-1983

	Additive Assumption			Multiplicative Assumption		
	Stable	% Contribution		Stable	% Contribution	
Jurisdiction	F value	Season.	Irreg.	F value	Season.	Irreg.
Arlington Heights[a]				Zero Observations		
Aurora	3.6	31%	68%	4.0	32%	68%
Cicero	1.4*	18*	78*	Zero Observations		
Decatur	8.3	40	58	7.3	32	68
Des Plaines[a]				Zero Observations		
Elgin	5.2*	28*	71*	4.9*	25*	75*
Evanston	5.7	21	79	6.8	30	70
Joliet	2.9	23	74	1.8	26	72
Peoria	14.1	41	58	14.5	44	55
Quincy	1.3	19	81	Zero Observations		
Rockford	6.0	21	78	5.7	16	83
Rock Island	4.4	25	75	Zero Observations		
Skokie	3.3	28	71	3.0	22	77
Springfield	10.2*	41*	57*	10.9	40	58
Chicago**						
Firearm	17.9	40	59	14.7	38	62
Knife	11.9	32	67	11.2	29	71
Other Weapon	27.7	49	51	26.0	52	47
Hands, Feet, etc.	4.5	22	77	5.1	22	77
Non-Chicago**						
Firearm	20.0*	49*	49*	21.4	48	50
Knife	15.0*	41*	56*	17.5	42	56
Other Weapon	45.4*	60*	39*	54.8	60	40
Hands, Feet, etc.	17.3	42	55	20.7	42	56

[a]Not analyzed because mean number of crimes per month was less than five.
*F value of moving seasonality greater than or equal to 2.41, indicating that this adjustment is not trustworthy.
**Years 1974-1983 analyzed.

Index Burglary

None of the 14 Index burglary series (see Table E) was significantly seasonal according to the Plewes criteria.[32] The highest percent contribution of the seasonal component was in Rockford, with 46 or 47 percent. Since Rockford's stable seasonality F value was also high (21.6), Rockford burglary may fluctuate with the seasons. One other jurisdiction, Rock Island, had a high seasonal contribution (42 percent), but its stable seasonality F value was only 7.6. On the other hand, burglary in Peoria and Skokie had both relatively high seasonal contributions (38 and 34 percent, respectively) and relatively high F values (13.2 and 13.1, respectively), suggesting that some seasonal fluctuation was present.[33]

Table E. Index Burglary Seasonality Analysis: 1972-1983

	Additive Assumption			Multiplicative Assumption		
	Stable	% Contribution		Stable	% Contribution	
Jurisdiction	F value	Season.	Irreg.	F value	Season.	Irreg.
Arlington Heights	8.8	28%	71%	8.5	24%	76%
Aurora	3.7*	23*	73*	4.0*	21*	76*
Cicero	1.0	16	83	1.3	2	98
Decatur	3.4	22	77	3.0	21	77
Des Plaines	6.1	29	70	6.2	29	70
Elgin	2.6	30	67	3.0	30	66
Evanston	6.2*	32*	66*	5.7	27	69
Joliet	7.7	22	75	8.4	27	69
Peoria	13.2	38	60	12.9	39	60
Quincy	2.5	24	72	2.3	24	72
Rockford	21.6	46	51	19.0	47	51
Rock Island	7.4*	33*	63*	7.6	42	55
Skokie	13.1	34	64	13.1	32	66
Springfield	1.5	20	80	1.2	19	77

*Moving seasonal F value greater than or equal to 2.41. This indicates that the results of this adjustment are not trustworthy and should be ignored.

[32]The significant moving seasonality F values for Evanston and Rock Island Index burglary, additive adjustment, indicate that the additive results are not trustworthy and that the multiplicative results should be used. Aurora had significant moving seasonality F values under both the additive and the multiplicative assumption. This indicates a problem with the data.

[33]Because the additive F value was higher (13.2), the additive assumption was used here for Peoria. With the additive assumption, the seasonal contribution is 38 percent.

Index Larceny/Theft

Index larceny/theft (see Table F) showed the most seasonal fluctuation of the four Index crimes analyzed in the descriptive seasonal analysis.[34] The only larceny/theft series that showed no sign of seasonal fluctuation was Cicero [35] Although none of the 14 jurisdictions was significantly seasonal according to the Plewes criteria, nine had a seasonal contribution higher than 40 percent--Arlington Heights, Decatur, Des Plaines, Elgin, Evanston, Joliet, Peoria, Rockford, and Springfield.[36] The highest seasonal contribution was in Rockford, which had 67 percent. All of the larceny/theft series except Cicero had a stable F higher than 10.0, and eight of the 14 had values higher than 20.0.[37]

Table F. Index Larceny/Theft Seasonality Analysis: 1972-1983

Jurisdiction	Additive Assumption: Stable F value	Additive: % Contribution Season.	Additive: % Contribution Irreg.	Multiplicative Assumption: Stable F value	Multiplicative: % Contribution Season.	Multiplicative: % Contribution Irreg.
Arlington Heights	24.2	50%	50%	24.8	42%	57%
Aurora	49.2*	60*	38*	42.7*	60*	38*
Cicero	3.7	19	78	2.6	9	90
Decatur	43.8	52	46	46.3	52	47
Des Plaines	23.3	44	56	23.6	43	57
Elgin	19.4	53	46	20.1	53	46
Evanston	20.6	52	48	20.7	60	40
Joliet	16.1	52	45	17.3	55	43
Peoria	21.5	43	57	25.3	35	64
Quincy	10.5	35	63	11.4	36	61
Rockford	56.0	67	32	51.5	64	35
Rock Island	11.1	27	71	11.7	34	64
Skokie	14.9	37	62	14.1	35	65
Springfield	34.2	50	46	29.2*	46*	50*

*Moving seasonal F value greater than or equal to 2.41. This indicates that the results of this adjustment are not trustworthy and should be ignored.

[34] This is consistent with the findings of Block (1984a:25-28).

[35] ARIMA analysis indicates that Cicero Index larceny/theft was not seasonal before 1978, but may have become seasonal in the later years (see Figure 11).

[36] Aurora had significant F values for moving seasonality under both the additive and the multiplicative assumption. This indicates that the Aurora X-11 results cannot be trusted. Therefore, Aurora is not included in this list. Burglary in Aurora had the same problem; thus seasonal fluctuation of burglary and larceny/theft possibly changed over time in Aurora.

[37] Because both of Aurora's adjustments had a significant F of moving seasonality, neither can be used here.

Summary

Not one of these offense series contains enough seasonal fluctuation so that it meets the Plewes criteria for seasonality. However, a number of them had high seasonal contributions and stable F values, so that the presence of some seasonal fluctuation was a reasonable conclusion. This was especially true for Index larceny/theft, in which nine of the 14 jurisdictions had some indication of seasonality.

There is considerable variation in seasonal fluctuation from jurisdiction to jurisdiction for the same type of crime. The F of stable seasonality for Index larceny/theft, for example, varies from 3.7 in Cicero to 56.0 in Rockford (see Table F). The other Index crimes also vary widely in their F values. The stable F value for Index robbery (see Table C) varies from 1.4 (Cicero) to 22.8 (Illinois non-Chicago firearm); for Index aggravated assault (see Table D), it varies from 1.3 (Quincy) to 54.8 (Illinois non-Chicago other weapon); for Index burglary (see Table E), it varies from 1.3 (Cicero) to 21.6 (Rockford). In general, crime in some jurisdictions tends to fluctuate with the seasons, regardless of the type of crime, while crime in other jurisdictions does not.

This variation among jurisdictions in the amount of seasonal fluctuation in officially recorded criminal offenses may be evidence of variation from jurisdiction to jurisdiction in crime measurement. Block (1984a) argues that crime does not necessarily ***occur*** in seasonal patterns, but becomes ***officially known to the police*** in seasonal patterns. In other words, victim reporting practices and police recording practices--in some jurisdictions but not all--have the unintended effect of being more inclusive in some months (usually the summer) than in others. Thus, seasonality of crime within a jurisdiction may have more to do with the police department's data administration practices than with actual crime patterns.

The descriptive seasonal analysis discussed in this section is based on a different definition of seasonality than the ARIMA modeling method. The Plewes criteria are relatively conservative; they look for strong, consistent seasonal fluctuations. ARIMA models may sometimes include very small seasonal relationships, if by including them, the predictive accuracy is improved. Thus, even though none of these crimes was seasonal according to descriptive seasonal analysis, it is possible that the best ARIMA model may contain a seasonal term.

Discussion

This descriptive analysis of patterns of change over time was the basis of the unexpected assessment of time series data quality, which became a methodological goal of the Predictability Project. The simple description of each time series uncovered that some could not be analyzed (for example, Berwyn) and others could be analyzed only by some correction of the data (see footnotes to tables H, J, L and N).

Another indicator of data quality is that so many of these offense series contain significant moving seasonality. In previous analysis of numerous crime data series (Block, 1984a), the Authority found that moving seasonality was very unusual, and that, if moving seasonality did occur, it almost never occurred under both the additive and the multiplicative assumption, as happened with Aurora Index burglary and larceny/theft and Elgin Index aggravated assault. Moving seasonality may indicate some discontinuity or sudden change in data definition that violates the basic assumptions of descriptive seasonal analysis, and also of ARIMA modeling.

In addition to the discovery of missing or obviously incorrect observations, the initial descriptive analysis also pointed out characteristics of each time series that would affect later

ARIMA modeling. Discontinuities in the data were found, such as an increase or decrease after 1973, or the obvious changes in Rock Island Index aggravated assault after 1981, Decatur Index burglary after 1981, Evanston Index burglary after 1978, Rock Island Index burglary after 1978, or Cicero Index larceny/theft after 1977.

Is Crime Predictable?

Predictability by Type of Crime

In this section, the question, "Is crime predictable?" is answered. For each Index crime, we first discuss whether the crime was predictable by the yearly and the monthly criteria for accuracy in 1982 and 1983.[38] Second, we discuss the most common types of ARIMA model for each Index crime.

These analyses were done for four Index crimes and 14 jurisdictions, except in instances where there were too few offenses in the average month (five or fewer) for ARIMA analysis to be possible (see Table B). In addition, as part of the Chicago Intervention Analysis, predictability analyses were done for four types of robbery and four types of aggravated assault in Chicago and in total Illinois (non-Chicago). The total Illinois (non-Chicago) results are presented here, but not the Chicago results because 1983 was not expected to be predictable in Chicago. Predictability of Chicago Index robbery and Index aggravated assault will be discussed in the section, "Chicago Intervention Analysis" (page 115).

Index Robbery

The list below summarizes the results of the analysis of predictability of Index robbery in each of the 10 jurisdictions that had enough offenses per month for analysis and of the four weapon types of Index robbery in total Illinois (non-Chicago).[39] The list below includes, for each Index robbery series, the best-fitting type of ARIMA model (p,d,q)(Sp,Sd,Sq).

Models Meeting Yearly but not Monthly Criteria

	(p,d,q)(Sp,Sd,Sq)
Aurora	(2,1,0)(1,0,0)
Cicero	(1,0,0)(0,0,0)
Elgin (1975-1983)	(1,0,0)(1,0,0)
Evanston	(0,1,1)(0,0,0)
Rockford	(2,0,0)(0,1,1)
Springfield	(1,0,0)(1,0,0)

[38] Predictability for 1981 was also calculated. The results do not appear in the tables in this section, but are discussed in the narrative when applicable.

[39] The Chicago findings are not included here, but are discussed later in this report.

Serendipitous Intervention

Decatur (1982)	(0,1,2)(0,0,0)
Joliet (1982 & 1983)	(0,0,2)(0,0,1)
Peoria (1983)	(1,0,0)(0,1,1)
Rock Island (1982)	(0,1,1)(0,0,0)

Results for Total Illinois (non-Chicago)

Successful Predictions

Knife	(2,1,0)(1,0,0)
Other Weapon	(1,0,0)(0,0,0)
Strongarm	(0,1,2)(0,1,1)

Serendipitous Intervention

Firearm (1983)	(0,1,1)(0,1,1)

The robbery series in this list are categorized according to their degree of predictability for the total year and the average month of 1982 and 1983 with the year-ahead method as given in Table G. The criteria for a successful predictive model is very generous --accuracy within 20 percent for the total year and 30 percent for the average month, for both years. In cases where serendipitous intervention was discovered in 1982 or 1983, ARIMA modeling and prediction was done for 1981.[40] For Joliet, ARIMA modeling and prediction were done for 1980 and 1981. If a model did not successfully predict at least two years, it would have been categorized as a poor predictive model here.

Predictability

None of the index robbery local-level time series was predictable by both the yearly and monthly criteria in both 1982 and 1983. Robbery was predictable for the total years 1982 and 1983, though not on a monthly basis, in six of the 10 jurisdictions (Aurora, Cicero, Elgin, Evanston, Rockford, and Springfield). In contrast, all four weapon types of total Illinois (non-Chicago) index robbery were highly predictable (see Table G).[41]

The ability to predict the year but not the months may be related to the number of observations in each month. In the six local-level index robbery time series in which both years were predictable but the average month was not, the number of index robberies known to the police per month (see Table B) ranges from seven in Elgin to 23 in Springfield. Such a low number of crimes means that a 30 percent error in any given month would be relatively likely. For example, Aurora averaged 15 index robberies per month, so that an error of five either way would exceed the 30 percent criterion. In comparison, all the total Illinois (non-Chicago) index robbery time series contained higher numbers in the average month, and it was possible to

[40]Decatur met yearly but not monthly criteria in 1981 and 1983, but also had a possible intervention in 1982.

[41]Firearm robbery in Illinois (non-Chicago) was highly predictable in 1981 and 1982, although the drop in 1983 was not accurately predicted (see "Chicago Intervention Analysis," page 115).

predict the months more precisely.[42]

Support for the argument that predictive accuracy is related to the number of observations is found in a detailed look at the predictability of Index robbery in each jurisdiction in which the year was accurately predicted, but not the average month In the largest of these six jurisdictions--Springfield with 23 and Rockford with 28 Index robberies per month on the average (see Table B)-- the ARIMA model predicted the average month accurately in three of the four possible comparisons.[43] In both jurisdictions, the error of the 1982 prediction for the average month (year-ahead method) was only slightly over the criterion (31 percent in Rockford and 32 percent in Springfield) In contrast, Elgin, which averaged only seven Index robberies per month, did not reach the monthly predictability criterion in either year or by either method. Aurora, Cicero, and Evanston, with an intermediate number of Index robberies in the average month (15, 12, and 16, respectively), each met the monthly predictability criterion in two of the four possible comparisons. This may indicate that Index robbery is predictable both yearly and monthly in those jurisdictions where the number of occurrences in the average month exceeds 20 or 30, but predictable only yearly in those jurisdictions where the number per month is fewer.

Because the total of all Illinois (non-Chicago) robberies is much higher per month than any individual jurisdiction (see note 42), it might be expected that predictions would be more accurate. In fact, 1982 predictions were very accurate. For every weapon type, 1982 robberies were predicted within 10 percent with the year-ahead method. In 1983, however, only the prediction for strongarm robbery was within 10 percent. Actual firearm robbery offenses were 23 percent higher than the prediction, and actual knife and other-weapon robbery offenses were respectively 10 percent and 17 percent lower than the predictions. For both 1982 and 1983, all monthly predictions were within 30 percent. The worst monthly predictions, for other-weapon robbery, may reflect the relatively low numbers for that weapon type (34 per month).

In the other four jurisdictions (Decatur, Joliet, Peoria, and Rock Island), and in total Illinois (non-Chicago) Index firearm robbery, robbery was predictable in 1981, 1982, or 1983, but not in all years. In each jurisdiction, predictability results suggest that the level of Index robbery was unusually low in the year or years that could not be predicted successfully. At the same time, however, the total number of Index firearm robberies in Illinois (non-Chicago) increased in 1983. Thus, the drop in total Index robbery in Decatur, Joliet, Peoria, and Rock Island seems to have been contrary to an increase in one kind of robbery for the total state.

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[42]The mean number per month over the period 1975 to 1983 was 261 for firearm robbery, 62 for knife robbery, 34 for other-weapon robbery, and 295 for strongarm robbery.

[43]The four possible comparisons in Table G are year-ahead 1982 and 1983 and intervention 1982 and 1983.

Table G. Percent Error of Predictions: Robbery

Jurisdiction	Year-Ahead Method 1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month	Intervention Method 1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month
Arlington Heights[a]								
Aurora	6%*	10%*	23%*	54%	2%*	6%*	28%*	57%
Cicero	14*	6*	40	15*	12*	6*	41	14*
Decatur[b]	37	18*	65	54	0*	13*	30*	37
Des Plaines[a]								
Elgin	14*	6*	47	34	11*	4*	46	37
Evanston	5*	12*	47	27*	7*	2*	41	29*
Joliet[c]	99	74	111	86	2*	6*	31	36
Peoria[d]	1*	56	26*	69	1*	35	27*	49
Quincy[a]								
Rock Island[e]	71	10*	111	23*	30	8*	72	22*
Rockford	11*	16*	31	21*	8*	6*	30*	16*
Skokie[a]								
Springfield	7*	5*	32	22*	4*	2*	27*	21*
Chicago								
Firearm	17*	8*	26*	11*	11*	4*	24*	1*
Knife[f]	9*	20*	29*	26*	7*	19*	28*	26*
Other Weapon	2*	38	20*	36	3*	28	18*	28*
Strongarm	11*	42	18*	39	7*	27	20*	26*
Non-Chicago								
Firearm[g]	9*	23	13*	24*	0*	0*	11*	14*
Knife	1*	10*	14*	14*	2*	2*	15*	1*
Other Weapon	4*	17*	29*	27*	3*	10*	22*	23*
Strongarm	7*	1*	11*	12*	2*	3*	6*	12*

*Meets predictability criteria: 20 percent for total year predictions, 30 percent for average month predictions.

[a]Not analyzed because average number of crimes per month was less than five (see Table B).

[b]Predictions for 1981 in Decatur, using the same ARIMA model (0,1,2)(0,0,0), were much better than in 1982--within 8 percent for the year and 31 percent for the average month (year-ahead method). This suggests that 1982 was unusually low.

[c]Predictions for 1981 in Joliet, using the same ARIMA model (0,0,2)(0,0,1), were much better--within 7 percent for the year-ahead method and 12 percent for the intervention method. Year-ahead predictions for 1980 were within 14 percent for the year and 27 percent for the average month. The bad predictions in 1982 and 1983 suggest interventions in both years.

[d]In Peoria, the same ARIMA model (1,0,0)(0,1,1) predicted 1981 within 10 percent and the average 1981 month within 18 percent (year-ahead method).

[e]Predictions for 1981 in Rock Island, using the same ARIMA model (0,1,1)(0,0,0), were much better than predictions in 1982--within 10 percent with the year-ahead method and within 4 percent with the intervention method. This suggests that 1982 was an exceptionally low year for Index robbery in Rock Island.

[f]Based on an ARIMA model (0,0,0)(1,0,0) (see Table H).

[g]Predictions for 1981 were 1.5 percent too high for the year and 10 percent wrong for the average month (year-ahead).

Decatur

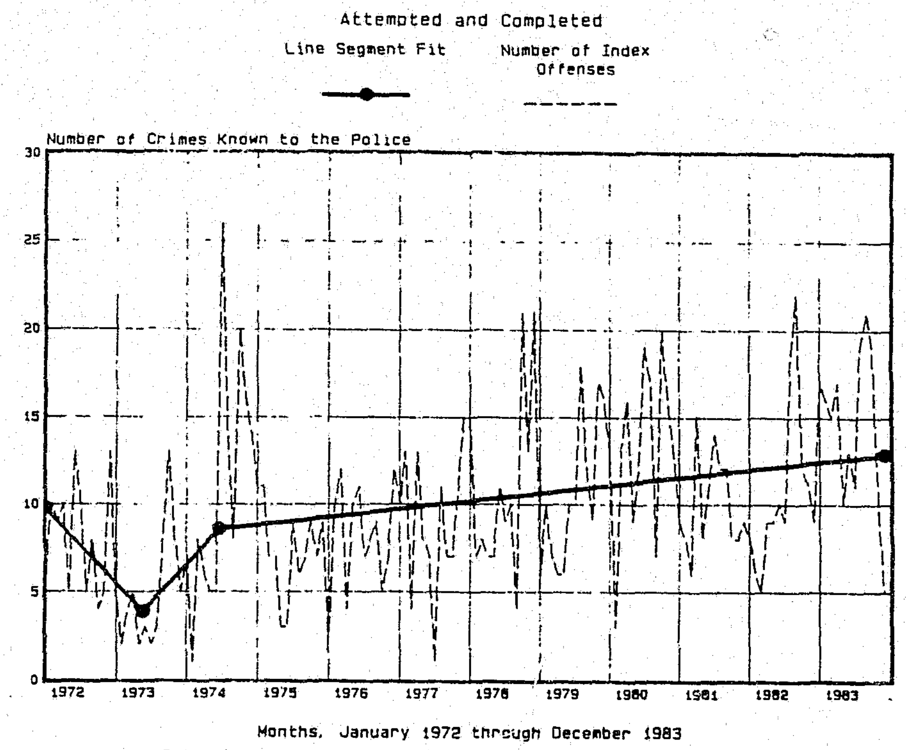
Although the best pattern description for Decatur robbery (see Figure 13) shows that the typical number of offenses increased steadily from 1974 through 1983, the ARIMA analysis indicates that the number declined from October 1981 to July 1982. All of the monthly predictions for this period were too high, and the total 1982 prediction (year-ahead method) was 37 percent higher than the actual number. In contrast to the low number of robberies in these 10 months, the number in the two following months, August and September 1982, was extremely high. However, even though the level of robbery appeared to fall in these 10 months, the best ARIMA model did not change. The same ARIMA model (0,1,2)(0,0,0) produced an almost perfect prediction of 1982, measured by the intervention method (see Table G). The 1983 prediction was within the 20 percent criterion, but was not particularly accurate (within 18 percent with the year-ahead method and 13 percent with the intervention method). This was partly due to another extreme month. In December, there were only five offenses, compared to the prediction of 18.2. Overall, the general impression of Decatur robbery in this analysis is that it contains a number of extremely high or low months, and is not very predictable.

Rock Island

The pattern of Rock Island Index robbery (see Figure 14) was also very erratic, especially in the years 1972 through 1981. An ARIMA model (0,1,1)(0,0,0) was a good statistical fit for this period, but the predictions this model generated were usually poor. As can be seen in the graph, high or low extreme months were frequent from 1972 to 1981. For example, the prediction for the year 1980 was 41 percent too high, and the prediction for the average 1980 month was in error by 72 percent (year-ahead method). One of the monthly predictions in 1980 was 357 percent wrong. In 1981, the prediction of the total year was much more accurate, within 10 percent, but the average error for 1981 months was 49 percent. Although the extreme number of offenses in August 1981 accounted for part of this inaccuracy, the predictions for other 1981 months were also in error, by as much as 181 percent. These large predictive errors in 1980 and 1981 do not seem to be the result of an intervention (a change in level or ARIMA model), but simply the result of erratic change from month to month that was not explained by the best model. In other words, Rock Island robbery seems to have been unpredictable during this period.

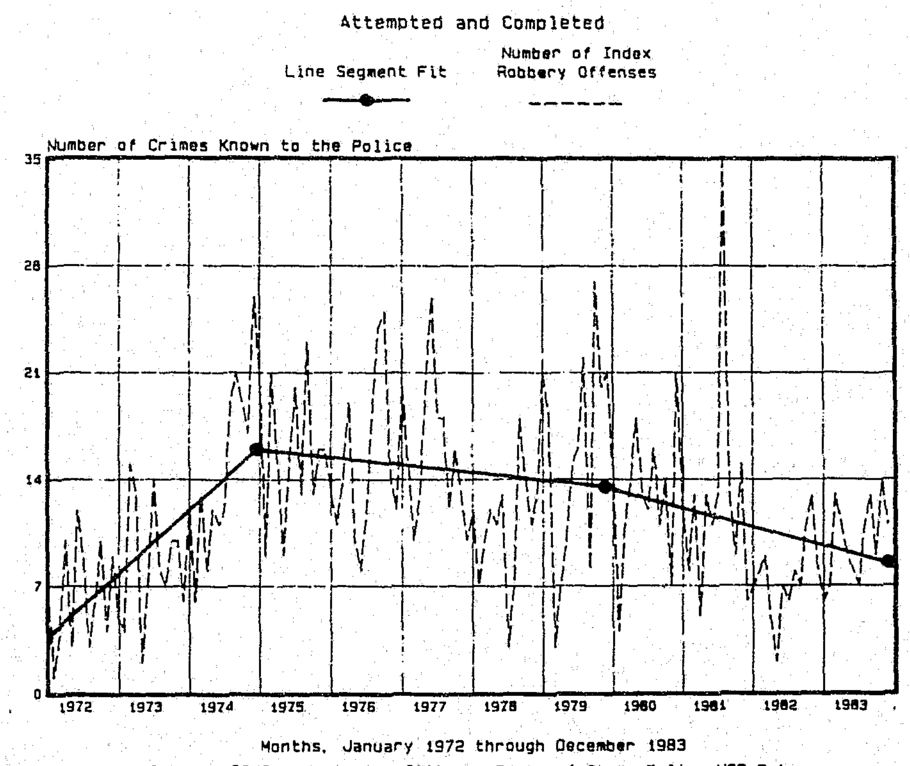
In contrast, the month-to-month pattern of Rock Island robbery seems to have become less erratic and more predictable in 1982 and 1983. There was a drop in 1982, which can be seen in Figure 14, and which was not predicted by the ARIMA model. However, in 1983 there was no extreme month, and the degree of predictability was very high, higher than in any other year analyzed. Thus, the years up to 1981 were erratic and therefore unpredictable, the year 1982 was unusually low and was therefore not accurately predicted, but 1983 was accurately predicted. If such an orderly month-to-month fluctuation continues, Index robbery will be predictable in Rock Island in the future.

Figure 13. Patterns of Change Over Time in Decatur Index Robbery, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 14. Patterns of Change Over Time in Rock Island Index Robbery, 1972-1983



Source: ICJIA version of Illinois Dept. of State Police UCR Data

Peoria

The drop in 1983 in Peoria Index robbery was found in the pattern description graph (see Figure 15), as well as in the ARIMA analysis The ARIMA model for Peoria Index robbery predicted the year 1981 within 10 percent, the average 1981 month within 18 percent, the year 1982 within 1 percent, and the average 1982 month within 26 percent (year-ahead method). Thus, if we were to consider only the years 1981 and 1982, Peoria would be the only individual jurisdiction in which Index robbery met both the yearly and the monthly predictability criteria. One reason for this may be that, of all the jurisdictions other than Chicago, Peoria had the most Index robbery offenses in the average month (30) (see Table B).

On the other hand, the 1983 prediction for Peoria Index robbery with the same ARIMA model (1,0,0)(0,1,1) was 56 percent too high, and the prediction for the average 1983 month was 69 percent wrong. Since the predictions calculated with the intervention method were also inaccurate for 1983 (see Table G), and since the ARIMA model is statistically good by the tests in Appendix 1 for the 1972-1980, 1972-1981, and 1972-1982 time periods, but not as good for the 1972-1983 time period, it is possible that the best model for Index robbery may have changed in 1983.[44] In any case, the level of robbery seems to have dropped in 1983 in Peoria.

Total Illinois (non-Chicago) Firearm Robbery

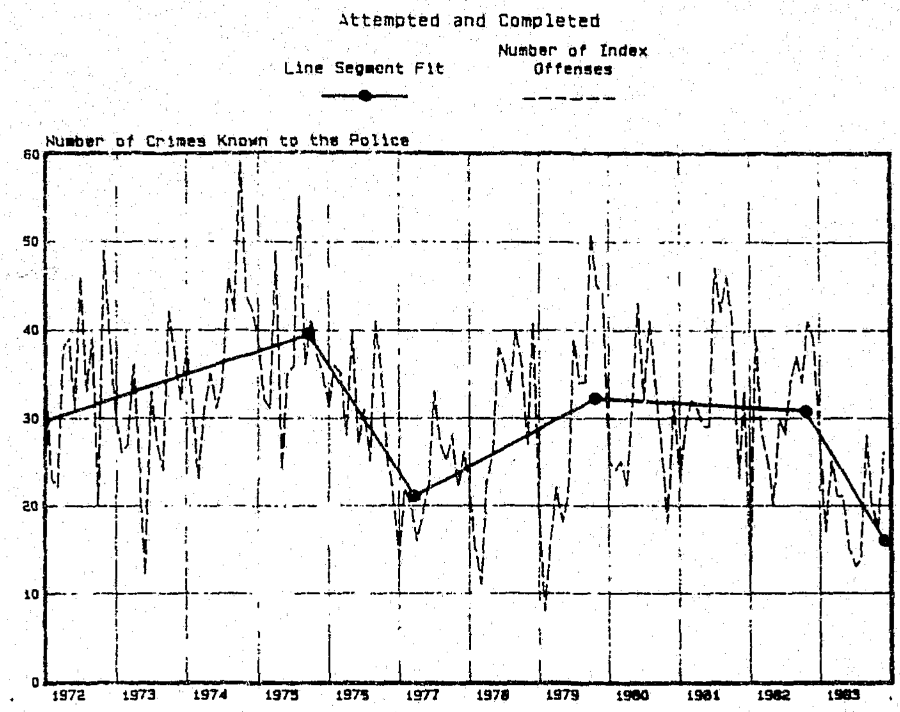
The number of Index firearm robbery offenses per month in total Illinois (non-Chicago) dropped steadily from a peak in 1979 to 1983 (see Figure 16). However, ARIMA analysis indicates that this steep decline may have stopped in mid-1983. Monthly predictions for July to December 1983 are all too low, by as much as 47 percent. In total, the number of firearm robbery offenses in 1983 was 2,406, but the predicted number was only 1,842, which is 23 percent too low. In contrast, the same model predicted the year 1981 within 2 percent and 1982 within 9 percent (year-ahead method). Also, the intervention method prediction for 1983 was very accurate, with an error of only 0.07 percent. Therefore, the ARIMA model appears to have remained the same, but the number of firearm robberies appears to have stopped declining, and leveled off, in the second half of 1983.

Joliet

In Joliet Index robbery (see Figure 17), the ARIMA analysis discovered drops in 1982 and in 1983. Predictions for both 1982 and 1983 were much higher than the actual numbers, 99 percent in 1982 and 74 percent in 1983 (year-ahead method). The predictions of the average month were even worse (errors of 111 percent in 1982 and 86 percent in 1983). However, predictions of 1981, using the same ARIMA model, were very good, within 7 percent (year-ahead method) and 12 percent (intervention method). Also, the 1980 prediction with the same model was accurate within 14 percent. The high degree of accuracy of the 1982 and 1983 yearly predictions with the intervention method (2 percent high and 6 percent high, respectively) suggests that the change in both years was a decrease in level, not a change in the best-fitting ARIMA model. This decrease in 1982 and 1983 can be seen in the pattern description graph of Joliet Index robbery, which shows a peak at the beginning of 1981 followed by a rapid decline.

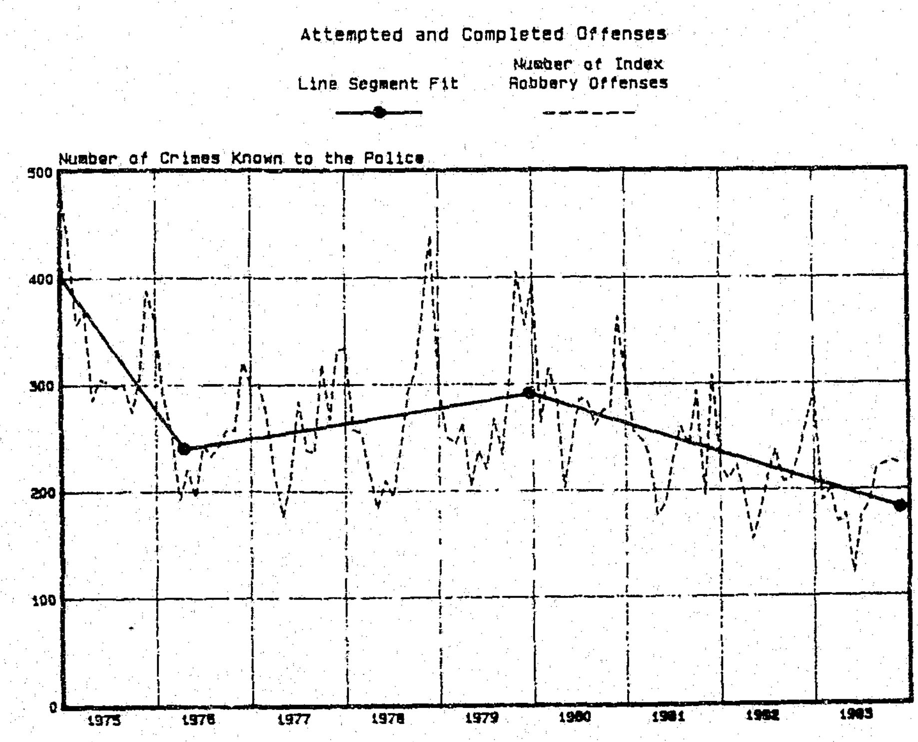
[44]There is conflicting evidence about a change in the ARIMA model for Peoria Index robbery. An ARIMA (2,0,0)(0,1,1) model is a better fit statistically for the period 1972-1983 than the ARIMA model (1,0,0)(0,1,1) in Table H. However, the (2,0,0)(0,1,1) model does not generate 1983 predictions (either method) that are any more accurate than (1,0,0)(0,1,1).

Figure 15. Patterns of Change Over Time in Peoria Index Robbery, 1972-1983



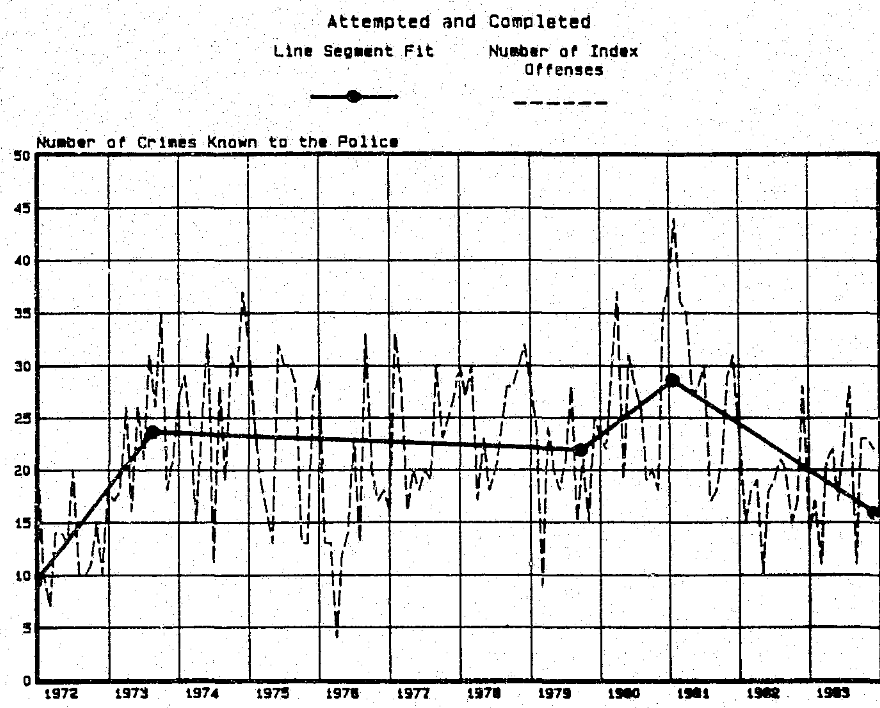
Months, January 1972 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 16. Patterns of Change Over Time in Illinois (non-Chicago) Index Firearm Robbery, 1975-1983



Months, January 1975 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 17. Patterns of Change Over Time in Joliet Index Robbery, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Summary

Thus, in four Illinois jurisdictions, the ARIMA predictions offer some evidence that a precipitous drop in the number of index robberies known to the police occurred in 1982 or 1983. In other words, an intervention of some kind may have occurred in index robbery in these four jurisdictions.[45] This is not, of course, experimental evidence of a time series intervention, because no intervention had been hypothesized in advance. The lack of predictive accuracy in one or two years does not tell us, in itself, whether there was an actual change in level or ARIMA model in that year, or whether robbery in that jurisdiction is simply unpredictable. The preponderance of evidence from both ARIMA analysis and pattern description suggests that robbery in Decatur was unpredictable. On the other hand, Rock Island robbery appears to have dropped in 1982, Peoria robbery to have dropped in 1983, and Joliet robbery to have dropped in 1982 and remained low in 1983. In contrast, the steady drop in total Illinois (non-Chicago) firearm robbery may have reversed at the end of 1983.

[45]As discussed earlier, Elgin (see Figure 10) may also have experienced a change or intervention, but in 1974. For this reason, the Elgin ARIMA model (see Table H) is based on data from 1975 to 1983.

Best ARIMA Models for Predicting Index Robbery

Is there a particular class of ARIMA model that seems to provide a better fit for Index robbery than others? Table H lists the ARIMA model type for each Index robbery series, and includes the parameters (estimated weights) for each term. For example, the Aurora model (2,1,0)(1,0,0) contains a seasonal autoregressive term, which means that each observation is related to the observation 12 months ago. The best estimate of the strength of this relationship (see under "Seasonal Autoregressive Estimate" in Table H) is .15, the low estimate is -.03, and the high estimate is .32. This means that the strength of the AR(12) effect is very small and may even be zero.[46] Thus, the Aurora model may be compared to other models containing an AR(12) term, such as Elgin, Springfield, and many of the Chicago and Illinois (non-Chicago) robbery series.

What similarities are there among these Index robbery ARIMA models? Very few of the models are exactly the same, if we consider both the serial part of the model (p,d,q) and the seasonal part (Sp,Sd,Sq) simultaneously. However, there are some similarities if we consider the two parts separately.

Serial Relationships

The most common model for serial relationships (p,d,q) in the 10 Illinois (non-Chicago) jurisdictions was ARIMA (1,0,0)(Sp,Sd,Sq), which described Cicero, Elgin, Peoria, and Springfield.[47] ARIMA (1,0,0)(Sp,Sd,Sq) is a very simple serial model that says that each observation is related to the preceeding observation. In Cicero and Elgin, this relationship was small (.15 and .25, respectively), and each of the low estimates reach or approach zero. In contrast, the estimated weight of the AR(1) relationship in Peoria and Springfield was moderate (.43 in Peoria and .40 in Springfield). In addition, the model for Index robbery in Rockford, ARIMA (2,0,0)(Sp,Sd,Sq), was similar, except that there were two autoregressive terms instead of only one. Both AR(1) and AR(2) weights were moderately high, indicating that Peoria, Springfield, and Rockford had similar serial terms in Index robbery ARIMA models.

The models of Evanston and Rock Island, ARIMA (0,1,1)(0,0,0), were similar to each other in both serial and seasonal terms. Both models thus required first differencing and a moving average term. The weights of the moving average terms (.75 and .81) were close to each other, and in fact, the estimates plus and minus two standard errors overlap each other. This means that, from the standpoint of an ARIMA model, the patterns over time in Index robbery in Rock Island and Evanston were essentially the same. In addition, the Peoria and Rockford ARIMA models were very similar to each other. If the Peoria model were actually ARIMA (2,0,0)(0,1,1) as analysis suggested may be the case (see note 44), models for the two jurisdictions would be the same.

The four total Illinois (non-Chicago) Index robbery series had models that were not unique, but similar to the best models in individual jurisdictions. The serial model for other-weapon robbery was the same ARIMA model (1,0,0)(Sp,Sd,Sq) as in Cicero, Elgin, Peoria, and Springfield, and the serial model for firearm robbery was the same ARIMA model (0,1,1)(Sp,Sd,Sq) as in Rock Island and Evanston. The ARIMA model (2,1,0)(1,0,0) for total Illinois (non-Chicago) knife robbery was the same as the model for Aurora robbery, and the serial model (0,1,2)(Sp,Sd,Sq) for total Illinois (non-Chicago) strongarm robbery was the same as the model for Decatur.

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[46] Although one criterion for model adequacy (see Appendix 1) was that the parameter estimate not cross zero plus or minus two standard errors, in this case, an ARIMA (2,1,0)(1,0,0) model with a very small AR(12) weight was better by other criteria than alternative models.

[47] The phrase ARIMA (1,0,0)(Sp,Sd,Sq) means that the (p,d,q) serial part of the ARIMA model is (1,0,0), but that the (Sp,Sd,Sq) seasonal part of the model could be anything.

It is interesting that the serial term for Chicago strongarm robbery before the hypothesized intervention in 1983 was similar to one of the two most common robbery models, (1,0,0)(Sp,Sd,Sq), and that the serial term after the intervention was similar to the other most common model (0,1,1)(Sp,Sd,Sq). The ARIMA models for the other Chicago robbery series, however, were more similar to each other than to models for the other Illinois jurisdictions.

Seasonal Relationships

These Index robbery time series show relatively little seasonal fluctuation in their ARIMA models. Five series--Cicero, Decatur, Evanston, Rock Island, and total Illinois (non-Chicago) robbery with another weapon--had no seasonal term (Sp,Sd,Sq) at all; in other words, the seasonal part of the model was ARIMA (p,d,q)(0,0,0). This agrees with the findings of the descriptive seasonal analysis (see Table C), where the F of Stable Seasonality was less than 3.0 in all cases.

Each of the best ARIMA models for four other jurisdictions--Aurora, Elgin, Joliet and Springfield--had an AR(12) or MA(12) seasonal term, but the estimated weights of these terms were small.[48] An ARIMA (p,d,q)(1,0,0) model was also the best fit for total Illinois (non-Chicago) knife robbery, but in this case the estimated weight of the seasonal AR (12) term was higher (.41).

In contrast, Peoria, Rockford, Chicago firearm robbery, total Illinois (non-Chicago) firearm robbery, and total Illinois (non-Chicago) strongarm robbery contained more seasonal fluctuation. Their models, ARIMA (p,d,q)(0,1,1), required seasonal differencing and an MA(12) term. Peoria and Rockford are the most populous non-Chicago jurisdictions in the study, and total Illinois (non-Chicago) firearm robbery and strongarm robbery had many more crimes per month than the other two robbery types (see note 42). It is possible, therefore, that a seasonal ARIMA term of (p,d,q)(0,1,1) will appear only if the number of observations is large. On the other hand, even though each of the four Chicago Index robbery time series had many observations per month (see Table B), only one--firearm robbery--was modeled by ARIMA (p,d,q)(0,1,1) for the seasonal term. Thus, a high number of observations may be a necessary but not a sufficient condition for the (p,d,q)(0,1,1) model.

The other three Chicago Index robbery time series, both before and after the hypothesized intervention in 1983, had the same seasonal term (p,d,q)(1,0,0) in the best ARIMA model, although the weight of this AR(12) term was usually very small. In addition, the best model for total Illinois (non-Chicago) knife robbery was also (p,d,q)(1,0,0). The fact that every ARIMA model for Chicago Index robbery, whatever the weapon type or time period, contained a seasonal term indicates that Chicago robbery fluctuated with the seasons, at least slightly.

Thus, the most common seasonal term in Illinois (non-Chicago) jurisdictions was no seasonal term, although a few jurisdictions had AR(12) or MA(12) models with very small estimated weights for the seasonal terms, and Peoria and Rockford had strong seasonal models. Also, the total Illinois (non-Chicago) type of robbery that had the fewest offenses in the average month--other-weapon robbery with 34 offenses per month--had no seasonal term in its best ARIMA model. In contrast, the best seasonal term in the two most populous jurisdictions and in the total Illinois (non-Chicago) robbery types with the most cases in the average month was either ARIMA (p,d,q)(0,1,1) or ARIMA (p,d,q)(1,0,0) with a large estimated AR(12) weight. In Chicago, the seasonal term was either ARIMA (p,d,q)(0,1,1) or ARIMA (p,d,q)(1,0,0).

