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T2	________________	F2	________________
T3	________________	F3	________________
T4	________________	F4	________________

2010

13th Annual High School Mathematical Contest in Modeling (HiMCM) Summary Sheet
(Please attach a copy of this page to each copy of your Solution Paper.)

Team Control Number: 2663

Problem Chosen: B

Please type a summary of your results on this page. Please remember not to include the name of your school, advisor, or team members on this page.

While the problem did not give any specific goal for decreasing the incidence of crime in the city, we determined that an effective and practical goal for the city is to reduce violent crime by 10% by the year 2020. In order to reduce the amount of crime in the city, we first created a model that calculated incidence of violence as a function of different data that we were given. We determined that some of the provided data had little to no impact on the amount of violent crime. Trying to incorporate this unhelpful information into our model would make it less accurate, so we developed a way to decide if a set of data was worth considering. When we applied this method to all of the sets of data, we were left with five that had a noticeable correlation with violence. These five values were City Population, High School Graduation Rate, High School Dropout Rate, Prison Population, and Percent of Parole Violations. With these five variables determined, we checked to make sure that each relationship with violence was roughly linear, then ran a multivariate linear regression to create a function that outputs an approximate incidence of violence given the City Population, High School Graduation Rate, High School Dropout Rate, Prison Population, and Percent of Parole Violations. When we tested this model against data that we already had, there was relatively low error, with discrepancies in incidence of violence ranging from 15 crimes to less than 1 crime.

Once we could predict an approximate amount of violent crime for any set of data, we found which variable(s) affected the function most. We found that High School Graduation and Dropout Rates had the biggest effect, which supports the comment that the city had problems with gang violence (we assumed high school dropouts were much more likely to join gangs). Because these variables held the most weight in our model, we set out to create a relation which could model increases in graduation rate and decreases in dropout rate as a function of the percent increase in school funding. We felt that this model would be beneficial in our proposal to the mayor, as it allows us to state specific and concrete changes that the city can make, instead of trying to generally increase the number of graduates and stop students from dropping out. There was error in this model as well, which compounded the

error of our original model. However, we felt that it allowed us to make a stronger and more realistic proposal to the mayor.

As part of our report, we created a computer program that could accept proposed changes in funding, convert it to an approximate change in graduation and dropout rates, produce the multivariable linear regression function, and input the modified data (modified by the change in school funding) to output a projected incidence of violence in a given year, and the amount eliminated. By using this program, we were able to test different values for the proposed change in funding and assess how well it reduced crime. From this testing, we were confident that by increasing school funding by 275% by the year 2020, the crime would decrease by 10%. However, in the creation of our models we consistently used conservative estimates, so we believe that the true percent increase of funding necessary to reduce the incidence of violence by 10% may be less than that. In addition, our proposal includes qualitative measures for the city to introduce to continue to reduce crime. These measures could not be included in our computer program, so the percent increase in funding may be even less.

Assumptions:

1. This city can be accurately modeled by the existing town of Salinas, California.

Many statistics for the town of Salinas, California and its county, Monterey Bay, very closely reflect those of the given city. Over the past nine years, from 2000-2008, the homicide count for Salinas is almost identical[1]. Salinas's population also follows similar trends to that of the given city and is identical in the year 2000 (the year of the census)—the same is true of Monterey Bay and the given county population[2]. Because Salinas is nearly equivalent to our city in population and crime rate, we assumed that other statistics from Salinas could be used to model data for our predictions.

2. The statistics given for juvenile inmates and prison population (and data associated with these) reflect statistics for the state, not only for the city.

The given statistics for juvenile inmates exactly reflect those for the state of California[3]. In addition, the data for prison population in the entire state of California are analogous to those given[4]. Considering that the city given can be accurately modeled by the city of Salinas in California, it seems logical that the statistics given for juvenile inmates and prison population are reflective of the state and not the town (there are also more prison inmates than residents of the city, so it would not make sense for the prison to only hold inmates from the immediate city). However, we assume that the trend in these numbers reflect the crime rate in our town.

3. High school dropouts are more likely to become involved in gang activity.

We assume that high school students who drop out of school are at a higher risk for joining gangs, which is reflected in the data.

4. Factors for which we are given statistics in the problem will continue to follow current trends.

In our model, we use City Population, High School Graduation Rate, High School Dropout Rate, Percent Parole Violations, and Prison Population. Our model is used to project these factors, along with the effect of increased school funding, in the future to predict incidence of violence in a given year. For some of these data, there was no apparent trend over the eight years given (they essentially remain constant) and we assume that this will continue to be true in the future. For population, which has followed a trend in recent years, we used a function fitting the data to project the population into the future and factor an estimated population into the predicted incidence of violence (See Appendix B).

Restatement of Problem/Goal Statement:

A city has a large amount of gang violence and crime. We need to identify values that are predictors of violence and minimize or maximize them in order to reduce violence. We will create a proposal that describes ways to change these predictors over the next ten years so that violent crime will be reduced by 10% by the year 2020. In order to ensure that our methods are effective, we will model violence as a function of other given data as well as the changes outlined in the proposal and use that to compute an estimate amount of violent crime in the year 2020.

Proposal:

[1] http://www.salinaspd.com/statistics.html
[2] http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2001-10/
[3] http://www.cdcr.ca.gov/Juvenile_Justice/Research_and_Statistics/index.html
[4] http://www.cdcr.ca.gov/Reports_Research/Offender_Information_Services_Branch/Population_Reports.html

To the mayor, chief of police, and city council:

With the provided statistics from the years 2000-2008, we have completed a report that details our analysis of the data and recommendation for decreasing violent crime in your city. We have determined that incidence of crime can be effectively predicted by a number of controllable factors in your community. The population of the city and high school graduation rate are inversely related to the incidence of violent crime. The high school dropout rate, prison population, and percent of parole violations increase are proportional to the crime—as they increase, so does the crime rate. It would therefore be beneficial to reduce the dropout rate, prison population, and percent of parole violations, and to raise the high school graduation rate and city population. However, to be both realistic and effective, we have carefully examined which factors are most strongly correlated to the incidence of violence and we have proposed changes that will maximize our effectiveness by addressing these factors. Our conclusion is that through careful budgeting and implementation of our proposal, the city can cut violent crime by 10% by the year 2020.

Of these five factors, the two that are most strongly correlated to violent crime, and therefore the two that reduce crime most effectively, are the high school graduation and dropout rates. Therefore, our proposal is focused largely on increasing the graduation rate and lowering the dropout rate. These two quantities are of great concern nationwide, so there is a large amount of information published on them.

In addition to changes in the high school graduation and dropout rates, there should be noticeable changes in the population of the city by the year 2020. While the population of the city does not follow a well defined function with respect to time, the population of the county does. Moreover, the population of the city is proportional to the population of the county. We were therefore able to express the city's population as a function of time by first using a function that relates the county's population. From this projection, we found that the population of the city will continue to increase through 2020 and are able to model this growth and estimate the city's population for specific years. Because violent crime is inversely related with population, we can expect to see drops in violence as long as the city's trend of growth continues.

In order to take advantage of this growth, we recommend that you create a campaign to attract citizens to your city and supplement the natural growth of the population by highlighting the benefits of your community and encouraging others to move there. If this campaign is successful over the next ten years, the population we predicted for 2020 will be an underestimation, which will make our prediction for crime reduction more conservative.

Finally, it would be beneficial to address some aspects of the prison located in your town. Decreasing the population of a state prison and reducing the percentage of parole violations is largely out of your control; however, taking steps to minimize these can only have a positive effect on the amount of violent crime in your city. We recommend advocating for harsher consequences for parole violations in your political agendas. If these changes could be implemented in the local prison (if not on the state level), we believe there would be a decrease in parole violations, and by extension, incidence of violence in your city.

It is important to remember, however, that the key element of this proposal is the increase of state and local funding to the city's high schools. The dropout and population rates are the most powerful indicators of violent crime in the city, most likely because they affect the amount of gang activity. In order to reach the goal of a 10% reduction in crime by 2020, the 275% increase in school funding is necessary. We have modeled the effect of increased school funding on graduation and dropout rates and consequently its effect on the incidence of violence in your town, and we have determined that this is the most effective and practical course of action. Along with the increase in school funding, launching a publicity campaign for the town and petitioning the state government to increase parole violation penalties will further reduce the amount of violent crime. If our proposal is implemented, it not only will decrease the incidence of violence in your city for the next ten years, but the progress will be evident in your community and as the amount of violence drops, the ability to continue lowering the crime rate in your city will only become more manageable in years to come.