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[48]The estimated weights are AR(1) = .15 for Aurora, AR(1) = .20 for Elgin, MA(1) = -.22 for Joliet, and AR(1) = .20 for Springfield (see Table H).

Table H. Index Robbery ARIMA Models, 1972-1983

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
			Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Aurora	(2,1,0)(1,0,0)	--	-.78	-.62	-.45	--	--	--	-.03	.15	.32	--	--	--
			-.45	-.28	-.12									
Cicero	(1,0,0)(0,0,0)	11.9	-.02	.15	.32	--	--	--	--	--	--	--	--	--
Decatur	(0,1,2)(0,0,0)	--	--	--	--	.57	.73	.89	--	--	--	--	--	--
						.03	.20	.37						
Elgin 1975-1983	(1,0,0)(1,0,0)	6.8	.06	.25	.44	--	--	--	.18	.20	.21	--	--	--
Evanston	(0,1,1)(0,0,0)	--	--	--	--	.64	.75	.86	--	--	--	--	--	--
Joliet	(0,0,2)(0,0,1)	21.5	--	--	--	-.51	-.35	-.18	--	--	--	-.39	- 22	-.05
						-.43	-.27	-.10						
Peoria[a]	(1,0,0)(0,1,1)	--	.27	.43	.59	--	--	--	--	--	--	.84	89	.94
Rockford	(2,0,0)(0,1,1)	--	.14	.31	.48	--	--	--	--	--	--	.83	.88	.93
			.22	.39	.56									
Rock Island	(0,1,1)(0,0,0)	--	--	--	--	.71	81	.91	--	--	--	--	--	--
Springfield	(1,0,0)(1,0,0)	22.7	.24	.40	.56	--	--	--	.05	.20	.35	--	--	--
Chicago Firearm[b]	(0,0,3)(0,1,1)	--	--	--	--		zero		--	--	--	.80	.87	.94
							zero							
						-.61	-.40	-.19						
Non-Chicago Firearm[c]	(0,1,1)(0,1,1)	--	--	--	--	.47	.62	.78	--	--	--	.79	.87	.95

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
			Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Chicago Knife														
1975-1982	(0,0,0)(1,0,0)	145.0	--	--	--	--	--	--	-.01	.11	.24	--	--	--
1975-1983	(3,0,0)(1,0,0)	149.2	-.09	.10	.30				.14	.15	.15	--	--	--
			-.03	.17	.37									
			.03	.24	.44									
Non-Chicago Knife[c]	(2,1,0)(1,0,0)	--	-.79	-.61	-.42	--	--	--	.23	.41	.59	--	--	--
			-.56	-.38	-.19									
Chicago Other-Weapon[c]	(0,0,3)(1,0,0)	186.0	--	--	--	-.51	-.33	-.15	-.05	.14	.33	--	--	--
						-.51	-.33	-.15						
						-.60	-.42	-.24						
Non-Chicago Other-Weapon[c]	(1,0,0)(0,0,0)	34.3	.24	.42	.60	--	--	--	--	--	--	--	--	--
Chicago Strongarm														
1975-1982	(1,0,0)(1,0,0)	539.1	.13	.33	.53	--	--	--	.02	.17	.32	--	--	--
1975-1983	(0,1,1)(1,0,0)	--	--	--	--	.41	.58	.74	.14	.34	.55	--	--	--
Non-Chicago Strongarm[c]	(0,1,2)(0,1,1)	--	--	--	--	.31	.51	.71	--	--	--	.82	.89	.96
						.02	.22	.41						

[a]Data for August 1979 are missing, and the figure for September 1979 was about twice as high as other Septembers. This is true for every Index crime. For this analysis, one half of the September figure was used for August and September.

[b]Model based on 1976-1983 data. MA(1) and MA(2) estimates crossed zero within two standard errors, and were set to zero in the final model.

[c]Model based on 1975-1983 data.

Summary: Index Robbery

The degree of accuracy of yearly predictions for Index robbery in the 10 jurisdictions analyzed was fairly good. In seven of them, predictions for at least one year were accurate within 10 percent (year-ahead method). Analysis in four of the 10 suggested that an intervention may have occurred in 1982, 1983, or in both years. Even these four jurisdictions, however, had accurate predictions in other years. For example, the Peoria model predicted 1981 within 10 percent and 1982 within 1 percent. Although Index robbery was not predictable in all years in those jurisdictions, the analysis did reveal some interesting information--that robbery in certain years was much lower than its normal level. In contrast, total Illinois (non-Chicago) Index firearm robbery was slightly higher in 1983 than its normal level.

In total Illinois (non-Chicago), the year-ahead predictions for strongarm robbery were within 10 percent in 1982 and 1983, and the predictions for firearm robbery were within 10 percent in 1981 and 1982. Predictions for knife robbery and other-weapon robbery were not, in general, as accurate, though they were within the 20 percent yearly and 30 percent monthly criteria. This may reflect the relatively low number of offenses per month in these two weapon types.

Predictive accuracy for the next year seems to be possible in Index robbery, but varies widely from jurisdiction to jurisdiction, and may also vary by weapon type. The most accurate 1982 and 1983 predictions were in Aurora and Springfield. In addition, Peoria predictions were very accurate in 1981 and 1982, but the drop in 1983 was not accurately predicted, and Rock Island predictions were within 10 percent in 1981 and 1983, but the drop in 1982 was not accurately predicted. No other jurisdiction had Index robbery predictions that came within at least 10 percent for at least two years. Thus, in general, Index robbery is predictable in the total year. However, in jurisdictions having fewer than 20 or 30 robberies per month, Index robbery is not predictable in the average month. The one jurisdiction in which Index robbery predictions were accurate both yearly and monthly for two years (1981 and 1982) was Peoria, which had 30 offenses per month.

While there is no single class of ARIMA model that fits every Index rob[illegible] time series, some model classes seem to appear more often than others. The ser[illegible] term, ARIMA (1,0,0)(Sp,Sd,Sq), was the most common, and ARIMA (0,1,1)(Sp,Sd,Sq) was the second most common. In general, robbery time series had either no seasonality or a very slight degree of seasonality in their best ARIMA model. Jurisdictions and robbery types with more Index robberies in the average month were more likely to have a seasonal term in the model than robbery time series with fewer observations on the average.

In summary, the analysis found the following to be true for Index robbery:

- The accuracy of Index robbery predictions varied widely from jurisdiction to jurisdiction.
- In many jurisdictions, Index robbery was predictable for the next year, but not for the next month.
- The predictability of Index robbery tended to be better in jurisdictions and robbery types with more offenses per month.
- Firearm robbery and strongarm robbery were the most predictable types of robbery in total Illinois (non-Chicago).
- The best model for Index robbery depended on the number of offenses per month. For example, jurisdictions with more robberies were more likely to have a seasonal model.

Index Aggravated Assault

The list below summarizes the results of the analysis of predictability of Index aggravated assault in each of the jurisdictions that had enough offenses per month for analysis (11 of the 14 jurisdictions) and of predictability in the four weapon types of Index aggravated assault in total Illinois (non-Chicago) [49] Quincy, which did not have enough cases for the analysis of Index robbery, did have enough for the analysis of aggravated assault (six per month) (see Table B). Cicero and Rock Island met yearly but not monthly criteria; they also had a possible intervention. Since poor predictability was expected in Index aggravated assault in Chicago in 1983, the Chicago findings are not included here, but are discussed in the section, "Chicago Intervention Analysis." The list below also includes, for each Index aggravated assault series, the best-fitting type of ARIMA model (p,d,q)(Sp,Sd,Sq).

Successful Predictive Models

	(p,d,q)(Sp,Sd,Sq)
Evanston	(3,0,0)(0,1,1)
Joliet	(0,1,1)(0,0,0)
Peoria	(0,1,1)(2,0,0)
Rockford	(0,1,1)(0,1,1)
Springfield	(2,1,0)(2,0,0)

Models Meeting Yearly but not Monthly Criteria

Aurora	(0,1,1)(1,0,0)
Elgin	(0,0,2)(1,0,0)

Serendipitous Intervention

Cicero (1983)	(0,1,1)(0,0,0)
Quincy (1983)	(3,0,0)(0,0,0)
Rock Island (1972-1981)	(0,1,1)(0,0,0)
(1972-1983)	(0,1,1)(0,0,1)

Poor Predictive Model

Decatur	(0,1,1)(0,1,1)

Results for Total Illinois (non-Chicago)

Successful Predictions

Firearm	(3,0,0)(0,1,1)
Knife	(1,0,0)(0,1,1)
Other Weapon	(1,0,0)(0,1,1)

[49] Although this predictive accuracy analysis was not done with Skokie, seasonality analysis was done (see Table D).

Serendipitous Intervention

Body-as-Weapon (1983) (1,1,0)(0,1,1)

Predictability

The exact degree of predictability for each Index aggravated assault time series, for the total year and the average month of 1982 and 1983, and for the year-ahead and intervention method, is given in Table I, and the overall results of the year-ahead predictive accuracy analysis are summarized in the list above. The criteria in this list for a successful predictive model are very generous--accuracy within 20 percent for the total year and 30 percent for the average month, for both years. One model, in Decatur, did not meet even these criteria, and is therefore categorized as a poor predictive model. Two models, in Aurora and Elgin, met the yearly but not the monthly criterion. In cases of a serendipitous intervention being discovered in 1982 or 1983, ARIMA modeling and prediction was done for 1981. For Cicero, it was done for 1980 and for 1981.[50]

Predictability was somewhat more successful in Index aggravated assault than in Index robbery, perhaps because the average number of occurrences per month was higher in most jurisdictions. In five of the 11 Illinois (non-Chicago) jurisdictions in which ARIMA analysis could be done (Evanston, Joliet, Peoria, Rockford, and Springfield), Index assault was predictable with the year-ahead method for 1982 and 1983, for the average month as well as the total year. In Evanston, Joliet, and Rockford, both yearly predictions were accurate within 10 percent (see Table I). These five jurisdictions had relatively high numbers of assaults per month, ranging from 16 in Evanston to 89 in Peoria. In three of the four Illinois (non-Chicago) Index aggravated assault time series, each of which had at least 250 offenses per month, the models also generated successful yearly and monthly predictions with the year-ahead method in both years, all within 10 percent for the year and 15 percent for the average month.[51]

Index assault in three jurisdictions--Aurora, Elgin, and Rock Island--was predictable in both 1982 and 1983, but not always in the average month. Because Aurora had 23 Index assaults per month over the 12 years, and Elgin and Rock Island had 12 and 15, respectively, the lack of accuracy in monthly predictions could be due to low numbers. Compared to Index robbery predictions, which were often based on even lower numbers, Index aggravated assault predictions were better. In Aurora, the 1983 average month was predicted within 38 percent, and in Elgin it was predicted within 31 percent.[52] In Index robbery by comparison, the prediction for the average 1983 month was 54 percent wrong in Aurora and 34 percent wrong in Elgin.[53]

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[50]Cicero and Rock Island met yearly but not monthly criteria for at least two years; they also had a possible intervention.

[51]The average number of offenses per month from 1974 to 1983 was 317 for firearm assault, 294 for knife assault, 285 for other-weapon assault, and 396 for body-as-weapon assault.

[52]Rock Island was unusual, in that a change in model type may have occurred. See the following sections for details.

[53]The significant moving seasonality under both the additive and the multiplicative assumption for Index aggravated assault in Elgin indicates a possible data quality problem. See "Descriptive Seasonal Analysis," page 31. Aurora burglary and larceny/theft, but not aggravated assault, had the same problem.

Table I. Percent Error of Predictions: Aggravated Assault

	Year-Ahead Method				Intervention Method			
Jurisdiction	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month
Arlington Heights[a]								
Aurora	12%*	13%*	30%*	38%	5%*	4%*	34%	36%
Cicero[b]	14*	49	44	47	3*	8*	58	36
Decatur[c]	50	12*	50	47	14*	12*	20*	34
Des Plaines[a]								
Elgin[d]	10*	17*	19*	31	20*	3*	23*	25*
Evanston	6*	3*	25*	20*	2*	1*	27*	21*
Joliet	5*	1*	22*	16*	1*	1*	21*	18*
Peoria	14*	3*	18*	14*	2*	4*	15*	16*
Quincy	5*	23	38	31	5*	13*	47	30*
Rock Island[e]	11*	15*	29*	42	5*	8*	29*	41
Rockford	2*	8*	22*	23*	0*	7*	17*	22*
Skokie[a]								
Springfield	2*	15*	14*	25*	2*	4*	13*	19*
Chicago								
Firearm	16*	35	18*	31	2*	8*	17*	16*
Knife[f]	10*	38	23*	37	12*	16*	14*	17*
Other Weapon	5*	45	16*	38	0*	17*	19*	17*
Hands, Feet, etc.	1*	36	27*	34	12*	15*	34	20*
Non-Chicago								
Firearm	5*	9*	10*	12*	2*	4*	9*	8*
Knife	3*	5*	6*	8*	7*	2*	7*	7*
Other Weapon	6*	8*	9*	11*	1*	3*	6*	11*
Hands, Feet, etc.[g]	16*	29	16*	36	3*	8*	8*	13*

*Meets predictability criteria: 20 percent for total year predictions, 30 percent for average month predictions.

[a]Not analyzed because average number of crimes per month was less than five (see Table B). In Des Plaines, the mean over-all number from 1972 to 1983 was 7.3 per month, but the mean from 1975 to 1983 was 5.0 per month. In Skokie, the mean from 1972 to 1981 was 6.3 per month, but the mean in 1982 and 1983 was 4.5 per month.

[b]With the same ARIMA model (0,1,1)(0,0,0), 1981 was predicted within 18 percent for the year and 30 percent for the average month (year-ahead method).

[c]The 1982 predicted monthly values for November and December 1982 were negative.

[d]An ARIMA model (0,0,2)(0,0,1) yielded better forecasts for 1982 but worse forecasts for 1983 than an ARIMA model (0,0,2)(1,0,0) (see Table J). The model used in this table was (0,0,2) (0,0,1).

[e]Based on an ARIMA model (0,1,1)(0,0,0) (see Table J). With this model, predictions for 1981 were within 3 percent (year-ahead) and 1 percent (intervention).

[f]Based on an ARIMA model (0,1,1)(0,1,1) (see Table J).

[g]The same ARIMA model (1,1,0)(0,1,1) predicted 1981 within 1 percent (year-ahead) and 0 percent (intervention).

The predictability analysis of Index aggravated assault, like the analysis of Index robbery, suggested that interventions may have taken place in some series. However, serendipitous interventions were not as common in aggravated assault as in robbery, and the presence of an intervention was not always so clear-cut. For example, the 1983 prediction in Quincy was 23 percent too low, but this may reflect the extremely small number of offenses in Quincy (six in the average month).

Total Illinois (non-Chicago) Index Aggravated Assault with Hands, Feet, etc.

The 1983 prediction for Index aggravated assault with the body as a weapon in Illinois (non-Chicago) (see Figure 18) was 29 percent too high, even though 1981 was predicted within 1 percent and 1982 within 16 percent.[54] Although the prediction for January 1983 was fairly accurate, every prediction after that was too high. The degree of error increased over time, until the prediction for December was too high by 107 percent. As Figure 18 shows, the number of body-as-weapon assaults in Illinois (non-Chicago) dropped sharply in 1983, after having climbed steadily since 1977.

Cicero

In Cicero, the pattern of Index aggravated assault over time was very erratic (see Figure 19). Although an ARIMA model (0,1,1)(0,0,0) fits well statistically in every time period examined, the predictive errors of this model are large in every time period. The model was 41 percent too low in predicting 1978, 62 percent too low in predicting 1979, and 103 percent too low in predicting 1980 (year-ahead method), indicating that some change in Cicero aggravated assault took place in all three years. Predictions for 1981 and 1982, with the same model, were somewhat better, 18 percent too low and 14 percent too low, respectively. Because these predictions were within the 20 percent criterion, Cicero assault technically qualifies as predictable, although its predictability over the years 1978 to 1982 is borderline at best. In 1983, the same ARIMA model (0,1,1)(0,0,0) was 49 percent too low in predicting the 300 actual offenses, an average error of 47 percent in each 1983 month. As the pattern description graph shows, there may actually have been a sharp increase in 1983, over and above the general increasing pattern since 1976. However, given the consistently poor performance of Cicero aggravated assault predictions in almost every previous year, it does not seem likely that this serendipitous intervention indicates an actual increase in offenses known to the police.[55]

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[54]The degree of predictability decreases from 1981 to 1982 to 1983, but there is no indication that the ARIMA model changed for total Illinois (non-Chicago) Index assault with the body as a weapon. The AR(1) and MA(12) weights are almost the same for models of time periods 1972-1980, 1972-1981, 1972-1982, and 1972-1983. Also, the Box-Pierce statistic (see Appendix 1) indicates that the residuals are random for models of each time period.

[55]In Cicero, because the number of Index aggravated assaults in the average month over the entire 1972-1983 period was only 11, it is not surprising that monthly predictions do not meet the 30 percent criterion.

Figure 18. Patterns of Change Over Time in Illinois (non-Chicago) Index Aggravated Assault with Hands, Feet, etc., 1974-1983

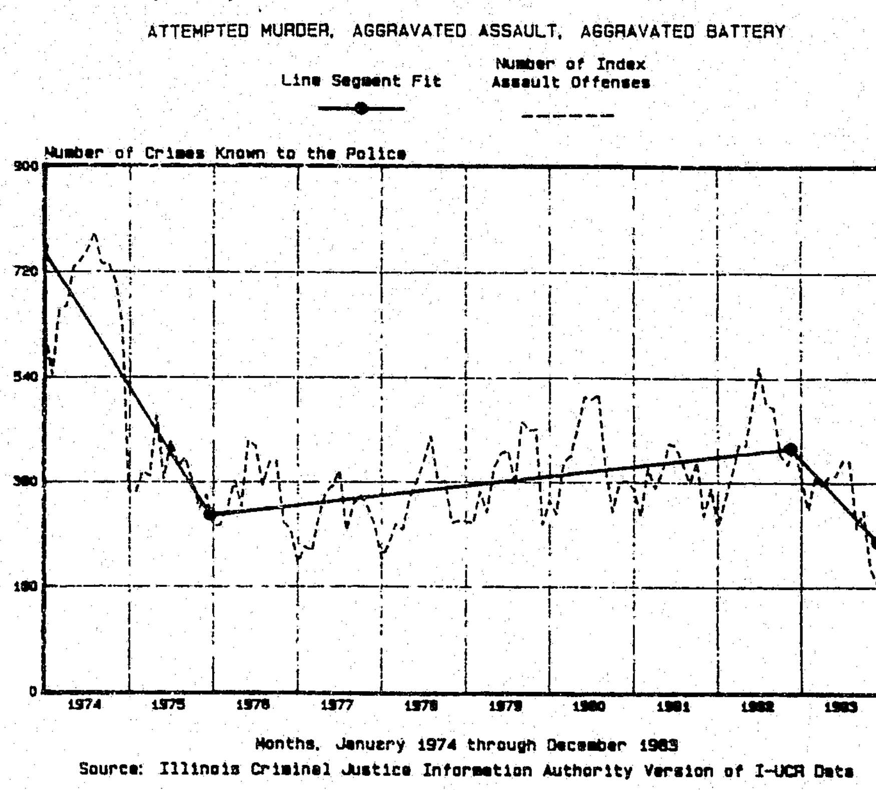
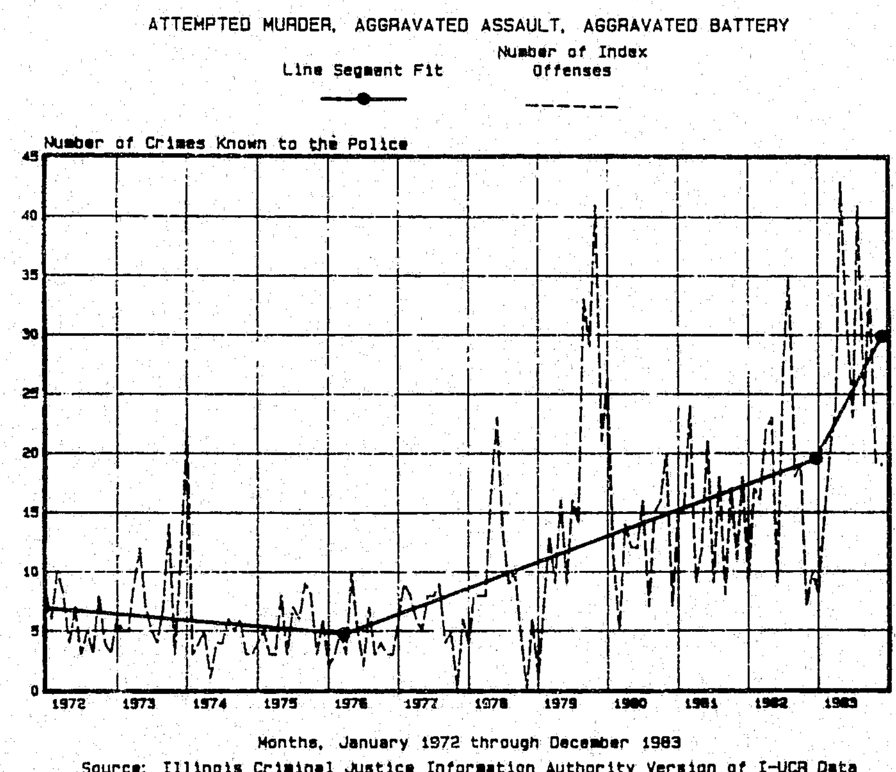


Figure 19. Patterns of Change Over Time in Cicero Index Aggravated Assault, 1972-1983



Decatur

The Decatur Index aggravated assault series was very difficult to model, and the best model generated very poor predictions. The best 1981 prediction was 70 percent too high, and the prediction of the average 1981 month was 134 percent wrong (year-ahead method). Although predictions for 1982 and 1983 were somewhat better than for 1981, they still did not meet the rather generous 20 percent and 30 percent criteria. The best model predicted 1982 within 50 percent, the average 1982 month within 50 percent, 1983 within 12 percent, and the average 1983 month within 47 percent (year-ahead method) (see Table I).

Two extreme values, in November and December 1981, affected the accuracy of both 1981 and 1982 Decatur predictions. However, predictability was not improved by correcting the two extreme values. It is worth noting that the Decatur Index robbery series contained numerous high or low extreme months and was not really predictable, even though it did meet the 20 percent yearly criterion in two years.

Best ARIMA Models for Predicting Index Aggravated Assault

Is there a particular class of model that tends to fit Index aggravated assault? Table J lists the best ARIMA model for each Index aggravated assault time series. As with Index robbery, we will consider the two parts of the model separately, the serial (p,d,q) part and the seasonal (Sp,Sd,Sq) part.

Serial Relationships

The serial term of the ARIMA model for aggravated assault in many jurisdictions--Aurora, Cicero, Decatur, Joliet, Peoria, Rockford, and Rock Island--was best described by ARIMA (0,1,1)(Sp,Sd,Sq).[56] The estimates of the MA(1) weight in these models were all positive and relatively high, ranging from .46 in Joliet to .82 in Aurora. In addition, the same ARIMA serial term (0,1,1)(Sp,Sd,Sq) was the best model for Chicago Index knife robbery in the later years. In general, if an Index assault series required first differencing, the best serial model was usually ARIMA (0,1,1)(Sp,Sd,Sq).[57]

Only two other types of ARIMA model were best for more than one aggravated assault time series. The best model in Springfield and Chicago firearm assault was ARIMA (2,1,0)(Sp,Sd,Sq); the related ARIMA (1,1,0)(Sp,Sd,Sq) was the best model in body-as-weapon Index assault in total Illinois (non-Chicago). The other model that appeared more than once was ARIMA (3,0,0)(Sp,Sd,Sq) in Evanston, Quincy, Chicago knife assault in the early years, and Illinois (non-Chicago) firearm assault.

Seasonal Relationships

In Index aggravated assault models, there was less consistency in the seasonal term than in the serial term. Three jurisdictions--Cicero, Joliet, and Quincy--had no evidence of seasonal fluctuation, and in Rock Island, seasonal fluctuation was evident only in the final two years. All the Chicago and the total Illinois (non-Chicago) Index assault series, as well as eight of the 11 Illinois (non-Chicago) jurisdictions, had some sort of seasonal ARIMA model. However, the form of this model differed.

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[56] Since the Decatur model is not a good fit statistically, the reader should place little emphasis on Decatur results.

[57] For a discussion of first differencing, see Appendix 1.

The seasonal term in all four of the total Illinois (non-Chicago) assault types, all four of the Chicago assault types, as well as Index assault in three other jurisdictions--Decatur, Evanston, and Rockford--was ARIMA (p,d,q)(0,1,1).[58] Aurora, Elgin, Peoria, and Springfield had models with one or two autoregressive seasonal terms, ARIMA (p,d,q)(1,0,0) or ARIMA (p,d,q)(2,0,0). Thus, while most Index aggravated assault series had some evidence of seasonality in the best ARIMA model, some had no seasonal term at all. Of the assault series with a seasonal term, some indicated a very slight amount of seasonality, such as Rock Island in the final two years, and others indicated strong seasonal fluctuation, such as Peoria and Springfield.

Model Change in Rock Island

Even though 1982 and 1983 predictions for aggravated assault were within the 20 percent criterion in Rock Island, predictive accuracy with the year-ahead method decreased steadily from 3 percent in 1981 to 11 percent in 1982 to 15 percent in 1983. In addition, the best ARIMA model for the period 1972-1981 did not meet statistical tests after 1982 and then 1983 were added to the series, as well as it did for the 1972-1981 period alone. Together, these facts suggest that Index aggravated assault in Rock Island, like Index robbery in Rock Island, changed in 1982 and 1983 relative to the pattern in earlier years.

The early years in Rock Island show no evidence of seasonal fluctuation, but a seasonal term improves the model in the final two years. The best model for the period 1972-1981 was ARIMA (0,1,1)(0,0,0), but the addition of a seasonal term, ARIMA (0,1,1)(0,0,1), produced a statistically better model for 1972-1983. Because an ARIMA model cannot be estimated with only two years of data, it was impossible to estimate a separate model for 1982 and 1983. However, the strength of the MA(12) parameter appears to increase over time:

	Estimates	
Time Period	MA(1)	MA(12)
1972-1981	.74	-.08
1972-1982	.73	-.10
1972-1983	.71	-.13

Even though the MA(12) weight is still very small in the 1972-1983 model and could be estimated to be zero (see Table J), the statistical diagnostics (Appendix 1) are good. If this pattern continues, the best model for Index aggravated assault in Rock Island will have an even stronger MA(12) weight when 1984 and succeeding years are added to the data.[59]

Predictive accuracy for 1982 and 1983 was better with the ARIMA model (0,1,1)(0,0,1). The year 1982 was predicted within 1 percent, the average 1982 month within 35 percent, the year 1983 within 7 percent, and the average 1983 month within 35 percent (year-ahead method). Because the number of Index aggravated assault offenses per month in Rock Island is only 15 (see Table B), the low accuracy of monthly predictions is not surprising.

[58]The high MA(12) estimates in these ARIMA (p,d,q)(0,1,1) seasonal terms, which range from .86 for Chicago firearm assault to .92 for Illinois (non-Chicago), and Chicago other-weapon assault, may indicate that seasonal differencing was not necessary (see Appendix 1).

[59]The model used to predict 1984 was ARIMA (0,1,1)(0,0,1).

Table J. Index Aggravated Assault ARIMA Models, 1972-1983

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
			Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Aurora	(0,1,1)(1,0,0)	--	--	--	--	.73	.82	.92	.03	.20	.37	--	--	--
Cicero[a]	(0,1,1)(0,0,0)	--	--	--	--	.40	.54	.68	--	--	--	--	--	--
Decatur	(0,1,1)(0,1,1)	--	--	--	--	.61	.73	.85	--	--	--	.81	.87	.92
Elgin	(0,0,2)(1,0,0)	11.8	--	--	--		zero[b]		.18	.32	.45	--	--	--
						-.45	-.28	-.12						
Evanston	(3,0,0)(0,1,1)	--	.03	.20	.38	--	--	--	--	--	--	.85	91	.97
			-.03	.14	.32									
			.03	.20	.37									
Joliet	(0,1,1)(0,0,0)	--	--	--	--	.31	.46	.61	--	--	--	--	--	--
Peoria[c]	(0,1,1)(2,0,0)	--	--	--	--	.50	.63	.76	.19	.33	.47	--	--	--
									.33	.48	.62			
Quincy	(3,0,0)(0,0,0)	6.2	-.00	.16	.32	--	--	--	--	--	--	--	--	--
				zero[b]										
			.13	.29	.45									
Rockford	(0,1,1)(0,1,1)	--	--	--	--	.59	.71	.85	--	--	--	.81	.87	.92
Rock Island														
1972-1981	(0,1,1)(0,0,0)	--	--	--	--	.63	.76	.87	--	--	--	--	--	--
1972-1983	(0,1,1)(0,0,1)	--	--	--	--	.60	.71	.83	--	--	--	-.30	-.13	.05
Springfield[d]	(2,1,0)(2,0,0)	--	-.73	-.57	-.41	--	--	--	.04	.19	.34	--	--	--
			-.45	-.29	-.13				.34	.49	.65			
Chicago Firearm[e]	(2,1,0)(0,1,1)	--	-.76	-.55	-.35	--	--	--	--	--	--	.76	.86	.96
			-.42	-.21	-.01									

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Non-Chicago Firearm[f]	(3,0,0)(0,1,1)	--	.30	.50	.70	--	--	--	--	--	--	.84	.90	.97
			.14	.35	.56									
			-.34	-.14	.06									
Chicago Knife 1974-1980	(3,0,0)(0,1,1)	--		zero[b]		--	--	--	--	--	--	.73	.85	.96
				zero[b]										
			.01	.24	.48									
1974-1983	(0,1,1)(0,1,1)	--	--	--	--	.51	.66	.81	--	--	--	.80	.86	.95
Non-Chicago Knife[f]	(1,0,0)(0,1,1)	15.3	.20	.38	.56	--	--	--	--	--	--	.81	.87	.93
Chicago Other-Weapon[f]	(2,0,0)(0,1,1)	--	.51	.69	.88	--	--	--	--	--	--	.87	.92	.97
			.07	.25	.44									
Non-Chicago Other-Weapon[f]	(1,0,0)(0,1,1)	9.4	.23	.41	.59	--	--	--	--	--	--	.86	.92	.98
Chicago Hands, Feet, etc.[e]	(0,0,3)(0,1,1)	--	--	--	--	-.45	-.26	-.06	--	--	--	.82	.88	.94
						-.45	-.25	-.05						
						-.63	-.44	-.24						
Non-Chicago Hands, Feet[f]	(1,1,0)(0,1,1)	--	-.56	-.38	-.20	--	--	--	--	--	--	.86	91	.96

[a]November 1979 is an extreme value, 41. The mean of all other Novembers is 6.6.

[b]MA(1) parameter crossed zero in Elgin, and MA(1) was set to zero in the final model. In Quincy, the same thing happened with the AR(2) parameter.

[c]Data for August 1979 are missing and the figure for September 1979 was about twice as high as other Septembers. This is true for every Index crime. For this analysis, one half of the September figure was used for August and September. Updated figures obtained from the Department of State Police.

[d]Updated figures obtained from the DSP.

[e]Model based on 1975-1983 data.

[f]Model based on 1974-1983 data.

Summary: Index Aggravated Assault

Compared to Index robbery, Index aggravated assault was more often predictable for both years and for both the total year and the average month. However, this may have been due to the higher number of assault offenses per month in most jurisdictions. In Index robbery, all of the total Illinois (non-Chicago) models successfully predicted both the years and the months, and six of the 10 jurisdictions successfully predicted at least the years. In aggravated assault, three of the four Illinois (non-Chicago) models and five of the 11 jurisdiction models successfully predicted both the year and the average month in 1982 and 1983, and two additional jurisdictions successfully predicted at least the two years.

In Index aggravated assault, as in Index robbery, the analysis in several jurisdictions discovered a serendipitous intervention in 1982 or 1983. However, there were fewer interventions discovered in aggravated assault than in robbery, and for most of these the existence of an actual change in the level of offenses was not clear. When an intervention is discovered through analysis and not hypothesized beforehand, the cause could be that the predictive accuracy for the analysis of that series tends to be poor for every year. In Quincy, with only six offenses per month on the average, a predictive error of 23 percent should not be surprising in any year. In Cicero, predictive accuracy in most years was poor; it may be an accident that 1981 and 1982 were predicted within the 20 percent criterion, while 1983 was not. In Illinois (non-Chicago) body-as-weapon assault, the 1982 error (16 percent) was suspiciously high. However, in such cases, the line segment fit can provide additional evidence as to whether or not there was an actual increase or decrease in the number of offenses. In Cicero (see Figure 19) we can see an increase in 1983, and in Illinois body-as-weapon assault (see Figure 18) we can see a decline in 1983.

Except for Rock Island, the jurisdictions and crime types in which the predictability results suggested an intervention were not the same for Index robbery as for Index aggravated assault. In Decatur, Joliet, and Peoria, the number of robberies may have dropped in 1982 or 1983, but not the number of assaults.[60] Non-Chicago firearm robbery increased slightly in 1983, but firearm assault did not. On the other hand, the number of body-as-weapon assaults in Illinois (non-Chicago) dropped sharply in 1983, while the number of strongarm robberies did not. Cicero Index aggravated assault increased in 1983, but Index robbery did not. However, in Rock Island, both Index robbery and Index aggravated assault changed in 1982 and in 1983.

Predictions for Index aggravated assault were very accurate in three jurisdictions--Evanston, Joliet, and Rockford; both 1982 and 1983 were predicted within 10 percent (year-ahead method). In a fourth jurisdiction--Rock Island--the ARIMA model (0,1,1)(0,0,1) predicted 1982 and 1983 within 10 percent. The 1982 and 1983 predictions for total (non-Chicago) Illinois Index aggravated assault with a firearm, knife, or other weapon were also accurate well within 10 percent. In Elgin, Peoria, Quincy, and Springfield, at least one yearly prediction was accurate within 10 percent (year-ahead method). In contrast, no prediction in Aurora or Cicero was accurate within 10 percent, and Decatur aggravated assault could not be successfully modeled at all. Thus, the predictive accuracy for Index aggravated assault ranged from very accurate to completely unpredictable, depending on the jurisdiction.

Even though the number of offenses per month was usually higher in Index aggravated assault than in Index robbery, it was often difficult to identify a good model in Index aggravated assault. The Decatur assault time series could not be successfully modeled, even by the generous Predictability Project criteria. Also, the Cicero assault series barely met the criteria. In contrast, every Index robbery time series was successfully modeled within the 20 percent yearly criterion for at least two years.

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[60]Because of the poor model for Decatur, little can be said about aggravated assault in 1982 and 1983, but it apparently did not decline.

In assault, more than in robbery, there is a single class of ARIMA model that is likely to describe Illinois (non-Chicago) jurisdictions, at least their serial relationships. Seven of the 11 Illinois (non-Chicago) jurisdictions were best described by ARIMA (0,1,1)(Sp,Sd,Sq).

Although the degree of seasonal fluctuation found in these Index aggravated assault series was generally very small, this small degree of fluctuation was found in more jurisdictions than for Index robbery. Also, in contrast to Index robbery, the degree of seasonality did not seem to be related to the number of offenses in the average month. For example, Joliet, with 46 Index assaults known to the police in the average month, had no seasonal term in the best ARIMA model, but Elgin, with only 12 assaults on the average, had a seasonal term of ARIMA (p,d,q)(1,0,0) with a moderately high AR(12) estimate of .32.

In summary, the analysis found the following to be true for Index aggravated assault:

- Index aggravated assault predictions varied from very accurate to completely inaccurate, depending on the jurisdiction.
- Aggravated assault had relatively few serendipitous interventions.
- There was some consistency from jurisdiction to jurisdiction in the best ARIMA model for aggravated assault. The serial term tended to be (0,1,1)(Sp,Sd,Sq).
- The higher degree of predictability in Index aggravated assault, compared to Index robbery, seemed to be related to the higher number of offenses per month.
- The degree of seasonality in Index aggravated assault was not related to the number of offenses per month. Some large jurisdictions had no seasonality, while assault in some small cities was seasonal.

Index Burglary

The list below summarizes results of the analysis of the predictability of Index burglary in each of the 14 jurisdictions. All of the jurisdictions had enough burglary offenses per month for analysis (see Table B), though the average number ranged from 46 in Des Plaines to 265 in Rockford. Neither Chicago nor total Illinois (non-Chicago) burglary was analyzed in the Predictability Project. The list below also includes, for each Index burglary series, the best-fitting type of ARIMA model (p,d,q)(Sp,Sd,Sq).

Successful Predictive Models

	(p,d,q)(Sp,Sd,Sq)
Cicero	(0,1,1)(0,0,0)
Peoria	(0,1,2)(0,1,1)
Springfield	(0,1,2)(0,0,0)

Model Meeting Yearly but not Monthly Criteria

Arlington Heights	(2,1,0)(0,1,1)

Serendipitous Intervention

Aurora (1983)	(3,1,0)(0,0,0)
Decatur (1972-1981)	(0,1,1)(0,0,0)
(1972-1983)	(0,1,2)(1,0,0)
Elgin (1983)	(0,1,1)(0,0,0)
Evanston (1972-1978)	(0,1,2)(0,0,0)
(1979-1983)	(1,0,0)(0,1,1)
Joliet (1983)	(2,0,0)(0,0,1)
Quincy (1981 & 1983)	(0,1,1)(0,0,1)
Rockford (1982)	(0,1,1)(1,0,0)
Rock Island (1972-1978)	(0,1,2)(0,0,1)
(1979-1983)	(0,1,1)(0,0,0)
Skokie (1982)	(1,0,0)(0,1,1)

Poor Predictive Model

Des Plaines	(2,0,0)(1,0,0)

Predictability

The degree of predictability for each index burglary time series, for the total year and the average month of 1982 and 1983, and with the year-ahead method and the intervention method, is given in Table K, and the overall results of the year-ahead predictive accuracy analysis are summarized in the list above. The criteria in this list for a successful predictive model are very generous--accuracy within 20 percent for the total year and 30 percent for the average month, for both years. Even so, the best model for Des Plaines did not qualify as successful, and is categorized as a poor predictive model. In cases of a serendipitous intervention being discovered in 1982 or 1983, ARIMA modeling and prediction was done for 1981. Because of their complexity, a number of burglary time series were analyzed for several additional years.

In general, it was harder to identify a successful ARIMA model for index burglary than for the other three index crimes, even though the number of burglary offenses per month was never less than 46 in any jurisdiction (see Table B). Of the 14 jurisdictions in which a model for index burglary was attempted,[61] only three models (Cicero, Peoria, and Springfield) successfully predicted both 1982 and 1983 for the total year and for the average month by the generous 20 percent and 30 percent criteria with the year-ahead method. Only the Peoria model predicted 1982 and 1983 within 10 percent.

Of the 14 index burglary analyses, nine indicated a serendipitous intervention. In six of these--Aurora, Elgin, Joliet, Quincy, Rockford, and Skokie--the level of the series apparently changed. In three other jurisdictions--Decatur, Evanston, and Rock Island--the best model apparently changed.

[61] Since the Chicago Intervention Analysis was not done for index burglary, only Illinois (non-Chicago) jurisdictions are analyzed here.

Table K. Percent Error of Predictions: Burglary

	Year-Ahead Method				Intervention Method			
Jurisdiction	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month
Arlington Heights	9%*	16%*	25%*	31%	5%*	7%*	26%*	29%*
Aurora[a]	15*	34	19*	37	0*	5*	21*	15*
Cicero	14*	8*	15*	22*	11*	0*	14*	20*
Decatur[b]	25	23	32	32	3*	8*	22*	24*
Des Plaines	40	40	47	48	18*	21	31	28*
Elgin[c]	6*	38	14*	45	0*	10*	13*	26*
Evanston	d	6*	d	18*	d	4*	d	15*
Joliet[e]	2*	30	14*	34	3*	10*	12*	21*
Peoria	6*	2*	27*f	12*	1*	7*	23*f	16*
Quincy	6*	27	29*	43	0*	11*	32	35
Rock Island	h	6*	h	18	h	1*	h	16*
Rockford[g]	21	4*	26*	11*	1*	2*	14*	11*
Skokie[i]	27	15*	40	41	7*	3*	25*	31
Springfield	14*	9*	20*	15*	6*	2*	12*	13*

*Meets predictability criteria: 20 percent for total year predictions, 30 percent for average month predictions.

[a]The same ARIMA model (3,1,0)(0,0,0) predicted 1981 within 10 percent (year-ahead) and 0 percent (intervention), and within 10 percent and 14 percent for the average month, in Aurora.

[b]In these predictions, an ARIMA model (0,1,1)(0,0,0) was used for Decatur burglary. However, in 1982 and 1983 the model changed to (0,1,2)(1,0,0) (see Table L). This model predicted 1981 within 8 percent and the average month within 24 percent (year-ahead method).

[c]In Elgin, the same ARIMA model (0,1,1)(0,0,0) predicted 1981 within 8 percent (year-ahead) and 1 percent (intervention) and the average 1981 month within 16 percent and 14 percent.

[d]In Evanston, a 1979-1982 model was used to predict 1983. This series was too short to predict 1982 (see text, page 75).

[e]In Joliet, 1981 was predicted within 2 percent, and the average 1981 month within 11 percent (year-ahead method).

[f]In 1982, there is one extremely low month, January, with only 72 Index burglaries, compared to 256 for the average month. If this month is excluded, the other 1982 months were each predicted within 15 percent (year-ahead) and 11 percent (intervention) on the average.

[g]An ARIMA model (0,1,1)(1,0,0) for Rockford burglary predicted 1981 within 1 percent (both year-ahead and intervention methods), but the 1982 year-ahead prediction was 21 percent too high. As the pattern description indicates (Figure 24a), there was a drop in 1982.

[h]In Rock Island, a 1979-1982 model was used to predict 1983. This series was too short to predict 1982 (see Table L).

[i]The same ARIMA model (1,0,0)(0,1,1) for Skokie burglary (see Table L) predicted 1981 within 4 percent (year-ahead) and 2 percent (intervention). The 1982 year-ahead prediction was too high because January and February 1982 were extremely low. The other 10 months of 1982 were predicted within 18 percent on the average (see Figure 25).

Arlington Heights

In Arlington Heights, the best model predicted 1982 within 9 percent, the average 1982 month within 25 percent, and the year 1983 within 16 percent, but the prediction for the average 1983 month was slightly worse than the 30 percent criterion (31 percent). Because the statistical fit of the ARIMA model (2,1,0)(0,1,1) is not particularly good (although better than the fit of alternative models for Arlington Heights), it is probable that the poor prediction in 1983 is symptomatic of an erratic, unpredictable series, rather than of a real change in the number of burglary offenses.

Des Plaines

Index burglary in Des Plaines could not be successfully modeled at all. The best model was 22 percent too high in predicting 1981, 40 percent too high in predicting 1982, and 40 percent too high in predicting 1983 (year-ahead method).

Aurora

Despite indications of data problems in Aurora index burglary (see Figure 20), a model was identified that successfully predicted 1981 and 1982. There were two indications of data problems. First, the number of burglary offenses was extremely high in two months, September and October 1977, when there were 315 and 304 burglaries known to the police.[62] Second, in the descriptive seasonal analysis, there was a significant F of moving seasonality under both mathematical assumptions (see Table E). However, the year 1981 was predicted within 10 percent, 1982 was predicted within 15 percent, and the average month was predicted successfully in both years (year-ahead method). In 1983, the same ARIMA model (3,1,0)(0,0,0) was 34 percent too high, and the monthly predictions in 1983 were an average of 37 percent in error. The model predicted that about 164 offenses would occur in each month of 1983, but there were actually about 122 offenses. Because the intervention method predictions for 1983 were accurate, it appears that the model did not change. Rather, the decline of mid-1981 to 1982 became steeper in 1983.

Elgin

In Elgin, a similar thing seems to have happened in 1983. The best model, ARIMA (0,1,1)(0,0,0), predicted 1981 and 1982 accurately, within 8 percent in 1981 and 6 percent in 1982. However, the same model was 38 percent too high in predicting 1983. This decline was found not only in the ARIMA analysis, but also in the pattern description (see Figure 21). Thus, the increase in burglary in Elgin that occurred from 1978 to 1982 was reversed in 1983.

Joliet

In Joliet (see Figure 22), 1981 and 1982 were each predicted within 2 percent and the average months within 11 and 14 percent, respectively (year-ahead method). However, the prediction for 1983, using the same ARIMA model (2,0,0)(0,0,1), was 30 percent too high. As for Aurora and Elgin, the predictions with the intervention method were accurate, indicating that the best ARIMA model did not change. The pattern description graph of Joliet index burglary (see Figure 22) suggests that the years 1980 to 1982 were generally declining. However, in 1983, the number of index burglary offenses seems to have declined even more than would be expected from the earlier pattern.

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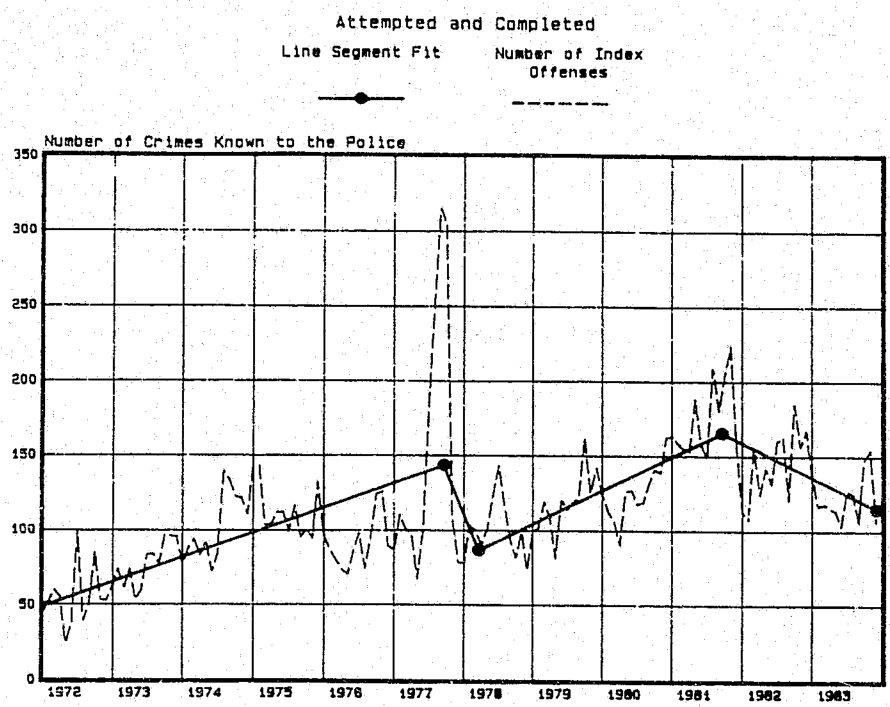
[62] In contrast, overall there were 144 index burglaries per month in Aurora.

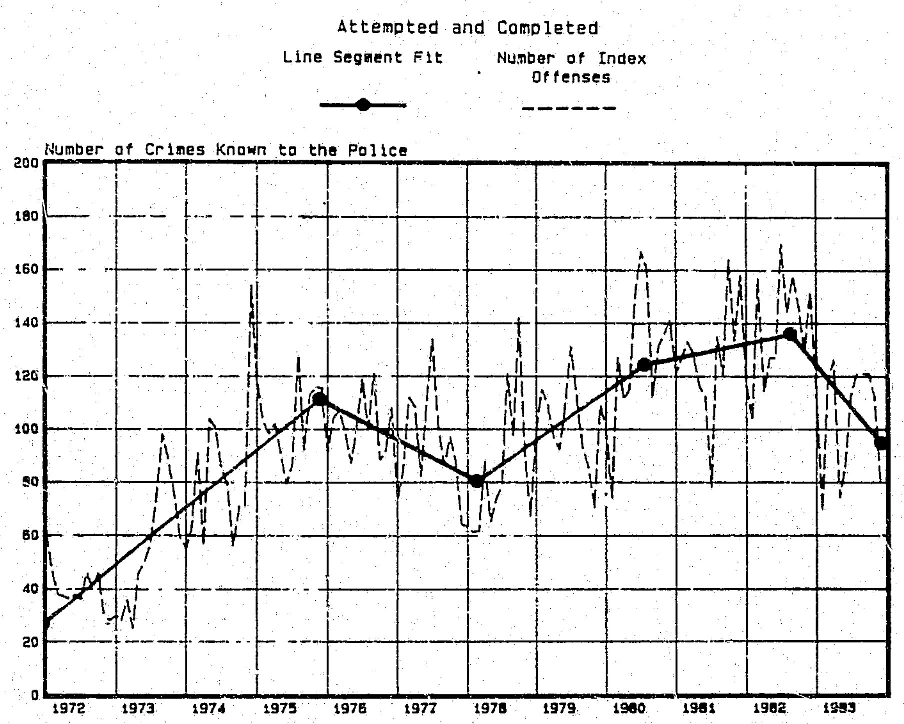
Figure 20. Patterns of Change Over Time in Aurora Index Burglary, 1972-1983



Months, January 1972 through December 1983

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

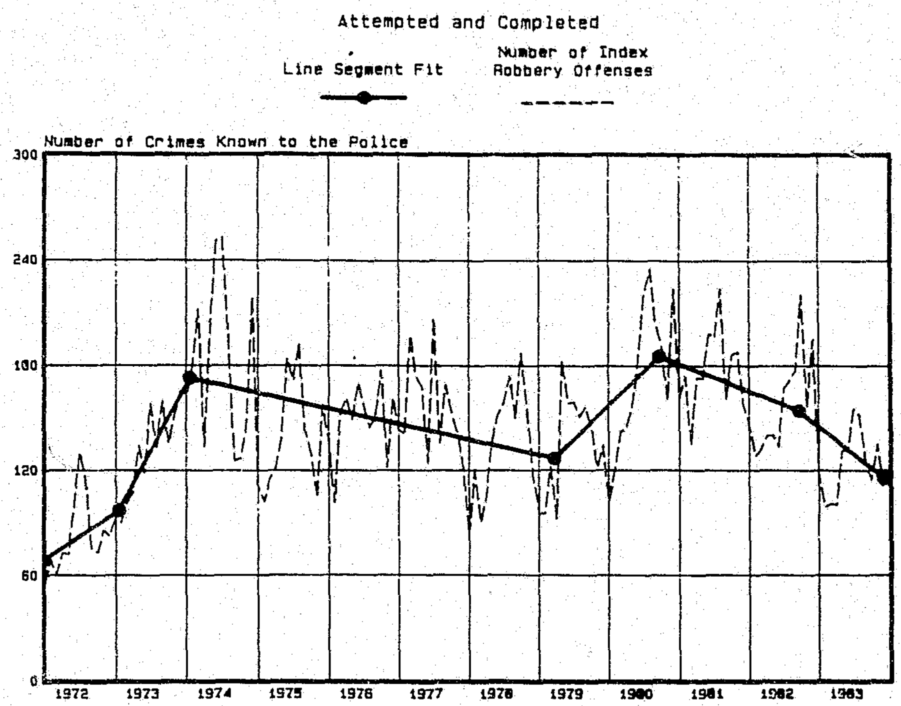
Figure 21. Patterns of Change Over Time in Elgin Index Burglary, 1972-1983



Months, January 1972 through December 1983

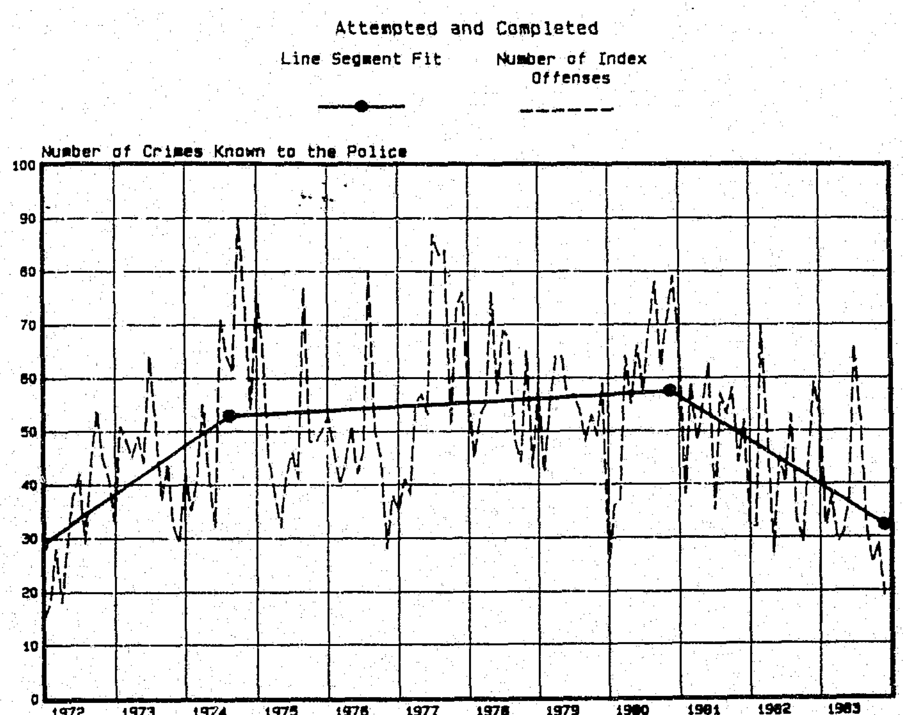
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 22. Patterns of Change Over Time in Joliet Index Burglary, 1972-1983



Months, January 1972 through December 1983
Source: ICJIA version of Illinois Dept. of State Police UCR Data

Figure 23. Patterns of Change Over Time in Quincy Index Burglary, 1972-1983



Months, January 1972 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Quincy

In Quincy (see Figure 23), predictability results indicate that the pattern over time of Index burglary may have changed not only once, but twice. After a relatively stable pattern that lasted from 1975 through 1980, the number of burglary offenses dropped in 1981 and the same decline continued in 1982. In 1983, the decline was even sharper than the 1981 to 1982 decline. These changes are reflected in the predictive accuracy of the ARIMA model (0,1,1)(0,0,1), which was a good statistical fit in all years:

Percent Prediction Error: Quincy

	Year-Ahead Method		Intervention Method	
	Year	Average Month	Year	Average Month
1979	12%	13%	2%	11%
1980	1	29	5	24
1981	48	53	8	22
1982	6	29	0	32
1983	27	43	11	35

As can be seen, predictive accuracy for Quincy burglary was fairly good in 1979 and 1980, but the prediction for 1981 was 48 percent too high. Predictive accuracy with a 1972-1981 model was again good for 1982, because the same declining pattern of 1981 continued through 1982. However, the 1983 prediction was 27 percent too high. It appears, then, that the number of Index burglaries in Quincy dropped in 1981 and 1982, and dropped even more in 1983.

Rockford

In Rockford, a drop in Index burglary apparently occurred in 1982, according to ARIMA analysis. Both 1981 and 1983 were predicted very accurately; 1981 was predicted within 1 percent and 1983 was predicted within 4 percent (year-ahead method). However, the same ARIMA model (0,1,1)(1,0,0), based on 1972-1981 data, was 21 percent too high in predicting 1982, and the months were in error by 26 percent, on the average. All 1982 months except December were actually much lower than the ARIMA prediction. This drop in 1982 is not immediately apparent in the pattern description graph of Rockford burglary offenses (see Figure 24a). However, according to descriptive seasonal analysis (see Table E), burglary fluctuated with the seasons more in Rockford than in any other jurisdiction analyzed. This relatively strong fluctuation could obscure other patterns in the Rockford data. In fact, when the seasonal fluctuation is removed (see Figure 24b), the drop that ARIMA analysis found in 1982 becomes clear.[63] Rockford burglary offenses dropped in 1982, and remained at that low level through 1983.

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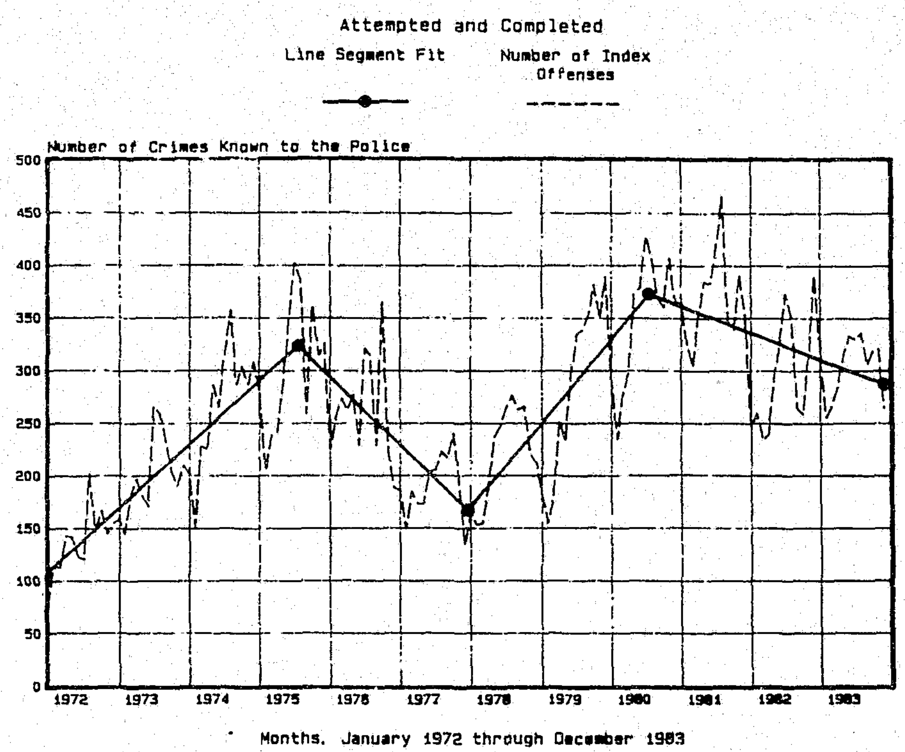
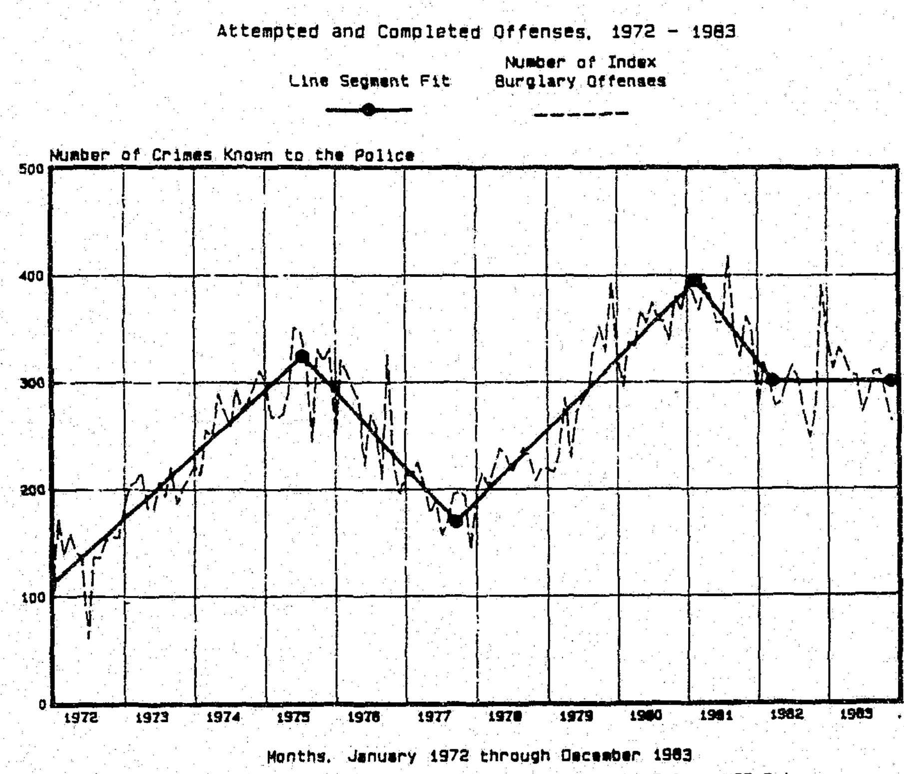
[63]The seasonally adjusted figures in Figure 24b were calculated by the X-11/ARIMA program, under the additive assumption (see Appendix 1).

Figure 24a. Patterns of Change Over Time in Rockford Index Burglary, 1972-1983



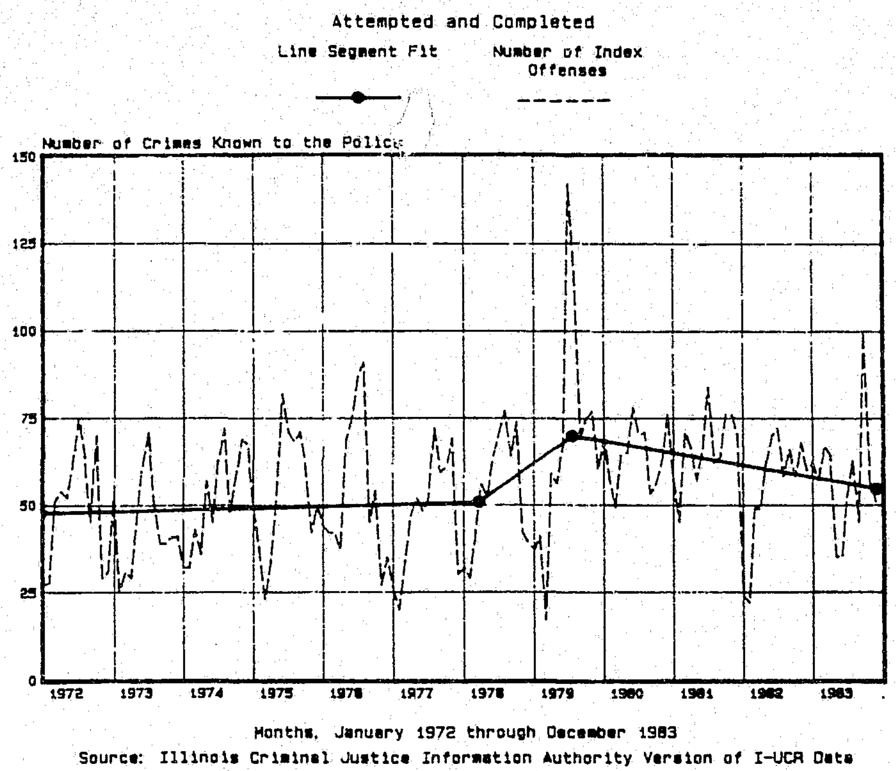
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 24b. Patterns of Change Over Time in Rockford Index Burglary, 1972-1983 (Seasonally Adjusted)



Source: ICJIA version of Illinois Dept. of State Police UCR Data

Figure 25. Patterns of Change Over Time in Skokie Index Burglary, 1972-1983



Skokie

The situation for Skokie Index burglary (see Figure 25) was somewhat different. The year-ahead predictions for 1981 and 1983 (see Table K) were fairly accurate (within 4 percent and 15 percent, respectively), but the prediction for 1982 indicates that the number of Index burglaries dropped somewhat in 1982, relative to the other years. Actually, the predictions for most months of 1982 were well within the 30 percent criterion, with two exceptions. The January prediction was 154 percent higher than the actual number (24), and the February prediction was 137 percent higher than the actual number (22). Thus, in Skokie, Index burglary was generally predictable, except for two extremely low months in 1982.

Best ARIMA Models for Predicting Index Burglary

Because Index burglary was, in general, more difficult to model, we might expect less consistency in the type of ARIMA model that finally produced successful predictions and statistical diagnostics. However, as Table L shows, there were some types of model that tended to be successful for burglary.

Serial Relationships

The most common ARIMA model type for the serial term of Index burglary was ARIMA (0,1,1)(Sp,Sd,Sq), which occurred in Cicero, Decatur (1972-1981), Elgin, Quincy, Rockford, and Rock Island (1979-1983). This, as we have seen, was the most common type of ARIMA serial model for Index aggravated assault, and also for Index robbery in the larger jurisdictions.

Table L. Index Burglary ARIMA Models, 1972-1983

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Arlington Heights	(2,1,0)(0,1,1)	--	-.76	-.58	-.40	--	--	--	--	--	--	.84	.89	.94
			-.32	-.15	.03									
Aurora	(3,1,0)(0,0,0)	--	-.22	-.05	.12	--	--	--	--	--	--	--	--	--
			-.35	-.19	-.02									
			-.30	-.12	.05									
Cicero[a]	(0,1,1)(0,0,0)	--	--	--	--	.64	.75	.86	--	--	--	--	--	--
Decatur														
1972-1981	(0,1,1)(0,0,0)	--	--	--	--	.45	.60	.75	--	--	--	--	--	--
1972-1983	(0,1,2)(1,0,0)	--	--	--	--	.40	.57	.74	.01	.19	.37	--	--	--
						.02	.19	.36						
Des Plaines	(2,0,0)(1,0,0)	46.4	.24	.40	.57	--	--	--	.00	15	.31	--	--	--
			.08	.20	.37									
Elgin	(0,1,1)(0,0,0)	--	--	--	--	.51	.64	.76	--	--	--	--	--	--
Evanston														
1972-1978	(0,1,2)(0,0,0)	--	--	--	--	.16	.38	.61	--	--	--	--	--	--
						-.14	.09	.31						
1979-1983	(1,0,0)(0,1,1)	--	-.02	.26	.54	--	--	--	--	--	--	.71	.84	.97
Joliet	(2,0,0)(0,0,1)	144.0	.36	.51	.67	--	--	--	--	--	--	-.44	-.27	-.10
			.11	.26	40									
Peoria[b]	(0,1,2)(0,1,1)	--	--	--	--	.17	.34	.51	--	--	--	.82	.87	.92
						.12	.29	.47						
Quincy	(0,1,1)(0,0,1)	--	--	--	--	.44	.58	.72	--	--	--	-.30	-.13	.04

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Rockford	(0,1,1)(1,0,0)	--	--	--	--	.36	.51	.66	.47	.60	.73	--	--	--
Rock Island														
1972-1978	(0,1,2)(0,0,1)	--	--	--	--	.08	.29	.50	--	--	--	-.32	-.08	.16
						.17	.38	.59						
1979-1983	(0,1,1)(0,0,0)	--	--	--	--	.20	.43	.66	--	--	--	--	--	--
Skokie	(1,0,0)(0,1,1)	1.6	.23	.39	.55	--	--	--	--	--	--	.84	.90	.95
Springfield	(0,1,2)(0,0,0)	--	--	--	--	.28	.44	.60	--	--	--	--	--	--
						.19	.35	.51						

[a]In Cicero, the number of crimes known to the police in November 1977 was extremely low relative to other Novembers. This was true for every Index crime. For Index burglary, there was one burglary in November 1977, but an average of 57 burglaries in all other Novembers. The other 11 months of 1977 averaged 55 burglaries. This led us to suspect the accuracy of the November 1977 figure, but we were unable to obtain additional information from Department of State Police. Therefore, in the analysis in this report, 57 is used for November 1977.

[b]Data for August 1979 are missing, and the figure for September 1979 was about twice as high as other Septembers. This is true for every Index crime. For this analysis, one half of the September figure was used for August and September.

The second most common serial term for Index burglary was ARIMA (0,1,2)(Sp,Sd,Sq), which occurred in Decatur (1972-1983), Evanston, (1972-1978), Peoria, Rock Island (1972-1978), and Springfield. As can be seen in comparing tables H, J, and L, ARIMA (0,1,2)(Sp,Sd,Sq) was not a common serial model type for Index robbery or aggravated assault.[64] The only other serial model type appearing more than once in burglary models was ARIMA (1,0,0)(Sp,Sd,Sq), which was the best model for Evanston (1979-1983) and for Skokie.

Seasonal Relationships

In most jurisdictions, the best ARIMA model for Index burglary showed little seasonal fluctuation. Two of the three successful models, in Cicero and Springfield, had no seasonal term. On the other hand, the third jurisdiction with a successful ARIMA model, Peoria, had a model containing strong seasonal fluctuation. This agrees with the descriptive seasonal analysis above (see Table E), in which the F of stable seasonality was less than 2.0 for Cicero and Springfield, but more than 10.0 for Peoria.

The six jurisdictions in which the level of Index burglary apparently changed also differed greatly in the degree of seasonal fluctuation in their best ARIMA model. The models for Aurora and Elgin had no seasonal term. However, the Joliet model had a seasonal moving average term with an estimated -.27 weight, the Quincy model had a seasonal moving average term with a very small -.13 weight, the Rockford model had a seasonal autoregressive term with an estimated .60 weight, and the Skokie models required 12th differencing. Rockford's ARIMA model (p,d,q)(1,0,0), with an AR(12) weight of .60, indicates a relatively high level of seasonal fluctuation. The descriptive seasonality analysis (see Table E) agrees with this. Rockford had the highest seasonal contribution and F value of any burglary time series.

Thus, there seems to be no consistency in the type of seasonal term in Index burglary ARIMA models, and even no consistency in whether or not an Index burglary ARIMA model contains a seasonal term at all. In fact, in the three jurisdictions with an apparent intervention in model type, the change in model involved a change from no seasonal term to a seasonal term, or vice versa. These models are discussed in the following sections.

Model Change in Decatur

In Decatur, a relatively simple ARIMA model (0,1,1)(0,0,0) provided a good statistical fit for the period before 1982. With this model, the year 1981 was predicted within 8 percent and the average 1981 month within 24 percent. However, this simple model provided neither good predictions for 1982 and 1983, nor an acceptable statistical fit for the 1972-1982 or 1972-1983 time period.

It is impossible to fit an ARIMA model to only two years of data, 1982 and 1983. However, an ARIMA model (0,1,2)(1,0,0) fit the total time periods 1972-1982 and 1972-1983 better, according to statistical diagnostics (see Appendix 1), than the simpler ARIMA model (0,1,1)(0,0,0). In addition, predictions for 1982 and 1983 were more accurate with the more complex model (0,1,2)(1,0,0).[65]

Perhaps the more complex ARIMA model (0,1,2)(1,0,0) was actually the best model for the entire 1972-1983 time period, including the earlier years. As a check on this, we estimated ARIMA (0,1,2)(1,0,0) for the time period 1972-1980, and compared the results to ARIMA (0,1,1)(0,0,0). The simpler model was better statistically and also produced more accurate

[64] ARIMA (0,1,2)(Sp,Sd,Sq) did occur as the serial term in two Index robbery models--in Decatur and in total Illinois (non-Chicago) strongarm robbery.

[65] However, the 1982 and 1983 predictions with ARIMA (0,1,2)(1,0,0) were still not particularly accurate. The 1982 prediction was 22 percent too high, and the 1983 prediction was 21 percent too high.

forecasts of 1981. Therefore, we concluded that the best ARIMA model for Index burglary in Decatur changed in 1982. Before 1982, there was no seasonal fluctuation in Decatur burglary, but in 1982 and 1983, there was a slight amount of seasonal fluctuation.[66] Although the degree of seasonality in the 1972-1983 model was slight, a seasonal AR(12) term was still necessary for a well-fitting model

Model Change in Evanston

There were two best-fitting models for Index burglary offenses in Evanston (see Figure 12), one for the time period 1972-1978, and another for the time period 1979-1983. The best model for the earlier time period was ARIMA (0,1,2)(0,0,0). The MA(1) and MA(2) estimates for such a model, fit to three time periods, were the following:

Time Period	MA(1)	MA(2)
1972-1977	.37	.18
1972-1978	.38	.09
1972-1979	.37	-.01

The MA(1) estimate is about the same in all three models, but the MA(2) estimate obviously changes. The estimated weight is .18 for the earliest time period, but with the addition of 1978 and 1979, it becomes zero. There is one other indication that the model may have changed. Although the ARIMA model (0,1,2)(0,0,0) is statistically adequate (see Appendix 1) for the 1972-1977 period, it is less so for the 1972-1978 period or for the 1972-1979 period. On the other hand, the model's prediction of 1978 was good, within 1 percent for the total year and 28 percent for the average 1978 month.[67] In contrast, the prediction for 1979 was somewhat less accurate, 13 percent too low. This suggests that the change in the best ARIMA model occurred between 1978 and 1979.

The five remaining years, 1979 to 1983, are not really enough to identify a reliable ARIMA model, but exploratory analysis indicated that the later period seemed to contain much less serial fluctuation, and a great deal more seasonal fluctuation, than the earlier years. The best model for these later years was ARIMA (1,0,0)(0,1,1), with the following estimates for the AR(1) and MA(12) terms:

Time Period	AR(1)	MA(12)
1979-1982	.24	.84
1979-1983	.26	.84

The prediction for 1983 with an ARIMA (1,0,0)(0,1,1) model was within 6 percent with the year-ahead method and within 4 percent with the intervention method. The average month was predicted within 18 percent and 15 percent, respectively. An alternative model with no serial pattern over time and no serial differencing, ARIMA (0,0,0)(0,1,1), predicted 1983 just as well, but was not a good statistical fit.

There seems to have been a rather radical change in the pattern over time of Index burglary in Evanston, beginning about January 1979. The period after that date had strong seasonal fluctuation, but very slight serial fluctuation. The period before that date had weak or

[66]The AR(1) weight of the ARIMA model (0,1,2)(1,0,0) for the period 1972-1983 was estimated at .19 (see Table L).

[67]The accuracy of the prediction for the 1978 average month was decreased by the prediction for January, which was 72 percent too high. January 1978 had an extremely low number of burglaries (59) compared to the overall mean (118) or compared to the three previous Januaries (163, 100, and 99).

nonexistent seasonal fluctuation but relatively strong serial fluctuation. This change, even though it is a change in the ARIMA model and not in the number of burglaries, is strong enough to see in a graph (see Figure 12).

This apparent change suggests that the phenomenon being measured in the earlier time period may not be the same as the phenomenon being measured in the later time period. It is possible, for example, that an increased proportion of burglary occurrences were reported to the police in the later years. As a matter of fact, there was an increased emphasis on burglary prevention in Evanston beginning in 1979, and it is possible that this prevention program could have increased public awareness of burglary. This might have resulted in greater likelihood that a burglary offense, whatever its seriousness, would be reported to the police. If the burglaries reported after the prevention campaign fluctuated with the seasons more than the burglaries reported before the campaign, then the total Index burglary time series would become seasonal. However, because the apparent intervention in 1979 had not been hypothesized beforehand, we cannot say with any certainty that a change actually occurred.

Model Change in Rock Island

An ARIMA model (0,1,2)(0,0,1) for Rock Island burglary (see Figure 7) had the following parameters for four time periods:

Time Period	MA(1)	MA(2)	MA(12)
1972-1977	.25	.30	-.13
1972-1978	.29	.38	-.08
1972-1979	.46	.02	-.22
1972-1980	.48	.15	-.19

The two earlier and the two later time periods seem to differ in their MA(1) and MA(2) estimated weights, and possibly also in their MA(12) estimated weights.[68] The 1972-1977 model fit well statistically, and predicted 1978 within 12 percent. The 1972-1978 model also fit well statistically, but was 21 percent too low in predicting 1979 (see Figure 7). The 1972-1979 model was also a good fit, but was 74 percent too high in predicting 1980. The monthly 1980 predictions were wrong by as much as 190 percent. Further, the model for the 1972-1980 time period was a very poor fit statistically. All this suggests that the best ARIMA model for Rock Island Index burglary changed in 1980, and possibly as early as 1979.

The best model for the periods 1979-1982 and 1979-1983 was ARIMA (0,1,1)(0,0,0). This can be estimated only in an exploratory sense, because the time period is so short. The estimated MA(1) weight was .43 for both the 1979-1982 and the 1979-1983 model, and the statistical fits were adequate. With this model, 1983 predictions were correct within 6 percent, and the average 1983 month was predicted within 18 percent (year-ahead method).

Thus, in Rock Island as in Decatur, the pattern of Index burglary seems to have changed from a seasonal pattern to a pattern without seasonal fluctuation.

[68]The low MA(12) estimate could be zero in each of the four models. However, in the earlier time periods, an MA(12) term is necessary for a good fit.

Summary: Index Burglary

Of the 14 jurisdictions in which Index burglary was analyzed, only three models generated successful predictions, two jurisdictions could not be successfully modeled at all (Des Plaines and Arlington Heights), and in the remaining nine the analysis discovered a serendipitous intervention.

In general, the degree of predictive accuracy for Index burglary is less than for Index robbery or aggravated assault. In only one jurisdiction, Peoria, was the number of burglary offenses accurately predicted within 10 percent for 1982 and 1983. In four other jurisdictions--Elgin, Evanston, Joliet, and Rockford--at least two years were predicted within 10 percent. In Elgin, 1981 and 1982 were predicted within 8 percent and 6 percent, respectively, but the sharp decline in 1983 was not predicted accurately. Although there was apparently a change in the best model in Evanston, the years in which prediction was possible were both accurately predicted (within 1 percent in 1978 and 6 percent in 1983). The number of Index burglary offenses was predicted within 2 percent in Joliet in 1981 and 1982, but the drop in 1983 was not predicted accurately. Rockford burglary was predicted within 1 percent in 1981 and 4 percent in 1983, but the drop in 1982 was not predicted accurately. Thus, Index burglary appears to be predictable in Peoria, and also may be predictable in Elgin, Evanston, Joliet, and Rockford.

In five other jurisdictions, Index burglary was predicted within 10 percent in 1982 or 1983, but not in both years. The degree of accuracy in these jurisdictions--Arlington Heights, Cicero, Quincy, Rock Island and Springfield--was not, therefore, particularly high. However, it was still better than the accuracy in Aurora, Decatur, and Skokie,[69] which were not predicted very accurately in any year, and in Des Plaines, where Index burglary could not be modeled at all.

What type of ARIMA model was best for Index burglary? The serial term in the best ARIMA model for Index burglary in these jurisdictions was likely to be either ARIMA (0,1,1)(Sp,Sd,Sq) or ARIMA (0,1,2)(Sp,Sd,Sq). In contrast, the seasonal term in Index burglary models had no consistency from jurisdiction to jurisdiction. Many of the best-fitting and best-predicting models had no seasonal term at all, ARIMA (p,d,q)(0,0,0). However, many others had terms describing a strong pattern of seasonal fluctuation.

Not only is there no consistency from jurisdiction to jurisdiction in the seasonal term in burglary models, but there is not necessarily any consistency in the seasonal term over time within the same jurisdiction. In the jurisdictions in which there was an apparent change in ARIMA model over time, all three changed from seasonal to nonseasonal or vice versa. The 1972-1981 model in Decatur had no seasonal term, but the 1972-1983 model had an ARIMA (p,d,q)(1,0,0) seasonal term. Similarly, Evanston had no seasonal fluctuation in its 1972-1978 model, but rather strong seasonal fluctuation in the 1979-1983 model. Rock Island, on the other hand, changed from a slightly seasonal model in 1972-1978 to a model with no seasonal term in 1979-1983.[70]

In summary, the analysis found the following to be true for Index burglary:

- Burglary was <u>not</u> predictable in the majority of jurisdictions analyzed, either in the total year or in the average month.

- A high proportion of jurisdictions had a serendipitous intervention in Index burglary.

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[69] Although the accuracy of the Skokie predictions in 1982 and 1983 is not high, this is due only to two extreme months in 1982.

[70] In Index aggravated assault in Rock Island, the change was in the opposite direction. In the model for the early time period, 1972-1981, there was no seasonal term, but when the years 1982 and 1983 were added to the series, the model became seasonal.

- There was no consistency from jurisdiction to jurisdiction in the type of ARIMA model (especially not in the seasonal part of the model) that best fit index burglary.

Index Larceny/Theft

The list below summarizes results of an analysis of the predictability of index larceny/theft in each of the 14 jurisdictions. On the average, there were more larceny/theft offenses than the other three types of offense per month (see Table B). The average number of offenses ranged from 88 in Cicero to 506 in Peoria. Thus, larceny/theft could be analyzed in all jurisdictions. However, index larceny/theft was not analyzed s in Chicago or total Illinois (non-Chicago). The list below also includes, for each index larceny/theft series, the best-fitting type of ARIMA model (p,d,q)(Sp,Sd,Sq).

Successful Predictive Models

	(p,d,q)(Sp,Sd,Sq)
Arlington Heights	(0,1,1)(0,1,1)
Decatur	(0,1,1)(0,1,1)
Evanston	(0,1,1)(0,1,1)
Joliet	(0,1,2)(0,1,1)
Peoria	(1,1,0)(0,1,1)
Quincy	(0,1,1)(2,0,0)
Rock Island	(2,0,0)(0,1,1)
Skokie	(3,1,0)(0,1,1)
Springfield	(1,0,0)(1,1,0)

Serendipitous Intervention

Aurora (1982)	(0,1,2)(0,1,1)
Cicero (1972-1977)	(2,1,0)(1,0,0)
(1978-1983)	(1,0,0)(0,1,1)
Des Plaines (1983)	(2,0,0)(0,1,1)
Elgin (1982 & 1983)	(0,1,1)(0,1,1)
Rockford (1983)	(0,1,2)(0,1,1)

Predictability

The degree of predictability for each index larceny/theft time series, for the total year and the average month of 1982 and 1983, and for the year-ahead and intervention method, is given in Table M, and the overall results of the year-ahead predictive accuracy analysis are summarized in the list above. The criteria in this list for a successful predictive model are very generous--accuracy within 20 percent for the total year and 30 percent for the average month, for both years. There was no index larceny/theft series that was categorized as a poor predictive model under these criteria. In cases in which a serendipitous intervention was discovered in 1982 or 1983, ARIMA modeling and prediction were done for 1981. For Elgin and Cicero, the analysis was done for a number of years.

Table M. Percent Error of Predictions: Larceny/Theft

	Year-Ahead Method				Intervention Method			
Jurisdiction	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg Month	1982 Total Year	1983 Total Year	1982 Avg. Month	1983 Avg. Month
Arlington Heights	6%*	3%*	19%*	13%*	1%*	3%*	16%*	14%*
Aurora[a]	29	9*	29*	13*	4*	2*	12*	10*
Cicero[b]	a	3*	a	17*	a	2*	a	17*
Decatur	15*	11*	17*	17*	1*	3*	1*	11*
Des Plaines[c]	7*	27	12*	28*	1*	10*	12*	12*
Elgin[d]	21	26	22*	31	2*	10*	10*	15*
Evanston	1*	12*	11*	22*	0*	8*	10*	14*
Joliet	2*	9*	16*	11*	1*	3*	11*	1*
Peoria	11*	18*	24*	22*	0*	7*	24*	12*
Quincy	2*	1*	0*	14*	1*	1*	11*	16*
Rock Island	5*	6*	15*	10*	4*	3*	16*	12*
Rockford[e]	12*	27	13*	28*	1*	8*	7*	10*
Skokie	8*	18*	14*	21*	1*	1*	15*	13*
Springfield	10*	13*	12*	15*	3*	3*	10*	14*

*Meets predictability criteria: 20 percent for total year predictions, 30 percent for average month predictions.

[a]In Aurora, the same ARIMA model (0,1,2)(0,1,1) predicted 1981 within 2 percent for the year and 11 percent for the average month (year-ahead method) and within 2 percent for the year and 9 percent for the average month (intervention method).

[b]Based on 1978-1982 model, ARIMA (1,0,0)(0,1,1). Note that this is only five years of data. A model predicting 1982 with four years was not attempted (see Table N).

[c]In Des Plaines, the same ARIMA model (2,0,0)(0,1,1) predicted 1981 within 4 percent for the year and 16 percent for the average the month (year-ahead method) and within 1 percent for the year and 14 percent for the average month (intervention method).

[d]In Elgin, predictions for 1981 with an ARIMA model (0,1,1)(0,1,1) are better than predictions for 1982--within 4 percent for the year and 15 percent for the average month (year-ahead method). The same model predicted 1980 within 7 percent and 1979 within 17 percent.

[e]In Rockford, the same ARIMA model (0,1,2)(0,1,1) predicted 1981 within 3 percent (year-ahead method) and 1 percent (intervention method), and the average month within 9 percent (year-ahead) and 8 percent (intervention).

Index larceny/theft was, by far, the most predictable of the index crimes examined (see Table M). All of the 14 larceny/theft series were possible to model. In nine of them, the best ARIMA model successfully predicted both 1982 and 1983, both the total year and the average month. In five, the analysis suggested a possible intervention. In Aurora, Des Plaines, Elgin, and Rockford, there was an apparent change in level, and in Cicero, there seemed to be a change in the best ARIMA model.

Aurora

In Aurora (see Figure 26), an ARIMA model (0,1,2)(0,1,1) predicted 1981 within 2 percent, and the average 1981 month within 11 percent. The 1982 prediction, however, was 29 percent too high. Because the 1982 prediction with the intervention method was accurate (within 4 percent), and because the same ARIMA model successfully predicted 1983 (see Table M), it seems that the level of larceny/theft, but not the best model, changed in 1982. This slight drop is not easy to see in the pattern description graph, because it is obscured by seasonal fluctuation.[71] However, notice that the peak months in 1982 are lower than the peak months in 1981. Also, the number of larceny/thefts in 1983 remained at about the 1982 level.

Des Plaines

Des Plaines Index larceny/theft (see Figure 27) was quite predictable in 1981 and 1982. An ARIMA model (2,0,0)(0,1,1) predicted both years within 10 percent--1981 within 4 percent and 1982 within 7 percent (year-ahead method). However, the 1983 prediction was 27 percent too high. In fact, the actual number of larceny/theft offenses in every 1983 month was lower than the predicted number, by as much as 67 percent (in November). The number of larceny/thefts in Des Plaines had been declining since 1980, but apparently the drop in 1983 was even sharper than the previous decline.