Choosing variables:

In order to reduce violence in the town, our first objective was to identify values that were indicative of (correlated to) the amount of violence. Our first guess was that the unemployment rate, dropout rate, number of juvenile inmates, and number of parole violations would be the most important factors in predicting violence. To test this, we ran linear regressions of violence with respect to each value with the statistical analysis software MINITAB. None of the regressions produced high coefficients of determination; however, the R^2 values for violence vs. juvenile inmates and violence vs. unemployment were nearly zero. Because of this we decided that using intuition to determine factors of violence prediction was inaccurate. Using MINITAB, we then ran linear regressions of all values vs. all other values and outputted the coefficient of determination from each regression. This information represents the strength of the relationship. Because we were primarily concerned with data that is related to violence, we made a list of all factors with a high coefficient of determination when compared to the incidence of violence in each year. To further ensure that this list of values could be used to predict incidence of violence, we conducted hypothesis tests that would determine the probability that the slope of our regression line was 0. If the slope was equal to 0, the two variables would have no correlation, because the response variable would not be affected by the explanatory variable. In essence, by finding the probability that the slope was 0, we were finding the probability that the variable did not affect violent crime. To apply both of these criteria, we made a list of all data sets which had a coefficient of determination greater than 0.1 and a P-value less than 0.5. This produced the list: Year, Homicides, Assaults, City Population, County Population, HS Enrollment, HS Dropouts, Graduation Rate, HS Dropout Rate, Prison Population, Parole Violations, and Percent of Parole Violations. Homicides and Assaults were removed for this list because they are the same thing as Incidence of Violence, and Year and County Population were removed because they cannot be controlled by the city. This left the list: City Population, HS Enrollment, HS Dropouts, Graduation Rate, HS Dropout Rate, Prison Population, Parole Violations, and Percent of Parole Violations. To trim this list down further, we removed any quantities that were strongly correlated. For this reason, HS Enrollment was removed (it correlated strongly with Graduation Rate), HS Dropouts was removed (it correlated strongly with HS Dropout Rate), and Parole Violations was removed (it correlated strongly with Percent of Parole Violations). The resulting list, which we used for our analysis, was composed of City Population, Graduation Rate, HS Dropout Rate, Prison Population, and Percent of Parole Violations. Each of these data sets have a coefficient of correlation of at least 0.1, which is enough to be noticeable, and a better than 50% probability of being correlated with incidence of violence.

Explanation of multivariate regression:

To estimate the incidence of violence in any given year, we created a linear model that weighted each variable that we felt had a significant effect on violence. To do this, we created a multivariable linear regression. From the bivariate regressions we created previously, we knew that all variables related in a roughly linear manner because the individual residual plots had no structure (See appendix A). Therefore, modifying data (through exponents, logs, etc) was not necessary. The five explanatory variables we considered were city population, dropout rate, graduation rate, prison population, and number of parole violations. Because each relation was linear, we knew our model would take the form:

$$y_i = \beta_0 + \beta_1 * x_{1i} + \beta_2 * x_{2i} + \beta_3 * x_{3i} + \beta_4 * x_{4i} + \beta_5 * x_{5i} + e_i$$

Where y_i is the incidence of violence at any year 2000 + i, β_0 is a constant, e_i is the error at any year 2000 + i, β_n is the true coefficient for each explanatory variable x_n, x_{ni} is the value of x_n at any year 2000 + i, and x_n is as follows:

x_1 = High school dropout rate
x_2 = Graduation rate
x_3 = Number of parole violations
x_4 = Prison population
x_5 = City Population

Because we have nine years of data, nine such equations exist. To be written more concisely, this system of equations can be written as an equation of matrices, $\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{e}$. Bold letters will be used to denote matrices.

-Matrix $\mathbf{y}$ is a 9x1 matrix composed of all y_i from i=0 to i=8.

-Matrix **X** is a 9x6 matrix composed of 9 rows representing each year, 5 columns made up of x_1-x_5, and a column of 1's for the constant value, β_0.

-Matrix $\boldsymbol{\beta}$ is a 6x1 matrix representing the solution to the system of equations and the coefficients for our linear model.

-Matrix **e** is a 9x1 matrix composed of all e_i from i=0 to i=8, which represents the naturally occurring error in the model.

However, this vector equation cannot be computed because β cannot be found without taking a census**.** We only had nine data points, so to estimate β we used a 9x1 matrix **b** which contains b_i for all i=0 to i=8, where b_i is an approximation for β_i. The new equation is: $y = Xb +$ **ê,** where **ê** represents the error when **b** is used instead of β **.**

In order to make this a least squares regression linear fit, we chose **b** to minimize the sum of the squares of **ê** **(**$\sum_{i=0}^{8} \hat{e}_i^2$**)** **.** This value is equivalent to $\hat{e}^t *$ **ê.** Since **ê** = $y - Xb$ **,** we want to minimize ($y - Xb$)^t($y - Xb$ **).**

In order to minimize this quantity, vector differentiation is necessary. It follows that **b = (X^{t}X)$^{-1}$X^{t}y.**

Returning to the original vector equation, we now have **ŷ = Xb**. **ŷ** represents the approximate value of violence incidence. **ê** has been removed from the equation because it has been minimized and is accounted for by the fact that **ŷ** is now an approximate value. When this equation is rewritten into separate equations, we obtain the linear function

$\hat{y}_i = b_0 + b_1 * x_{1i} + b_2 * x_{2i} + b_3 * x_{3i} + b_4 * x_{4i} + b_5 * x_{5i}$

Explanation of Program:

The model we have created uses multivariate regression to predict the incidence of violence in the city for a given year. The model is a program written in Java and uses two dimensional arrays to represent the matrices required for the regression. The program has the data of Incidence of Violence, City Population, HS Dropout Rate, HS Graduation Rate, Prison Population, and Percent of Parole Violations coded into it. It then takes this information and performs the functions described above to create the approximate coefficient matrix **b**. The program then asks for the year being considered. For all of our calculations we used the year 2020 because that was the target year. With this input, the program then calculates an approximate value of the city population during that year based on an approximation of the county population. (See Appendix B). This new population will be used in the final computation of the amount of violent crime in 2020. The program then prompts the user to input the goal increase in school funding by that year. It uses the function described in the section "Predicting the Effect of Additional Spending in the School System" to convert the percent increase in funding to a percent increase in graduation rate and decrease in dropout rate. The program now has a predicted population, HS dropout rate and HS graduation rate. Because the prison population and percent of parole violation has stayed relatively constant in recent years, we assumed that it would stay relatively constant until 2020. Because of this assumption, we coded the 2008 values for these two quantities into the program as constants. With these five values now stored, the program then plugged in each to the formula generated by the multivariable linear regression, and outputted the predicted incidence of violence in 2020. It also calculated the predicted amount of violence if the increase in funding had not been applied in order to show the effectiveness of our proposal to the mayor.

Predicting the effect of additional spending in the school system:

Since there is a high correlation between both Graduation Rate and HS D/O Rate, it makes the most sense to improve these numbers in some way. There are several options for the way in which this can be done. These include: raising teacher salary, decreasing the class size, creating after-school programs for young students[5]. All of these options require additional spending money budgeted for the school system. Our goal is to improve incidence of violence by 10%, so we would like to predict how much additional spending money is required in order to do so. Since Graduation Rate and HS D/O Rate are directly related to the incidence of violence in our model, we need to determine how additional spending money affects Graduation Rate and HS D/O Rate.

Graduation Rate and HS D/O Rate are directly related to each other by a linear model so we can focus on only one of these as a response variable to the function of spending money. We chose to use Graduation Rate because there is the most data available for it online. There were several criteria we used for a function which would map additional spending money onto Graduation Rate.

-The function must be asymptotic at (Graduation Rate) = 1(100%)

-With 0 additional spending, the function must give back the same Graduation Rate as before.

-Since the function has no inflection points, it must be concave down to satisfy the above requirements.

Based on these parameters, a function with the form:

k/(1 - gradratefinal) – k/(1 – gradrateinitial) = percent increase in spending (%increase), with k being a constant.

This can also be written as: gradratefinal = 1-(k/(%increase + (k/(1 – gradrateinitial)))).

In order to solve for the constant, k, we took data from 2001 and 2007 in the school district of Salinas, California for spending per student[6] and from our given Graduation Rates. We divided the spending/student from 2007 by the spending/student in 2001 to obtain a % increase in spending which can be used in the function with initial and final rates of graduation from 2001 and 2007 respectively. K was determined to be .485 from these values. Our final formula was:

Gradratefinal = 1 - (.485/(%increase + (.485/(1 – gradrateinitial)))).

Strengths:

- Our model takes more than one variable into account at a time, reducing the effect of confounding variables.
- Our model allows any of the five variables to be artificially varied, which lets us assess its relative strength in the model.