Elgin

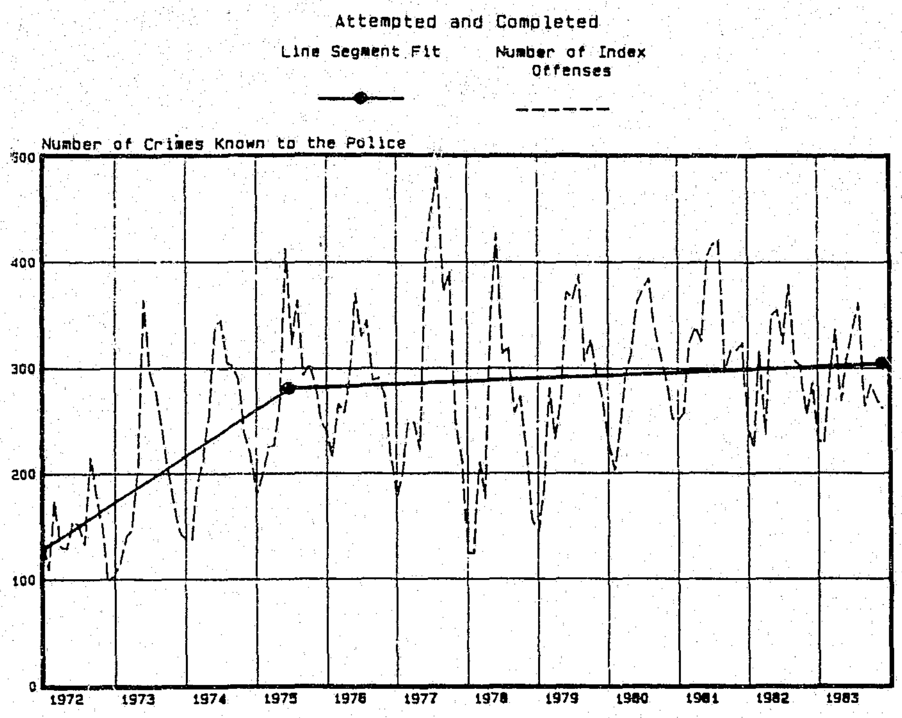
In Elgin, the number of Index larceny/theft offenses apparently fell slightly in both 1982 and 1983 (see Figure 28), although the best ARIMA model did not seem to change. ARIMA (0,1,1)(0,1,1) fit each time period from 1972-1978 through 1972-1983, according to the diagnostic tests in Appendix 1, and the estimated MA(1) and MA(12) weights were about the same for models in each time period. However, as can be seen below, neither the 1982 prediction nor the 1983 prediction was within the 20 percent criterion. The actual number in both years was lower than the predicted number. In fact, every month in 1982 and every month except March in 1983 had fewer larceny/theft offenses than the predicted number. The 119 offenses that actually occurred in December 1983 were 132 percent less than the predicted number of 251. Thus, the slight decline in Elgin larceny/theft that began in 1979 continued and apparently became an even steeper decline in 1982 and 1983.

Percent Prediction Error: Elgin

	Year-Ahead Method		Intervention Method	
	Year	Average Month	Year	Average Month
1979	17%	17%	8%	9%
1980	7	9	3	9
1981	4	15	1	15
1982	21	22	2	10
1983	26	31	10	15

[71]The seasonally adjusted series cannot be analyzed for Aurora larceny/theft, because the seasonal adjustment under both mathematical assumptions contains significant moving seasonality (see Table F) and therefore cannot be trusted.

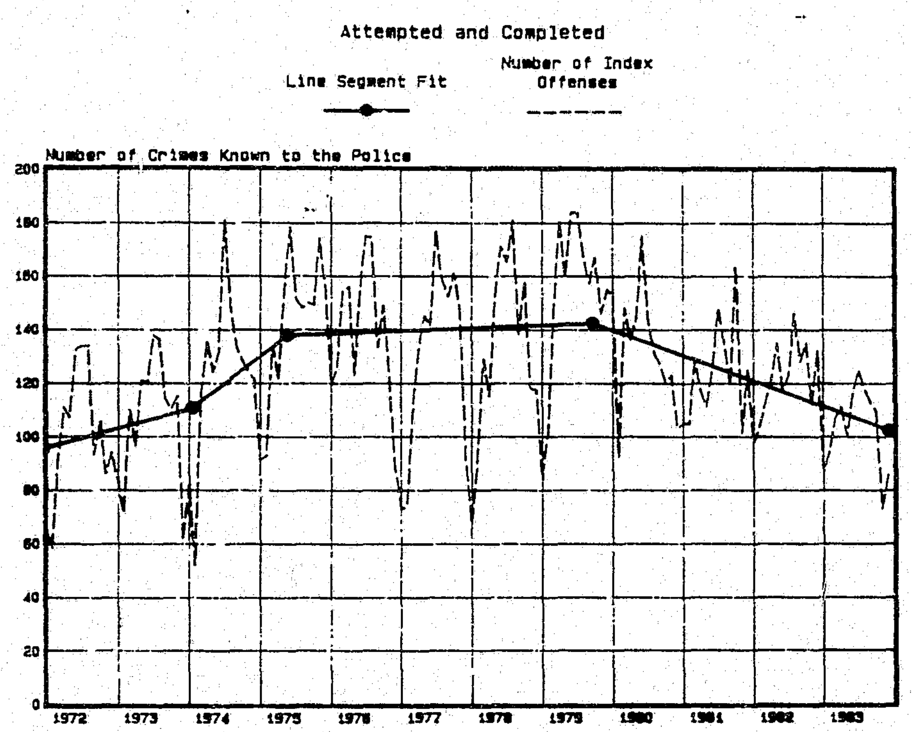
Figure 26. Patterns of Change Over Time in Aurora Index Larceny/Theft, 1972-1983



Months, January 1972 through December 1983

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

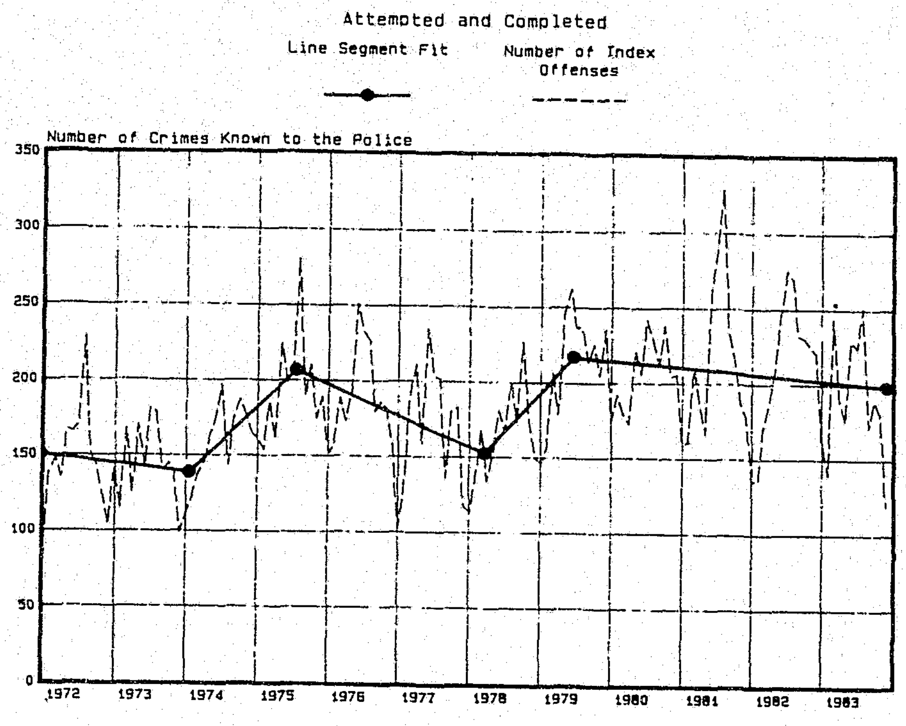
Figure 27. Patterns of Change Over Time in Des Plaines Index Larceny/Theft, 1972-1983



Months, January 1972 through December 1983

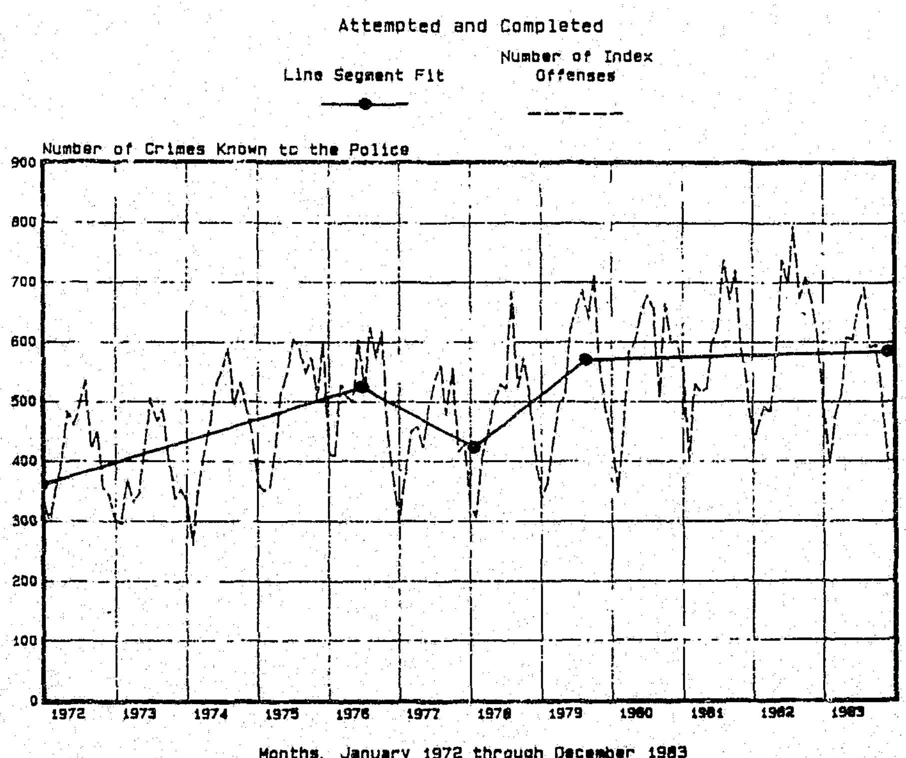
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 28. Patterns of Change Over Time in Elgin Index Larceny/Theft, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 29. Patterns of Change Over Time in Rockford Index Larceny/Theft, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Rockford

In Rockford (see Figure 29), as in Des Plaines, the number of Index larceny/thefts was somewhat low in 1983 The number in 1981 was predicted within 3 percent, and the average 1981 month within 9 percent (year-ahead method). In 1982, the same model was correct within 12 percent for the year and 13 percent for the average month. However, the 1983 prediction was 27 percent too high. In fact, the number of larceny/theft offenses in every 1983 month was lower than the predicted number, from 10 percent lower in April to 63 percent lower in December. Since the intervention method prediction for 1983 was accurate within 8 percent, the best ARIMA model apparently did not change. However, the number of Index larceny/thefts, which had been steady since 1979, fell in 1983.

Best ARIMA Models for Predicting Index Larceny/Theft

Serial Relationships

A moving average model seems to be the most common ARIMA model type for Index larceny/theft (see Table N). In five of the 14 jurisdictions, the serial term in the best ARIMA model was (0,1,1)(Sp,Sd,Sq), and in three others, the best serial term was ARIMA model (0,1,2)(Sp,Sd,Sq). In fact, as with Index aggravated assault, if the series required first differencing, the best serial term was usually moving average ARIMA (0,1,1)(Sp,Sd,Sq) or (0,1,2)(Sp,Sd,Sq).

On the other hand, several of the best ARIMA models for Index larceny/theft were autoregressive in the serial term. In this respect again, larceny/theft patterns are similar to aggravated assault patterns. The serial terms for Cicero (1978-1983), Des Plaines, Rock Island, and Springfield were ARIMA (2,0,0)(Sp,Sd,Sq) or ARIMA (1,0,0)(Sp,Sd,Sq).

Seasonal Relationships

Seasonal fluctuation in Index larceny/theft was generally strong (see Table N). The most common model type was ARIMA (p,d,q)(0,1,1), which described 12 of the 14 jurisdictions.

Cicero was the only jurisdiction in which the descriptive seasonal analysis (see Table F) indicated no seasonal fluctuation in larceny/theft. However, the ARIMA analysis found that the later years of the series (1978 to 1983) contained much more seasonal fluctuation than the earlier years.

Model Change in Cicero

The best ARIMA model for Cicero larceny/theft (see Figure 11) in the early years was ARIMA (2,1,0)(1,0,0). This model had the following AR(1), AR(2), and AR(12) weights when estimated for six time periods:

Time Period	AR(1)	AR(2)	AR(12)
1972-1977	-.30	-.31	-.34
1972-1978	-.28	-.35	-.45
1972-1979	-.31	-.27	-.02
1972-1980	-.34	-.25	.04
1972-1981	-.36	-.25	.05
1972-1982	-.35	-.25	.08

Table N. Index Larceny/Theft ARIMA Models, 1972-1983

			Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Arlington Heights	(0,1,1)(0,1,1)	--	--	--	--	.55	.68	.81	--	--	--	.87	.91	.95
Aurora	(0,1,2)(0,1,1)	--	--	--	--	.28	.45	.62	--	--	--	.83	.88	.94
						.10	.27	.44						
Cicero[a]														
1972-1977	(2,1,0)(1,0,0)	--	-.54	-.30	-.06	--	--	--	-.59	-.34	-.10	--	--	--
			-.55	-.31	-.07									
1978-1983	(1,0,0)(0,1,1)	--	.13	.37	.61	--	--	--	--	--	--	.66	.80	.94
Decatur	(0,1,1)(0,1,1)	--	--	--	--	.57	.69	.82	--	--	--	.86	.91	.96
Des Plaines	(2,0,0)(0,1,1)	--	.25	.42	.58	--	--	--	--	--	--	.84	.89	.94
			.15	.31	.48									
Elgin	(0,1,1)(0,1,1)	--	--	--	--	.54	.68	.81	--	--	--	.84	.90	.96
Evanston	(0,1,1)(0,1,1)	--	--	--	--	.76	.85	.94	--	--	--	.88	92	.97
Joliet	(0,1,2)(0,1,1)	--	--	--	--	.21	.38	.55	--	--	--	.81	.87	.93
						.13	.30	.47						
Peoria[b]	(1,1,0)(0,1,1)	--	-.66	-.52	-.37	--	--	--	--	--	--	.79	.85	.91
Quincy	(0,1,1)(2,0,0)	--	--	--	--	.50	.63	.76	.09	.25	.40	--	--	--
									.18	.34	.50			
Rockford	(0,1,2)(0,1,1)	--	--	--	--	.28	.46	.64	--	--	--	.83	.89	.94
						.03	.21	.39						

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Rock Island	(2,0,0)(0,1,1)	--	.25	.43	.60	--	--	--	--	--	--	.86	91	.96
			.04	.21	.38									
Skokie	(3,1,0)(0,1,1)	--	-.82	-.66	-.50	--	--	--	--	--	--	.84	.90	.96
			-.69	-.51	-.33									
			-.54	-.37	-.20									
Springfield	(1,0,0)(1,1,0)	--	.62	.74	.86	--	--	--	-.73	-.66	-.58	--	--	--

[a]In Cicero, the number of crimes known to the police in November 1977 was extremely low relative to other Novembers. This was true for every Index crime. For Index larceny/theft, there were 8 in November 1977, but an average of 85 in all other Novembers. The other 11 months of 1977 averaged 69. This led us to suspect the accuracy of the November 1977 figure, but we were unable to obtain additional information from Department of State Police. Therefore, in the anaysis in this report, 85 is used for November 1977.

[b]Corrected data for August and September 1979 (see Table 12). Also, data were corrected based on updated Department of State Police files.

The estimated weights of the AR(1) and AR(2) terms remained fairly constant over time, but the weight of the AR(12) term changed as 1979 and later years were added to the series. In addition, the statistical diagnostics (see Appendix 1) of an ARIMA model (2,1,0)(1,0,0) were not good for the models 1972–1979 and later. In particular, the residuals of these models indicated that seasonal fluctuation was not accounted for by ARIMA (2,1,0)(1,0,0).

For all these reasons, the project searched for another ARIMA model for the period 1978–1983. Although this six-year period is short for reliable model-fitting, the best model appeared to be ARIMA (1,0,0)(0,1,1). The estimated weights of the AR(1) and MA(1) terms for the final two time periods were the following:

Time Period	AR(1)	MA(12)
1978-1982	.36	.82
1978-1983	.37	.80

In summary, the best ARIMA model for Cicero Index larceny/theft in the later years contained much more seasonal fluctuation and much less serial fluctuation than the best ARIMA model for the earlier years. The model for 1978–1983 required 12th (seasonal) differencing, but not first (serial) differencing.[72] With this ARIMA model, (1,0,0)(0,1,1), 1983 was predicted within 3 percent and the average 1983 month within 17 percent (year-ahead method). Such accurate predictions indicate that the level of the series did not change in 1983. As the pattern description graph (see Figure 11) shows, larceny/theft in Cicero increased steadily from 1978. The different patterns in 1972–1977 and 1978–1983 can also be seen in the graph.

Summary: Index Larceny/Theft

Index larceny/theft was, by far, the most predictable type of crime that the Predictability Project examined. The number of offenses in the total year was predicted within 10 percent in at least one year (1981, 1982, or 1983) in 11 jurisdictions, and in four cities both 1982 and 1983 were predicted within 10 percent. Further, in the four jurisdictions in which there was a change in level in 1982 or 1983, the year 1981 was predicted within 10 percent (2 percent in Aurora, 4 percent in Des Plaines, 4 percent in Elgin, and 3 percent in Rockford). In Cicero, which had such a complex larceny/theft time series that only 1983 could be predicted, that 1983 prediction was correct within 3 percent.

Even the years indicating a change in level in larceny/theft were predicted more accurately than intervention years in other Index crimes. The most *inaccurate* prediction for Index larceny/theft was 29 percent in 1982 in Aurora. Compare this to the most inaccurate yearly prediction for Index burglary (40 percent in Des Plaines), for Index aggravated assault (49 percent in Cicero), or for Index robbery (99 percent in Joliet).

Compared to the models for the other Index crimes, the models for Index larceny/theft were more similar to each other. The serial term was likely to be ARIMA (0,1,1)(Sp,Sd,Sq) or ARIMA (0,1,2)(Sp,Sd,Sq), and the seasonal term was likely to be ARIMA (p,d,q)(0,1,1).

Why is Index larceny/theft more predictable than the other Index crimes? One reason may be that there are many more observations per month (see Table B). The average number of larceny/theft offenses ranged from 88 in Cicero to 506 in Peoria. Burglary, in contrast, ranged from 51 in Quincy to 265 in Rockford. Another reason for the comparatively good predictions may be that every larceny/theft time series contained strong seasonal fluctuation, and in almost every series this fluctuation was modeled by a simple (p,d,q)(0,1,1) seasonal term. A

[72] Note that these changes in the best ARIMA model also occurred in Evanston burglary.

great deal of the variation in larceny/theft can be described simply by knowing this seasonal pattern. This produces accurate forecasts rather easily.

In summary, the analysis found the following to be true for Index larceny/theft:

- Of the four types of crime analyzed by the project, Index larceny/theft was by far the most predictable.
- The best model for a larceny/theft series was likely to be a moving average, seasonal model.
- There was more consistency from jurisdiction to jurisdiction in the best ARIMA model for larceny/theft than for the other crime types.
- Index larceny/theft was strongly seasonal in every jurisdiction analyzed.

Summary: Predictability by Type of Crime

One answer to the question, "Is crime predictable?" seems to be that some types of crime are predictable and others are not. In general, the number of Index larceny/theft offenses known to the police was likely to be predictable within 10 percent for the next year and within 20 percent for the next month (year-ahead method). Even when a serendipitous intervention was apparent in a larceny/theft time series, the year in which the change in level occurred was still predictable within 25 percent.

In contrast, Index burglary was usually not predictable in the 14 sampled jurisdictions, using the methods of this study. Only three jurisdictions had successful burglary predictions, by the 20 percent yearly and 30 percent monthly criteria, for both the total year and the average month in 1982 and 1983. These three successful cases show that, even though it was usually difficult to identify a burglary model that fit well and predicted accurately, it was not impossible. However, even in the three successful burglary predictions, the degree of accuracy tended to be less than for larceny/theft. In general, successful yearly predictions in Index burglary were accurate within 10 percent to 20 percent, in comparison to successful Index larceny/theft predictions, which were accurate within 5 percent to 10 percent.[73]

The most interesting characteristic about the predictability of Index burglary, when compared to the other Index crimes that were examined, was the high proportion of jurisdictions in which an intervention may have occurred. Why were there so many more serendipitous interventions in burglary than in the other Index crimes? One possibility is that the time period we happened to choose for the Predictability Project, 1972-1983, was a volatile period for burglary victimization in Illinois. There may have been a number of successful programs aimed at reducing the number of burglaries. There also may have been changes in the likelihood of citizens to report burglaries to the police, or changes in the administration of recording those burglaries that were reported. Alternatively, Index burglary may simply not be predictable, and the apparent interventions found by the ARIMA models may reflect only the essentially random character of the number of burglaries over time.

If Index larceny/theft and Index burglary represent the two extremes of predictable and unpredictable crime types, Index robbery and Index aggravated assault represent a middle ground. Index robbery was predicted within 20 percent for at least two years in every jurisdiction analyzed, and within 10 percent in some jurisdictions. In contrast, Index aggravated

[73]The one exception to this was Peoria, where Index burglary was predicted within 6 percent in 1982 and 2 percent in 1983.

assault predictions ranged from very accurate to completely unpredictable, depending on the jurisdiction.

There were many serendipitous interventions discovered in Index robbery, and, unlike Index larceny/theft, the accuracy of robbery predictions in years with possible interventions was usually very bad. This inaccuracy for intervention years, like the inaccuracy for monthly predictions, may reflect the low number of observations per month in most Index robbery time series. Thus, for example, Index firearm robbery in total Illinois (non-Chicago) had a serendipitous intervention, but with 261 offenses in the average month, the prediction in the intervention year was only 23 percent in error. In contrast, robbery predictions in individual jurisdictions with an intervention were as much as 99 percent in error (Joliet).

Of the four Index crimes analyzed, aggravated assault was the least likely to show a serendipitous intervention. In only one of the 14 jurisdictions, Cicero, was there a definite change in level. (In Quincy, the 23 percent inaccuracy of the 1983 prediction may have been due to small numbers. The analysis in Rock Island indicated a possible change in the model, not in the level.) The reason for this is unclear. One possible explanation is that the actual number of assault victimizations is less likely to change suddenly than other types of victimization. Because assault is a violent, impulsive crime usually committed between friends or relatives, perhaps it responds less dramatically to crime prevention measures or to other societal changes than does a property crime such as burglary. A second possible explanation is that the recording in official records of Index aggravated assault may have been more consistent over the time period analyzed than the recording of other crime types.

In contrast, the analysis of Chicago Index aggravated assault by weapon type, which is discussed in detail in the Chicago Intervention Analysis, suggests the presence of not one but two interventions. One of these, a drop in the number of offenses with a knife, other weapon, or body as a weapon in 1981 and 1982, may have been due to a drop in victimizations resulting from increased enforcement. The second, a 1983 increase in offenses, may have been due to a change in recordkeeping practices.

Predictions for Index aggravated assault were generally more accurate for total Illinois (non-Chicago) offenses by weapon type than for each individual jurisdiction. As for Index robbery, this greater accuracy may reflect the higher numbers in the total Illinois series. Even when a serendipitous intervention was discovered--1983 Index assault with body as a weapon--the year was predicted within 29 percent (year-ahead method). This was more accurate than the 1983 prediction in Cicero, which was apparently also an intervention year. The year-ahead prediction was 49 percent wrong.

Low observations may affect the accuracy of monthly predictions of Index robbery. The only average monthly predictions that were within 30 percent for two years were in Peoria in 1981 and 1982, and Peoria had the most robbery offenses per month of any Illinois (non-Chicago) jurisdiction analyzed (see Table B). In the four weapon types of robbery in Illinois outside Chicago, all predictions were within 30 percent for the average month. The number of observations per month for these four weapon types ranged from 34 to 295 (see note 42).

In Index aggravated assault as well, there seemed to be some relationship between the degree of predictability and the number of occurrences per month. In general, those time series with fewer than 20 or 30 offenses per month over the 1972-1983 period were less likely to have ARIMA models that predicted each month, although the models often successfully predicted the total year.

This does not appear to be an explanation for the difficulty of model-fitting and the low predictability in Index burglary. The number of Index burglary offenses in the average month in any jurisdiction was never fewer than 40, and most jurisdictions had 90 or more per month. On the other hand, perhaps burglary is different from robbery or aggravated assault. The minimum number of offenses per month that is required for adequate predictability may be larger for burglary. The one Index burglary time series that could not be modeled was in Des Plaines, which had the fewest number per month of any burglary series, 46. Arlington Heights, which had 54 offenses per month, did not reach the monthly predictability criterion. However, Quincy, with 51 offenses per month, and Skokie, with 55, were among the nine jurisdictions in which a change in level may have occurred, and Cicero, with 60, was predictable by all criteria.

What are the most common types of ARIMA model? In all four Index crimes, the most common serial term was (0,1,1)(Sp,Sd,Sq), although for Index robbery this was likely to be the best model only in series with more than 30 offenses per month. The second most common type of serial ARIMA model depended on the type of crime. In Index robbery and Index larceny/theft, autoregressive models were common--(1,0,0)(Sp,Sd,Sq) or (2,0,0)(Sp,Sd,Sq). The third order autoregressive model (3,0,0)(Sp,Sd,Sq) was the best model for several Index aggravated assault series. However, for Index burglary the second most common serial term was (0,1,2)(Sp,Sd,Sq), which was also seen in some robbery and larceny/theft series but never in aggravated assault.

The most common seasonal term in the ARIMA models varied not only by the type of crime but also by the number of crimes per month. In robbery and aggravated assault, the majority of jurisdictions had no seasonal term at all, or a very slight degree of seasonality. In burglary, several of the best-fitting and best-predicting models had no seasonal term. In contrast, every larceny/theft model had some sort of seasonal term. If a jurisdiction did have a seasonal term, it was likely to be (p,d,q)(0,1,1), but (p,d,q)(1,0,0) also occurred, especially in smaller jurisdictions and in robbery and aggravated assault.

Overall, then, Index larceny/theft is the most predictable of the Index crime types analyzed, Index burglary the least predictable, and Index robbery and aggravated assault fall between the two extremes. However, the range of predictive accuracy within each crime type was great. Index larceny/theft is not as predictable in every jurisdiction; Index burglary is more predictable is some jurisdictions than others. In the following section, the question, "Is crime predictable?" is answered for each of the 14 jurisdictions.

Predictability by Jurisdiction

Some of the consistency in successful predictions seems to occur within jurisdictions, not within types of crime. In certain jurisdictions, predictive accuracy was usually poor, whatever the crime type. In other jurisdictions, predictive accuracy was usually good, whatever the crime type. In this section, the predictability of crime in each jurisdiction will be discussed. For a list of the best ARIMA model for each jurisdiction, see Appendix 3.

Arlington Heights

With only one Index robbery and four Index aggravated assaults per month over the 1972-1983 period (see Table B), Arlington Heights had enough observations for analysis in only burglary and larceny/theft (see Figure 30).

The burglary model predicted 1982 and 1983 fairly accurately, but the 1983 predictions were slightly over the 30 percent criterion for the average month. The ARIMA model (2,1,0)(0,1,1) for Index burglary, though it was better than alternative burglary models, did not fit as well after 1982 and 1983 were added to the series as it did to the 1972-1981 time period. The Box-Pierce statistic (see Appendix 1) at lags 12 and 50 were good for the earlier time period, a little worse when 1982 was added, and not really good at all after 1983 was added.[74] The larceny/theft model, on the other hand, was very successful, predicting 1982 within 6 percent, 1983 within 3 percent, and the average month within 19 percent and 13 percent, respectively.

Thus, in general, Arlington Heights burglary and larceny/theft offenses appear to be predictable. However, the degree of predictability is higher for larceny/theft than for burglary. Further, because even the best burglary model is still not particularly good statistically, the confidence in a burglary prediction is not as high as in a larceny/theft prediction.

Aurora

In Aurora, Index robbery and aggravated assault models predicted the total 1982 and 1983 years successfully, but not the average month. The average number of offenses per month over the entire 1972-1983 period was 15 Index robberies and 23 Index aggravated assaults (see Table B). These small numbers could account for the lack of accuracy in monthly predictions. However, Aurora Index robbery yearly predictions were among the most accurate in the jurisdictions analyzed.

Index burglary and Index larceny/theft had significant moving seasonality under both the additive and the multiplicative assumptions, which suggests the presence of data quality problems. Indeed, the pattern descriptions (see Figures 20 and 26) of these two series show extreme values in 1977. Despite this, however, both series were successfully modeled. In both, an intervention may have occurred. The model for Index burglary was 34 percent too high in predicting 1983, and 1981 and 1982 predictions were not very accurate. The model for Index larceny/theft was 29 percent too high in predicting 1982, but 1981 and 1983 were both predicted within 10 percent.

In Aurora, predictive accuracy depended on the type of crime. Index robbery and larceny/theft were generally predicted accurately, but not Index aggravated assault or burglary.

Cicero

With only 12 Index robbery offenses and 11 Index aggravated assault offenses per month (see Table B), Cicero predictions for these crimes would not be expected to be particularly accurate. However, Index robbery (see Figure 31) was predicted more accurately in Cicero than in most jurisdictions for the total years 1982 (within 14 percent) and 1983 (6 percent), though not for the average month.

In contrast, Index aggravated assault (see Figure 19) was not predictable in most years, though 1981 and 1982 were predicted within 14 percent and 18 percent, respectively. The actual number in 1983 was 49 percent more than the predicted number. Even though Cicero aggravated assault predictions were poor in many years, including 1978, 1979, and 1980 as well as 1983, the pattern description graph indicates that the serendipitous intervention in 1983 may be the result of a real increase rather than the reflection of a poor model.

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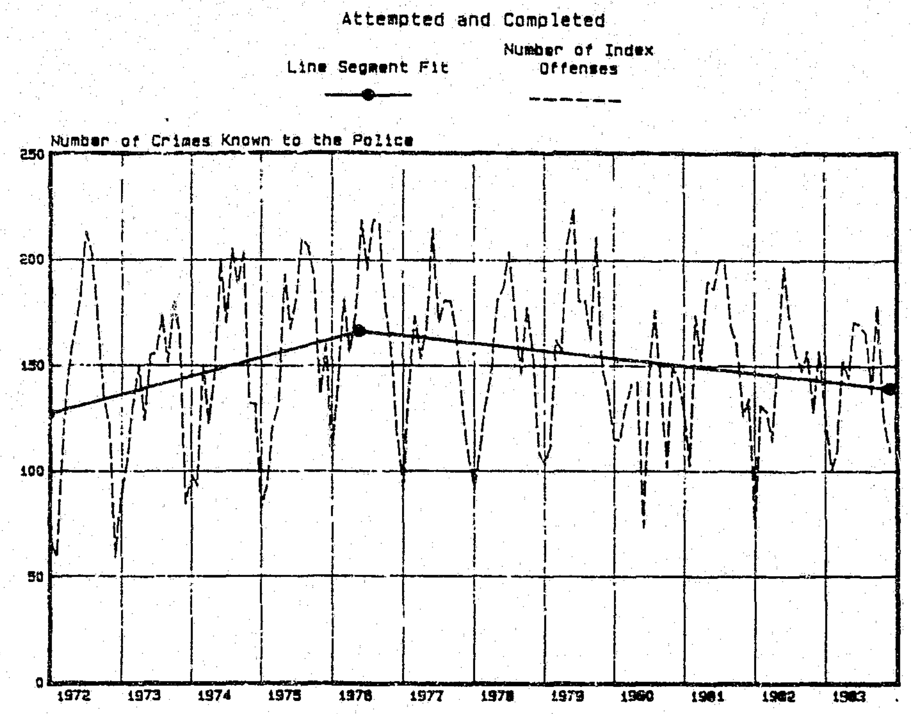
[74]The Box-Pierce statistic (see Appendix 1) is 14.3 at lag 12 and 66.2 at lag 50 for the 1972-1983 model. However, alternative model types have worse diagnostics.

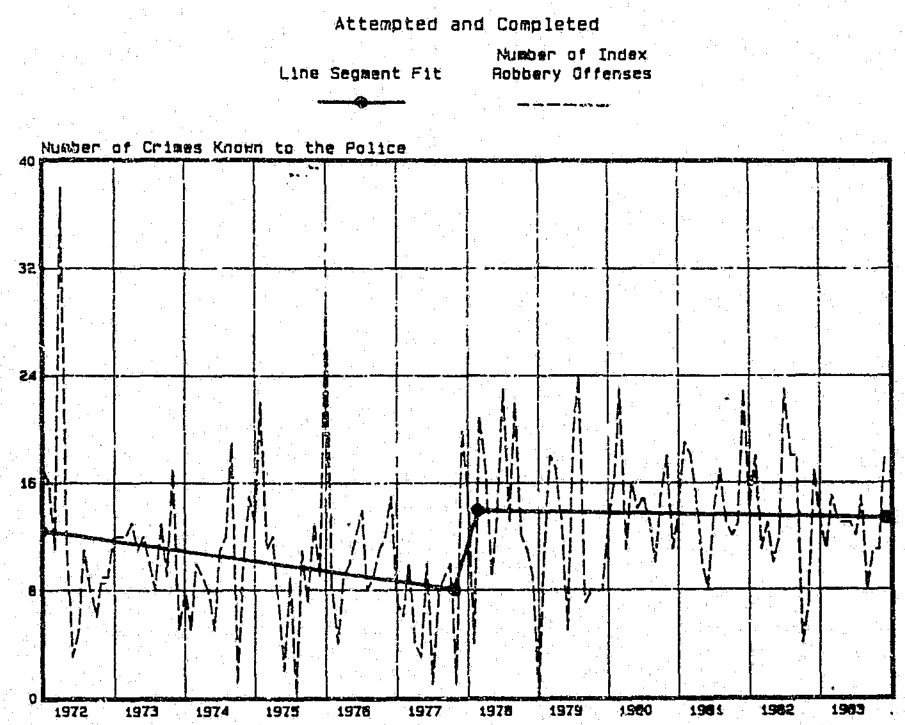
Figure 30. Patterns of Change Over Time in Arlington Heights Index Larceny/Theft, 1972-1983



Months, January 1972 through December 1983

Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 31. Patterns of Change Over Time in Cicero Index Robbery, 1972-1983



Months, January 1972 through December 1983

Source: ICJIA version of Illinois Dept. of State Police UCR Data

Burglary was modeled successfully in Cicero, but predictions were not very accurate. The 1982 prediction was within 14 percent, and the 1983 prediction within 8 percent. Again the pattern description graph (see Figure 9) of Cicero burglary indicates that a precipitous change took place midway through the time period. In November 1977 there were extraordinarily few burglary offenses. This was followed by a high number in 1978, and a sharp drop in 1979.

There was also an apparent model change in Index larceny/theft (see Figure 11). The best ARIMA model for 1978-1983 was not the same as the best model for the period 1972-1977. However, the only year in which it was possible to calculate a prediction, 1983, was predicted within 3 percent of the actual number.

Actually, a change in 1977 or 1978 can be seen in the pattern description graphs of all four Cicero Index crimes. The graph of Index robbery suggests a change in 1978, and the graph of Index burglary suggests a sharp drop between 1978 and 1979. Both the graph of Index aggravated assault and the ARIMA analysis suggest that there was not only an increase in 1983, but also changes in 1977, 1978, and 1979. In addition, for each of the four crimes, the number of Index offenses in November 1977 was extremely low relative to other Novembers. For example, there was only one burglary offense in contrast to an average of 57 in the other Novembers.

If models for all four crime types were shown to have changed between 1977 and 1978, it would indicate that the change in the larceny/theft model in Cicero was not unique to larceny/theft. This would suggest that the change in the number of larceny/theft offenses known to the police did not reflect change in the number of larceny/theft victimizations, but reflected rather a change in police administration. A hypothesis for further study would be that there was a change in the administration of data collection and maintenance in Cicero that affected all types of crime and occurred at the end of 1977.

Thus, overall, the predictability analysis in Cicero was characterized by serendipitous interventions in every type of crime. Possibly because of this, predictive accuracy in Cicero depended on the crime. Although robbery and larceny/theft were predicted fairly accurately, burglary was predicted with less accuracy, and predictions for aggravated assault were not accurate at all.

Decatur

Decatur Index robbery (see Figure 13) was exceptionally low during the ten months between October 1981 and July 1982; predictions for every month in this period were too high. In 1983, predictions were still inaccurate. The prediction of the 1983 year was 18 percent too high, and the extremely low number of robberies in December 1983 made that prediction almost three times as high as the actual number (five).

Index aggravated assault (see Figure 32) could not be successfully modeled. Predictions with the best model were 70 percent too high in 1981, and predictions for the average 1981 month were 134 percent in error, and as much as 658 percent wrong. The 1982 prediction was 50 percent too low, and the 1983 prediction was 12 percent too high. Although the prediction for the total 1983 year seems to be fairly good, the prediction for the average 1983 month was wrong by 47 percent.

The best ARIMA model changed for Index burglary in 1982 and 1983, and even though the alternative model fit better, it still generated inaccurate predictions.

The most successful Decatur model was for Index larceny/theft, but even larceny/theft showed signs of a change in 1982 and 1983. The ARIMA model (0,1,1)(0,1,1) that fits the

1972-1981 period is not a good fit when 1982 and 1983 are added to the series.[75] Also, Decatur was the only jurisdiction of those analyzed in which Index larceny/theft was not predicted within at least 10 percent in at least one year.

In general it seems that crime in Decatur was not predictable in 1982 and 1983 with the methods used here. The numbers of offenses in these years seem to increase and decrease erratically, following no pattern that can be described easily by an ARIMA statistical model. This occurs in every crime examined in Decatur.

Des Plaines

In Des Plaines, only two models were attempted--one for Index burglary and the other for Index larceny/theft--because the average number of Index robbery (three) and Index aggravated assault (five from 1975 through 1983) offenses in the average month was too small for analysis (see Table B). Burglary could not be successfully modeled, and there was an apparent change in the level of Index larceny/theft in 1983. The actual number of larceny/theft offenses known to the police in 1983 was 27 percent fewer than the predicted number (see Figure 27).

Even though the Index burglary model was poor, the Index larceny/theft model was very good, by any measure. For example, statistical diagnostics (see Appendix 1) for an ARIMA model (2,0,0)(0,1,1) were adequate for each of the four time periods from 1972-1980 through 1972-1983. Predictions were within 4 percent for 1981 and within 7 percent for 1982. Thus, the decline in 1983 indicated by ARIMA analysis is probably a real decline and not due to erratic changes in the time series.

Unlike the situation in Decatur, predictive accuracy seems to be possible in Des Plaines. Even though Index burglary could not be modeled, the model for Index larceny/theft was not problematic.

Elgin

Index robbery in Elgin (see Figure 10) was predicted successfully for the total years, though not for the average month. Also, one yearly prediction was accurate within 10 percent, but the other was not. This was also true for Index aggravated assault. Since there were only seven robbery offenses and 12 aggravated assault offenses per month over the 1972-1983 period (see Table B), low numbers may account for the low accuracy of these predictions.

Predictions for Index burglary in Elgin (see Figure 21) were better. They were relatively accurate for both the total year (within 10 percent) and the average month (within 20 percent) in 1981 and 1982. However, the 1983 prediction was 38 percent higher than the actual number of burglary offenses. In addition, although both 1982 and 1983 predictions for Index larceny/theft (see Figure 28) were somewhat higher (21 percent and 26 percent, respectively) than the actual numbers, 1981 was predicted within 4 percent, and 1980 within 7 percent.

Despite the problems of low numbers, serendipitous interventions, and the extreme 1974 months in robbery, a well-fitting ARIMA model was identified for each type of crime in Elgin, and these models generated predictions that were accurate within 6 percent to 17 percent for total years without interventions, and within 21 percent to 38 percent for years with interventions. Thus, these four Index crimes seem to be somewhat predictable in Elgin.

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[75] The Box-Pierce statistic (see Appendix 1) at lag 50 is 64.9 for the 1972-1983 period. However, alternative models for this period have even worse statistical diagnostic results.

Evanston

In Evanston, Index robbery was successfully predicted for the total years, and Index aggravated assault and Index larceny/theft were successfully predicted by all criteria. The degree of accuracy was usually high. Even though there were only 16 Index robbery and 16 Index aggravated assault offenses per month (see Table B), robbery and assault were predicted more accurately in Evanston than in some larger jurisdictions. Robbery was predicted within 5 percent in 1982 and 12 percent in 1983, aggravated assault within 6 percent (1982) and 3 percent (1983), and larceny/theft within 1 percent (1982) and 12 percent (1983).

A change in the model (and the level) of Index burglary offenses (see Figure 12) apparently occurred in 1979. Because of this change, no burglary prediction could be calculated for 1982. However, the prediction for 1983 was correct within 6 percent. Further, the model for the earlier years predicted 1978 within 1 percent and 1979 within 13 percent.

All five models (two for burglary) were statistically sound, according to the diagnostic tests discussed in Appendix 1. In general, then, the four Index crimes examined in this study were predictable in Evanston.

Joliet

In Joliet, the number of Index robbery offenses (see Figure 17) apparently dropped sharply in 1982 and remained low in 1983. In addition, the number of Index burglaries (see Figure 22) apparently declined more sharply in 1983 than the decline of the previous years. However, neither Index aggravated assault (see Figure 33) nor Index larceny/theft (see Figure 34) seems to have declined in 1982 or 1983. Thus, the serendipitous interventions in robbery and burglary seem to reflect change in these two crime types only, not in all crime in Joliet.

Except for the years in which the level of the time series appeared to change, predictions in Joliet were generally accurate, and the models were statistically sound. Index robbery offenses were predicted within 14 percent in 1980 and within 7 percent in 1981. Joliet had the most accurate predictions for Index aggravated assault offenses of the jurisdictions analyzed--5 percent in 1982 and 1 percent in 1983. Index burglary was predicted within 2 percent in both 1981 and 1982, and Index larceny/theft was predicted within 2 percent in 1982 and 9 percent in 1983.

Models in Joliet were generally well-fitting, according to the statistical tests in Appendix 1. The exception to this was the burglary model, which did not have perfect statistical diagnostics, but which did generate good predictions. Overall, then, these four Index crimes seem to be predictable in Joliet.

Figure 32. Patterns of Change Over Time in Decatur Index Aggravated Assault, 1972-1983

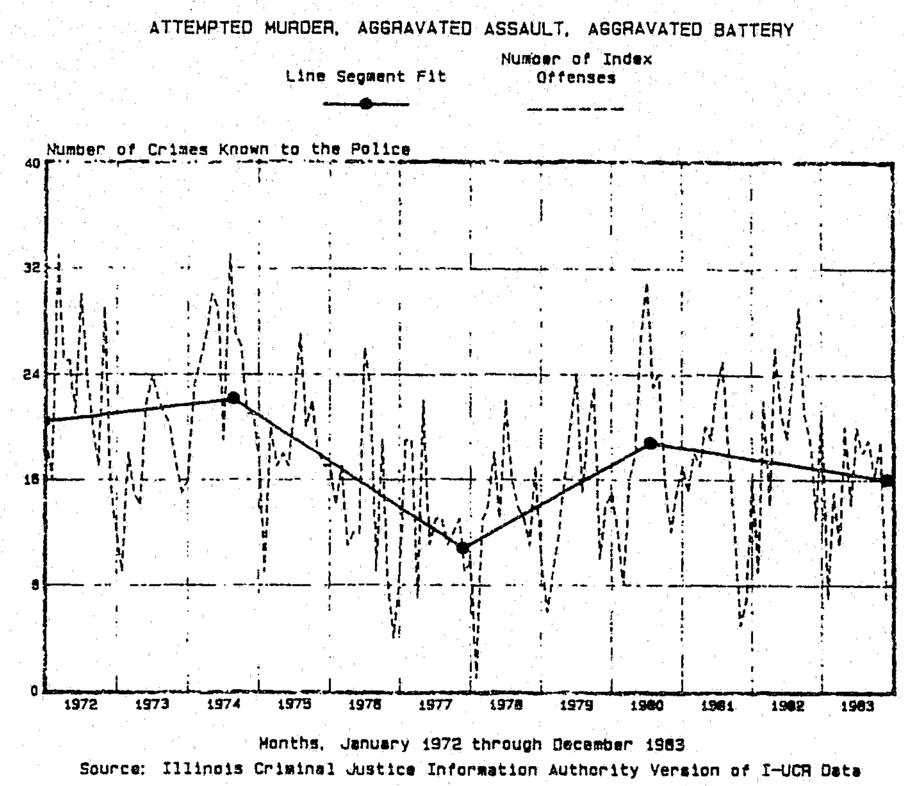


Figure 33. Patterns of Change Over Time in Joliet Index Aggravated Assault, 1972-1983

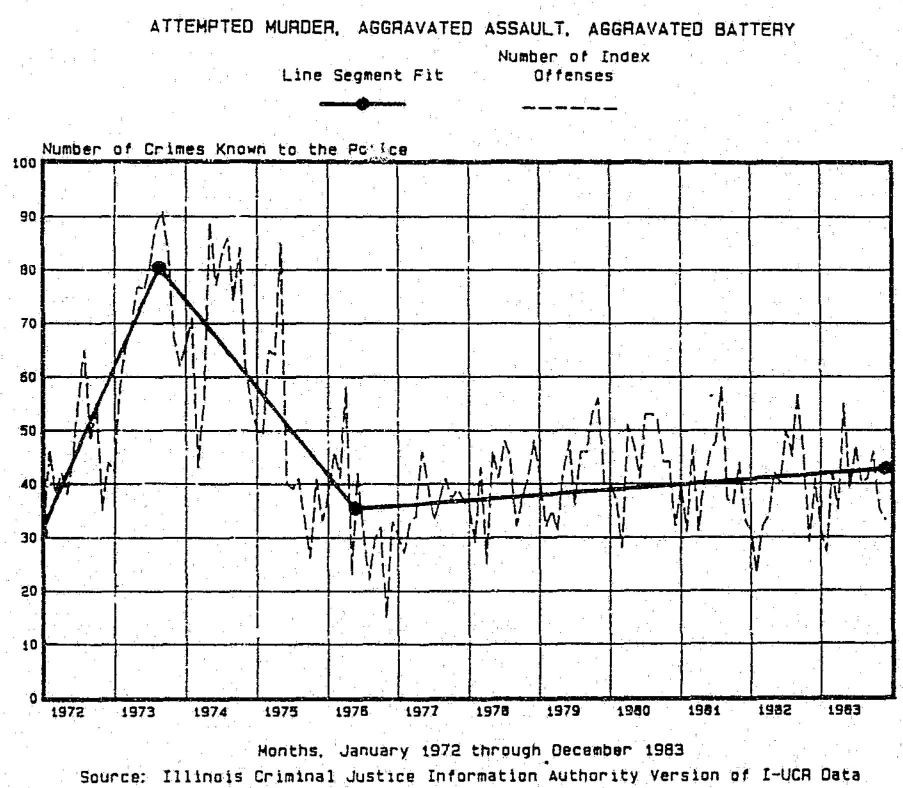
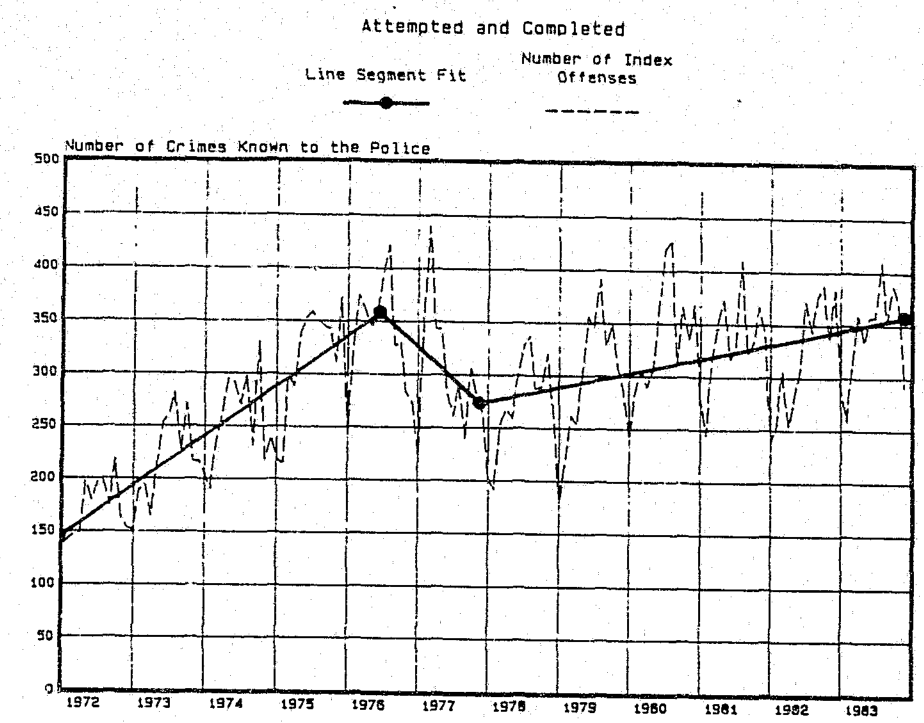
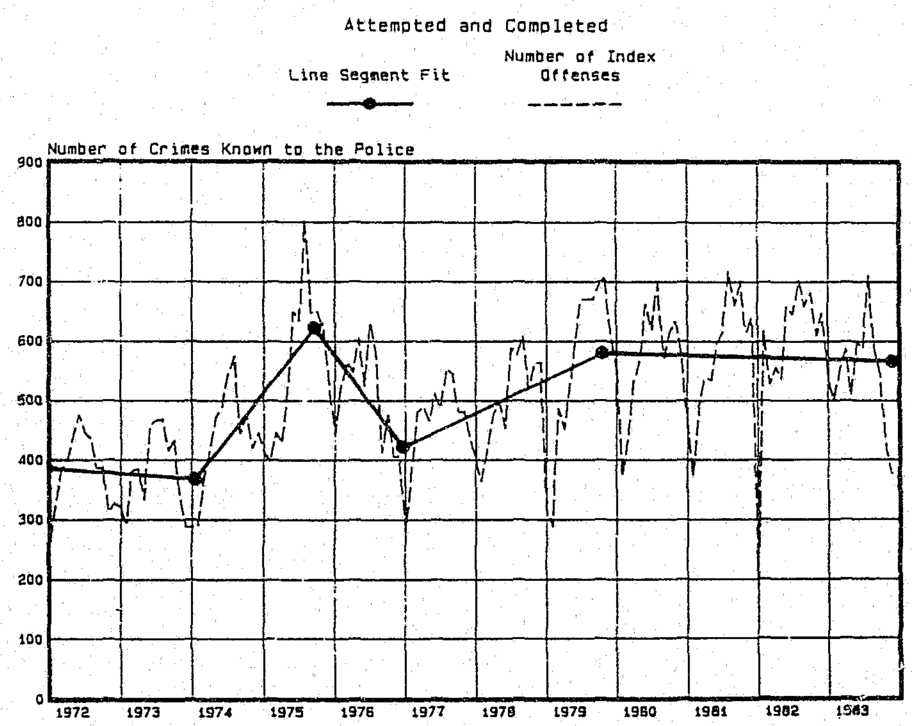


Figure 34. Patterns of Change Over Time in Joliet Index Larceny/Theft, 1972-1983



Months, January 1972 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 35. Patterns of Change Over Time in Peoria Index Larceny/Theft, 1972-1983



Months, January 1972 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Peoria

The four Index crimes were more consistently predictable in Peoria than in most other jurisdictions. Although the number of Index robbery offenses (see Figure 15) dropped in 1983, relative to previous years, 1982 was predicted within 1 percent and 1981 within 10 percent. In fact, Peoria was the only jurisdiction in which both monthly and yearly accuracy criteria were met for two years for Index robbery. The number of Index aggravated assault offenses was predicted within 14 percent in 1982 and 3 percent in 1983. Predictions of the number of Index burglary offenses were accurate within 6 percent in 1982 and 2 percent in 1983, making Peoria the only jurisdiction in which burglary was predicted within 10 percent for two years.

The number of Index larceny/theft offenses was predicted within 11 percent in 1982 and 18 percent in 1983. This degree of accuracy is rather low for larceny/theft predictions, compared to the accuracy in other jurisdictions. However, the relatively low accuracy in Peoria is accounted for by one extreme month, January 1982 (see Figure 35). There were only 188 offenses in that January, but 388 on the average in the other Januaries. The average 1982 month was predicted within 24 percent, if January is counted, but the months other than January were predicted within 10 percent on the average. It is interesting that Index burglary offenses (see Figure 36) and Index robbery offenses (see Figure 15) also were exceptionally low in January 1982, but that Index aggravated assault offenses (see Figure 37) were not.[76] Perhaps some clerical change in the recording of property offenses took place in Peoria in that month.

Except for the 1972-1983 Index robbery model, which suggested a possible intervention, all the Peoria models were exceptionally well-fitting. Even the Index burglary model fits very well for all time periods, which is unusual for burglary models. In fact, burglary and robbery predictions were more accurate in Peoria than in any other jurisdiction analyzed. Overall, the four Index time series in Peoria were easy to model, and produced accurate predictions.

Quincy

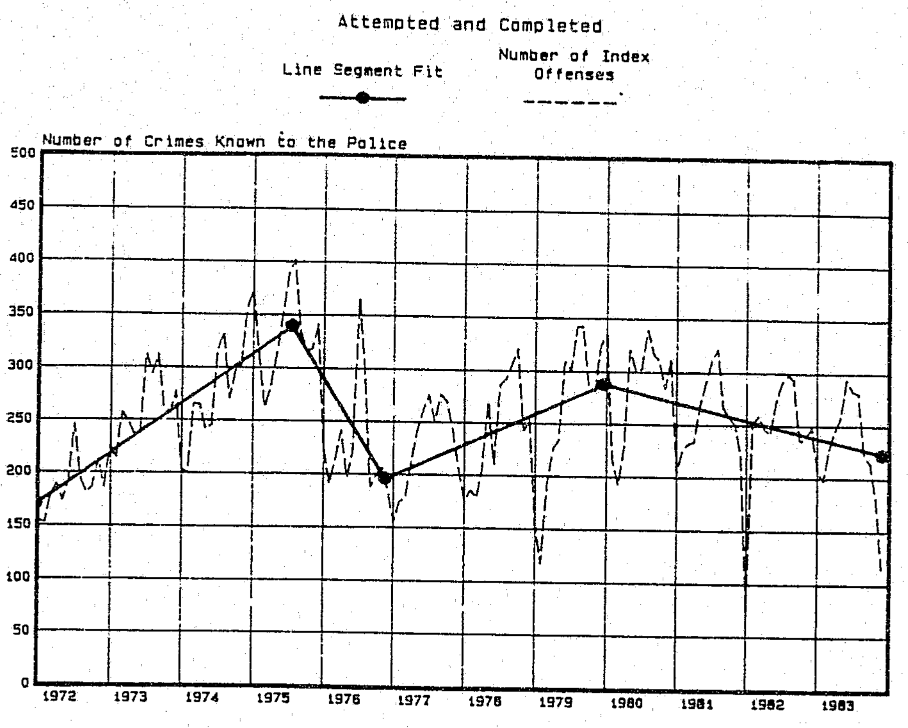
Quincy, the least populous jurisdiction in the sample, had too few Index robberies per month (three) (see Table B) for a model to be attempted. The best model for Index aggravated assault was accurate within 5 percent in predicting 1982, but was 23 percent too low in predicting 1983, which may reflect the small number of assault offenses per month (six) in Quincy.

Index burglary (see Figure 23) had enough offenses per month (51) to model, but there were two serendipitous interventions, a decline in 1981 that continued through 1982, and then an additional decline in 1983. However, predictions for Index burglary were accurate in other years: within 12 percent in 1979, 1 percent in 1980, and 6 percent in 1982.

In contrast, Index larceny/theft was successfully predicted by all criteria. In fact, the larceny/theft predictions in Quincy were more accurate than predictions in any other jurisdiction analyzed. The number of offenses in 1982 was predicted within 2 percent, and 1983 within 1 percent.

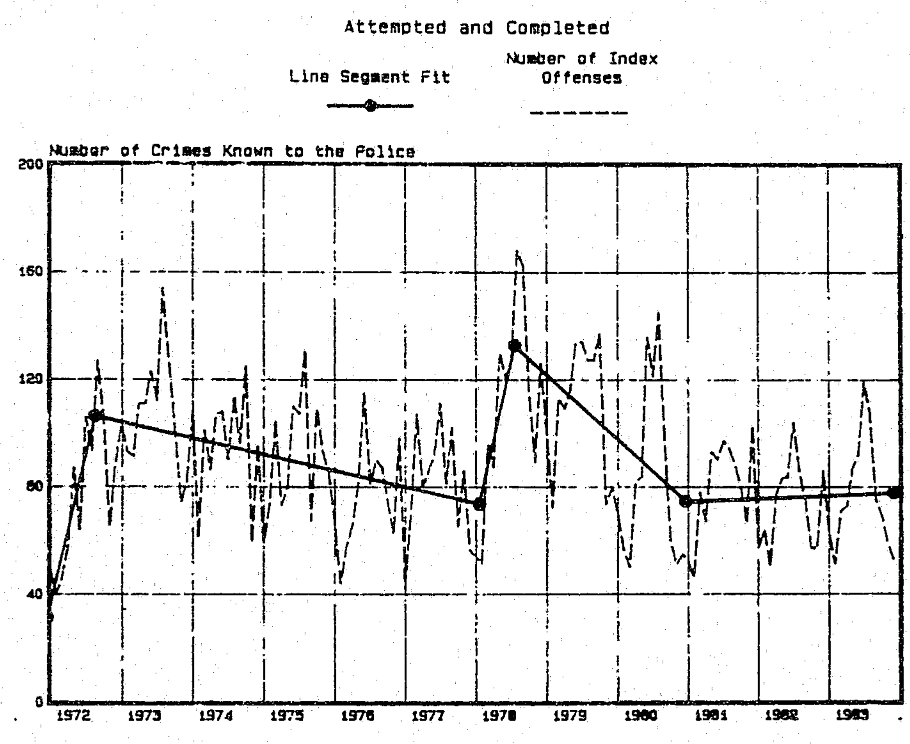
[76] Although January 1982 was not exceptionally low, there were unusually high numbers of aggravated assault offenses in Peoria in December 1981 and December 1982 (see Figure 37).

Figure 36. Patterns of Change Over Time in Peoria Index Burglary, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 37. Patterns of Change Over Time in Peoria Index Aggravated Assault, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Statistical diagnostics indicated that the three Quincy models fit the data. The fits were either excellent (aggravated assault) or adequate (burglary and larceny/theft). In general, then, larceny/theft and probably aggravated assault were predictable in Quincy. Although the pattern of index burglary offenses was somewhat erratic the burglary time series was possible to model, and the model produced accurate predictions for most years. Overall, the analysis in Quincy demonstrates that it is possible for crime to be predictable, even in a jurisdiction in which the average number of offenses per month is relatively low.

Rock Island

Rock Island robbery (see Figure 14) seems to have followed an erratic pattern from 1972 to 1981, but to have become easier to model and to predict in 1983. The number of index robbery offenses in 1982 was 71 percent lower than the predicted number, but the same model predicted 1983 quite accurately (within 10 percent), especially considering that there was an average of only 10 offenses per month in 1983.

The analysis of index aggravated assault (see Figure 38) was also complex in Rock Island; the best ARIMA model apparently changed in the last two years (see Table J). Despite this complexity, however, predictions were accurate. Even with the old model, 1981 was predicted within 3 percent, 1982 within 11 percent, and 1983 within 15 percent (year-ahead method). With the new ARIMA model (0,1,1)(0,0,1), predictions were even better--1982 within 1 percent and 1983 within 7 percent.

Index burglary (see Figure 7) was no exception in Rock Island; it was also difficult to model. The best ARIMA model for the period 1972-1978 was different from the best model for the period 1979-1983. However, in the years in which predictions were possible, they were fairly accurate: within 13 percent in 1978, 12 percent in 1979, and 6 percent in 1983.

Index larceny/theft was the only straightforward model in Rock Island, and even this time series was rather erratic in the early years. In fact, Rock Island larceny/theft dropped sharply between 1976 and 1977, and there were several extremely high months in 1979 (see Figure 39). This was followed by a relatively smooth, predictable period from 1980 through 1983. Despite the erratic pattern of the early years, the larceny/theft model generated accurate predictions, within 5 percent in 1982 and 6 percent in 1983.

Extreme values in 1979 are seen not only in Rock Island larceny/theft, but also in burglary and aggravated assault, though not in robbery. In fact, all four crimes seem to have followed two different patterns, one month-to-month pattern in the early years through 1979 or 1980, and another pattern in the later years from 1980 or 1981 through 1983. This suggests the hypothesis that some basic change took place, perhaps a change in crime recording, in Rock Island between 1979 and 1980.

However, the years 1982 and 1983 were both predicted within 10 percent for all four index crimes (except 1982 burglary, for which a prediction was not possible). Thus, crime in Rock Island seems to be predictable in the more recent time period, though it was not predictable in the early years of this analysis.

Figure 38. Patterns of Change Over Time in Rock Island Index Aggravated Assault, 1972-1983

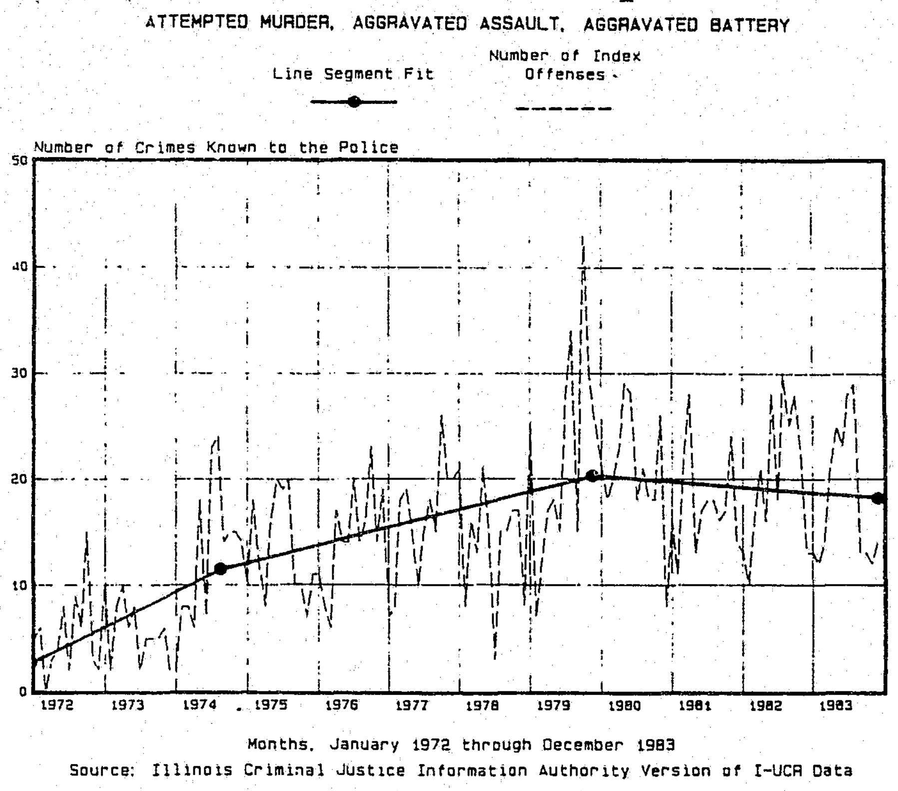
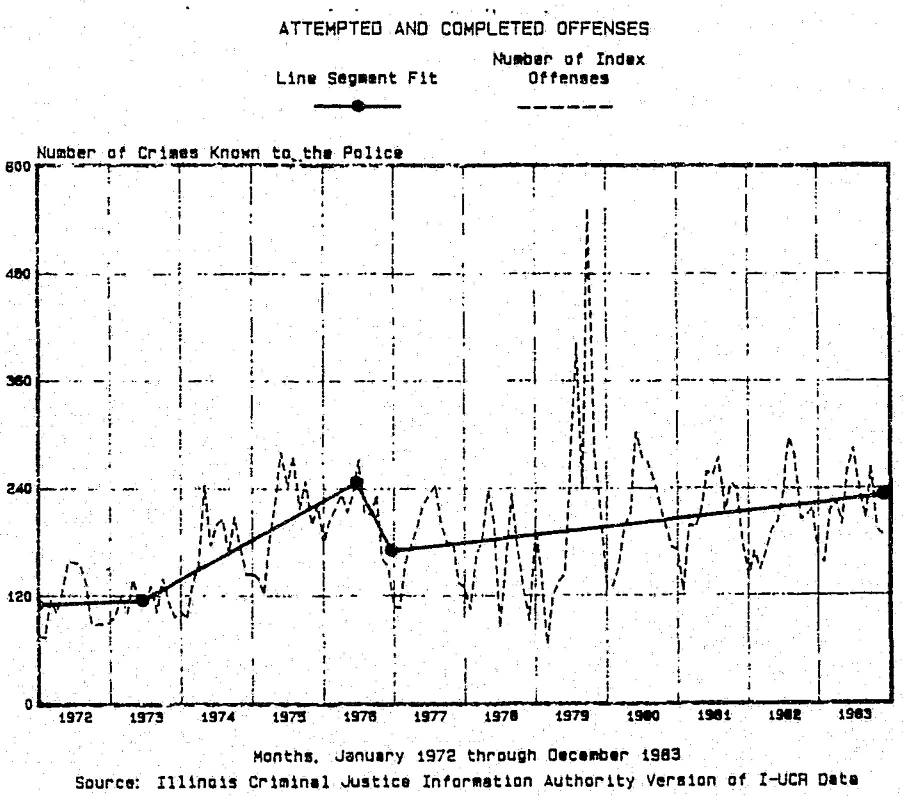


Figure 39. Patterns of Change Over Time in Rock Island Index Larceny/Theft, 1972-1982



Rockford

Rockford was the most populous jurisdiction, except for Chicago, analyzed in the Predictability Project (see Table A), and all four Index crimes had sufficient offenses per month for analysis. However, even in Rockford, Index robbery was not always predictable in the average month. Although the years were predicted within the 20 percent criterion--1981 within 10 percent, 1982 within 11 percent, and 1983 within 16 percent--the average 1981 month was predicted only within 29 percent, the average 1982 month within 31 percent, and the average 1983 month within 21 percent.

The model for Index aggravated assault had very good statistical diagnostic results, and predictions were within 2 percent in 1982 and 8 percent in 1983. This was one of the most accurate aggravated assault predictions of any jurisdiction analyzed.

The Rockford models for Index burglary and Index larceny/theft also had good statistical diagnostics, but indicated serendipitous interventions. The number of burglary offenses apparently fell in 1982 and remained low in 1983 (see Figures 24a and 24b), and the number of larceny/theft offenses fell in 1983 (see Figure 29). On the other hand, predictions for the other years were very good: Index burglary was predicted within 1 percent in 1981 and 4 percent in 1983, and Index larceny/theft was predicted within 4 percent in 1981 and 12 percent in 1982.

In general, crime in Rockford seems to be predictable. Each of the four time series was relatively easy to model. Except for the two serendipitous interventions, most crimes and years were predicted within 10 percent.

Skokie

In Skokie, there were too few Index robberies (three) and Index aggravated assaults (six) per month for either model to be attempted.[77]

The Index burglary model in Skokie predicted 1981 within 4 percent, and the average 1981 month within 16 percent. However, two months of 1982 were extremely low, and were not predicted within the 30 percent criteria (see Figure 25). Because these 1982 months were so low, and the model used them to predict 1983, the accuracy of 1983 predictions in those months was also low. Except for those months, however, Index burglary was predictable in Skokie.

Skokie Index larceny/theft was predictable by all criteria. (Unlike Index burglary, January and February 1982 were not extreme months for Index larceny/theft.) However, the degree of predictive accuracy for larceny/theft was less in Skokie than in most jurisdictions--8 percent in 1982 and 18 percent in 1983.

In summary, Index burglary and larceny/theft in Skokie were predictable by the generous 20 percent yearly and 30 percent monthly criteria. However, in both crime types, the degree of accuracy was less than in other jurisdictions that were considered predictable.

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[77] Skokie aggravated assault had an average of more than five per month if the entire 1972-1983 period is considered, but had fewer per month, on the average, if only the final years of the time period are considered. Therefore, it was not analyzed.

Springfield

In Springfield, all four Index crimes were predictable. Even Index robbery (see Figure 40), which had only 23 offenses per month, was predictable within 7 percent in 1982 and 5 percent in 1983, the most accurate of any jurisdiction analyzed. The 1982 prediction for the average month was only slightly too high (32 percent).

All four crimes were difficult to model in Springfield, but Index aggravated assault was the most difficult. The best assault model had relatively poor statistical diagnostics, but 1982 was still predicted within 2 percent, and 1983 within 15 percent.[78]

Although Index burglary and Index larceny/theft were sometimes difficult to model in Springfield, the final models produced accurate predictions. Index burglary had an extremely high month in 1978 (see Figure 41), and the year 1975 was high for Index larceny/theft (see Figure 42a). The high number of larceny/theft offenses from January 1975 through March 1976 is not an artifact of seasonal fluctuation, because it is also seen after seasonality has been removed from the series (see Figure 42b). Despite these difficulties, the statistical diagnostics of the Index burglary and the Index larceny/theft models were good, and so were the predictions. Burglary was predicted within 14 percent in 1982 and 9 percent in 1983, and larceny/theft within 10 percent in 1982 and 13 percent in 1983.

Although all four Index crimes were difficult to model in Springfield, the models that were finally identified generated accurate predictions. The Index robbery model was quite accurate--within 10 percent in both years. However, the models for the other three crime types generated predictions that were more than 10 percent wrong in at least one year.

Summary: Predictability by Jurisdiction

Although the circumstances of each jurisdiction are unique, it is possible to make some generalizations about the degree of predictability of the four Index crimes in the 14 jurisdictions analyzed in the Predictability Project.

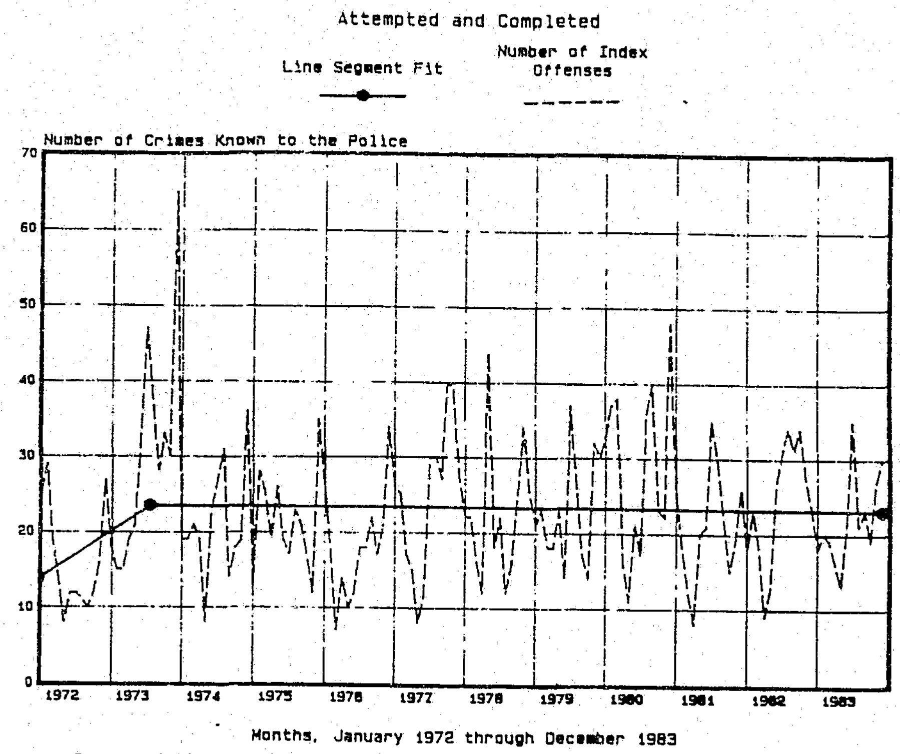
Jurisdictions in which Crime was Usually Predictable

In five of the 14 jurisdictions the four Index crimes were, in general, predictable. In these jurisdictions, for each Index crime with at least five observations per month, it was possible to identify an ARIMA model that had adequate statistical diagnostics according to the tests in Appendix 1. This model generated forecasts that were more accurate than the forecasts generated for the same crime in other jurisdictions. These jurisdictions were the following:

- Elgin
- Evanston
- Joliet
- Peoria
- Rockford

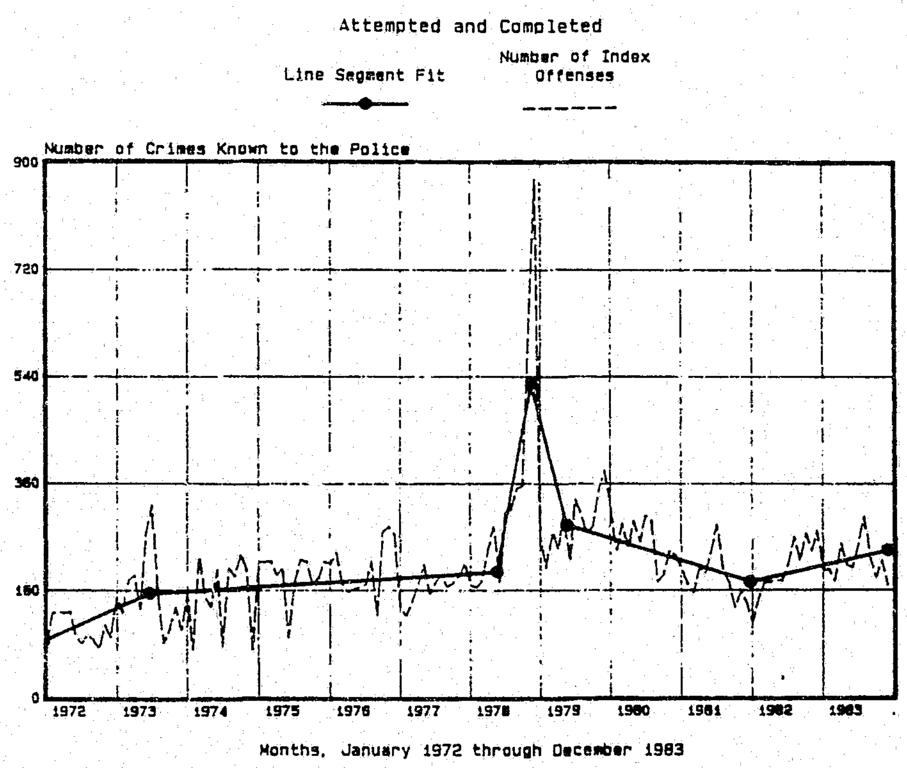
[78] The Box-Pierce statistics at lag 12 are all right, but the statistics at higher lags are not good. This is true for every model from 1972-1981 through 1972-1983.

Figure 40. Patterns of Change Over Time in Springfield Index Robbery, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 41. Patterns of Change Over Time in Springfield Index Burglary, 1972-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 42a. Patterns of Change Over Time in Springfield Index Larceny/Theft, 1972-1983

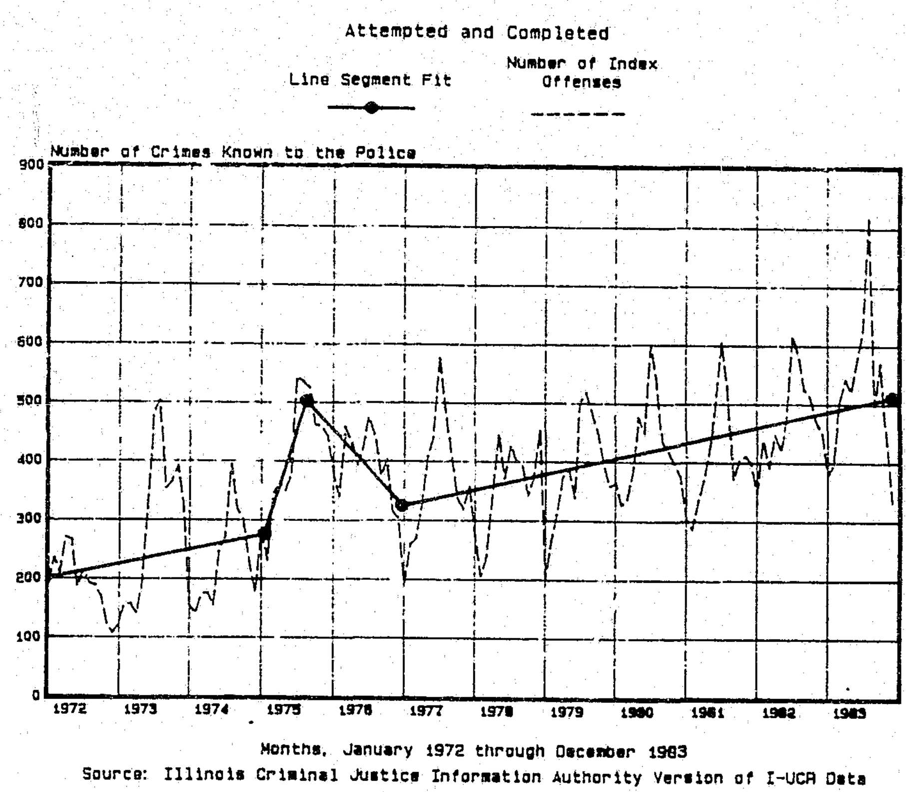
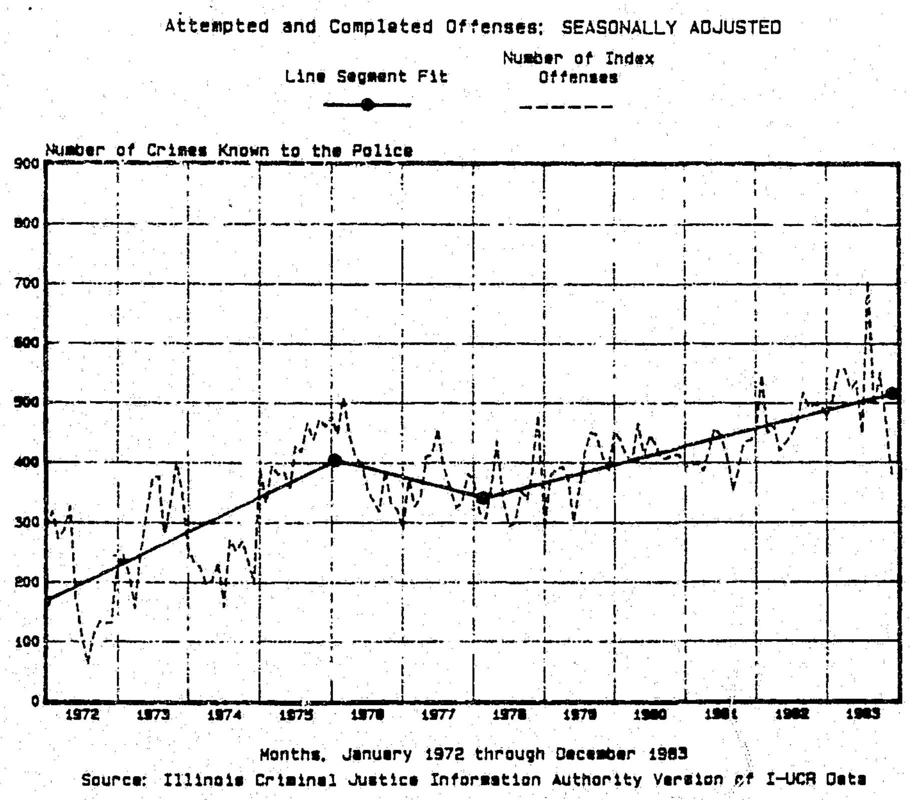


Figure 42b. Patterns of Change Over Time in Springfield Index Larceny/Theft, 1972-1983 (Seasonally Adjusted)



In these five jurisdictions, all four Index crimes were predictable, with no qualification. The time series were easy to model. Predictions were usually within 10 percent for each year and 20 percent for the average month. Even Index robbery, which was problematic in most jurisdictions, was adequately predicted in these jurisdictions.

These jurisdictions were some of the most populous in the sample. Peoria and Rockford were the two largest jurisdictions analyzed, except for Chicago, and Elgin, the smallest of these five, still had a population of 63,798 in 1980.

Jurisdictions in which Some Crimes, but not Others, were Predictable

Three of the following four jurisdictions had too few robberies, and two had too few aggravated assaults, for analysis. Of the crimes that could be analyzed, only one or two of the models were both well-fitting and predicted accurately. These jurisdictions and their predictable crime types were:

- Arlington Heights: larceny/theft
- Aurora: robbery and larceny/theft
- Des Plaines: larceny/theft
- Quincy: larceny/theft

The best model for Arlington Heights burglary was neither accurate nor a good statistical fit, but the larceny/theft model predicted 1982 and 1983 within 10 percent. Aurora Index robbery predictions were among the most accurate in the jurisdictions analyzed, and predictions for larceny/theft were within 10 percent for two years. However, aggravated assault and burglary were not predicted accurately.

The Des Plaines burglary model was poor statistically, and also inaccurate in the predictions it generated, but the larceny/theft model fit and predicted well. In Quincy, the pattern of Index burglary over time was somewhat erratic, and the number of observations was very low for aggravated assault. However, predictions for Index larceny/theft were better than those in any other jurisdiction, and considering the small numbers, predictions for other crime types were good in Quincy.

Jurisdictions with Serendipitous Interventions in Every Crime

The jurisdictions with serendipitous interventions in every crime were:

- Cicero
- Rock Island

In Cicero, the analysis of each of the four crime types indicated that a change had occurred in 1977 or 1978. Robbery and larceny/theft were predicted fairly accurately, burglary was predicted with less accuracy, and the aggravated assault predictions were not accurate at all.

In Rock Island, the period before 1980 was generally erratic and unpredictable, but after 1980, all four Index crimes had very accurate predictions.

Jurisdictions with Borderline Predictability

Two other jurisdictions had various difficulties in analysis, but in the end had adequate predictions, according to the generous 20 percent yearly and 30 percent monthly criteria:

- Skokie
- Springfield

In Skokie, both burglary and larceny/theft--the only crimes analyzed--were predictable within 20 percent for both 1982 and 1983. However, larceny/theft was predicted within 8 percent in 1982 and 18 percent in 1983, which is not particularly accurate for larceny/theft. Burglary was predicted accurately in 1981 (within 4 percent), but 1982 was only predicted within 27 percent and 1983 within 15 percent.

In Springfield all four Index crimes were difficult to model, and the predictive results were borderline. All of the years were predicted within 20 percent, but only half within 10 percent.

Jurisdiction in which Crime was Not Predictable

There was one jurisdiction in which crime was not predictable:

- Decatur

All of the models in Decatur were poor statistical fits and did not predict accurately. The most accurate predictions, in larceny/theft, were less accurate than larceny/theft predictions in any other jurisdiction.

Summary and Discussion

Methodological Goals

Time Series Data Quality Assessment

One of the methodological goals of the Predictability Project was to assess the availability of data of sufficient quality and quantity to conduct time series modeling and prediction analyses.

Quantity of Data

The analysis discovered that the minimum number of observations per month that is necessary in order to calculate accurate monthly predictions of criminal offenses with ARIMA is about 20. Crimes with fewer than 20 occurrences per month are not as likely as crimes that occur more frequently to meet either the statistical fit criterion or the predictive accuracy criterion. This is one reason why Index larceny/theft, which occurs more frequently than the other three types of crime, was predictable in more jurisdictions than the other crime types. In the three jurisdictions where only one crime was predictable, it was larceny/theft that was predictable; in the one jurisdiction in which two crimes were predictable, the crimes were robbery and larceny/theft.

The minimum number of years of data necessary to identify a model was especially important in Index burglary because the analysis discovered unexpected evidence of an intervention in most jurisdictions. The period available for a separate model after the occurrence of an intervention may be only a year or two. Generally, the project was not unable to identify a model when the number of years of monthly data was five or fewer. However, the practical experience of this project indicated that, for some series, model identification and accurate prediction seem to be possible with five years of monthly data, instead of the minimum of seven that is usually recommended.

Also, in many of the situations in which an unexpected intervention occurred in the last year or two, the project was able to determine whether or not the level or the ARIMA model probably had changed in the final year or two of the series. Although a separate ARIMA model cannot be identified for only one or two years and we did not use a computer package that would have measured the exact effect of an intervention, it seemed to be possible to determine whether a change in model may have occurred in the final year or two. In a number of time series, changes in level or even model were identified, even when the change apparently occurred in the final year. Even without calculating an exact transfer function, much can be discovered about change in a time series by the relatively simple and straightforward comparison of intervention-method versus year-ahead method projections, and by the comparison of model parameters as each year is added to the series.

Quality of Data

The initial pattern description analyses that were conducted routinely on every series revealed missing or obviously questionable data in many cases. These apparent errors had not been noticed earlier because previous analyses had used aggregate groups of months, jurisdictions, and crime types. This indicates that, for the continuing improvement of data quality, pattern description analyses should be conducted on a routine basis, as a check for missing data and outliers. This routine analysis should not be conducted on aggregate totals, but rather on the smallest available data categories.

An additional data-quality issue arises because of the surprisingly high number of serendipitous interventions found in the analysis of these 14 jurisdictions. The results of this study suggest that it would be dangerous to assume that the number of Index burglaries in Illinois jurisdictions follow a simple, consistently defined pattern from year to year. Whether the discontinuous changes in the number of officially recorded burglaries in a given jurisdiction is due to change in the number of burglary victimizations, in the willingness of victims to report burglaries to the police, or in police recordkeeping practices, cannot be ascertained from the Predictability Project analysis. However, other research (Cook, 1985:483) suggests that "the fraction of all robberies reported to the police (and included in the police departments' annual crime reports) differs among cities and varies over time."

It is often argued that, although Uniform Crime Reports offense data may not be comparable from jurisdiction to jurisdiction, the data can be used to compared over time the level of crime within the same jurisdiction. However, this analysis found a surprising number of cases in which this was not so. This argues against the assumption that crime patterns can be analyzed over time within a jurisdiction. Therefore, analysts should not assume that a rapid increase or decrease in officially recorded crime is due to an increase or decrease in the number of victimizations, unless there is corroborative evidence that this is the case.

Predictive Modeling Methods

This methodological goal of the Predictability Project was twofold:

1) to determine whether *any* type of ARIMA model would successfully fit crime series, and

2) to determine whether *certain kinds* of model would tend to fit certain kinds of crime, or crime in certain places.

Statistical Adequacy and Predictive Accuracy

In the process of trying to find the best ARIMA model for each of the local-level offense series in this project, we discovered that an ARIMA model could generally be found to fit most but not all of them. However, the project also discovered that merely finding a good-fitting model, by statistical criteria, is not enough to insure that accurate predictions would be generated. This is true for two reasons. In the first place, these crime series contained many unexpected (serendipitous) interventions, few of which could have been predicted before they happened. In the second place, a good statistical fit is not the same thing as predictive accuracy.

In the course of analysis, it often occurred that an ARIMA model that seemed to be a perfect fit according to statistical diagnostic tests was actually a terrible predictor. On reflection, this should not be very surprising. The adequacy of a statistical fit is based on analysis of the residuals--the difference between the fitted data and the actual data. These residuals must be random for the fit to be considered adequate. However, though the residuals are required to be random, they are not required to be small. In other words, there is no requirement that the fitted data (or the predicted data) be close to the actual data, only that the difference between the fitted and the actual data be random. Therefore, as the analysis progressed, it became clear that the criterion of predictive accuracy (in predictions for 1981, 1982, and 1983) was just as important as the requirement for statistical adequacy in determining whether or not a particular ARIMA model successfully fit a crime series.[79]

Common Types of ARIMA Model for Crime Data

If we knew that a certain type (or types) of ARIMA model was very common for a particular type of crime in most jurisdictions, it would be possible to construct standard programs that would attempt to fit the more common ARIMA model types for a given type of crime. Were there particular types of ARIMA models that seemed to fit certain types of crime, or crime in certain jurisdictions?

In the 14 jurisdictions analyzed, there was some consistency from place to place in the best-fitting type of ARIMA model for a certain type of crime. Similarly, the seasonal patterns identified by the project showed some consistency. For example, in Index robbery, the degree of seasonality seemed to be related to the number of offenses in the average month. Index larceny/theft was strongly seasonal in every jurisdiction analyzed. This information may make model identification in the future somewhat easier than it was in this project.