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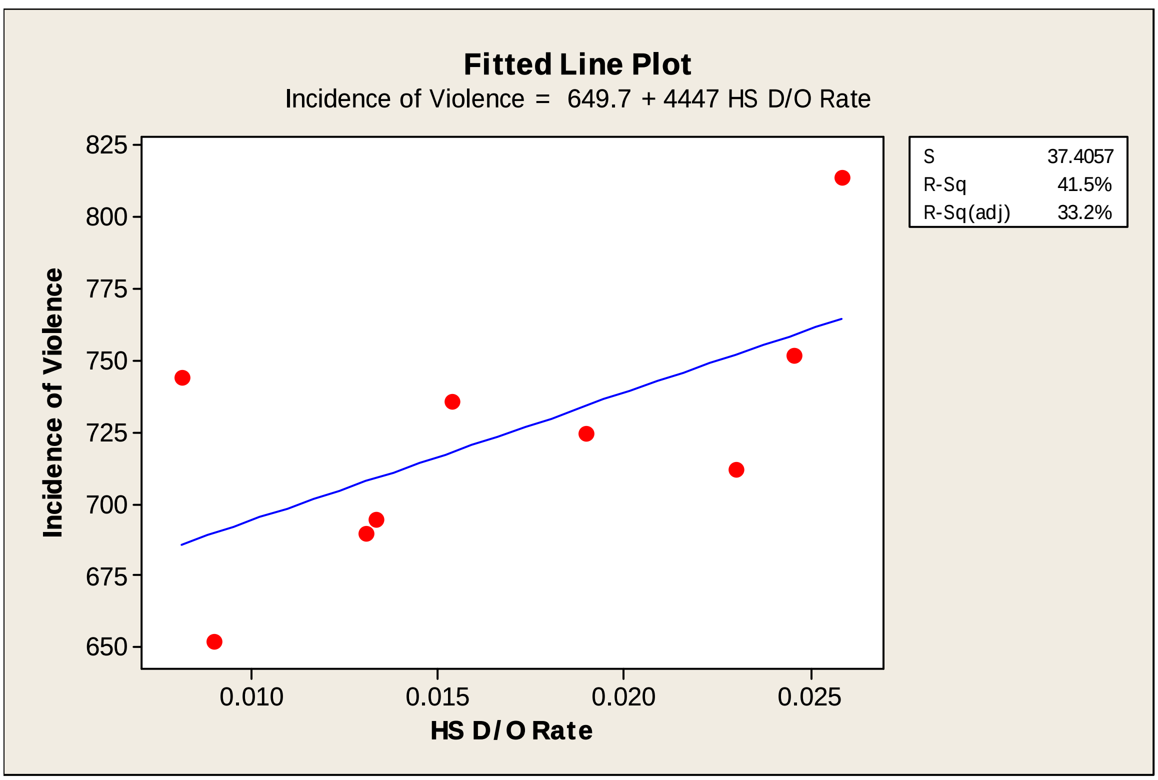
[5] www.cbcse.org/media/download_gallery/Leeds_Report_Final_Jan2007.pdf
[6] http://nces.ed.gov/ccd/bat/output.asp

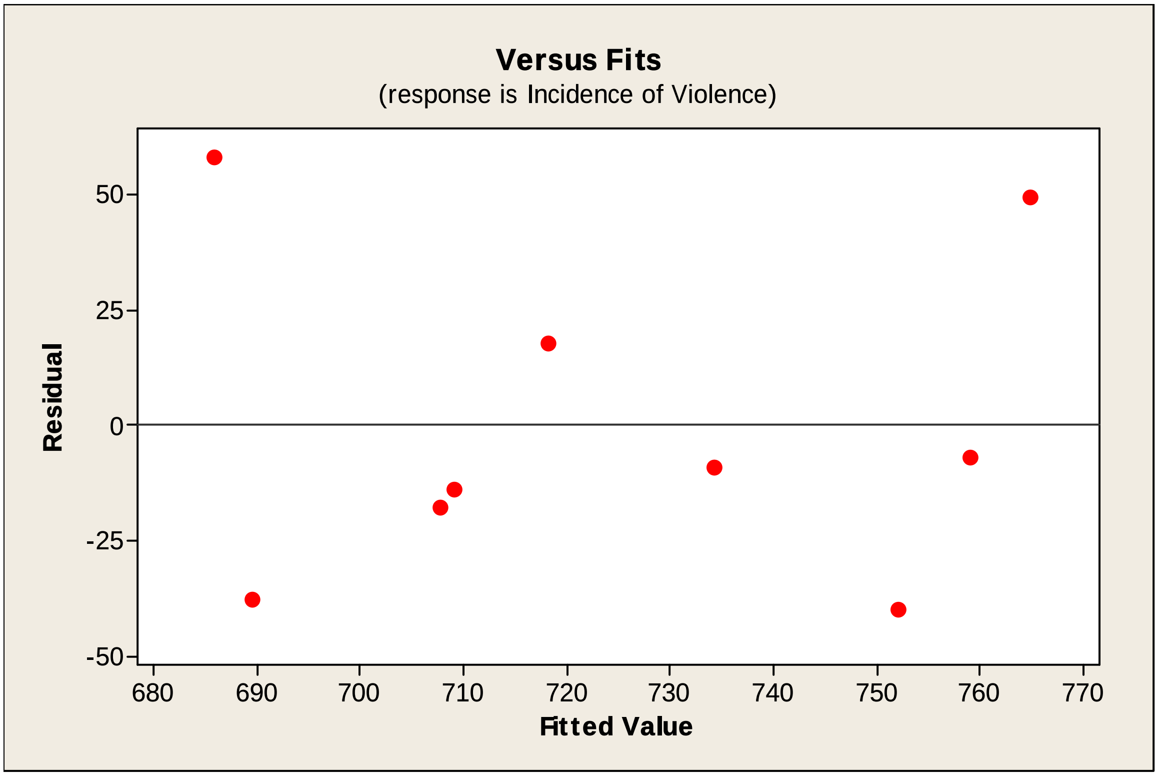
- Our program allows us to come up with a concrete number (the percent increase in school spending) that can be presented to the mayor. This is more realistic and allows the mayor to know exactly what needs to be done.
- Our model does not include extraneous information, which would make its predictions less accurate.

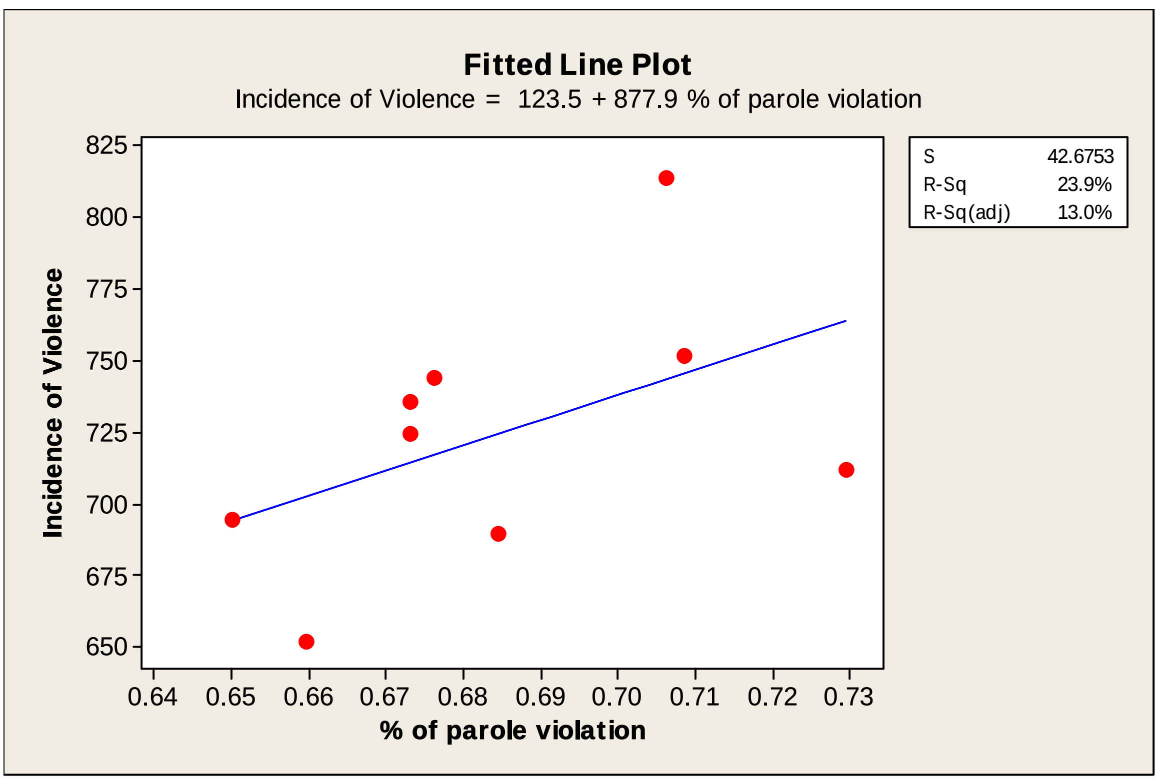
Weaknesses:

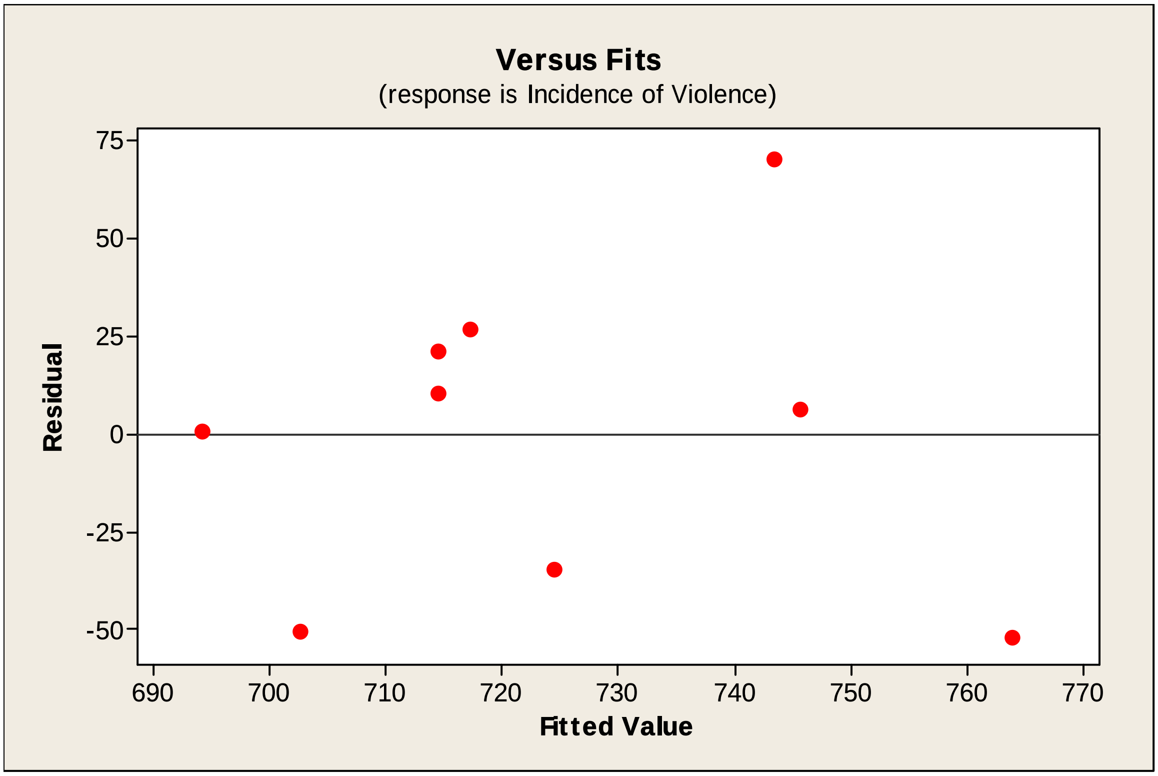
- Our model uses approximate values produced by other models. This means that the error becomes compounded and final values (like the predicted crime in 2020) has more variability than we would like.
- The error in our model is unbounded. We know that the error for the model is minimized (through the differentiation), but it is still important to be able to explicitly define it. Because of this, we cannot quantitatively express our confidence in the model.

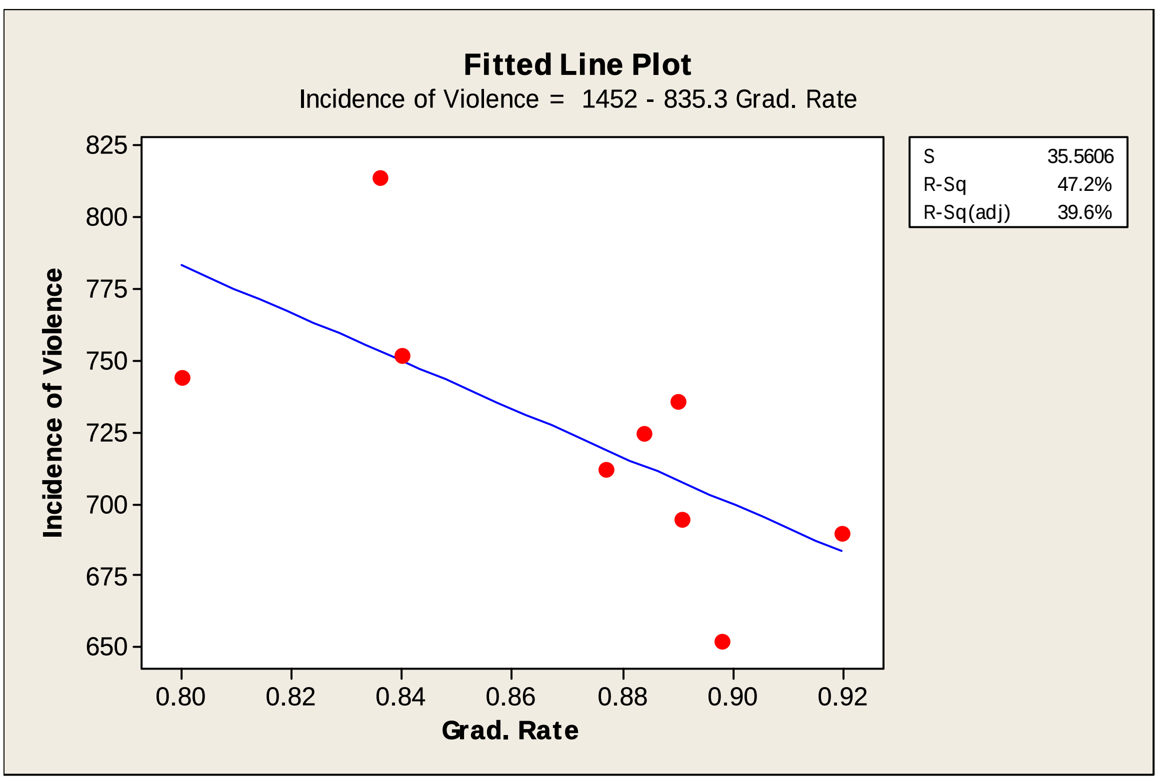
Appendix A:

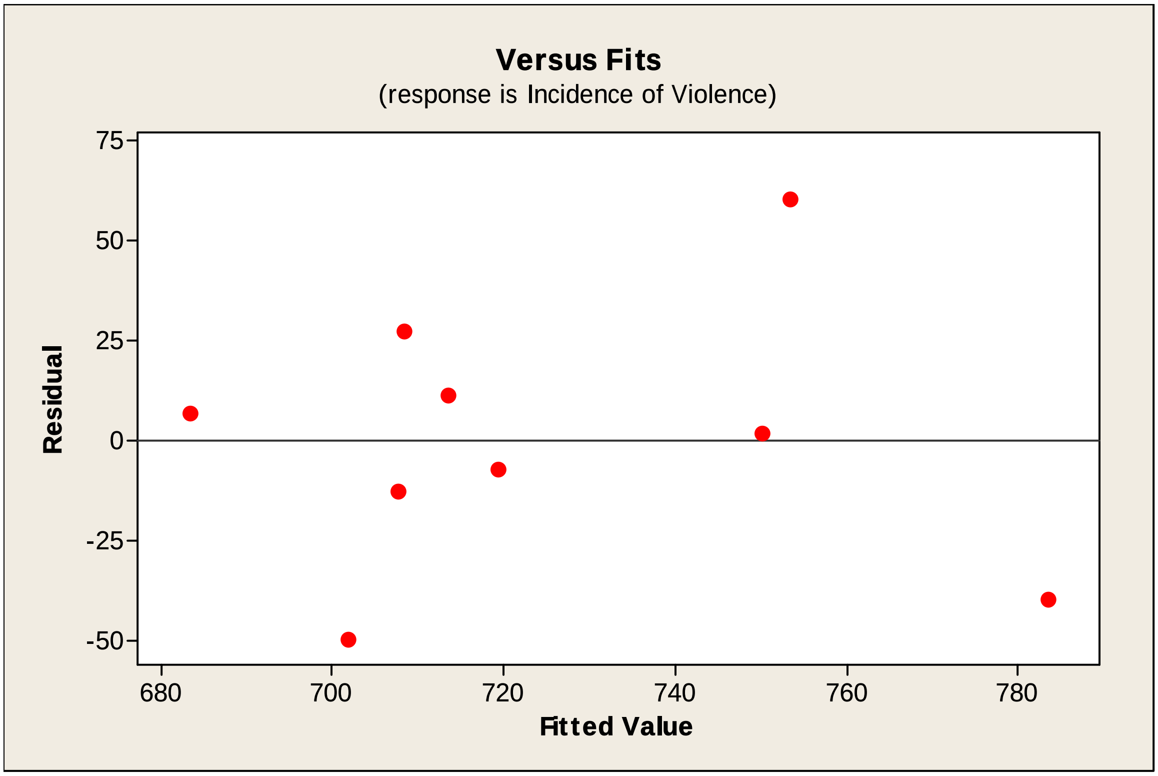


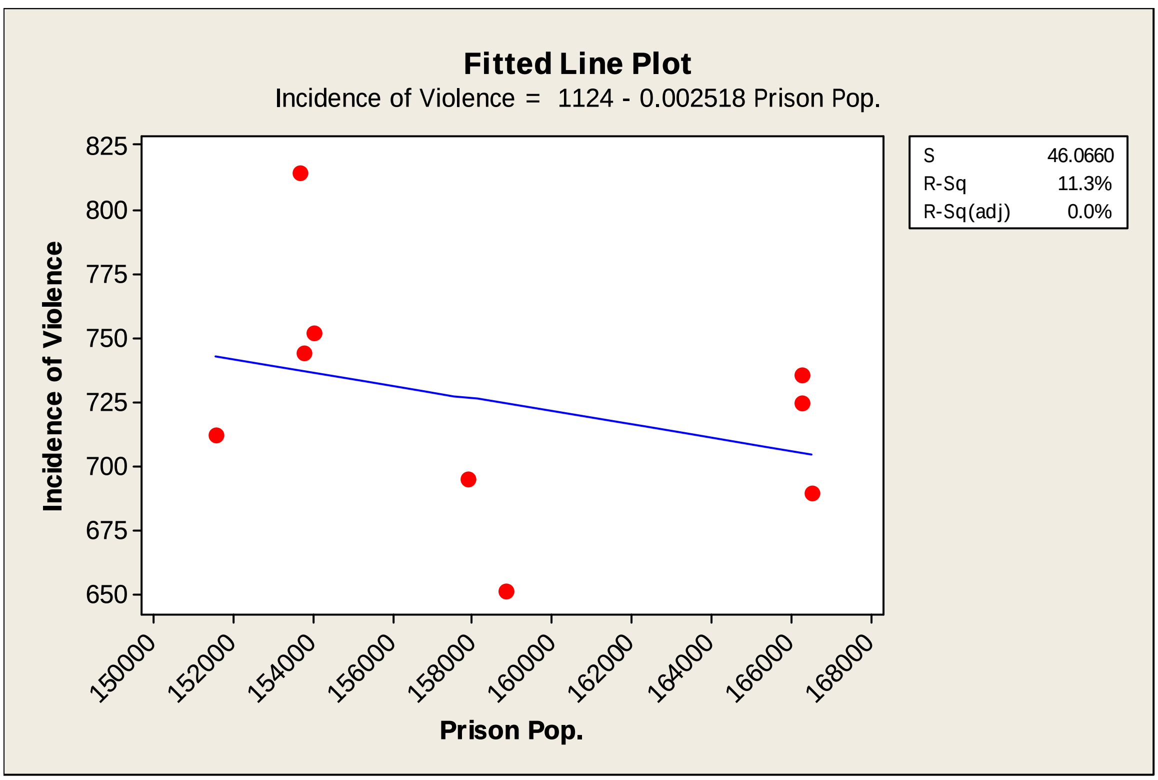

Versus Fits
(response is Incidence of Violence)
Residual
50
25
0
-25
-50
680
690
700
710
720
730
740
750
760
770
Fitted Value

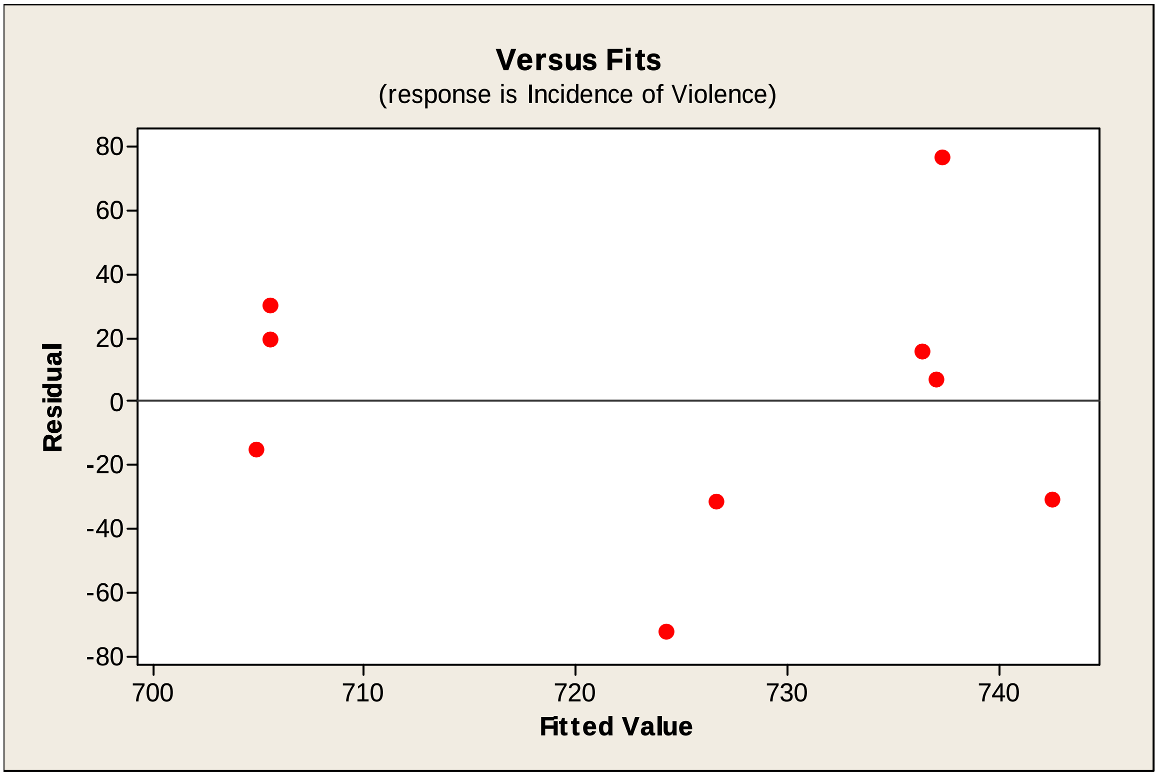

Fitted Line Plot
Incidence of Violence = 123.5 + 877.9 % of parole violation
S 42.6753
R-Sq 23.9%
R-Sq(adj) 13.0%
Incidence of Violence
825
800
775
750
725
700
675
650
0.64
0.65
0.66
0.67
0.68
0.69
0.70
0.71
0.72
0.73
% of parole violation

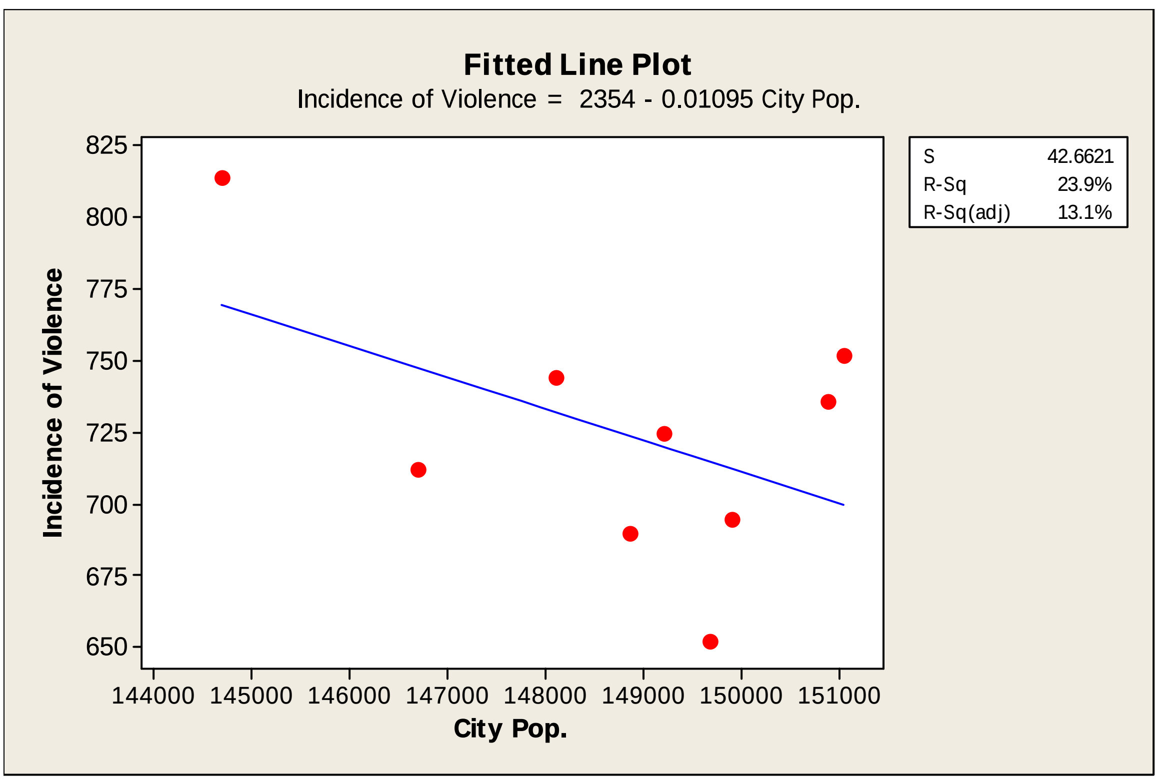

Versus Fits
(response is Incidence of Violence)
75
50
25
0
-25
-50
Residual
690
700
710
720
730
740
750
760
770
Fitted Value