What are the most common types of ARIMA model? In all four Index crimes, the most common serial term was (0,1,1)(Sp,Sd,Sq), although for Index robbery this was likely to be the best model only in series with more than 30 offenses per month. The second most common type of serial ARIMA model depended on the type of crime. In Index robbery and Index larceny/theft, autoregressive models were common--(1,0,0)(Sp,Sd,Sq) or (2,0,0)(Sp,Sd,Sq). The third order

[79] A good, practical example of this arose in analysis conducted after the Predictability Study had been completed. In an attempt to model the number of Index forcible rape (criminal sexual assault) offenses per month in Chicago from 1972 through 1986, the model for the periods 1974-1980, 1974-1981, and 1974-1982 were all very good statistical fits, but the predictions were extremely erroneous. For example, the prediction for the average 1981 month was 62 percent wrong. Since the monthly errors were randomly positive and negative, the problem seems to be an erratic series, not a change in level. After the reform in data collection practices in 1983 and 1984, the best-fitting ARIMA model is exactly the same as the model for the earlier period. However, the predictions are much more accurate. The prediction for 1985 was only 2 percent too low, and the average 1985 month was predicted within 7 percent; the prediction for 1986 was 5 percent too low, and the average 1986 month was predicted within 14 percent. Also, the level of the series increased in 1983 (by about 50 percent) and 1984 (by about 12 percent). It is tempting to conclude that the reform in data administration not only increased the number of Index rapes known to the police, but also decreased the random and erratic nature of the data.

autoregressive model (3,0,0)(Sp,Sd,Sq) was the best model for several Index aggravated assault series. For Index burglary the second most common serial term was (0,1,2)(Sp,Sd,Sq), which was also seen in some robbery and larceny/theft series but never in aggravated assault.

The most common seasonal term in the ARIMA models varied not only by the type of crime but also by the number of crimes per month. In robbery and aggravated assault, the majority of jurisdictions had no seasonal term at all, or a very slight degree of seasonality. In burglary, several of the best-fitting and best-predicting models had no seasonal term. In contrast, every larceny/theft model had some sort of seasonal term. If a jurisdiction did have a seasonal term, it was likely to be (p,d,q)(0,1,1), but (p,d,q)(1,0,0) also occurred, especially in smaller jurisdictions and in robbery and aggravated assault.

Resources Necessary for Prediction

How difficult and time-consuming is the accurate prediction of criminal offenses with the ARIMA method? What expert skills are needed? Can these skills and decisions be quantified into a list of standard instructions that can be followed by anyone who wants to predict crime?

In the Predictability Project, the identification of the best type of ARIMA model for a particular time series, using the dual criteria of statistical adequacy and predictive accuracy, was a difficult and lengthy process. It was also somewhat subjective. Once a model type has been identified, a number of computer packages will estimate the model. See Appendix 2 for a comparison of four of these packages. However, identifying the best type of model is difficult and subjective. Two models that are equally good according to statistical tests may actually describe the stochastic process in the series very differently, and produce completely different forecasts.

The difficulties presented by the ARIMA method were analyzed in a comparison of the accuracy of forecasting methods conducted by the best time series forecasters in the world (Makridakis, *et al*., 1984). In this comparison, over 1000 economic time series were used. The ARIMA Box-Jenkins method was found to require the most time, even for these experts (Makridakis, *et al*., 1984:105). Each analysis required over an hour, on the average. This was much more time than the other methods required, partly because the ARIMA analyses could not be automated to be run mechanically. They depended to a great extent on the judgment of the expert.

In the Predictability Project, the ability to find a model that met both statistical and accuracy criteria appeared to be strongly related to the experience of the analyst. The time series analyses were all done twice, once by a less experienced analyst and again by someone more experienced. Although the initial models were successful according to the generous criteria of the project, they tended to suffer from several problems. These problems are mentioned here as examples of possible pitfalls in ARIMA modeling for the unwary analyst.

The initial models tended to be very complex, containing in most cases AR as well as MA terms. This improved the statistical diagnostics, but the predictive accuracy of these models was not good. The simpler models presented in this report do not always fit perfectly, according to statistical tests, but they compensate by predicting much more accurately than the more complex models.

The initial models tended to fit well or predict well in one time period, but not in all time periods. In the final analysis, we strengthened the criteria for model fitting--models had to fit and to predict for at least two years, and if there was any question, the analysis was done for a third year to be sure. In addition, the final analysis set formal criteria for model-fitting in the case of a serendipitous intervention.

Thus, the analysis of each series in the Predictability Project included not only the usual ARIMA process of model identification, but the repetition of this process for at least two, usually three, and often many more time periods, as well as analyzing monthly and yearly predictive accuracy by two methods--intervention and year-ahead. This involved analysis generated a great deal of information about each series, but required a correspondingly great amount of analyst's time. In fact, each series required days of work in all, much more than the time required in the Makradakis forecasting study.

Is ARIMA analysis worth the expenditure of resources? Can it be useful on a daily basis in the field, or is it appropriate only for large-scale research projects? The ARIMA analysis as it was conducted in the Predictability Project is obviously useless to answer a quick question in the field that might require an answer within an hour or two, unless some background work has already been done. On the other hand, it would be possible to build on the knowledge obtained from the successes and failures of the Predictability Project to 1) quickly update the predictions for each of the offenses analyzed in the 14 jurisdictions of the project, and 2) to expand the projections to other jurisdictions, on request.

Once a well-fitting ARIMA model has been identified for a certain jurisdiction and crime type, the resources required to update the predictions yearly or monthly are much less, and the benefits of doing so are potentially high. For example, with any of the four crime types in the 14 jurisdictions analyzed in the Predictability Project, predictions for 1984, 1985, 1986, and so on could be calculated relatively easily and automatically, and updated on a regular basis. Any deviation (high prediction errors) could be analyzed, using the methods described in this report, to determine whether such a deviation indicates a true increase or decrease, or only erratic changes in the time series. In the following section, we discuss some rules of thumb for making this determination.

Time Series Intervention Methods

The Discovery of Serendipitous Interventions

An unexpected result of the predictability analysis was that it occasionally uncovered an apparent change in level of the series or ARIMA model, indicating that an intervention had taken place, even in jurisdictions, crimes, and times where no intervention had been predicted. Some of these unexpected findings are intriguing. For example, the best ARIMA model for Evanston burglary appears to be different in the time periods 1972-1978 and 1979-1983. The later period contains much more seasonal fluctuation. In addition, the number of burglaries is higher. A cause of both changes could be the burglary prevention program that began in 1979. One goal of a burglary prevention program would be to educate citizens to recognize and report suspicious situations. If there is an increase in the number of reported burglary attempts, and if these incidents follow a seasonal pattern, then the effects of a prevention program could be increased incidents known to the police and increased seasonality.

Time series pattern description, with its simple description of the general pattern over time, can often find, and point out to the user, a sharp change or discontinuity in the time series. For example, the drop in 1983 in the number of robbery offenses in Peoria, which can be seen in the pattern description graph (see Figure 15), was also found in the ARIMA analysis. However, the more precise and painstaking ARIMA analysis also discovered some serendipitous interventions that were too subtle to have been discovered in the pattern description graphs. Some of the interventions, Rock Island Index burglary for example, were changes in ARIMA model, not in the level of the series. However, ARIMA analysis also occasionally found increases or decreases in level that had not been discovered in the pattern description graph. Usually this happened when the number of offenses had been increasing or decreasing steadily for several years, and then suddenly the increase or decrease became much sharper. (For example, see the discussion of total Illinois (non-Chicago) firearm robbery and Joliet Index robbery, page 45.)

When an intervention is discovered through analysis and not hypothesized beforehand, the cause could be that the predictive accuracy for the analysis of that series tends to be poor for every year. How is it possible to differentiate between a series that is generally unpredictable, and a series that has an actual change in level? With the time series analyzed here, the Predictability Project found the following rules of thumb to be helpful:

- Look at the prediction errors for each individual month. Most monthly errors should be in the same direction (negative or positive) as the prediction error for the total year. Otherwise, there was probably not a real change in level. For example, if the prediction for the total year is too low, the predictions for most months should also be low, or they should become increasingly negative over time. If the monthly predictions are highly erroneous but some errors are in the positive direction and others are in the negative direction, the series is probably erratic.

- Conduct both pattern description analysis and ARIMA analysis. The results of these should agree.

- In the ARIMA analysis, predict several years, not just one year. If most years are unpredictable, then the series is probably unpredictable.

- Look for a change in the degree of predictive accuracy, occurring a year or two after the suspected intervention. If the same ARIMA model predicts much more accurately in the years after the suspected change in level took place than in the years before, an improvement in the consistency of data recording may be the reason. This may have happened with Chicago sexual assault data (see note 79).

Year-Ahead versus Intervention Predictions

The project found the calculation of year-ahead predictions and intervention predictions to be a useful tool, at least at the exploratory level, for describing the possible reasons for a change in a time series. (For a review of these two predictive methods, see "Method of Measuring Predictive Accuracy," page 21).

If the year-ahead predictions for a year and the average month in that year are not accurate, but the intervention predictions for the same time period are accurate, then there is some indication that the level of the series changed (increased or decreased) but not the best model. Conversely, if both the year-ahead predictions and the intervention predictions are not accurate, there is then an indication that the best ARIMA model changed.

However, these are exploratory indications only, not proof. To provide a convincing argument that the level or the model really changed, the indications from the year-ahead predictions and intervention predictions need to be backed up by corrobatory evidence. In the case of a suspected change in level, this evidence would be the rules of thumb just discussed above--pattern of monthly errors, agreement of pattern description analysis, analysis over several years, and a change in error patterns over time. In the case of a suspected change in model, the following would provide additional evidence that a change in ARIMA model type, suggested by intervention method predictions, in fact occurred:

- Statistical diagnostics of the model, such as the Box-Pierce statistics at lags 12 and 50, were good before the suspected model change, but not after.

- Estimated weights for AR or MA terms changed (change is indicated when the AR or MA term becomes zero within two standard errors, or increases more than two standard errors higher than the estimate was before the intervention occurred).

- A different model fits better and predicts better than the old model for the additional years, but the old model still fits and predicts better for the earlier period.

These are relatively simple analyses to do at an exploratory level, in order to decide whether or not a change in level or model is a reasonable hypothesis. At a more formal level, such hypotheses can be tested with an experimental design like the Chicago Intervention Analysis described in the following section or by the statistical analysis of a hypothesized transfer function. However, the descriptive methods discussed here should help to avoid the misspecification of these formal hypotheses.

Predictive Accuracy

What is the degree of accuracy that may be expected with crime data? Criteria for predictive accuracy for economic data are often set at 10 percent for the following year or month. If that criterion were used for these local-level criminal offense time series, most of them would be categorized as unpredictable. However, certain crime types, and crime in certain jurisdictions, did meet these classical criteria.

The reader may have noticed that predictions for 1981 and 1982 are often as accurate or more accurate than predictions for 1983. There were very few cases in which 1983 predictions were more accurate than 1982 predictions. However, this does not mean that radical changes took place in 1983 throughout Illinois. The poorer 1983 predictive accuracy was simply a result of the design of the study. Model-fitting was done first for the earlier years, and then models fitting the early years were fit to the later years.

Predictability by Type of Crime

It is often argued that, although Uniform Crime Reports offense data may not be comparable from jurisdiction to jurisdiction, the data can be used for comparisons over time of the level of crime within the same jurisdiction. However, this analysis found a surprising number of cases in which this was not so. Serendipitous interventions, or unexpected sharp increases or decreases, occurred repeatedly.

Index larceny/theft was by far the most predictable type of crime that the Predictability Project examined. The number of offenses in the total year was predicted within 10 percent in at least one year in 11 jurisdictions, and in four jurisdictions both 1982 and 1983 were predicted within 10 percent.

Of the 14 jurisdictions in which Index burglary was analyzed, only three models generated successful predictions, two jurisdictions could not be successfully modeled at all, and in the remaining nine the analysis discovered a serendipitous intervention.

The predictive accuracy for Index aggravated assault ranged from very accurate to completely unpredictable, depending on the jurisdiction.

Overall, predictability for Index robbery was more successful in places with more robberies per month. However, jurisdictions with fewer than 30 but more than 10 robberies per month could often meet the yearly predictability criterion, if not the criterion for the average month.

Predictability by Jurisdiction

Predictive accuracy is related to the jurisdiction as well as to the type of crime. The Predictability Project found that, in general, Index larceny/theft was likely to be predictable, but that Index burglary was not very predictable. Index robbery and aggravated assault were predictable in some jurisdictions but not in others. However, in certain jurisdictions, predictive accuracy was usually poor, whatever the crime type, and in other jurisdictions, predictive accuracy was usually good, whatever the crime type. Therefore, it seems that the answer to the question, "Is crime predictable?" depends on the jurisdiction as well as on the type of crime.

Why do offenses officially recorded by the police follow a predictable pattern is some jurisdictions, but not in others? It does not seem reasonable that the actual number of victimizations of a certain type of crime would be random and unpredictable in some jurisdictions but patterned and predictable in other jurisdictions. The definition and recording of crime is not always completely objective (Miller and Block, 1985). To become a crime known to the police, an incident first must be reported to the police,[80] and then must be recognized and recorded by the police as a crime (Block and Block, 1980). Whether or not a crime actually occurred is often a matter of interpretation. Therefore, the number of crimes known to the police each month is related not only to the number of crimes that occur but also to the law enforcement jurisdiction's administrative practices in defining and recording crime. Thus one result of the Predictability Project was that even though crime itself may be predictable, administrative decisions may be unpredictable, at least in some jurisdictions.

[80] The victim or a witness may report the incident to the police, or the police may discover the incident in other ways, such as through police patrol, offender's confession, and so on.

Chicago Intervention Analysis

The primary objectives of the Predictability Project were to determine whether or not crime is predictable for certain jurisdictions and particular types of crime, and to discover the best methods for making such a determination. An additional objective was to use the methods of crime prediction that were tested and refined in the first part of the Predictability Project in an analysis of the effect of an actual intervention in Chicago--a change in the collection and maintenance of criminal offense data.

The Chicago Intervention Analysis measures the effect of the change in the administration of recordkeeping--the intervention-- on the number of occurrences of offenses known to the police. The time series experiment design of this analysis is discussed in the sections, "Methodological Goals" (page 10) and "Project Design and Methods" (page 15). Here, we present and discuss the results of that analysis.

Answers to two practical questions were sought in the Chicago Intervention Analysis:

1) Did the change in data collection and recording practices in Chicago in 1983 affect the number of crimes officially recorded, or were the changes in the number of crimes due to actual increases in crime occurrences? and

2) How much of the increase in the number of each type of recorded crime was due to recordkeeping, and how much to changes in crime occurrence?

Statistical Evidence of Intervention

This section explains in detail the methods and criteria the study used to determine whether or not a change in the number of offenses for a particular crime type could have been due to the change in the administration of data collection and maintenance in Chicago.

The study hypothesized that if an intervention had occurred in the collection and recording of Chicago offense data for a particular crime in 1983, this change would result in an increase in the number of crimes known to the police, relative to the number in previous years. The accuracy of the prediction of 1983 would be less than the accuracy of the prediction of 1982 or 1981. The best ARIMA model might also change when the year 1983 was added to the series. In addition, the predictive accuracy for 1983 would be less than the predictive accuracy for the same year and the same crime in Illinois (non-Chicago).

Predictive Accuracy

If a change in the number of crimes was due to a change in recordkeeping practices occurring in 1983, predictions for the total year 1983 and the average 1983 month (year-ahead method) would be less accurate than predictions for 1981 or 1982, using the same model.

In addition, if the change in the number of recorded offenses in Chicago was due to the change in the administration of recordkeeping that occurred at that time only in Chicago, then predictions for the total year and the average 1983 month in Chicago (year-ahead method) would be less accurate than 1983 predictions for Illinois (non-Chicago), for the same crime.

Evidence of a Change in the Model

Other evidence of an intervention in Chicago would be a change in the best ARIMA model when the year 1983 was added to the data set. In other words, the best model for the period 1974-1982 would not be a good-fitting model for 1983 Unfortunately, a one-year period is too short to fit a separate model that could be compared to the best 1974-1982 ARIMA model.[81] Therefore, the project considered any of the following to indicate the presence of a change in ARIMA model in 1983:

- The adjusted Box-Pierce statistics (see Appendix 1) for important lags (such as 12 or 30) are worse in the 1974-1983 model than in the 1974-1981 model or the 1974-1982 model.

- The low or high estimate for one of the AR or MA weights crosses zero in the 1974-1983 model, but not in the 1974-1982 model or the 1974-1981 model.

- The estimates of the AR or MA terms are much higher or lower in the 1974-1983 model than in the 1974-1982 model or the 1974-1981 model.

- Using the intervention method, 1983 predictions are less accurate than 1982 or 1981 predictions.

Serendipitous Intervention Findings versus a Time Series Experiment

In the first part of the Predictability Project, a number of jurisdictions and crimes showed a change in the number of events in a typical month or a change in the best ARIMA model, both of which indicate a possible intervention. What is the difference between the discovery of an intervention in the first part of this project, and the analysis of an intervention in the second part of the project--the Chicago Intervention Analysis?

In the process of identifying the best ARIMA model for each crime and jurisdiction, the Predictability Project first predicted 1981, then 1982, then 1983, then 1984.[82] The 1981, 1982, and 1983 predictions were compared to actual figures for those years. For some crimes and jurisdictions, the best model for predicting 1981 and 1982 did not predict 1983 accurately. For others, the best model for predicting 1981 and 1983 did not predict 1982 accurately. These results were considered to suggest the presence of an intervention (see "Is Crime Predictable," page 39).

These findings of possible interventions were serendipitous; they had not been expected when the Predictability Project was designed. Because the apparent interventions were discovered in the course of analysis and not predicted beforehand, it cannot be said that a particular event caused the intervention. For example, even if the timing of the intervention coincided with an event that could provide a reasonable explanation for it, as in the case of

[81] At the time this report was written, a program that could compute a transfer function was not available at the Authority. A transfer function would provide an exact measure of the effect of an intervention. However, the exploratory measures used here provide other evidence of the presence of an intervention.

[82] Predictions for each month of 1984, using the models in tables H, J, L, and N, are available on request.

Evanston burglary, we cannot conclude that the increased emphasis on burglary prevention in Evanston caused the change in the Evanston Index burglary time series.

In contrast, the design of the Chicago Intervention Analysis stated in advance that, because of the occurrence of an intervention (a change in the administration of recordkeeping), certain changes were expected to have occurred at a certain time in the number of certain types of criminal offenses. Greater change was expected to have occurred for some crime types than for others.

To eliminate the possibility that some alternative explanation accounted for the changes in Chicago offenses, for example an unknown event that may have affected crime in Illinois as a whole, the design included a control group (total non-Chicago Illinois). Such a design is called an interrupted time series quasi-experiment with a nonequivalent no-treatment control group (Cook and Campbell, 1979:214). The terms "quasi-experiment" and "nonequivalent" indicate that this intervention design is not a classic experimental design in which cases would be assigned randomly to a treatment group and a no-treatment group. The change in the administration of recordkeeping in Chicago did not, of course, occur randomly. However, even a nonequivalent control group provides much stronger evidence for causality than do the descriptions and *post hoc* explanations of the analysis of serendipitous interventions. Thus, for example, if an increase in index robbery or aggravated assault offenses occurred both in Chicago and in Illinois (non-Chicago), then the cause of this increase could not possibly be the change in Chicago recordkeeping practices.

Index Robbery

The total number of officially recorded Index robbery offenses increased in Chicago in 1983, compared to previous years. This increase was attributed by some to Chicago crime recording practices, which began to change at the beginning of 1983 at the time of the press accusations and the internal audit (Chicago Police Department, 1983), and which had become official practice by the end of the year. However, the Chicago Intervention Analysis hypothesized that this increase in officially recorded offenses did not occur for every type of crime. If a type of robbery had been completely and accurately recorded before the administrative reforms, then the reforms would have had no effect on it.[83] The following analysis suggests that firearm robbery was just such a crime.

Index Firearm Robbery

If the number of firearm robbery offenses in Chicago (see Figure 8) increased in 1983, the ARIMA prediction for 1983 would be less accurate than either the 1981 or the 1982 prediction. However, the 1983 prediction was more accurate (see Table O). Even though the five-year period from 1976 through 1980 is short for reliable model-fitting, an ARIMA model (0,0,3)(0,1,1)

[83]By the same token, a type of crime that had been undercounted before the reforms took place might still be undercounted afterwards, provided that the reforms had no effect on it. Such a type of crime would also show no change in 1983.

did predict 1981 within 15 percent for the total year and 23 percent for the average month.[84] The same ARIMA model, based on 1976-1981 data, correctly predicted 1982 firearm robberies within 17 percent (year-ahead method). In contrast, 1983 firearm robbery offenses were predicted within 8 percent Thus, the number of Chicago firearm robbery offenses does not appear to have changed in 1983.

By comparison, firearm robbery offenses in total Illinois (non-Chicago) were predicted within 2 percent in 1981, within 9 percent in 1982, but only within 23 percent in 1983 (year-ahead method). The actual number of offenses in 1983 was 23 percent higher than the predicted number. As Figure 16 shows, the number of firearm robberies in total Illinois (non-Chicago) dropped beginning in 1980. However, ARIMA analysis suggests that the number began to level off in mid-1983. All 1983 predictions from July through December were too low.

In summary, if our criteria are those discussed in the section, "Statistical Evidence of an Intervention" (page 115), the number of Chicago firearm robberies did not change in 1983. First, the predictive accuracy in Chicago in 1983 was not worse than the accuracy in 1981 or 1982. Second, the predictive accuracy in Chicago in 1983 was not worse than the accuracy in total Illinois (non-Chicago). In fact, the predictive accuracy in Chicago in 1983 was better, not worse, in both cases.

Other evidence of an intervention would be a change in the model in 1983, but the model does not appear to have changed. The best ARIMA model in all time periods examined for Chicago firearm robbery was (0,0,3)(1,0,0). The MA(3) and MA(12) estimates for this model were similar in all time periods.[85]

Time Period	MA(1)	MA(2)	MA(3)	MA(12)
1976-1980	zero	zero	-.60	.87
1976-1981	zero	zero	-.62	.90
1976-1982	zero	zero	-.49	.90
1976-1983	zero	zero	-.40	.87

All four models have an MA(3) term but no MA(1) or MA(2) term. In other words, each observation is related to the error of the observation three months ago, but unrelated to the previous month or to the observation two months ago (see Appendix 1).

In summary, there is nothing in the ARIMA diagnostics to indicate a model change in 1983. Also, the intervention method predictions for Chicago in 1983 (see Table O) are as accurate, and even slightly more accurate, than the 1982 intervention method predictions. This, again, argues that there was no change in the ARIMA model in 1983.

Therefore, an intervention does not seem to have occurred in the number of firearm robberies known to the police in Chicago in a typical month of 1983, compared to the number known to the police between 1976 and 1982. The change in the administration of data collection and maintenance apparently had no effect on the likelihood that Index firearm robbery offenses would become part of the official record.

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[84]Because the initial pattern description of Index firearm robbery in Chicago (see Figure 8) indicated that the pattern changed in 1976, and because subsequent ARIMA diagnostic tests and model-fitting attempts agreed with this, the analysis for firearm robbery begins in the year 1976.

[85]The estimate of the MA(3) term may have decreased after 1982 was added to the series, but this may be due only to the short number of years available for analysis. Also, the estimate of the seasonal MA(12) term is the same in each of the four models, and all of the models fit well according to statistical diagnostics (see Appendix 1).

Since firearm robbery is a serious crime, it always had been accurately and completely recorded, even before the administrative changes in recording practices. Thus, the changes had no effect on the number of firearm robbery offenses in official records.

Table O. Chicago Intervention Analysis: Index Robbery, by Weapon

	Percent Error of Predictions											
	Year-Ahead Method						Intervention Method					
	1981		1982		1983		1981		1982		1983	
	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month
Firearm												
Chicago[a]	15%	23%	17%	26%	8%	11%	9%	16%	11%	24%	4%	1%
NonChicago	2	10	9	13	23	24	2	10	0	11	0	14
Knife												
Chicago[b]	15	24	9	29	21	27	13	24	7	28	19	26
NonChicago	14	14	1	14	10	14	1	14	2	15	2	1
Other Weapon												
Chicago	11	19	2	20	38	36	4	14	3	18	28	28
NonChicago	14	23	4	29	17	27	8	25	3	22	10	23
Strongarm												
Chicago[c]	12	20	11	18	42	39	7	17	7	20	27	26
NonChicago	1	1	7	11	1	12	1	1	2	6	3	12

[a]The period 1976-1980 was too short to calculate 1981 predictions reliably.
[b]Predictions of an ARIMA model (0,0,0)(1,0,0) (see Table H).
[c]Predictions of an ARIMA model (1,0,0,)(1,0,0) (see Table H).

Index Knife Robbery

There are indications that the best model for Chicago knife robbery (see Table H) changed in 1983.[86] The best model for the period 1975-1983 was (3,0,0)(1,0,0), a relatively simple model that predicts the current observation with the observation that occurred three months ago and the observation that occurred 12 months ago. However, the best model for the period 1975-1982 was not the same. The parameter weights for ARIMA (3,0,0)(1,0,0) in three time periods were the following:

Time Period	AR(1)	AR(2)	AR(3)	AR(12)
1975-1981	.02	.03	.15	.12
1975-1982	-.02	.04	.15	.12
1975-1983	.10	.17	.24	.15

The AR(1) and AR(2) estimates were essentially zero in the two earlier models. However, in the 1975-1983 model, they were both higher (though still not significant--.10 and .17, respectively), and were needed for the model to be considered adequate according to the statistical diagnostic tests (see Appendix 1). Thus, there appears to have been a change in the ARIMA model in 1983.

Further evidence for a change in the ARIMA model is this: An ARIMA model (0,0,0)(1,0,0) fit the 1975-1981 period very well, with a lower Box-Pierce statistic (see Appendix 1) at lag 30 than the alternative ARIMA model (3,0,0)(1,0,0). ARIMA (0,0,0)(1,0,0) predicted 1981 within 15 percent and 1982 within 9 percent, but the actual number in 1983 was 21 percent higher than the predicted number (see Table O). The intervention method prediction with ARIMA (0,0,0)(1,0,0) was 19 percent too low in 1983, indicating that the change in 1983 was a combination of a change in level and a change in model type. Also, an ARIMA model (0,0,0)(1,0,0) was not a good statistical fit for the 1975-1983 period.[87]

In addition to a change in the best ARIMA model, there was also a change in the level of Chicago knife robbery offenses in 1983. The year-ahead 1983 prediction with ARIMA (0,0,0)(1,0,0) was 21 percent too low, and the prediction with ARIMA (3,0,0)(1,0,0) was 18 percent too low. In fact, the prediction for every month from May through December 1983 was too low, by an average of 27 percent. The number in November (242) was 94 percent higher than the predicted number. This rapid increase in 1983 can be seen in the pattern description graph (see Figure 43).

In contrast, there was no change in the number of knife robberies in total Illinois (non-Chicago) in 1983 (see Figure 44). The best model for total Illinois (non-Chicago) Index knife robbery predicted 1981 within 14 percent, 1982 within 1 percent, and 1983 within 10 percent.

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[86] The analysis of Index robbery with a knife began in 1975, because time series pattern description analysis suggested that 1974 differed from the following years.

[87] The Box-Pierce statistic (see Appendix 1) at lag 30 is 47.1 for an ARIMA (0,0,0)(1,0,0) model fit to the 1975-1983 time period, but 31.1 at lag 30 for the 1975-1982 period.

Figure 43. Patterns of Change Over Time in Chicago Index Knife Robbery, 1974-1983

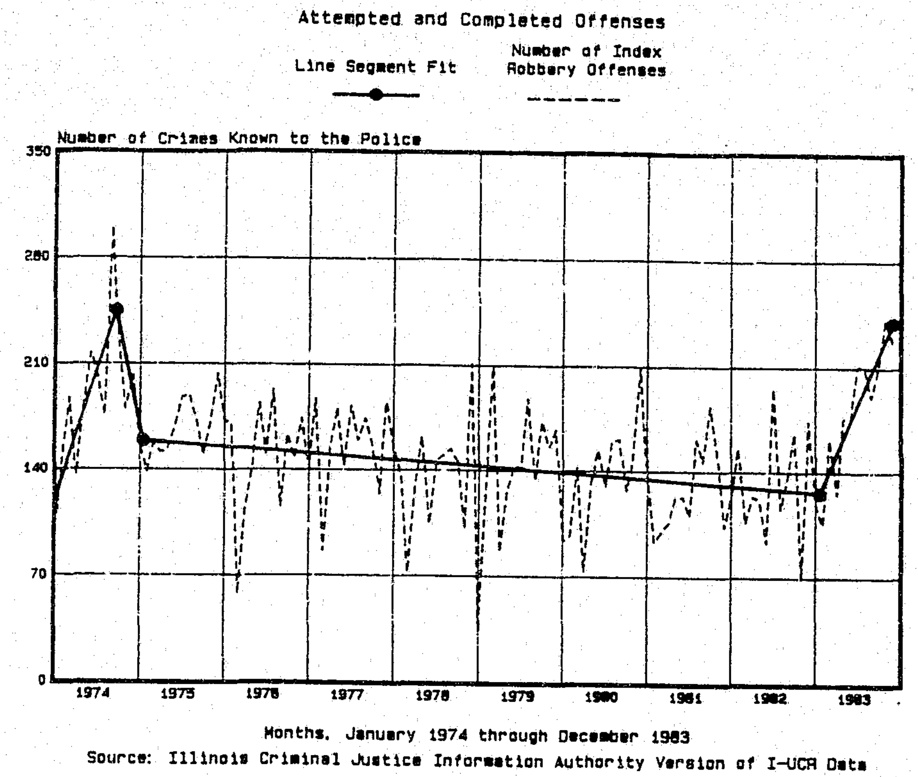
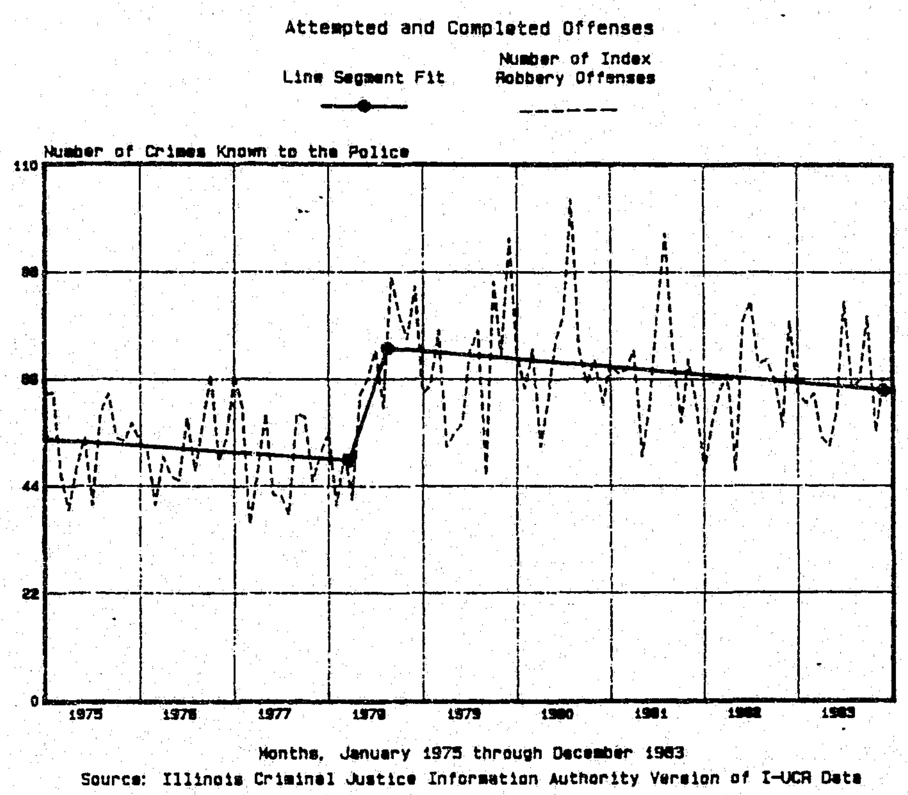


Figure 44. Patterns of Change Over Time in Illinois (non-Chicago) Index Knife Robbery, 1975-1983



Therefore, the number of officially recorded Index knife robbery offenses in 1983 in Chicago was apparently affected by the change in recording practices. If the same conditions had existed in 1983 as in the period 1975-1982, the number of Index knife robberies known to the police in Chicago in 1983 would have been closer to the ARIMA model (0,0,0)(1,0,0) year-ahead prediction of 1,703 than was the actual figure of 2,150.[88] Taking into account the 10 percent year-ahead prediction error for 1983 in total Illinois (non-Chicago), we can estimate that there were at least 10 percent more knife robberies in Chicago in 1983, due to the change in recording practices. (This figure was calculated by subtracting the 10 percent Illinois (non-Chicago) error from the 21 percent Chicago error, and rounding.)

Index Robbery with Another Weapon

The number of Index robberies with another weapon in Chicago (see Figure 45) increased even more sharply in 1983 than the number of Index robberies with a knife. Every month except April was actually higher than the number predicted with the year-ahead method and the average monthly error was more than 36 percent.[89] An ARIMA model (0,0,3)(1,0,0) for the number of Chicago Index robbery offenses committed with another weapon (not a firearm or a knife) predicted 1981 and 1982 within 11 percent and 2 percent, respectively, but the 1983 prediction was 38 percent too low (see Table O).[90]

Because the intervention method prediction for 1983 was also too low, by 28 percent (see Table O), there may have been a change in the best ARIMA model as well as in the number of offenses. Although the type of model did not change, the estimated weights of the terms in the model did change, as can be seen below:

Time Period	MA(1)	MA(2)	MA(3)	MA(12)
1975-1981	-.07	-.08	-.19	.12
1975-1982	-.05	-.09	-.20	.12
1975-1983	-.33	-.33	-.42	.14

The MA(1) and MA(2) estimates were close to zero in the two earlier time periods, but became significantly negative when 1983 was added to the series (see Table H).[91] This, coupled with the fact that the prediction error for 1983 was still high with the intervention method (see Table O), indicates that the ARIMA model may have changed in 1983.

While the number of other-weapon robbery offenses increased in Chicago in 1983, it appears that the number in total Illinois (non-Chicago) declined slightly (see Figure 46). This decline can be seen in the pattern description graph, and was also found in the ARIMA analysis. In 1981 and 1982, a very simple ARIMA model (1,0,0)(0,0,0) predicted the total years within 14 percent and 4 percent, respectively, but the 1983 prediction was 17 percent too high. In fact, the prediction for each 1983 month, except one, was too high by an average of 27 percent.

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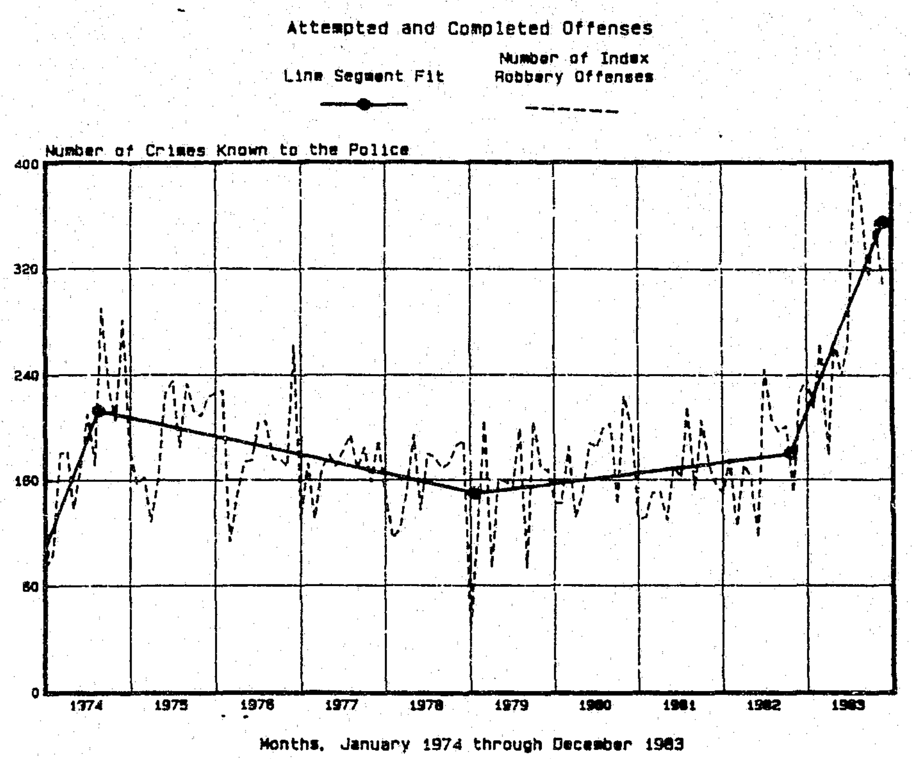
[88] The figure 1,847 is the year-ahead prediction with an ARIMA model (0,0,0)(1,0,0) based on 1975-1982 knife robbery data.

[89] Predictions for the eleven months except April were too low by an average of 39 percent.

[90] Note that models begin in 1975, because time series pattern description analysis (see Figure 45) suggested a change between 1974 and 1975.

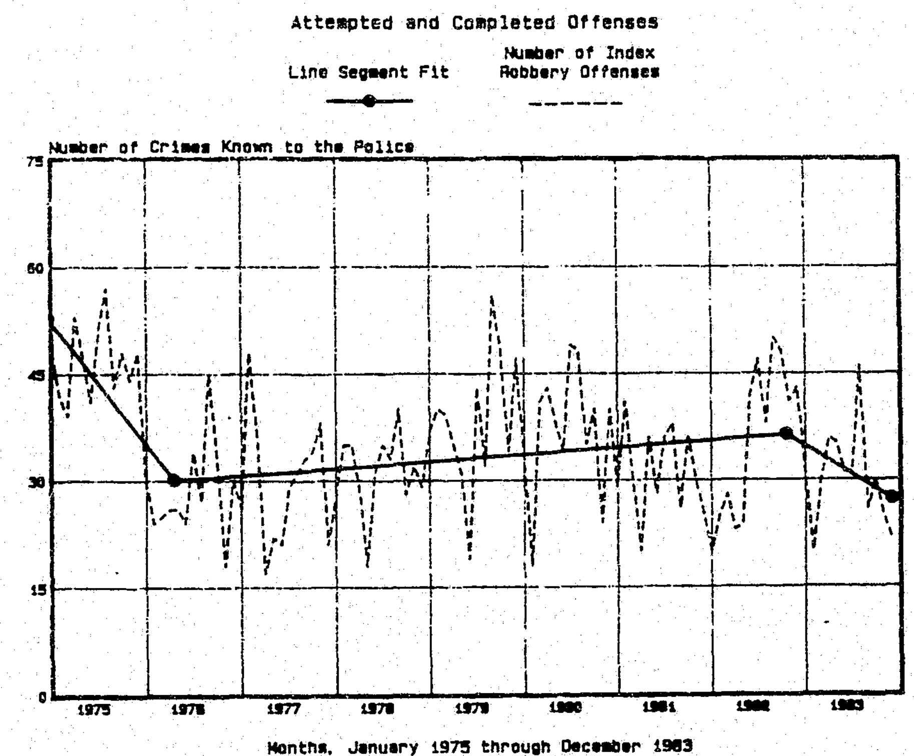
[91] This change in the best model is similar to the change in the model for Index knife robbery in Chicago, as discussed on page 120. In the case of Index knife robbery in Chicago, the AR(1) and AR(2) estimates were close to zero until 1983 was added to the series.

Figure 45. Patterns of Change Over Time in Chicago Index Other-Weapon Robbery, 1974-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 46. Patterns of Change Over Time in Illinois (non-Chicago) Index Other-Weapon Robbery, 1975-1983



Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

This indicates that the 1983 increase in Chicago Index robbery with another weapon was at least partially due to the administrative changes in recordkeeping practices. If the same conditions had existed in 1983 as in the years 1975-1982, the number of other-weapon robberies known to the police in Chicago would have been about 20 percent less in 1983 than it was. (This figure was calculated by subtracting the 17 percent non-Chicago error from the 38 percent Chicago error, and rounding.)

Index Strongarm Robbery

The number of Index strongarm robbery offenses in Chicago (see Figure 47) increased more in 1983 than any other type of robbery. The best model, ARIMA (1,0,0)(1,0,0), predicted 1981 within 12 percent and 1982 within 11 percent (year-ahead method) (see Table O). The average 1981 month was predicted within 20 percent, and the average 1982 month within 18 percent. However, Chicago strongarm robbery predictions for 1983 were much worse, 42 percent too low for the total year and 39 percent wrong for the average month. The prediction for every 1983 month from February through December was too high, and the degree of error was largest in the second half of the year (51 percent on the average in the last six months).

In contrast, total Illinois (non-Chicago) predictions for 1983 were just as accurate as 1981 and 1982 predictions had been, within 1 percent for the year and 12 percent for the average month. Predictions for 1981 and 1982 were within 1 percent and 7 percent for the year and 1 percent and 11 percent for the average month, respectively. The pattern description graph (see Figure 48) shows no indication of a change, certainly not an increase, in 1983. Instead, it indicates that the number of strongarm robbery offenses declined slowly but steadily from 1981 through 1983.

In addition to the change in the number of strongarm robbery offenses in 1983 in Chicago, there also may have been a change in the best ARIMA model. ARIMA (1,0,0)(1,0,0) predictions with the intervention method were good for 1981 and 1982, within 7 percent in both years, but the 1983 prediction was 27 percent too low. Was the best-fitting ARIMA model for Chicago strongarm robbery in 1983 the same as the best ARIMA model for the periods 1975-1981 and 1975-1982? Below is a summary of the characteristics of ARIMA models (1,0,0)(1,0,0) for three time periods:

			Box-Pierce Statistic	
Time Period	AR(1)	AR(12)	Lag 50	Lag 12
1975-1981	.41	.15	48.3	8.7
1975-1982	.33	.17	57.0	14.1
1975-1983	.76	.15	58.6	24.0

In the 1975-1983 model, the high Box-Pierce statistic at lag 12 (see Appendix 1) and the sharp increase in the AR(1) estimate indicate that the ARIMA model (1,0,0)(1,0,0) was not a good fit. The high AR(1) weight suggests that an ARIMA model (0,1,1)(1,0,0) would fit better, and indeed, it did (see Table H).[92] Such a model for the 1975-1983 time period was statistically sound according to the tests discussed in Appendix 1. For example, the Box-Pierce statistic at lag 12 was 11.9 for an ARIMA model (0,1,1)(1,0,0).

[92] A high AR(1) weight suggests an ARIMA (0,1,1)(1,0,0) model because an autoregressive process of 1.00 would mean that every observation was correlated perfectly with the preceeding observation. This would be equivalent to a trend in the series, which can be removed by a first difference transformation. See Appendix 1 or Block (1984b) for more detail.

Figure 47. Patterns of Change Over Time in Chicago Index Strongarm Robbery, 1974-1983

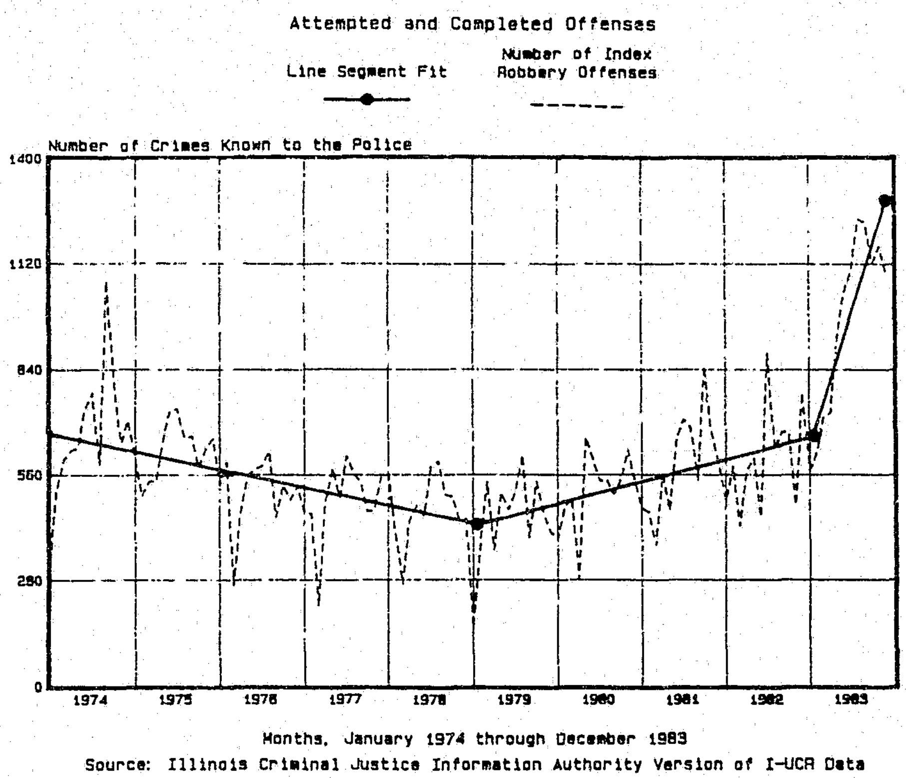
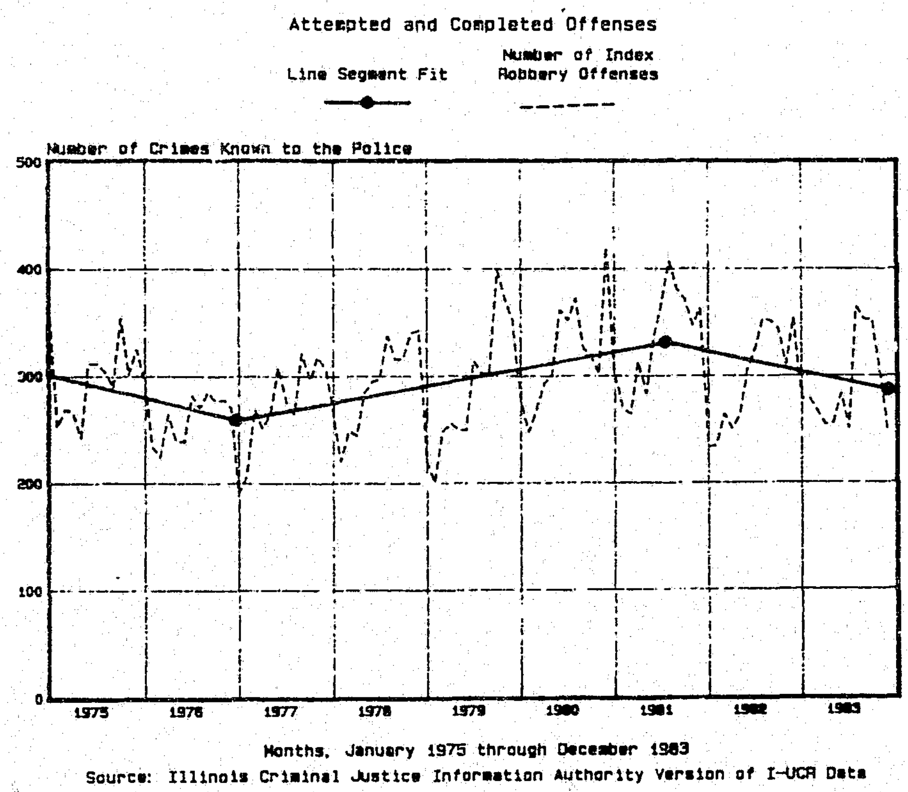


Figure 48. Patterns of Change Over Time in Illinois (non-Chicago) Index Strongarm Robbery, 1975-1983



Strongarm robbery meets several criteria for the presence of an intervention. The 1983 Chicago predictions were less accurate than 1981 or 1982 Chicago predictions; they were also worse than 1983 predictions for the rest of Illinois. In addition, the type of ARIMA model appears to have changed in 1983. Therefore, the increase in the number of Index strongarm robbery offenses known to the Chicago police in 1983 probably was due to a great extent to administrative changes. The number was about 40 percent higher (42 percent error minus the 1 percent error for the non-Chicago Illinois, rounded) than it would have been if all conditions, including recordkeeping practices, had been the same in 1983 as in the earlier years.

Index Aggravated Assault

The total number of officially recorded Index aggravated assault offenses increased in Chicago in 1983, even more than the number of Index robbery offenses increased. Again, the questions are whether this increase was due to data recording practices, and if so, what is the amount of change in the number of arrests that can be attributed to the change in data recording.

It is not entirely clear how to apply to aggravated assault the hypothesis that change in more serious offenses would be less than the change in less serious offenses. Index aggravated assault includes several offense types that vary in seriousness. The three types of offense defined as Index aggravated assault are attempted murder, aggravated battery, and aggravated assault. Attempted murder and aggravated battery are actual attacks, but aggravated assault is the threat to commit serious injury. It is difficult to measure the relative seriousness of the different types of aggravated assault with available data because injury information is not available for aggravated assault. The only available information is the type of weapon.

Index Firearm Assault

In contrast to Index firearm robbery, which did not change in 1983, Index firearm assault apparently did change. An increase in 1983 was apparent, both in the pattern description graph (see Figure 49) and in the ARIMA analysis (see Table P).

An ARIMA model (2,1,0)(0,1,1) for Chicago Index aggravated assault with a firearm predicted 1981 within 12 percent and 1982 within 16 percent (year-ahead method). Though these predictions were not extremely accurate, the prediction for 1983 was much worse-- it was 35 percent too low for the year and 31 percent wrong for the average 1983 month. In fact, the prediction for each 1983 month from April through December was too low.

In contrast, the best model for Index firearm assault in Illinois (non-Chicago) predicted 1981 within 3 percent, 1982 within 5 percent, and 1983 within 9 percent (see Table P). The pattern description graph (see Figure 50) shows a steady downward trend from 1979 through 1983. There is no evidence, either in the pattern description or in the ARIMA analysis, of an increase in 1983. This indicates that the 1983 increase seen in Chicago firearm assault probably was due more to the change in data collection practices in Chicago than to an actual increase in the number of crimes.

In Chicago, predictive accuracy for firearm assault was good when calculated with the intervention method, within 4 percent in 1981, 2 percent in 1982, and 8 percent in 1983. This indicates that there was no change in the best ARIMA model. Other evidence for this is that the AR(1), AR(2), and MA(12) estimates (see Table J) were about the same for ARIMA models

(2,1,0)(0,1,1) for each time period from 1974-1980 to 1974-1983, and that the statistical diagnostics were equally good for models for each time period.

Thus, although the best ARIMA model for Chicago Index aggravated assault with a firearm did not change in 1983, the level of the time series changed. The number of Index aggravated assaults with a firearm in 1983 was at least 20 percent higher (the 35 percent error in Chicago minus the 9 percent error for non-Chicago Illinois, rounded) than it would have been if there had been no change in the conditions of the earlier years (including recordkeeping practices).

Table P. Chicago Intervention Analysis: Index Aggravated Assault, by Weapon

Percent Error of Predictions

	Year-Ahead Method						Intervention Method					
	1981		1982		1983		1981		1982		1983	
	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month	Total Year	Avg. Month
Firearm												
Chicago	12%	22%	16%	18%	35%	31%	4%	23%	2%	17%	8%	16
NonChicago	3	10	5	10	9	12	2	8	2	9	4	8
Knife												
Chicago[a]	45	51	10	23	38	37	20	28	12	14	16	17
NonChicago	8	8	3	6	5	8	2	8	7	7	2	7
Other Weapon												
Chicago[b]	69	76	5	16	45	38	36	40	1	19	17	17
NonChicago	15	15	6	9	8	11	2	8	1	6	3	11
Hands, Feet, etc.												
Chicago[c]	65	70	1	27	31	31	32	42	12	34	13	23
NonChicago	1	8	16	16	29	36	0	9	3	8	8	13

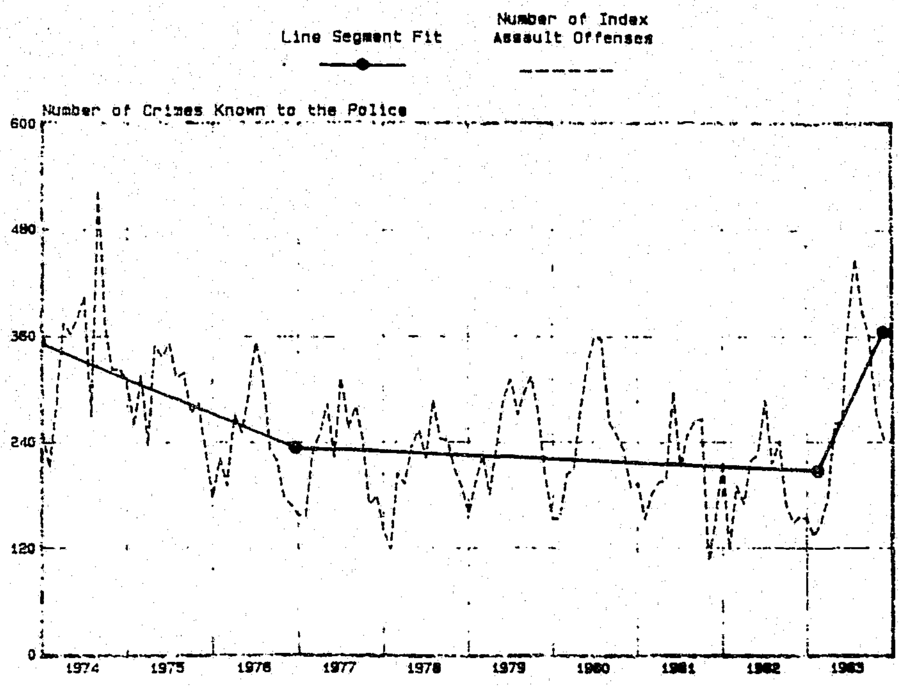
[a]The errors for Chicago knife assault in this table are for an ARIMA model (0,1,1)(0,1,1). The best model for the period 1974-1980, however, is ARIMA (3,0,0)(0,1,1) (see Table J). Based on data through 1979, this model predicted 1980 within 11 percent for the year (both methods) and 17 percent (year-ahead method) and 18 percent (intervention method) for the average month. However, the 1981 prediction with ARIMA model (3,0,0)(0,1,1) was 59 percent too high for the year and 66 percent wrong for the average month (year-ahead).

[b]The same model, ARIMA (2,0,0)(0,1,1), predicted 1980 within 15 percent (year-ahead method) and 6 percent (intervention method).

[c]Predictions for 1980 with the same ARIMA model (0,0,3)(0,1,1) were within 6 percent (both methods), and the average 1980 month was predicted within 22 percent (year-ahead) and 28 percent (intervention).

Figure 49. Patterns of Change Over Time in Chicago Index Aggravated Assault with a Firearm, 1974-1983

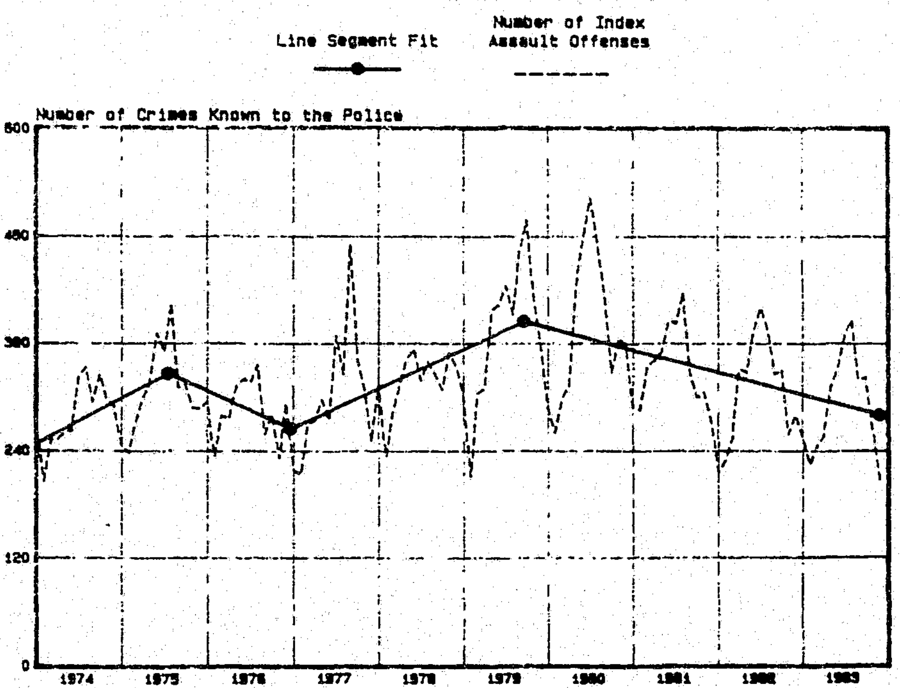
ATTEMPTED MURDER, AGGRAVATED ASSAULT, AGGRAVATED BATTERY



Months, January 1974 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Figure 50. Patterns of Change Over Time in Illinois (non-Chicago) Index Aggravated Assault with a Firearm, 1974-1983

ATTEMPTED MURDER, AGGRAVATED ASSAULT, AGGRAVATED BATTERY



Months, January 1974 through December 1983
Source: Illinois Criminal Justice Information Authority Version of I-UCR Data

Index Knife Assault

The pattern over time of Index knife assault in Chicago was even more complex than the pattern over time of Index firearm assault. ARIMA analysis indicated that the number of Index aggravated assaults with a knife in Chicago changed in 1981, as well as in 1983.

An ARIMA model (3,0,0)(0,1,1) for the time period 1974-1979 (see Table J) predicted 1980 within 11 percent for the total year and within 17 percent for the average 1980 month (year-ahead method). However, the prediction for 1981 with the same model was 59 percent higher than the actual number of Index knife assault offenses known to the police, and 66 percent wrong in the average 1981 month.[93] In fact, every monthly prediction in 1981 was too high. This drop in 1981 can be seen in the pattern description graph (see Figure 51a), and it is even clearer in the graph of the seasonally adjusted data (see Figure 51b). The seasonal fluctuation in the raw data obscures the precipitous drop at the beginning of 1981.[94] Apparently, the number of Index aggravated assaults with a knife in Chicago fell sharply in the first months of 1981, possibly as much as 59 percent. Note that Chicago firearm assault also dropped in 1981 and 1982 (see Figure 49), but not as precipitously as knife assault. The best ARIMA prediction for firearm assault was only 12 percent too high in 1981, compared to the prediction for knife assault, which was 59 percent too high.

In addition to the decline in level in 1981, the best ARIMA model also changed. Although an ARIMA model (3,0,0)(0,1,1) fit well statistically for all of the time periods-- 1974-1979, 1974-1980, and 1974-1981--the weights of the terms in the model changed. In the two earlier time periods, the AR(1) and AR(2) terms were zero (see Table J), but in the 1974-1981 time period both AR(1) and AR(2) estimates were significantly positive.[95] Actually, the best model for 1974-1981 was not ARIMA (3,0,0)(0,1,1), but ARIMA (0,1,1)(0,1,1). The latter was not a good fit for the early time period 1974-1980, but was a good statistical fit for 1974-1981. In addition, an ARIMA model (0,1,1)(0,1,1) had good statistical diagnostics (Appendix 1) for the 1974-1982 and 1974-1983 periods. This model, when fit to four time periods, had the following MA(1) and MA(12) estimates:

Time Period	MA(1)	MA(12)
1974-1980	.87	.84
1974-1981	.78	.86
1974-1982	.76	.86
1974-1983	.66	.88

The MA(12) estimates are about the same for models for all four time periods, indicating that the seasonal pattern did not change over time. However, the MA(1) estimate decreases somewhat at two points--once when 1981 is added to the series and again when 1983 is added to the series. This suggests that the model changed twice, in 1981 and in 1983.

[93]Note that these predictions are for an ARIMA model (3,0,0)(0,1,1); they are not the predictions made with an ARIMA model (1,0,0)(0,1,1) in Table P (see Table J and the footnotes to Table P).

[94]Figures 51a and 51b are both pattern descriptions of Chicago Index aggravated assault with a knife. Figure 51a is a description of the raw data, and Figure 51b is a description of the data adjusted for seasonality. In Figure 51b, seasonal fluctuations have been removed, so that month-to-month and long term patterns are clearer (see Appendix 1).

[95]The AR(3) and the seasonal MA(12) estimates are essentially the same in the models of all three time periods.

Figure 51a. Patterns of Change Over Time in Chicago Index Aggravated Assault with a Knife, 1974-1983

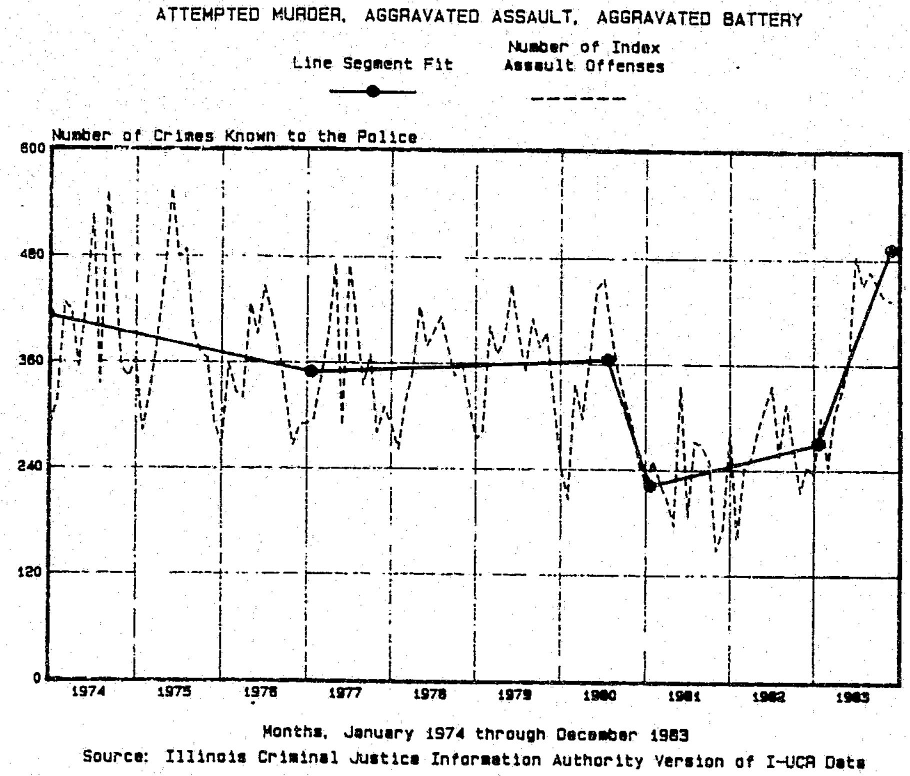
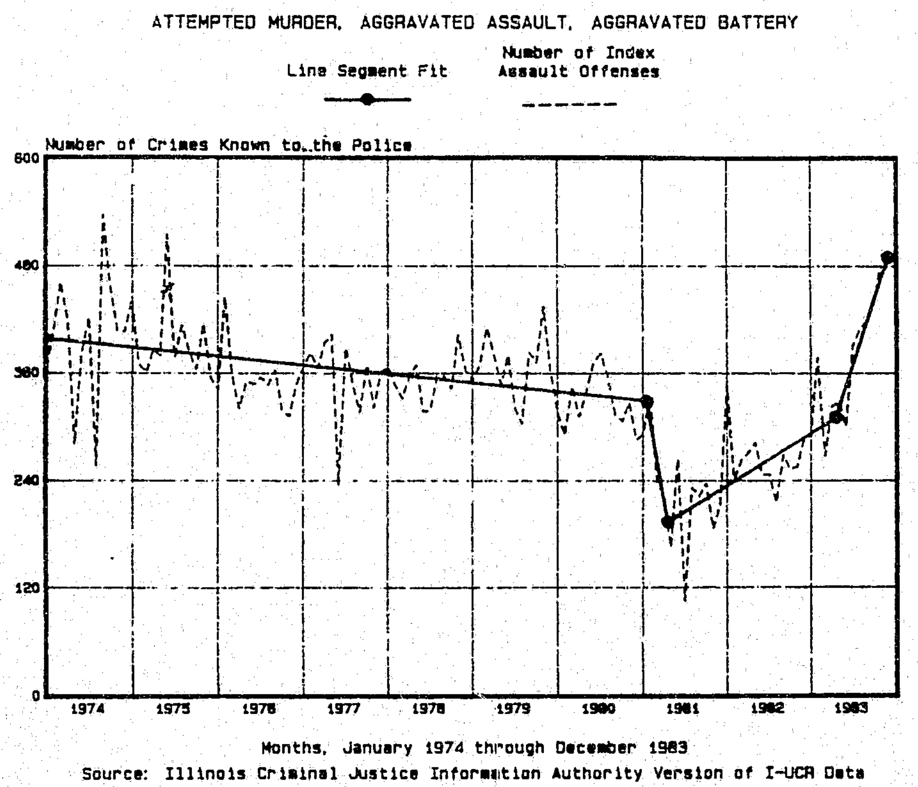


Figure 51b. Patterns of Change Over Time in Chicago Index Aggravated Assault with a Knife, 1974-1983 (Seasonally Adjusted)



Predictive accuracy results (see Table P) agree with the pattern description analysis and with the results of model-fitting: the number of Index aggravated assaults with a knife decreased sharply in 1981, climbed somewhat in 1982, and increased sharply in 1983. An ARIMA model (0,1,1)(0,1,1) was 45 percent too high in predicting Index knife assaults in Chicago in 1981, 10 percent too low in predicting 1982, and 38 percent too low in predicting 1983 (year-ahead method).

In contrast, predictive accuracy for the same crime in the rest of Illinois was much better--within 8 percent in 1981, 3 percent in 1982, and 5 percent in 1983. This stability is reflected in the pattern description graph (see Figure 52). In total Illinois (non-Chicago), there is no sign of the radical changes that took place in 1981 and 1983 in the number of Chicago Index knife assaults. Outside of Chicago, the number of knife assaults was almost stable in every year from 1980 through 1983.

Predictions with the intervention method for Chicago Index aggravated assault with a knife were better than predictions with the year-ahead method, but they were still not very accurate. The prediction for 1981 was 20 percent too high, the 1982 prediction was 12 percent too low, and the 1983 prediction was 16 percent too low. Thus, these predictions do not support the idea of the model changing in 1981 and 1983, but do not really contradict it, either.

In summary, there appear to have been two interventions in the number of Index aggravated assaults with a knife known to Chicago police, a serendipitous intervention in 1981 and the hypothesized intervention in 1983. In 1981, the actual number of crimes was 45 percent to 59 percent lower than it would have been had 1974-1980 conditions continued; in addition, the ARIMA model probably changed in 1981. In 1982, the number of knife assaults increased gradually, but the number was still low compared to 1974-1980. A prediction of 1982 based on 1974-1980 data was 47 percent too high, and the average 1982 month was 40 percent too high. By early 1983, however, the 1980 level of knife robberies had again been reached. Then, in July 1983, the number of offenses increased precipitously, and the ARIMA model may have changed as well. There were about 30 percent more offenses known to the police in Chicago in 1983 than would have been expected based on past history (38 percent minus the non-Chicago Illinois change of 5 percent, rounded off).

Index Assault with Another Weapon

Like Index aggravated assault with a knife, Index aggravated assault with a weapon other than a firearm or knife also decreased sharply in 1981, increased in 1982, and then increased sharply in 1983 (see Figure 53). The increase in other-weapon assault in 1983, in fact, was much sharper than the increase in knife assault in 1983.

Although an ARIMA model (2,0,0)(0,1,1) predicted 1980 within 15 percent and the average 1980 month within 26 percent (see footnote to Table P), the prediction for 1981 was 69 percent too high, and the average month was wrong by 76 percent (year- ahead method). Thus, a model based on the years 1974-1980 predicted 2,843 other-weapon assaults, but there actually were only 1,682. The prediction for one 1981 month was 157 percent too high. Though the numbers increased in 1982, they were still lower than usual; the actual 2,193 assault figure was over 30 percent lower than the number predicted by a 1974-1980 model. By November 1982, however, the number of other-weapon assaults had returned to the 1980 level.

Figure 52. Patterns of Change Over Time in Illinois (non-Chicago) Index Aggravated Assault with a Knife, 1974-1983

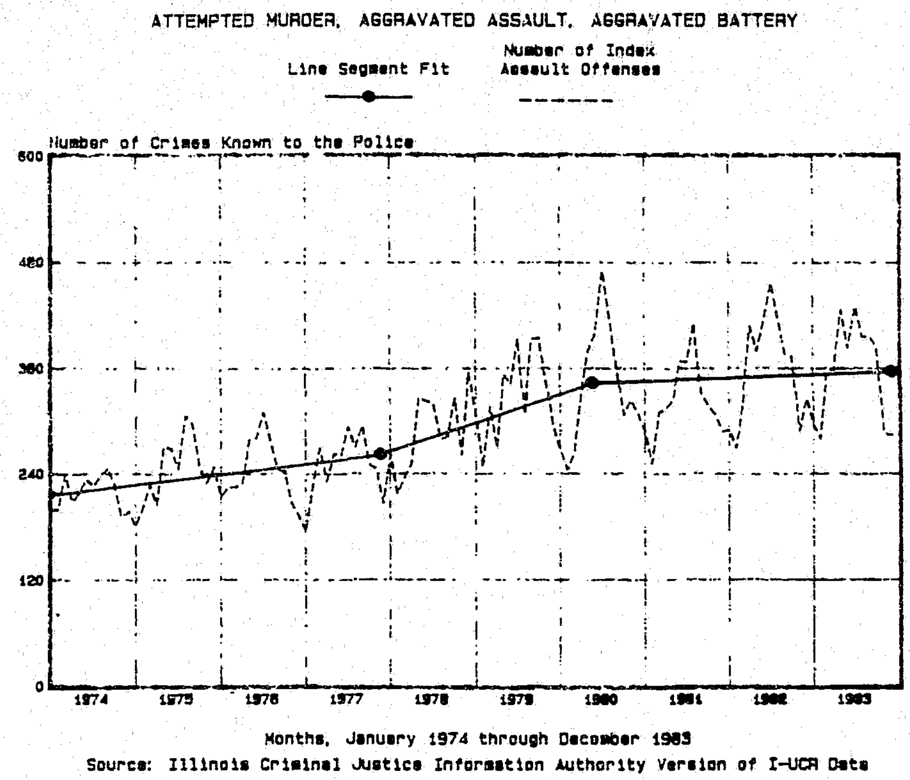
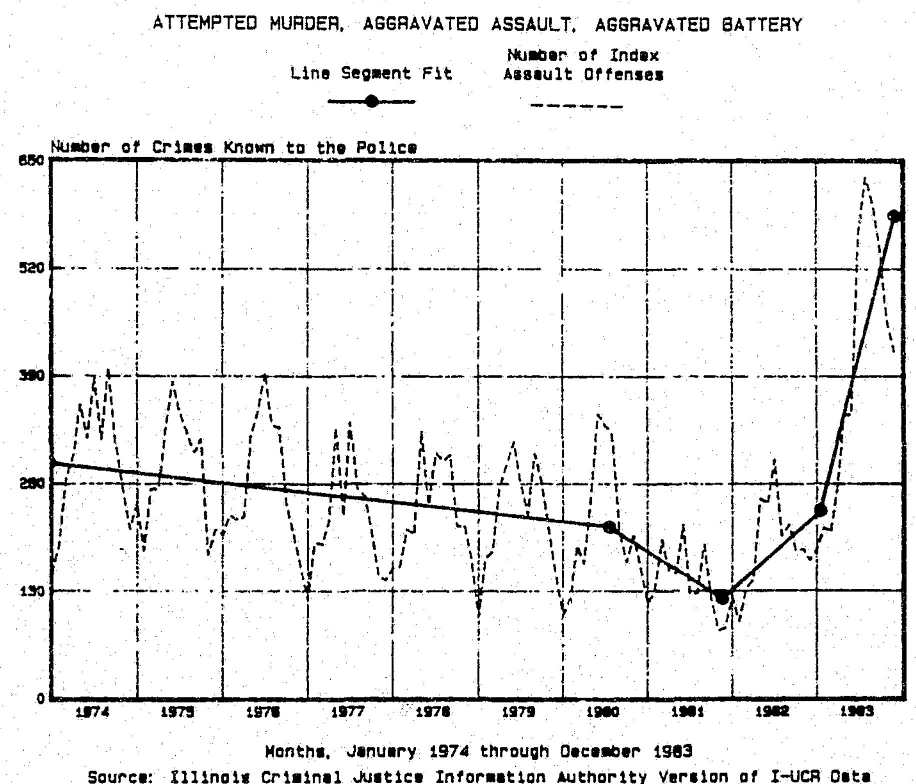


Figure 53. Patterns of Change Over Time in Chicago Index Aggravated Assault with Another Weapon, 1974-1983



In addition, the intervention-method prediction for 1981 was 36 percent too high, indicating a possible change in the model. The type of ARIMA model does not appear to have changed, since statistical diagnostics for an ARIMA model (2,0,0)(0,1,1) (see Appendix 1) are good when estimated for all time periods. However, the estimated weights of the terms may have changed, as can be seen below:

Time Period	AR(1)	AR(2)	MA(12)
1974-1979	.22	.38	.86
1974-1980	28	.26	.85
1974-1981	42	.33	.86
1974-1982	.42	.33	.86
1974-1983	.69	.25	.92

The MA(12) estimate is about the same in the first four models, either .85 or .86. This indicates that the seasonal pattern did not change during that time. However, the AR(1) estimate increased when 1981 was added to the series. This, coupled with the poor intervention method prediction in 1981, suggests that the model as well as the level of the series changed in 1981.

In contrast, the AR(1), AR(2) and MA(12) estimates were exactly the same for 1974-1981 and 1974-1982 models. Also, the same ARIMA model (2,0,0)(0,1,1) predicted 1982 within 5 percent and the average 1982 month within 16 percent (year-ahead method). A prediction based on only 1974-1980 was 30 percent too high in predicting 1982 with the year-ahead method. However, when the low numbers in 1981 are taken into account, a prediction based on the 1974-1981 period was only 5 percent too high in predicting 1982. The intervention method prediction for 1982 was almost identical to the actual figures--within 0.3 percent. This suggests that 1982 was the same as 1981 in both level and model. As can be seen in the pattern description graph (see Figure 53), the number of other-weapon assaults dropped steadily throughout 1981, and then increased steadily throughout 1982.

However, in 1983, the situation was different. The AR(1) and the MA(12) estimates both may have changed, and the 1983 intervention prediction was 17 percent too low. Further, the prediction for 1983 with the year-ahead method was 45 percent too low, and the prediction for the average 1983 month was 38 percent wrong (see Table P). Monthly errors were concentrated in the second half of the year. Beginning in April, every prediction was too low, and the degree of error increased with each month. The average error for the months August to December was 61 percent. Thus, Chicago Index aggravated assault with another weapon increased sharply in 1983, especially in the second half of the year. In addition, the best ARIMA model, describing month-to-month patterns, may have changed in 1983.

In contrast, predictions for the same crime in Illinois (non-Chicago) (see Figure 54) were much more accurate, reflecting an essentially stable pattern over time. The year 1981 was predicted within 15 percent, 1982 within 6 percent, and 1983 within 8 percent. Monthly predictions and intervention method predictions were also accurate (see Table P).

In summary, the pattern over time of Index aggravated assault with another weapon was similar to the pattern of Index aggravated assault with a knife. Both decreased sharply in 1981, and then increased sharply in 1983. In 1983, the number of aggravated assault offenses with a weapon other than a firearm or knife was almost 40 percent higher than it would have been had 1974-1982 conditions continued (45 percent error in Chicago minus the 8 percent error for non-Chicago Illinois, rounded).

Index Assault with the Body as a Weapon

An aggravated assault with the body as a weapon is an unarmed assault in which the body of the assailant can be considered to be a weapon, for example an attack by a person trained in karate Such assaults are also referred to as "aggravated assault with hands, feet, etc." In Chicago, the number of body-as-weapon aggravated assaults known to the police is very small, compared to other kinds of assault. There were only 65 per month over the 1975-1983 period, compared to an average of 248 firearm assaults, 341 knife assaults, and 242 other-weapon assaults per month. In contrast, Illinois (non-Chicago) had more body-as-weapon assaults in the average month (396) than firearm assaults (317), knife assaults (294), or other-weapon assaults (285). Thus, there were many more body-as-weapon aggravated assaults in Illinois (non-Chicago) than in Chicago (396 versus 65), even though the numbers of firearm, knife, and other-weapon assaults were about equal in Chicago and Illinois (non-Chicago).

If the proportion of body-as-weapon assault victimizations to all victimizations were actually the same in Chicago as in Illinois (non-Chicago), then the low proportion of these body-as-weapon assaults that are known to the police in Chicago suggests that the likelihood of a body-as-weapon assault victimization becoming officially recorded is less in Chicago than in the rest of Illinois. If this is true, then the change in Chicago data recording practices in 1983 might have had a greater effect on the recording of body-as-weapon assault than on other kinds of assault. If body-as-weapon assault had been undercounted more than other kinds of assault, then the reform in data recording should have affected it more strongly. However, this was not the case. The pattern description graph (see Figure 55) for Chicago body-as-weapon aggravated assault shows an increase in the number of offenses in 1983, and ARIMA analysis agrees with this. However, the amount of increase in body-as-weapon assault in 1983 was less, not greater, than the increase in other-weapon assault.

The best ARIMA model, (0,0,3)(0,1,1), predicted 1982 within 1 percent, but the prediction for 1983 was 31 percent too low (see Table P). Body-as-weapon assault decreased in 1981, as did knife assault and other-weapon assault. The 1981 prediction was 65 percent too high, and the prediction for the average 1981 month was 70 percent wrong. However, with this same model, 1980 was predicted within 6 percent, and the average 1980 month within 22 percent (year-ahead method).

At the same time that body-as-weapon aggravated assault increased in Chicago in 1983, it apparently decreased in Illinois (non-Chicago) (see Figure 18). An ARIMA model (1,1,0)(0,1,1) for body-as-weapon aggravated assault in total Illinois (non-Chicago) predicted 1981 within 1 percent and 1982 within 16 percent, but the 1983 prediction was 29 percent too high and the prediction for the average 1983 month was 36 percent wrong. Since all of these models fit very well statistically, and the estimates for the AR(1) and MA(12) weights were much the same from year to year, there does not seem to have been a change in model.

The number of Index aggravated assault offenses with the body as a weapon increased in Chicago in 1983, by about 31 percent, while in Illinois (non-Chicago) it decreased by 29 percent. Thus, the amount of change in Chicago and Illinois (non-Chicago) was the same, though Chicago body-as-weapon assaults increased and those in Illinois (non-Chicago) decreased. Given this anomaly as well as the apparent drop in 1981, it is difficult to estimate the amount of change in 1983 due to the change in data recording practices. Judging from the comparison with change in the control group, we could say, conservatively, that the 31 percent increase in Chicago body-as-weapon assault was within the realm of possibility and not due to the change in data collection practices. However, judging from the predictive accuracy in 1982, which was within 1 percent, we could say that the change in 1983 due to recording practices was 30 percent.

Figure 54. Patterns of Change Over Time in Illinois (non-Chicago) Index Aggravated Assault with Another Weapon, 1974-1983

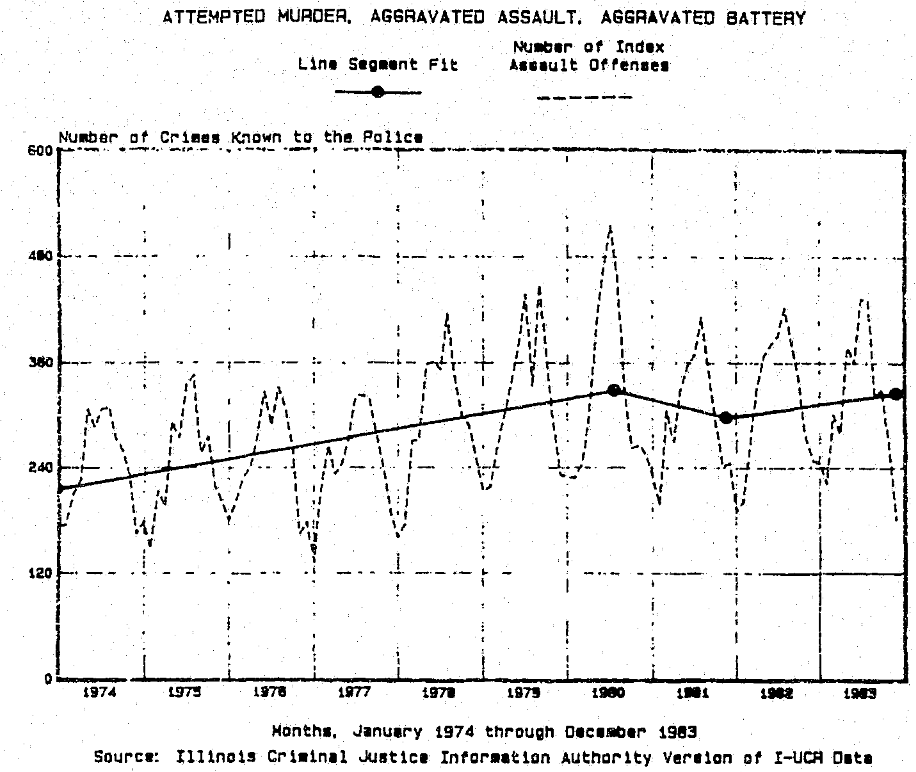
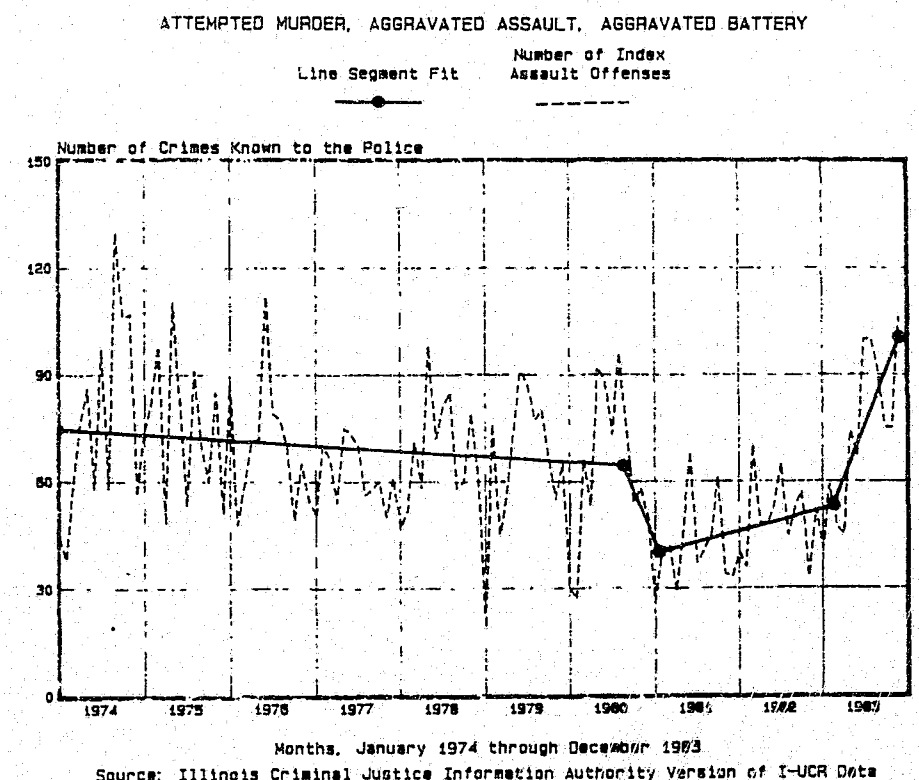


Figure 55. Patterns of Change Over Time in Chicago Index Aggravated Assault with Hands, Feet, etc., 1974-1983



In Chicago, aggravated assault with the body as a weapon had the least number of offenses of any kind of assault, while in Illinois (non-Chicago) it had the most. If the actual number of body-as-weapon assault victimizations is really much higher than the number of firearm, knife, or other-weapon assault victimizations in Chicago, as the number of reported assaults in Illinois (non-Chicago) might suggest, then the number in Chicago may have been undercounted before 1983 even more than the number of other kinds of assault. If so, then why was the increase in body-as-weapon assaults in 1983 less than the increase in the number of other kinds of assault? It may be that the change in recording practices affected the undercounting of other kinds of Index aggravated assault much more than it affected the undercounting of body-as-weapon assault.

Summary and Discussion

Index Robbery

In 1983, the numbers of knife robberies, other-weapon robberies, and strongarm robberies in Chicago were higher than they would have been if previous conditions, such as recordkeeping practices, had not changed. The increase seems to have been greatest in the second half of the year, as might be expected from the timing of the administrative changes. The media charges of undercounting began in December 1982 and January 1983, but the audit (Chicago Police Department, 1983) was not published until April, and the official administrative changes took effect late in the year. Knife robbery began to increase in May, other-weapon robbery also began to increase in May, and strongarm robbery, the type of robbery that increased most, began to increase in February.

In contrast, the number of firearm robberies in Chicago was not any higher in 1983 than it would have been if previous conditions had remained the same. In fact, the amount of change in firearm robbery offenses in 1983 was less than the change in previous years. Therefore, the change in the administration of data collection and maintenance that occurred in Chicago in 1983 apparently did not affect the number of Index firearm robbery offenses known to the police, though it did affect the number of all other kinds of Index robbery offenses.

It seems logical that the reason that Index firearm robbery did not increase in 1983 was that it had always been recorded as completely as possible. The new stricter recording policies did not, therefore, affect the likelihood that a firearm robbery would become an officially recorded offense. Though the definition of robbery may seem objective and clear-cut to the average citizen, the application of that definition in real situations often requires subjective interpretation (Miller and Block, 1985). Another analysis of Chicago robbery (Block and Block, 1980) found that both the victim's decision to report a robbery victimization to the police and the police decision to record a robbery incident in official records were more likely if the weapon was a firearm.

The Chicago Intervention Analysis estimated that Index knife robbery increased by about 10 percent in 1983, Index other-weapon robbery increased by about 20 percent, and Index strongarm robbery increased by about 40 percent, relative to the number of offenses that would have been officially recorded if recordkeeping practices had remained the same as in the years before 1983.

Thus, the administrative changes in Chicago data collection and maintenance had the greatest effect on strongarm robbery, less effect on other-weapon robbery, little effect on knife robbery, and no effect at all on firearm robbery. If these four types of robbery form a rough scale of seriousness, the most serious type of robbery did not change when recordkeeping changed, the least serious type of robbery changed the most, and the other types of robbery changed an intermediate amount.

Index Aggravated Assault

Unlike the number of firearm robbery offenses, the number of firearm assault offenses did change in 1983. The number known to the police was at least 20 percent higher than it would have been if earlier conditions, such as recordkeeping practices, had continued. The timing of the increase corresponded to the timing of the administrative changes. Beginning in April, all year-ahead predictions for 1983 months were too low In the second half of 1983, the actual number in each month was 41 percent higher than the predicted number, on the average. This increase can be seen not only in the predictions, but also in the pattern description graph (see Figure 49). It was argued earlier in this report that firearm robbery was always completely recorded, even before the change in recordkeeping practices. Therefore, it did not increase in 1983. Because firearm assault did increase--by 20 percent--it might be concluded that it had been undercounted before the change in recordkeeping practices.