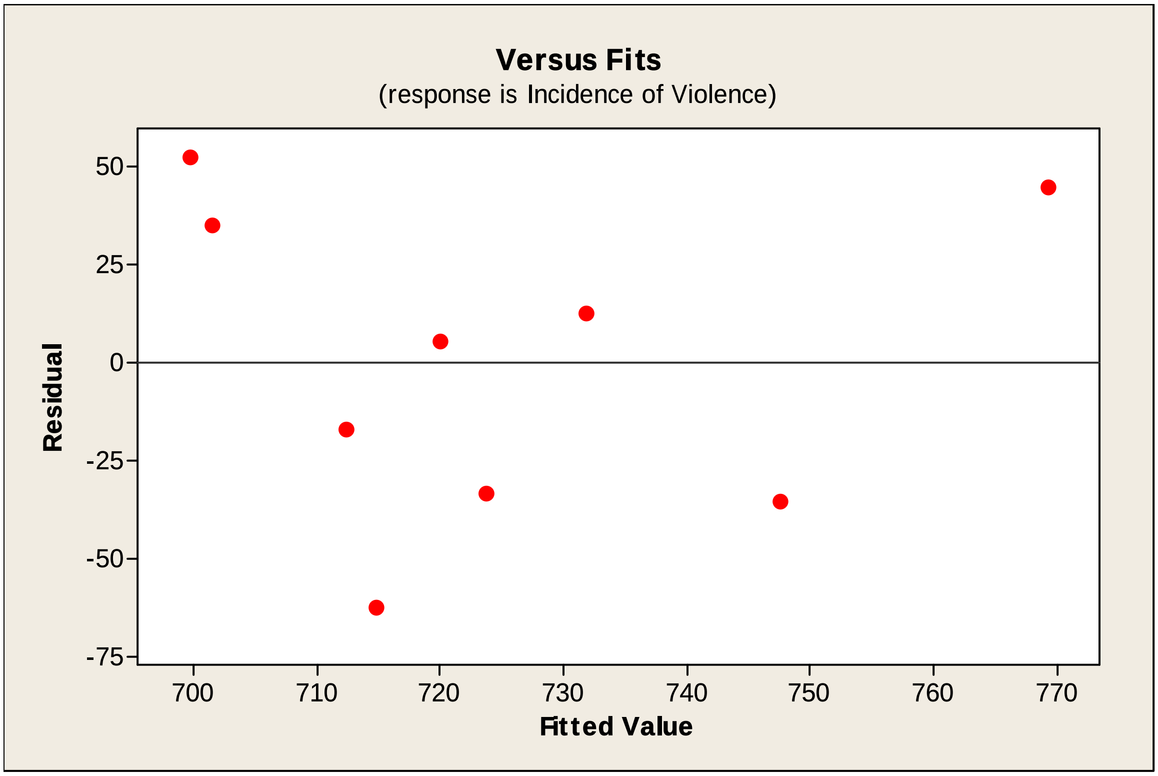

Fitted Line Plot
Incidence of Violence = 1452 - 835.3 Grad. Rate
S 35.5606
R-Sq 47.2%
R-Sq(adj) 39.6%
825
800
775
750
725
700
675
650
Incidence of Violence
0.80
0.82
0.84
0.86
0.88
0.90
0.92
Grad. Rate

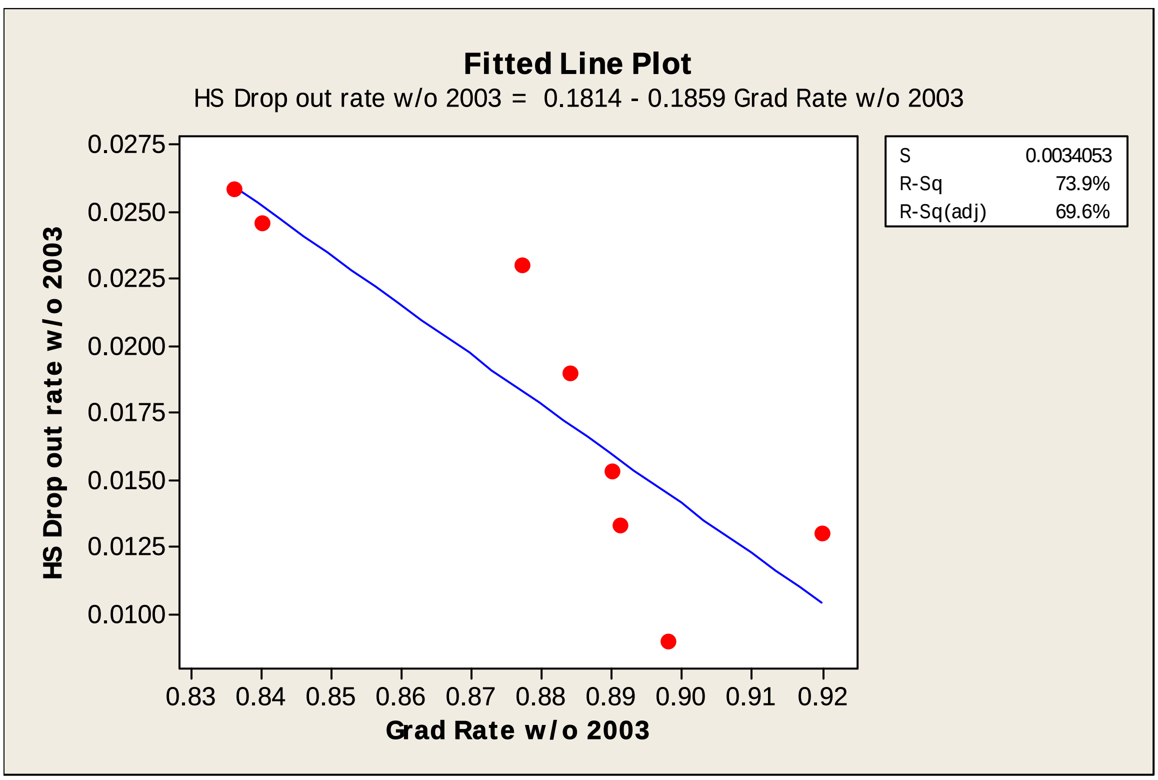

Versus Fits
(response is Incidence of Violence)
Residual
Fitted Value
75
50
25
0
-25
-50
680
700
720
740
760
780


Fitted Line Plot
Incidence of Violence = 1124 - 0.002518 Prison Pop.
S 46.0660
R-Sq 11.3%
R-Sq(adj) 0.0%
Incidence of Violence
Prison Pop.
825
800
775
750
725
700
675
650
150000
152000
154000
156000
158000
160000
162000
164000
166000
168000

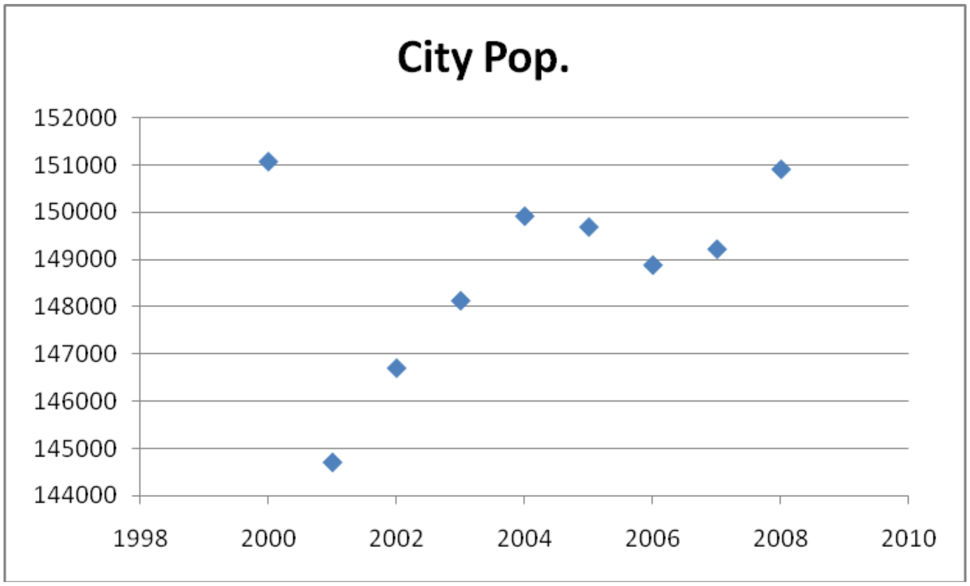

Versus Fits
(response is Incidence of Violence)
Residual
80
60
40
20
0
-20
-40
-60
-80
700
710
720
730
740
Fitted Value