On the other hand, compared to other types of Index aggravated assault, firearm assault increased less in 1983. While Index assault with a firearm increased 20 percent, Index assault with a knife increased by about 30 percent and Index assault with another weapon increased by about 40 percent. The actual number of knife assaults in every 1983 month was higher than the predicted number, by as much as 54 percent (in November). The last six months of the year were 42 percent higher on the average. From April to December 1983, the actual number of assaults with another weapon was higher than the predicted number, and the amount of error increased with each month. The number in December was 63 percent higher than the predicted number, and the last six months were high by 59 percent on the average.

In the same way, predictions for every month from April through December 1983 were too low for assault with the body as a weapon. The average error in the last six months was 46 percent. However, the number of body-as-weapon assaults in the control group, Illinois (non-Chicago), declined in 1983 more than the number in Chicago increased. The average error in the last six months of 1983, in fact, was 56 percent, more than that in Chicago. Therefore, the conservative conclusion would be that the 1983 change in Chicago was random, and not necessarily due to the change in recording practices.

Why did firearm assault increase more than firearm robbery? Perhaps weapon type is not a good indicator of the seriousness of an aggravated assault. The extent of injury might be a better measure, but these data are unavailable. Assault offenses in general, even firearm assault offenses, are considered to be less serious than firearm robbery offenses; but it is important to realize that Index aggravated assault consists of three types of offense: attempted murder, aggravated battery, and aggravated assault. Attempted murder and aggravated battery are actual attacks, but aggravated assault is the threat to commit serious injury. A police officer might mediate such a threat on the scene, and record it as a service call. In other circumstances, an aggravated assault might be written up as a crime. Therefore, it is quite possible that, under the new rules, less serious Index firearm assault occurrences were 20 percent more likely to be officially recorded as crimes.

Patterns over time of all types of Index assault, except for firearm assault, are similar to each other. In all types of aggravated assault except firearm assault, a change seems to have occurred in 1981 as well as in 1983. Index knife assault declined 45 percent to 59 percent in 1981, Index other-weapon assault declined by as much as 69 percent, and Index body-as-weapon assault declined by about 65 percent, relative to the predictions by a model based on the number of offenses in previous years.

The cause of the sharp drop in the number of offenses in 1981 can only be guessed, but it may be related to the Chicago Police Department's campaign against street crime, particularly youth gang related street crime, which began in 1981 and continued to 1982. If so, this demonstrates that administrative practices can affect not only the recording of crime, but the number of crimes that actually occur

On the other hand, even if the police department's campaign against street crime was responsible for the rapid decline in Index aggravated assault with knives, other weapons, or body-as-weapon, it apparently had no effect (or only a very slight effect) on the number of Index aggravated assaults with a firearm. The pattern description graph (see Figure 49) shows a decline, but the ARIMA model analysis indicates that the number of firearm assault offenses was only slightly lower in 1981 and 1982 than it had been in previous years.

It is difficult to know whether the change in the number of knife, other-weapon, and body-as-weapon assaults was due to the administrative changes or to a return to the normal number of offenses after the intensive campaign against street crime was stopped. However, as can be seen in the three graphs (see Figures 51a, 53, and 55), the return to normal apparently occurred in late 1982. Thus, the increase in the second half of 1983 is likely to have been due to the reform in data recording practices.

In summary, the intervention analysis of Index aggravated assault in Chicago was complex but revealing. It showed not only the increase in 1983 that had been expected, but also revealed an unexpected (serendipitous) decrease in 1981 in three of the four types of assault. The cause of the 1983 increase was, to a great extent, administrative change in the recording of offenses. In contrast, a likely cause of the 1981 decline was a decline in the actual number of victimizations. Thus, the analysis of aggravated assault in Chicago exemplifies two of the many possible reasons for inaccurate predictions of offense data.

Methods of Time Series Intervention Analysis

The Chicago Intervention Analysis had a methodological as well as a substantive purpose. Not only did it attempt to determine the effect of the reform in data recording practices in Chicago in 1983 on the number of officially recorded robberies and aggravated assaults, but it also served as a practical test of the methods developed in the first part of the Predictability Project. In particular, the analysis demonstrated the feasibility of using relatively simple ARIMA models in a time series quasi-experimental design as a gauge of the effect of an intervention on local-level crime statistics.

The combination of year-ahead and intervention prediction methods was, in general, successful in specifying whether there was a change in the model or a change in the level of the series. In fact, the Chicago analysis discovered an unexpected (serendipitous) intervention in 1981, in addition to describing the effect of the 1983 intervention. The rules of thumb used to identify a change in the level of the series or a change in the best-fitting model seemed to work well. (For a specific list of these rules, see "Evidence of a Change in the Model," page 116, and "Methods of Time Series Intervention," page 138.) It is important to remember that much of our confidence in the results of the Chicago Intervention Analysis did not stem from the statistical analysis, but rather from the design of the study. In the first place, the intervention had been hypothesized beforehand. In the second place, the analysis was designed with a control group. Control groups in such time series experiments are seldom if ever perfect, and this study was certainly no exception. The choice of total Illinois (non-Chicago) meant, for example, that we were comparing patterns in Chicago to patterns in rural, small-town, and small-city Illinois. On the other hand, had we chosen other large cities--for example, the five most populous American cities--as controls, there would also have been problems of comparability.

Estimated Actual Change in Robbery and Assault

The total number of officially recorded index robbery and index aggravated assault offenses in Chicago increased sharply from 1982 to 1983. The time series experiment of the Chicago Intervention Analysis was designed to estimate the amount of this increase that was due to the change in data recording practices. The total amounts of increase are illustrated in the following tables:

Change in Index Robbery, 1982 to 1983

	Officially Recorded Offenses			Minimum % Change due to Recording Practices
	1982	1983	% Change 1982-1983	
Firearm Robbery	5,373	6,356	+18.3%	0%
Knife Robbery	1,581	2,150	+36.0	10
Other-Weapon Robbery	2,120	3,406	+60.7	20
Strongarm Robbery	7,233	11,559	+59.8	40
Total	16,307	23,471	+43.9%	

Change in Index Aggravated Assault, 1982 to 1983

	Officially Recorded Offenses			Minimum % Change due to Recording Practices
	1982	1983	% Change 1982-1983	
Firearm Assault	2,357	3,211	+36.2%	20%
Knife Assault	3,167	4,497	+42.0	30
Other-Weapon Assault	2,193	4,742	+116.2	40
Body-as-Weapon Assault	600	880	+46.7	0-30
Total	8,317	13,330	+60.3%	

Because the estimates of the change due to data collection practices for each type of crime were derived not only from an analysis of predictive accuracy, but also from comparison with change in a control group (total non-Chicago Illinois), they are fairly reliable. However, they are conservative estimates; they state that the amount of change due to administrative data collection and maintenance was at least as great as the given estimate. Therefore, to use these estimates of the amount of change due to change in data recording practices to calculate the amount of actual change in the number of offenses, it would not be particularly accurate to subtract the percent due to administrative changes from the total change. While this would give you the maximum amount of change that could be actual change, it would not give you the best estimate. However, the calculation of a best estimate for change due to an actual change in the number of offenses is possible, as shown below.

For each crime type, the best ARIMA model predicted the number that would occur in 1983, given that patterns of earlier years continued. By comparing this prediction of 1983 to the number of officially recorded offenses in 1982, we have an estimate of the actual change in crimes known to the police from 1982 to 1983, the change that would have occurred if there had been no change in data recording practices. The estimates of actual change in index robbery and index aggravated assault are listed in the following tables:

Estimated Actual Change in Index Robbery, 1982 to 1983

	1982 Officially Recorded Offenses	1983 Year-ahead Prediction	% Change 1982-1983
Firearm Robbery	5,373	5,842	+8.7%
Knife Robbery	1,581	1,703	+7.7
Other-Weapon Robbery	2,120	2,108	-0.6
Strongarm Robbery	7,233	6,714	-7.2
Total	16,307	16,367	+0.4%

Estimated Actual Change in Index Aggravated Assault, 1982 to 1983

	1982 Officially Recorded Offenses	1983 Year-ahead Prediction	% Change 1982-1983
Firearm Assault	2,357	2,075	-12.0%
Knife Assault	3,167	2,773	-12.4
Other-Weapon Assault	2,193	2,596	+18.4
Body-as-Weapon Assault	600	607	+ 1.2
Total	8,317	8,051	- 3.2%

According to the ARIMA predictions, if it were not for the change in data collection practices in Chicago in 1983, the total number of index robberies would have stayed about the same in 1983 as it was in 1982, and the total number of index aggravated assaults would have declined slightly (3 percent). However, the 1982-1983 change would have been different for each type of index robbery and for each type of index aggravated assault; some would have increased, some would have decreased, and others would have stayed at the same level.

We have, then, estimated two components of the total change in officially recorded offenses from 1982 to 1983--change due to the change in recording practices, and actual change in crimes known to the police. However, when the estimates of these components are added together, they do not equal the total amount of 1982-1983 change. For example, the total 18.3 percent increase in firearm robbery is not accounted for by the zero percent change due to the change in data recording practices plus the 8.7 percent increase due to an actual increase in crime; the total 36 percent increase in knife robbery is not accounted for by the 10 percent increase due to the change in data recording practices plus the 7.7 percent increase due to an actual increase in crime; and so on. Why is this the case?

The changes in these two components do not add up to the total amount of 1982-1983 change in officially recorded crime because the estimates of change due to each cause are exactly that--estimates. In addition, the estimate of the change due to recording practices is a conservative estimate. The amount of change is probably not less than, but could be more than, the estimate. However, because the estimate was based on a time series experiment research design, we can be fairly confident in these conservative results. In contrast, the estimate of the change due to an actual change in crime was not a part of the time series experiment. (The control group had not experienced a change in data recording practices such as Chicago's, but there might have been a change in actual crime.) Therefore, we have less confidence in the estimate of actual reported crime; it could be higher or lower than the year-ahead prediction figures above.

Because the time series experiment design gives us a reliable estimate of the minimum amount of change due to the change in data recording practices, and because we know how much total change really occurred, we have an idea of the range of actual change in reported crime in Chicago from 1982 to 1983. These estimates are the following:

- The number of reported firearm robbery offenses probably increased about 8.7 percent from 1982 to 1983, and could not have increased any more than 18.3 percent.

- The number of reported knife robbery offenses probably increased about 7.7 percent from 1982 to 1983, and could not have increased any more than 26 percent.

- The number of reported other-weapon robbery offenses probably did not change from 1982 to 1983, and could not have increased any more than 40.7 percent.

- The number of reported strongarm robbery offenses probably decreased about 7.2 percent from 1982 to 1983, and could not have increased any more than 19.8 percent.

- The number of reported firearm assault offenses probably decreased about 12.0 percent from 1982 to 1983, and could not have increased any more than 16.2 percent.

- The number of reported knife assault offenses probably decreased about 12.4 percent from 1982 to 1983, and could not have increased any more than 12 percent.

- The number of reported other-weapon assault offenses probably increased about 18.4 percent from 1982 to 1983, and could not have increased any more than [illegible] 2 percent.

- The number of reported body-as-weapon assault offenses did not change from 1982 to 1983; it probably could not have increased any more than 16.7 percent, but the increase may have been greater.

The FBI also estimated the percent change in each index crime (except homicide) in Chicago between 1982 and 1983, but used a different method. First, instead of estimating the number of 1983 offenses that would have occurred if data recording practices had not changed, the FBI estimated the number of 1982 offenses that would have occurred if the data recording practices of 1983 had been in effect in 1982. Second, the method the FBI used to estimate 1982 was based on the assumption that Chicago's proportion of all crime in the United States remained constant from year to year--that the change in the actual number of crimes known to the police in Chicago between 1982 and 1983 was the same as the change in the nation as a whole. (See Appendix 4 for a discussion of the FBI/UCR estimation method.)

The Chicago Intervention Analysis method, on the other hand, did not associate change in Chicago with change in the nation. It did use a control group, but the purpose of the control group was completely different from the use of the total United States except Chicago as a benchmark in the FBI estimation method. The control group (in this case, total non-Chicago Illinois) was not used to estimate the change from year to year in Chicago. It was used, rather, as a guide to predictive accuracy. For example, 1983 predictions of firearm robbery in Illinois (non-Chicago) were accurate only within 23 percent (see Table O); therefore, we would not expect 1983 predictions of firearm robbery in Chicago to be any more accurate than 23 percent. In fact, the 1983 prediction for Chicago was accurate within 8 percent (see Table O). The conclusion from this is that the 1983 Chicago figures were not artificially inflated by the change in data recording practices. If we had used the Illinois (non-Chicago) 1982-1983 change as a benchmark for the Chicago 1982-1983 change, as the FBI estimation method does, we would have assumed that Chicago firearm robbery actually increased or decreased by exactly the same percent as Illinois (non-Chicago) firearm robbery. Thus, since Illinois (non-Chicago) firearm robbery dropped 5.5 percent from 1982 to 1983.[96] we would have concluded that Chicago offenses dropped 5.5 percent, instead of the 8.7 percent to 18.3 percent increase estimated by the Chicago Intervention Analysis method.

The FBI method estimated that the number of reported Index robbery offenses in Chicago fell more than 8 percent between 1982 and 1983, and that the number of reported aggravated assault offenses fell declined more than 2 percent. The Chicago Intervention Analysis time series experiment estimated that actual total Index robberies did not change, and that the actual number of total Index aggravated assaults decreased slightly. The estimated change in the total number of aggravated assaults was about the same as the FBI estimate. However, the estimated change for each type of aggravated assault, as well as the estimated change for each type of robbery, was quite different than the FBI overall estimates.

[96]Although the number of offenses fell, the prediction was 23 percent lower than the actual number. Based on the pattern in previous years, the ARIMA model predicted that the drop in 1983 would be much sharper than the drop that actually occurred.

Appendices

Appendix 1: Technical Methods

Time Series Pattern Description

Time series pattern description provides concrete and readily understandable answers to simple descriptive questions about the general pattern of change over time in a variable. It tells the user, in nonstatistical language, whether the variable generally increased, decreased, or stayed the same during the period in question; whether there was a change in the pattern (for example, from an increase to a decrease); and, if there was a change, approximately when the change occurred.

The mathematical tool used for times series pattern description is spline regression. For this descriptive, exploratory purpose, the Authority's Statistical Analysis Center has found spline regression to meet the criteria of simplicity, accuracy, and ease of communication. A linear spline regression fits a least squares regression line with two or more connected segments to the data. This line is continuous in that all the segments are connected. It is analytically discontinuous in that the definition of one segment is not the same as the definition of the next. We have found these properties to be useful in exploratory analyses.

The choice of the best spline regression, or line segment fit, for a series is not completely objective, but depends upon criteria for simplicity and accuracy (see Block, 1983). In the Predictability Project, the search for the best time series pattern description for each time series took the following steps:[97]

1) The Ertel/Fowlkes program searches for the best spline regression given options defined by the user and using a criterion of minimizing the sum of squared residuals.[98] A package of alternative line segment fits is produced having at least three alternative fits in the package (at least a three-segment fit, a two-segment fit, and a straight-line fit).

2) The choice among these alternatives was made using accuracy and simplicity criteria. The criterion for accuracy utilizes the C_p statistic (Block, 1983). Criteria for simplicity in the Predictability Project were that no line segment would be shorter than one year, and that the fit with the smaller number of line segments with a given accuracy would be chosen.

3) While the Ertel/Fowlkes search is based on the smallest sum of squared residuals, it is not exhaustive. However the Hudson/Fox computer program does an exhaustive search for the best two-segment fit; therefore, the Hudson/Fox program was always run as a check when the Ertel/Fowlkes results indicated that a two-segment fit was the best alternative.

[97] For more detail about each step, and for a flowchart showing the relationship of the steps to each other, see Bates (1987).

[98] For a complete description of the Ertel/Fowlkes algorithm, see Block (1983) and Bates (1987).

Descriptive Seasonal Analysis

There are two major approaches to defining and detecting seasonality. Although the two approaches are mathematically similar, there are practical differences in their emphases. One approach, which we refer to here as *descriptive seasonal analysis* emphasizes the separate description of seasonal fluctuation. The other approach, the most common example of which is ARIMA, emphasizes forecasting the future with a model that incorporates seasonality. The first approach focuses on seasonality itself, while the second focuses on seasonality as it affects the accuracy of a forecast.

In the initial, descriptive, stage of analysis, the Predictability Project used a standard kind of descriptive seasonal analysis, the seasonal adjustment, or X-11, method. In this method, the analyst imagines that each time series may have three components. The trend/cycle component consists of long-term trend and any nonseasonal but regular fluctuations. The seasonal component is "the intrayear pattern of variation which is repeated constantly or in an evolving fashion from year to year" (Shiskin, *et al.*, 1967:1). The irregular component consists of everything else, including error, or the residual variation. The problem of detecting and describing seasonality then becomes a problem of dividing a series into its three components, and comparing the relative strengths of the three. A statistic used for this comparison is the F of stable seasonality.

Two seasonality computer programs, a quick screener and a complete analysis, were used in the Predictability Project. The Bell/Canada program (see Block, 1984b; Bates, 1987) was used to screen each series for the presence of seasonal fluctuation. For each series with a Bell/Canada F of stable seasonality equalling at least 2.41, the X-11/ARIMA program was also run.[99] Both programs were run twice (except for series with one or more zero values), once under the additive assumption and again under the multiplicative assumption. Under the additive assumption, the three components are assumed to be independent; under the multiplicative assumption, they are assumed to be dependent (see Block, 1984b).

Of the many diagnostic tests available in X-11/ARIMA results, the most important for the Predictability Project were the F of stable seasonality, the percent contribution of the irregular component, and the percent contribution of the seasonal component.[100]

Because it cannot be assumed that observations in a time series are independent, the F of stable seasonality value must be interpreted as only one indicator of the degree of seasonality, not as an exact measure of significance. The Plewes rule of thumb uses the irregular component as a means of interpreting the the F value. The Plewes criteria are:

1) if the irregular component contributes 30 percent or more of the total month-to-month variation, there is no stable seasonality in the series, regardless of the F value;

2) if the percent contribution of the irregular component is 25 to 29 and the F value is at least 15, or if the percent contribution of the irregular component is between 15 and 24 and the F value is at least 2.41, the series is considered to be seasonal; and

3) if the F value is less than 2.41, there is no stable seasonality, regardless of the irregular contribution.

[99]The X-11/ARIMA program generates projections with ARIMA, then uses them in the calculation of seasonal fluctuation. This allows the analysis to utilize the entire time series for seasonal adjustment. For more detail, see Block (1984b) and Dagum (1979).

[100]See Block (1984b) for more details about the interpretation of these statistics and other X-11 results.

For some series that were seasonal or possibly seasonal, a line segment fit of the seasonally adjusted data was very useful as part of the complete pattern description analysis. In seasonal adjustment, which is one option of X-11 analysis, seasonal fluctuation is removed from the series. The remainder after the seasonal component is removed is the seasonally adjusted series. For example, Figure 51a is a pattern description of Chicago Index aggravated assault with a knife from January 1974 to December 1983, and Figure 51b is a pattern description of the same series, seasonally adjusted. Even though this series does not meet the Plewes criteria, the contribution of the seasonal component is rather high (34 percent) (see Table D), and this is enough to affect the line segment fit for the raw data. An additional line segment emerges in the beginning of 1982 in the seasonally adjusted data, because variation due to seasonal fluctuation has been removed.

Model Identification

In order to identify the best type of ARIMA model for each time series, the Predictability Project used routines available in the Interactive Data Analysis (IDA) computer package to conduct the following analyses:

1) plot of standardized values (an indicator of constant level and constant variance),

2) number of runs above and below the mean (another indicator of constant level; also an indicator of the presence of cycles),

3) correlogram of 50 lags (standard ARIMA diagnostic),

4) partial correlogram (used with correlogram as a standard indicator of the type of ARIMA model),

5) normal cumulative probability plot (shows the degree to which the series is distributed normally), and

6) cumulative periodogram (good diagnostic for the presence of seasonal fluctuation).

ARIMA models cannot be identified for a data series that does not have constant level and constant variance over time (this property is called *stationarity*). Therefore, for every series that did not, according to tests 1, 2, and 3, have a constant level, the series was transformed by a first difference.[101] The first difference transformation was then diagnosed for constant level with tests 1, 2, and 3. If these tests indicated stationarity, and if the standard deviation of the first difference was less than the standard deviation of the raw data, then the first difference transformation was assumed to be stationary.

This was usually enough to produce a series with a constant level that could be modeled with ARIMA. However, for some series, it was necessary to transform the series with 12th dif-

[101] In a first difference, each observation is subtracted from its neighboring observation (see Block, 1984b).

ferencing, square roots, or logs.[102] For other series, it was necessary to truncate the series or to divide it into two separate time periods, and to analyze each separately.

Durbin-ARIMA Analysis

Given an Arima model type, the mathematical calculation of the best fit is relatively straightforward (see Appendix 2). However, two or more ARIMA models that seem appropriate according to the initial diagnostic tests may produce entirely different projections (Pierce, 1980:130; Block, 1984b). It is difficult to distinguish between these models. Therefore, a second diagnostic step-- Durbin-ARIMA analysis--was added to the procedure. As suggested by Roberts (1984), Durbin-ARIMA analysis is a method for exploring the stochastic patterns in a times series so that the most appropriate type of ARIMA model can be chosen.

The Durbin-ARIMA method (see Durbin, 1960) estimates an autoregressive model by lagging the series one, two, or three months, and regressing the original series on these lags. A moving average model is more difficult to estimate, since in a moving average model the current observation is related to previous errors, and by definition, error is not measurable. However, the Durbin-ARIMA method estimates a moving average model by using the residuals of the above regression, lagging them one, two, or three months, and then regressing the original series on these lags.

Box/Jenkins Estimate

With the IDA program, the most appropriate ARIMA model--given the above diagnostic tests and the Durbin/ARIMA analysis--was calculated using the iterative method developed by Box and Jenkins (1970).

A model was rejected if a parameter reached or exceeded 1.00 (this is statistically unacceptable). Also, most models with either of the following qualities were rejected:

1) sum of moving average weights exceeds .90 (a sign of overdifferencing) (see Dagum, 1981),

2) the estimated weight of an AR or MA term, minus two standard deviations, was negative, but the estimated weight plus two standard deviations was positive (in other words, the weight of the term was likely to be zero).

A model with either of these qualities was accepted only if after a thorough search no better model could be found.

In addition, simplicity was a criterion. If two alternative models performed equally well on other criteria, the simpler of the two models was accepted. A model was considered to be simpler if it had only autoregressive or only moving average parameters, but not both; if it had

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[102]None of the models finally chosen as the best had log transformations or more than one degree of differencing. However, such transformations were part of the diagnostic analysis for several difficult-to-model series. Often, these difficult series contained an apparent intervention. When the series was split into two sub-series, the model for each half was easier to identify.

fewer degrees of differencing; if it had fewer total parameters; or if it contained serial or seasonal parameters, but not both.

Diagnostic Tests of Residuals

The residuals of each acceptable model were subjected to the following diagnostic tests:

1) correlogram of 50 lags (the residuals should vary randomly over time), and

2) cumulative periodogram (there should be no evidence of seasonal fluctuation in the residuals).

Analysis in this report refers to the Box-Pierce statistics, which is an objective criterion for randomness in a set of sample autocorrelations. This is also known as the Q statistic (Box and Pierce, 1970; Nelson, 1973:115). The Box-Pierce statistic is distributed approximately as chi-square, with degrees of freedom equal to the number of lags in the correlogram, minus the number of autoregressive and/or moving average processes in the model. It is used as a gauge of the degree of randomness in the correlogram

The cumulative periodogram is also very useful in evaluating the residuals of a model, especially when the series may contain seasonal fluctuation. It gives you the same sort of information as a correlogram, but from the perspective of spectral analysis.

Appendix 2: Comparison of ARIMA Programs

A comparison of the results of four computer programs, all of which estimate an ARIMA model using the methods developed by Box and Jenkins (1970), was done using some of the data from the Predictability Project. The analysis compared ARIMA equations generated by MINITAB, SPSS, X-11/ARIMA, and IDA, using the same type of ARIMA model. This appendix summarizes the results of that comparison.

The purpose of this exercise was not to determine whether or not the class of ARIMA model was the best possible model for the series, but rather to determine whether, given this model class, the equations generated by the four packages were equivalent.

At the time of the comparison, the Predictability Project had identified models for 42 time series, and a sample of 10 of these was used. The main criterion for selection was complexity of ARIMA model class. Complexity was measured by the presence or absence of seasonal as well as serial terms, moving average as well as autoregressive parameters, and second order as well as first order moving average and autoregressive terms. All but one of the 10 sampled time series display some combination of autoregressive and moving average parameters; and half contain both serial and seasonal differencing.

Statistical packages tend to vary slightly with respect to the Box/Jenkins algorithm each employs. This can lead to differences in the models and in the forecasts they generate. The purpose of this analysis was to compare the outputs of four available Box/Jenkins programs in order to uncover any of these equation differences. Therefore, the same class of ARIMA model was entered into the Box-Jenkins routine of each program.

Differences in the Structure of Output

Each statistical package is unique with respect to the structure of its output tables. The output relevant to this analysis is the estimate of each term, called the Beta value. Beta values refer to the relative forecast weights assigned to each component of a given model class. Confidence intervals are a test of statistical significance that take the following form:

Beta + or - 2 standard errors of estimates

The widely accepted criterion for statistical significance is that both elements of the confidence interval possess the same sign. If this is not the case, and the 95 percent confidence interval does include zero, then there is a reasonable possibility that the parameter either makes no contribution to the forecast (i.e., the "true" Beta value is 0), or that the parameter affects the forecast in the opposite direction as had been assumed (i.e., the "true" Beta value has the opposite sign of its initial estimate).

Another test of parameter significance is the T statistic. It is equivalent to the confidence interval, but takes a slightly different form:

T=Beta/Standard Error

A statistical criterion of T>2.00 is used for acceptability of the model.

The following table summarizes the differences in output of these statistics in the four programs:

Program	Statistical Test for Beta Values	Calculates Constant?	Statistical Test for K?
IDA	Confidence Interval	Yes	None
MINITAB	T Statistic	Yes	T statistic
SPSS	T Statistic	Yes	T statistic
X-11	None	No	None

Comparison of ARIMA Program Final Model Results

The Beta values and forecast results of the IDA, MINITAB, SPSS, and X-11 ARIMA Box/Jenkins subroutines were for the most part similar. However, in two of the 10 time series, IDA generated a final model that was deemed statistically acceptable, based on the criterion that no autoregressive Beta parameter exceed 1.00, while one or more of the other statistical packages yielded a final model that would have been rejected on the same criterion. Also, in each of the 10 time series at least one Beta value was generated that deviated at least 10 percent from the corresponding figure generated by IDA. In some cases, this deviation was much larger.

One area in which no wide discrepancy between programs was found, however, was in the statistical tests of standard errors. There was no case in which a Beta value generated by one program was statistically significant, but the other programs failed to find it significant.

Appendix 3: Best ARIMA Models by Jurisdiction, 1972 to 1983

			Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Arlington Heights														
Robbery[a]														
Aggravated Assault[a]														
Burglary	(2,1,0)(0,1,1)	--	-.76 -.32	-.58 -.15	-.40 .03	--	--	--	--	--	--	.84	.89	.94
Larceny/Theft	(0,1,1)(0,1,1)	--	--	--	--	.55	.68	.81	--	--	--	.87	.91	.95
Aurora														
Robbery	(2,1,0)(1,0,0)	--	-.78 -.45	-.62 -.28	-.45 -.12	--	--	--	-.03	.15	.32	--	--	--
Aggravated Assault	(0,1,1)(1,0,0)	--	--	--	--	.73	.82	.92	.03	.20	.37	--	--	--
Burglary	(3,1,0)(0,0,0)	--	-.22 -.35 -.30	-.05 -.19 -.12	.12 -.02 .05	--	--	--	--	--	--	--	--	--
Larceny/Theft	(0,1,2)(0,1,1)	--	--	--	--	.28 .10	.45 .27	.62 .44	--	--	--	.83	.88	.94

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Cicero														
Robbery	(1,0,0)(0,0,0)	11.9	-.02	.15	.32	--	--	--	--	--	--	--	--	--
Aggravated Assault	(0,1,1)(0,0,0)	--	--	--	--	.40	.54	.68	--	--	--	--	--	--
Burglary	(0,1,1)(0,0,0)	--	--	--	--	.64	.75	.86	--	--	--	--	--	--
Larceny/Theft[b]														
1972-1977	(2,1,0)(1,0,0)	--	-.54	-.30	-.06	--	--	--	-.59	-.34	-.10	--	--	--
			-.55	-.31	-.07									
1978-1983	(1,0,0)(0,1,1)	--	.13	.37	.61	--	--	--	--	--	--	.66	.80	.94
Decatur														
Robbery	(0,1,2)(0,0,0)	--	--	--	--	.57	.73	.89	--	--	--	--	--	--
						.03	.20	.37						
Aggravated Assault	(0,1,1)(0,1,1)	--	--	--	--	.61	.73	.85	--	--	--	.81	.87	.92
Burglary														
1972-1981	(0,1,1)(0,0,0)	--	--	--	--	.45	.60	.75	--	--	--	--	--	--
1972-1983	(0,1,2)(1,0,0)	--	--	--	--	.40	.57	.74	.01	.19	.37	--	--	--
						.02	.19	.36						
Larceny/Theft	(0,1,1)(0,1,1)	--	--	--	--	.57	.69	.82	--	--	--	.86	91	.96
Des Plaines														
Robbery[a]														
Aggravated Assault[a]														

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Des Plaines (cont.)														
Burglary	(2,0,0)(1,0,0)	46.4	.24 .08	.40 .20	.57 .37	--	--	--	.00	.15	.31	--	--	--
Larceny/Theft	(2,0,0)(0,1,1)	--	.25 .15	.42 .31	.58 .48	--	--	--	--	--	--	.84	.89	.94
Elgin														
Robbery 1975-1983	(1,0,0)(1,0,0)	6.8	.06	.25	.44	--	--	--	.18	20	.21	--	--	--
Aggravated Assault	(0,0,2)(1,0,0)	11.8	--	--	--	-.45	zero[c] -.28	-.12	.18	.32	.45	--	--	--
Burglary	(0,1,1)(0,0,0)	--	--	--	--	.51	.64	.76	--	--	--	--	--	--
Larceny/Theft	(0,1,1)(0,1,1)	--	--	--	--	.54	.68	.81	--	--	--	.84	.90	.96
Evanston														
Robbery	(0,1,1)(0,0,0)	--	--	--	--	.64	.75	.86	--	--	--	--	--	--
Aggravated Assault	(3,0,0)(0,1,1)	--	.03 -.03 .03	.20 .14 .20	.38 .32 .37	--	--	--	--	--	--	.85	.91	.97
Burglary 1972-1978	(0,1,2)(0,0,0)	--	--	--	--	.16 -.14	.38 .09	.61 .31	--	--	--	--	--	--
1979-1983	(1,0,0)(0,1,1)	--	-.02	.26	.54	--	--	--	--	--	--	.71	.84	.97
Larceny/Theft	(0,1,1)(0,1,1)	--	--	--	--	.76	.85	.94	--	--	--	.88	.92	.97

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
			Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Joliet														
Robbery	(0,0,2)(0,0,1)	21.5	--	--	--	-.51	-.35	-.18	--	--	--	-.39	-.22	-.05
						-.43	-.27	-.10						
Aggravated Assault	(0,1,1)(0,0,0)	--	--	--	--	.31	.46	.61	--	--	--	--	--	--
Burglary	(2,0,0)(0,0,1)	144.0	.36	.51	.67	--	--	--	--	--	--	-.44	-.27	-.10
			.11	.26	.40									
Larceny/Theft	(0,1,2)(0,1,1)	--	--	--	--	.21	.38	.55	--	--	--	.81	.87	.93
						.13	.30	.47						
Peoria[d]														
Robbery	(1,0,0)(0,1,1)	--	.27	.43	.59	--	--	--	--	--	--	.84	.89	.94
Aggravated Assault[e]	(0,1,1)(2,0,0)	--	--	--	--	.50	.63	.76	.19	.23	.47	--	--	--
									.33	.48	.62			
Burglary	(0,1,2)(0,1,1)	--	--	--	--	.17	.34	.51	--	--	--	.82	.87	.92
						.12	.29	.47						
Larceny/Theft	(1,1,0)(0,1,1)	--	-.66	-.52	-.37	--	--	--	--	--	--	.79	.85	.91
Quincy														
Robbery[a]														
Aggravated Assault	(3,0,0)(0,0,0)	6.2	-.00	.16	.32	--	--	--	--	--	--	--	--	--
				zero[c]										
			.13	.29	.45									

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate			Moving Average Estimate			Seasonal Autoregressive Estimate			Seasonal Moving Average Estimate		
			Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Quincy (cont.)														
Burglary	(0,1,1)(0,0,1)	--	--	--	--	.44	.58	.72	--	--	--	-.30	-.13	.04
Larceny/Theft	(0,1,1)(2,0,0)	--	--	--	--	.50	.63	.76	.09	.25	.40	--	--	--
									.18	.34	.50			
Rockford														
Robbery	(2,0,0)(0,1,1)	--	.14	.31	.48	--	--	--	--	--	--	.83	.88	.93
			.22	.39	.56									
Aggravated Assault	(0,1,1)(0,1,1)	--	--	--	--	.59	.71	.85	--	--	--	.81	.87	.92
Burglary	(0,1,1)(1,0,0)	--	--	--	--	.36	.51	.66	.47	.60	.73	--	--	--
Larceny/Theft	(0,1,2)(0,1,1)	--	--	--	--	.28	.46	.64	--	--	--	.83	.89	.94
						.03	.21	.39						
Rock Island														
Robbery	(0,1,1)(0,0,0)	--	--	--	--	.71	.81	.91	--	--	--	--	--	--
Aggravated Assault														
1972-1981	(0,1,1)(0,0,0)	--	--	--	--	.63	.76	.87	--	--	--	--	--	--
1972-1983	(0,1,1)(0,0,1)	--	--	--	--	.60	.71	.83	--	--	--	-.30	-.13	.05
Burglary														
1972-1978	(0,1,2)(0,0,1)	--	--	--	--	.08	.29	.50	--	--	--	-.32	-.08	.16
						.17	.38	.59						
1979-1983	(0,1,1)(0,0,0)	--	--	--	--	.20	.43	.66	--	--	--	--	--	--
Larceny/Theft	(2,0,0)(0,1,1)	--	.25	.43	.60	--	--	--	--	--	--	.86	.91	.96
			.04	.21	.38									

Jurisdiction	Model (p,d,q)(Sp,Sd,Sq)	Mean	Autoregressive Estimate Low	Best	High	Moving Average Estimate Low	Best	High	Seasonal Autoregressive Estimate Low	Best	High	Seasonal Moving Average Estimate Low	Best	High
Skokie														
Robbery[a]														
Aggravated Assault[a]														
Burglary	(1,0,0)(0,1,1)	1.6	.23	.39	.55	--	--	--	--	--	--	.84	.90	.95
Larceny/Theft	(3,1,0)(0,1,1)	--	-.82	-.66	-.50	--	--	--	--	--	--	.84	.90	.96
			-.69	-.51	-.33									
			-.54	-.37	-.20									
Springfield														
Robbery	(1,0,0)(1,0,0)	22.7	.24	.40	.56	--	--	--	.05	.20	.35	--	--	--
Aggravated Assault[e]	(2,1,0)(2,0,0)	--	-.73	-.57	-.41	--	--	--	.04	.19	.34	--	--	--
			-.45	-.29	-.13				.34	.49	.65			
Burglary	(0,1,2)(0,0,0)	--	--	--	--	.28	.44	.60	--	--	--	--	--	--
						.19	.35	.51						
Larceny/Theft	(1,0,0)(1,1,0)	--	.62	.74	.86	--	--	--	-.73	-.66	-.58	--	--	--

[a]Not analyzed due to low numbers (see Table B).

[b]In Cicero, the number of crimes known to the police in November 1977 was extremely low relative to other Novembers. This was true for every Index crime. For Index larceny/theft, there were eight in November 1977, but an average of 85 in all other Novembers. The other 11 months of 1977 averaged 69. This led us to suspect the accuracy of the November 1977 figure, but we were unable to obtain additional information from Department of State Police. Therefore, in the analysis in this report, 85 is used for November 1977.

[c]MA(1) parameter crossed zero in Elgin, and MA(1) was set to zero in the final model. In Quincy, the same thing happened with the AR(2) parameter.

[d]Data for August 1979 are missing, and the figure for September 1979 was about twi[illegible] high as other Septembers. This was true for every Index crime. For this analysis, one half of the September figure was used for August and September.

[e]Updated figures obtained from the Department of State Police.

Appendix 4: Imputation of Data in the Uniform Crime Reports

The method used in the Chicago Intervention Analysis can be considered an alternative to the Federal Bureau of Investigation's method of estimating percent change from year to year in situations in which a change in recording practices occurred.[103] The method of estimation used in the Chicago Intervention Analysis differs from the method used by the FBI in their Uniform Crime Reports (UCR) in two important ways. First, in the Chicago Intervention Analysis, individual categories of crime are estimated, not Index crime aggregate totals. Second, rather than assuming that Chicago patterns are the same as patterns in the nation as a whole, the Chicago Intervention Analysis method uses the past experience in the city itself to estimate the percent change from year to year.

Because published FBI/UCR statistics are meant to be total counts of all crimes in the United States, not an estimate based on statistical sampling techniques, the issue of how to estimate national and state totals, when certain agencies within the nation or state might not have reported in a given month or year, has been a problem since the UCR began more than fifty years ago. Without a statistical sample, the proper estimation technique is neither automatic nor immediately apparent.

Fortunately, the problem of incomplete reporting has diminished over the years, as the number of reporting agencies has increased to more than 90 percent (Schneider and Wiersema, 1985). However, as the analysis of reported offenses over time in the Predictability Study indicated, it may be relatively common for a law enforcement jurisdiction to suddenly improve the completeness and accuracy of its reporting of criminal offenses. When this occurs, the comparison of offense totals from year to year becomes problematic. This appendix reviews the method the FBI uses to impute, or estimate, offense totals in such situations.

Estimation of UCR Data

Over the years, many large cities have had discontinuous breaks in data collection. Either some months were not reported at all, as in New York City homicide in 1976 (Fox and Pierce, 1986), or there was a major change in data recording practices, as in Chicago. Cities that have had a substantial increase in reported offenses, due to improved data collection practices, are the following:[104]

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[103] We appreciate the assistance of Louise S. Miller in compiling information in this section.

[104] Sources: ***Uniform Crime Reports, 1959-1983***, and Zimring and Frase (1980).

City	Years	Increase
Baltimore	1964, 1965	40.5%
Buffalo	1961, 1963	94.7
Chicago	1959, 1960	71.9
Chicago	1982, 1983	32.8
Cleveland	1963, 1964	63.0
Indianapolis	1961, 1962	47.3
Kansas City, MO	1959, 1961	202.0
Las Vegas	1972, 1973	248.0
Memphis	1963, 1964	31 [illegible]
Memphis	1972, 1973	47.5
Miami	1963, 1964	26.6
Nashville	1962, 1963	41.7
Nashville	1974, 1975	22.3
Seattle	1972, 1973	55.1
Springfield, IL	1972, 1973	155.1
Shreveport, LA	1962, 1963	46.7
Syracuse	1963, 1964	34.5
Tucson	1973, 1974	35.6

Method Used to Estimate UCR Data

In ***Crime in the United States: 1983***, tables 2 and 3, estimated 1982 Chicago statistics are included in total regional, state, and national figures. However, the reported, not the estimated, 1982 statistics are presented in Table 5, in which Chicago is individually listed. In ***Crime in the United States: 1984***, the year 1983 was similarly estimated, but again, these estimated figures were presented only in tables giving regional, state, or national totals for two years. In other words, the FBI estimates are used only to calculate aggregate regional, state, or national totals, not to describe levels of crime in Chicago, but only to describe change from year to year in Chicago.

The goal of the FBI/UCR estimation (imputation) method is not to estimate the number of offenses in a given year in a given non-reporting or inaccurately reporting city, but rather to estimate the percent change from year to year in total national or state figures that include the given city. The most important motive of UCR estimation is to provide data users an accurate view of the increasing or decreasing pattern of a crime over time. The method of doing this has changed little since UCR data collection began, and is described in ***Crime in the United States***: 1984.

> Estimates ... have been adjusted due to a 1983 change in reporting practices in Chicago, Illinois. Prior procedures were determined not to be in accordance with established UCR standards, and it was necessary that earlier statistics for Chicago be adjusted through estimation procedures. Crime Index figures for that city were deducted from each year's United States total and revised figures were established as if no reports were received. Those crime volumes were then reincorporated to establish new national estimates.

Paul Zolbe, former chief of the FBI Uniform Crime Reporting Program, used the following example to clarify the estimation procedure (Zolbe, 1984). For index aggravated assault, estimated 1982 data were obtained as follows:

Year	Nation	Chicago	Nation minus Chicago
1983	639,807	13,330	626,477
1982	650,042	8,317	641,725

The figure officially reported by Chicago in 1982 (8,317) was replaced by an estimate of 13,654. This estimate was calculated by the following formula:

$$13{,}330 \times \frac{641{,}725}{626{,}477} = 13{,}654$$

Thus, according to this estimate, the number of index aggravated assaults known to the police in Chicago declined 2.4 percent between 1982 and 1983 (from 13,654 in 1982 to 13,330 in 1983).

The Effect of Estimation in Chicago

The FBI's estimation procedure assumes that the 1982-1983 change in Chicago is nearly the same as the change in the rest of the United States. The percentage change between the 1982 estimate and the 1983 number of crimes known to the police in Chicago, for each index crime except murder, is given below:[105]

	1982-1983 Percentage Change	
Index Crime	Chicago	United States except Chicago
Index forcible rape	-0.04%	+0.03%
Index robbery	-8.40%	-8.42%
Index aggravated assault	-2.40%	-2.42%
Index burglary	-9.20%	-9.20%
Index larceny/theft	-6.00%	-6.02%
Index motor vehicle theft	-5.10%	-5.12%

The FBI's assumption, of course, does not take into account the possibility that crime trends in a city with the characteristics of Chicago may not be the same as crime trends in the country as a whole. This problem has been noted by researchers such as Schneider and Wiersema (1985:22):

> [I]mputation based on crimes known to police on other jurisdictions depends on the number and type of comparable agencies that submit complete reports.

The President's Commission on Law Enforcement and Administration of Justice reached the same conclusion in 1967. The Commission's report, ***The Challenge of Crime in a Free Society***, reviewed the method of estimating crime totals in cases in which a city had changed its crime reporting procedures, using Chicago and New York City as specific examples. The conclusion of the Commission was the following:

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[105] Because index murder figures were assumed to be accurate, the FBI did not estimate them.

This system is perhaps as good as can be devised. It is obviously very hard, however, to estimate how much crime would have been reported in a major city in the year prior to that in which the system of reporting was changed, and even harder to say what the crime rate was five years earlier. . . . The real question is not the method of estimation, but whether the yardstick at the present time is too changeable to allow significant trend comparisons to be made at the national level.

In this report (see "Estimated Actual Change in Robbery and Assault," page 139), a method that does not depend on this yardstick assumption is used to estimate change in Index robbery and Index aggravated assault in Chicago. These estimates for individual types of crime were quite different from the estimates made by the FBI.

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