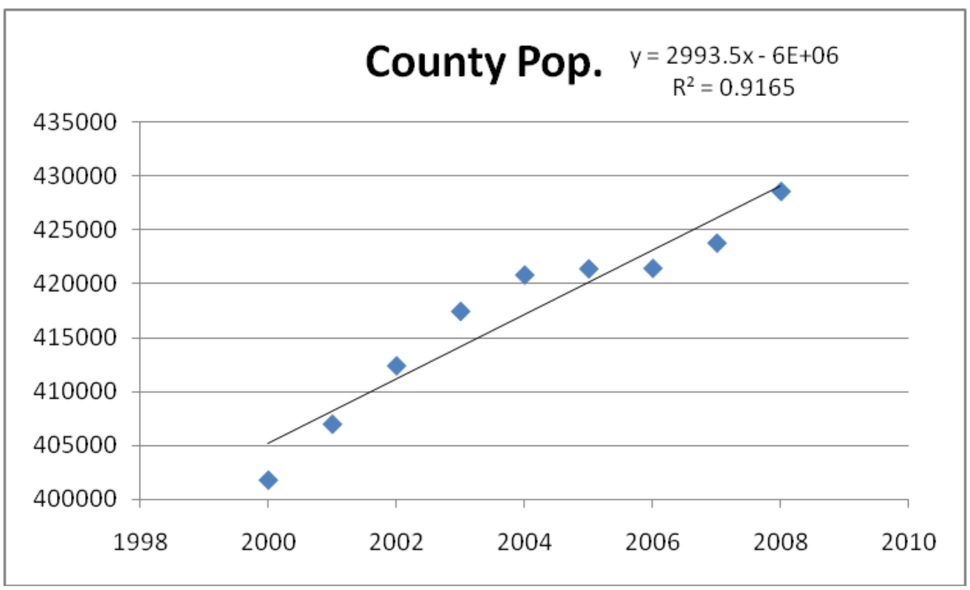

Fitted Line Plot
Incidence of Violence = 2354 - 0.01095 City Pop.
S 42.6621
R-Sq 23.9%
R-Sq(adj) 13.1%
Incidence of Violence
825
800
775
750
725
700
675
650
144000
145000
146000
147000
148000
149000
150000
151000
City Pop.

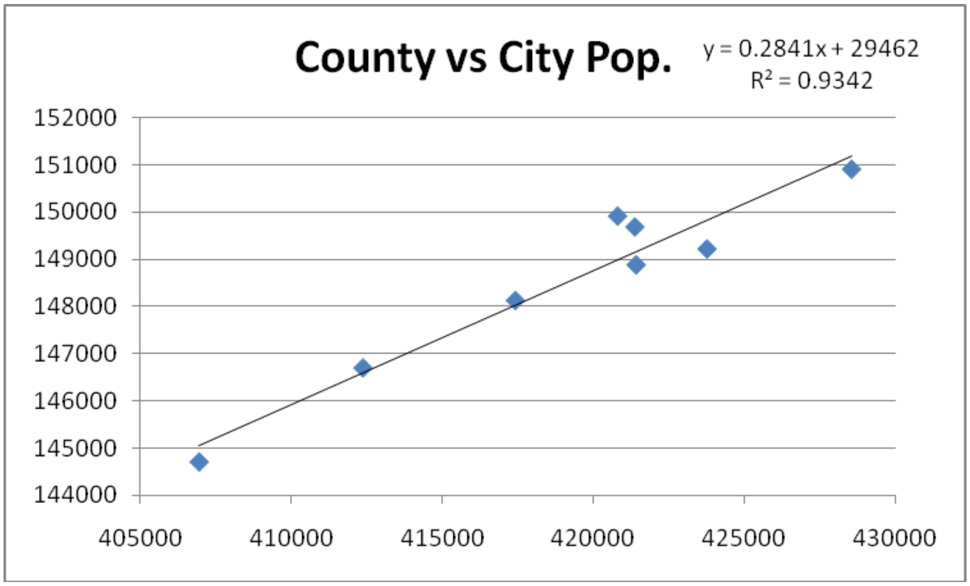

Versus Fits
(response is Incidence of Violence)
Residual
50
25
0
-25
-50
-75
700
710
720
730
740
750
760
770
Fitted Value


Fitted Line Plot
HS Drop out rate w/o 2003 = 0.1814 - 0.1859 Grad Rate w/o 2003
S 0.0034053
R-Sq 73.9%
R-Sq(adj) 69.6%
HS Drop out rate w/o 2003
0.0275
0.0250
0.0225
0.0200
0.0175
0.0150
0.0125
0.0100
0.83
0.84
0.85
0.86
0.87
0.88
0.89
0.90
0.91
0.92
Grad Rate w/o 2003

Appendix B:


City Pop.
152000
151000
150000
149000
148000
147000
146000
145000
144000
1998
2000
2002
2004
2006
2008
2010


County Pop.
y = 2993.5x - 6E+06
R² = 0.9165
435000
430000
425000
420000
415000
410000
405000
400000
1998
2000
2002
2004
2006
2008
2010



Appendix C:

Our program:

```
public class Matrices
{

   public static void main (String args[])
   {

   MatricesMethod Method = new MatricesMethod();

   // Find coefficient matrix. //
   double[][] CoefficientMatrix = Method.Coefficient(Method.DefineX(), Method.TransposeX(),
Method.DefineY());
   Method.PrintMatrix(CoefficientMatrix);

   System.out.println();

   // Ask for year. //
   int year = Method.AskYear();
   System.out.println("Year: " + year);

   // Find city population. //
   double citypop = 0;
   if(year >= 2000 && year <= 2008)
   {
      citypop = Method.AskCityPop();
   }
   else
   {
```

```
            double countypop = Method.CountyPop(year);
            citypop = Method.CityPop(countypop);
        }

        // Find predicted incidence of violence based on model. //
        double ViolInc, ViolIncFund, ViolIncDiff;
        double dropouts = 0.015374961; // High school dropout rate in 2008
        double gradrate = 0.89; // High school graduation rate in 2008
        double parviol = 0.67321753; // Number of parole violations in 2008
        int prispop = 166277; // Prison population in 2008
        double gradratefinal = Method.FundIncrease(gradrate);
        double dropratefinal = Method.EstDropChange(gradratefinal, gradrate, dropouts);

        double a = CoefficientMatrix[0][0];
        double b = CoefficientMatrix[1][0];
        double c = CoefficientMatrix[2][0];
        double d = CoefficientMatrix[3][0];
        double e = CoefficientMatrix[4][0];
        double f = CoefficientMatrix[5][0];

        System.out.println();
        System.out.println();

        ViolInc = a + b * dropouts + c * gradrate + d * parviol + e * prispop + f * citypop;

            System.out.println("The predicted incidence of violence without funding would be " +
ViolInc + ".");

        ViolIncFund = a + b * dropratefinal + c * gradratefinal + d * parviol + e * prispop + f * citypop;

            System.out.println("The predicted incidence of violence with funding is " + ViolIncFund +
".");

            ViolIncDiff = ViolInc - ViolIncFund;

            System.out.println("The incidence of violence has improved by " + ViolIncDiff);

            double PerViol = 100 * ViolIncDiff / ViolInc;

            System.out.println("The incidence of violence has improved by " + PerViol + "%");

        }

      }

import java.lang.*;
import javax.swing.*;
```

```
public class MatricesMethod
{

        // Method to ask for year. //
    public int AskYear()
    {
        String input = JOptionPane.showInputDialog("Year?");
            int year = Integer.parseInt(input);
            return year;
    }

        // Method to estimate county population in the future. //
    public double CountyPop(int year)
    {
        double CountyPop = 2993.5 * year - 5581820;
        return CountyPop;
    }

    // Method to estimate city population from county population. //
    public double CityPop(double countypop)
    {
        double citypop = 0.2841 * countypop + 29462;
        System.out.println("Estimated city population: " + citypop);
        return citypop;
    }

        // Method to solve for coefficient matrix. //
        public double[][] Coefficient(double[][] X, double[][] Xtr, double [][] y)
        {
            MatricesMethod Method = new MatricesMethod();

            double[][] CoefMatrix;
            CoefMatrix =
Method.Multiply(Method.Multiply(Method.InvertMatrix((Method.Multiply(Xtr, X))), Xtr), y);

            return CoefMatrix;
        }

        // Methods to ask for violence statistics. //

        /*// Ask for dropouts. //
    public double DropOutRate()
    {
        String input = JOptionPane.showInputDialog("High school dropout rate?");
            double dropouts = Double.parseDouble(input);
            System.out.println("HS dropout rate:" +dropouts);
            return dropouts;
    }*/
```

```
/*// Ask for high school graduation rate. //
public double GradRate()
{
        String input = JOptionPane.showInputDialog("High school graduation rate?");
                double gradrate = Double.parseDouble(input);
                System.out.println("HS graduation rate:" +gradrate);
                return gradrate;
}*/

/*// Ask for number of parole violations. //
public int ParViol()
{
        String input = JOptionPane.showInputDialog("Number of parole violations?");
                int violations = Integer.parseInt(input);
                System.out.println("Parole violations:" +violations);
                return violations;
}*/

/*// Ask for prison population. //
public int PrisPop()
{
        String input = JOptionPane.showInputDialog("Prison population?");
                int prispop = Integer.parseInt(input);
                System.out.println("Prison population:" +prispop);
                return prispop;
}*/

// Ask for city population. //
public double AskCityPop()
{
        String input = JOptionPane.showInputDialog("City population?");
                double citypop = Double.parseDouble(input);
                System.out.println("City population:" +citypop);
                return citypop;
}

// Ask for percent increase in funding. //
public double PerFund()
{
        String input = JOptionPane.showInputDialog("Percent increase in funding?");
                double perfund = Double.parseDouble(input);
                System.out.println("Percent funding increase:" +perfund);
                return perfund;
}

// Factor increase in graduation rate into dropout rate. //
public double EstDropChange(double gradratefinal, double gradrate, double dropouts)
```

```
{
        MatricesMethod Method = new MatricesMethod();
        double gradchange = gradratefinal - gradrate;
        double EstDropChange = 0.1859 * gradchange;
        double dropratefinal = dropouts - EstDropChange;
        return dropratefinal;
}

/*// OLD Method to account for increase in funding. //
public double FundIncrease(double gradrate)
{
        MatricesMethod Method = new MatricesMethod();
        double GradInc = 0.0005914 * Method.PerFund();
        System.out.println("The graduation rate has increased by " + GradInc + "%");
        double gradratefinal = gradrate + GradInc;
        return gradratefinal;
}*/

// Method to account for increase in funding. //
public double FundIncrease(double gradrate)
{
        MatricesMethod Method = new MatricesMethod();
        double gradratefinal, k = 0.485; // k based on Salinas data
        double perfund = Method.PerFund();
        gradratefinal = 1 - (k / ((perfund / 100) + (k/(1 - gradrate))));
        return gradratefinal;
}

        // Method to define matrix y. //
public double[][] DefineY()
{
        // Make matrix y. //
        double[][] MatrixY = new double[9][1];
        MatrixY[0][0] = 752;
        MatrixY[1][0] = 814;
        MatrixY[2][0] = 712;
        MatrixY[3][0] = 744;
        MatrixY[4][0] = 695;
        MatrixY[5][0] = 652;
        MatrixY[6][0] = 690;
        MatrixY[7][0] = 725;
        MatrixY[8][0] = 736;

        return MatrixY;
}

// Method to create matrix x. //
public double[][] DefineX()
```

```
    {
        // Make matrix x. //
        double[][] MatrixX = {{1, 0.0246, 0.84, 0.708572199, 154014, 151060},
                {1, 0.025876941, 0.836, 88972, 0.706177425, 144696},
                {1, 0.023017037, 0.877, 85574, 0.729468928, 146689},
                {1, 0.018169456 , 0.900, 78053, 0.676228514, 148117}, // Changed 2003 outlier value
for high school dropout rate
                {1, 0.013321874, 0.891, 76725, 0.650112695, 149906},
                {1, 0.008954909, 0.898, 80962, 0.659638088, 149675},
                {1, 0.013058130, 0.920, 89883, 0.684483875, 148870},
                {1, 0.018983337, 0.884, 92628, 0.67321753, 149208},
                {1, 0.015374961, 0.890, 92628, 0.67321753, 150898}};

        return MatrixX;
    }

    // Method to transpose matrix X. //
    public double[][] TransposeX()
    {
        MatricesMethod Method = new MatricesMethod();
        double[][] MatrixXt = new double[6][9];
                int i, j;
                double[][] X = Method.DefineX();
        for(i = 0; i < 6; i++)
        {
                for(j = 0; j < 9; j++)
                {
                        MatrixXt[i][j] = X[j][i];
                }
        }
        return MatrixXt;
    }

        // Method to multiply two matrices. //
        public double[][] Multiply(double[][] LeftM, double[][] RightM)
        {
                int m1rows = LeftM.length;
                int m1cols = LeftM[0].length;
                int m2rows = RightM.length;
                int m2cols = RightM[0].length;
                int a;

                double[][] ProdMatrix = new double[m1rows][m2cols];

                int i, j;
                for(i = 0; i < m1rows; i++)
                {
                        for(j = 0; j < m2cols; j++)
```

```
                    {
                            for(a = 0; a < m1cols; a++)
                            {
                                    ProdMatrix[i][j] += LeftM[i][a] * RightM[a][j];

                            }
                    }
            }
            return ProdMatrix;
    }


    // Method to print a matrix. //
    public void PrintMatrix(double[][] ToPrint)
    {
            System.out.print("[");

            int rows = ToPrint.length;
            int cols = ToPrint[0].length;

            for(int i = 0; i < rows; i++)
    {
            for(int j = 0; j < cols; j++)
            {
                    if(j < cols - 1)
                    System.out.print(ToPrint[i][j]+" , ");
                    else
                    System.out.print(ToPrint[i][j]);
            }
            if(i < rows - 1)
                    System.out.println();
    }
            System.out.print("]");
    }

    // Method to invert a Matrix. //
public double[][] InvertMatrix(double[][] ToInvert)
{
    int n = ToInvert.length;
            double x[][] = new double[n][n];
            double b[][] = new double[n][n];
            int index[] = new int[n];
            for (int i = 0; i < n; i++)
                    b[i][i] = 1;

            // Transform the matrix into an upper triangle. //
            gaussian(ToInvert, index);
```

```
    // Update the matrix b[i][j] with the ratios stored. //
        for (int i = 0; i < n - 1; i++)
        for (int j = i + 1; j < n; j++)
        for (int k = 0; k < n; k++)
        b[index[j]][k]

    -= ToInvert[index[j]][i]*b[index[i]][k];

    // Perform backward substitutions. //

    for (int i = 0; i < n; i++)
    {
            x[n-1][i] = b[index[n-1]][i]/ToInvert[index[n-1]][n-1];
        for (int j = n - 2; j >= 0; j--)
        {
            x[j][i] = b[index[j]][i];
                for (int k=j+1; k<n; ++k)
                {
                    x[j][i] -= ToInvert[index[j]][k]*x[k][i];
                }
            x[j][i] /= ToInvert[index[j]][j];
        }
    }
    return x;
}

    // Method to carry out the partial-pivoting Gaussian elimination. //

    public static void gaussian(double a[][], int index[])
    {
    int n = index.length;
    double c[] = new double[n];

        for (int i = 0; i < n; i++) index[i] = i;

    for (int i = 0; i < n; i++)
    {
            double c1 = 0;
        for (int j = 0; j < n; j++)
        {
            double c0 = Math.abs(a[i][j]);
            if (c0 > c1) c1 = c0;
            }
        c[i] = c1;
    }

    int k = 0;
    for (int j = 0; j < n - 1; j++)
```

```
        {
                double pi1 = 0;
                for (int i = j; i < n; i++)
                {
                                double pi0 = Math.abs(a[index[i]][j]);
                                pi0 /= c[index[i]];
                                if (pi0 > pi1)
                                {
                                        pi1 = pi0;
                                        k = i;
                        }
                        }

        int itmp = index[j];
        index[j] = index[k];
        index[k] = itmp;
        for (int i = j + 1; i < n; i++)
        {
                double pj = a[index[i]][j]/a[index[j]][j];

        // Record pivoting ratios below the diagonal. //
        a[index[i]][j] = pj;

          // Modify other elements accordingly. //
        for (int l = j + 1; l < n; l++)
                a[index[i]][l] -= pj*a[index[j]][l];
        }
                }

    }

}
```