# A Data-Driven Model of Portland Policing

**Ben Yarrish*, Laurel Ponce*, and Alex John Quijano***

*Department of Mathematics
College of Arts and Sciences, University of Portland

University of Portland

## Introduction

Policing and crime are the most complicated dynamical system in the United States. This project aims to examine the dynamics of policing and how it relates to criminal behavior in Portland, Oregon. We examine Portland police-crime dynamics through mathematical modeling of two forms of data:

- offence statistics, and
- police presence.

## Objectives

- → Collect and combine data sets
  - ◆ Gather public crime reports and police dispatches
  - ◆ Assemble neighborhood level population
- → Formulate a System of differential equations (DEs)
- → Fit the mathematical model into the Data

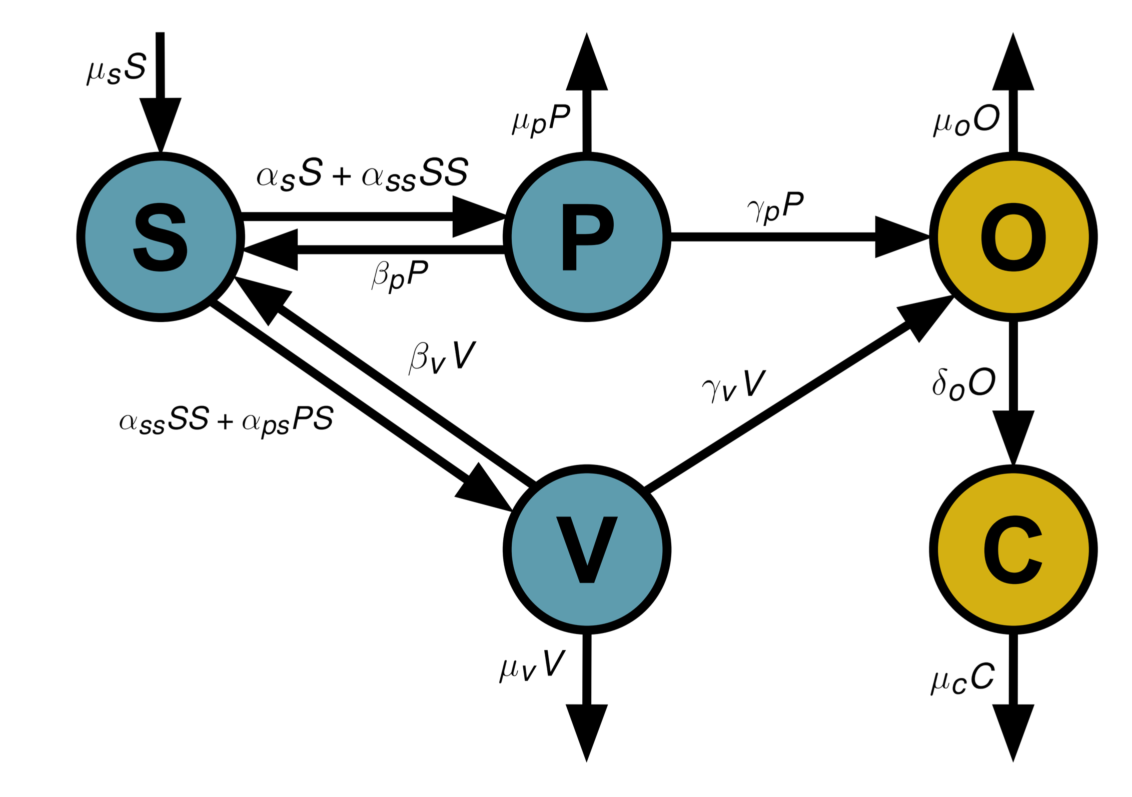
## Hypotheses of DE Terms

- → If an individual is prone to commit any offense, whether it involves victims or is victimless, they may become an offender.
- → An individual becomes a victim when there is a meaningful social interaction with another person.
- → If an individual commits an offense or is victimized, they have the option to report it through a social encounter with the police.
- → If the police considers the offense admissible, they file an official crime report.

## Background & Significance

- → Modeling criminal behavior was done by González-Parra et. al. (2018), through the use of a system of differential equations.
  - ◆ They introduced a model for understanding crime, emphasizing key relationships and behavioral changes between criminals and police.
  - ◆ They assumed that crime is a social epidemic, and their primary model was based on an epidemic model.
  - ◆ They estimated their parameters based on national data without any optimization.
- → Our model assumes criminal behavior as a social issue taking into account the encounter dynamics of the individuals and law enforcement.
  - ◆ Our primary model accounts for police presence and crime reports instead of criminal behavior.
  - ◆ We used an optimization method to fit our model using citywide data, which is a better approach.

## The Mathematical Model




A simplified diagram of the
**1st-order nonlinear system of ordinary differential equations.**

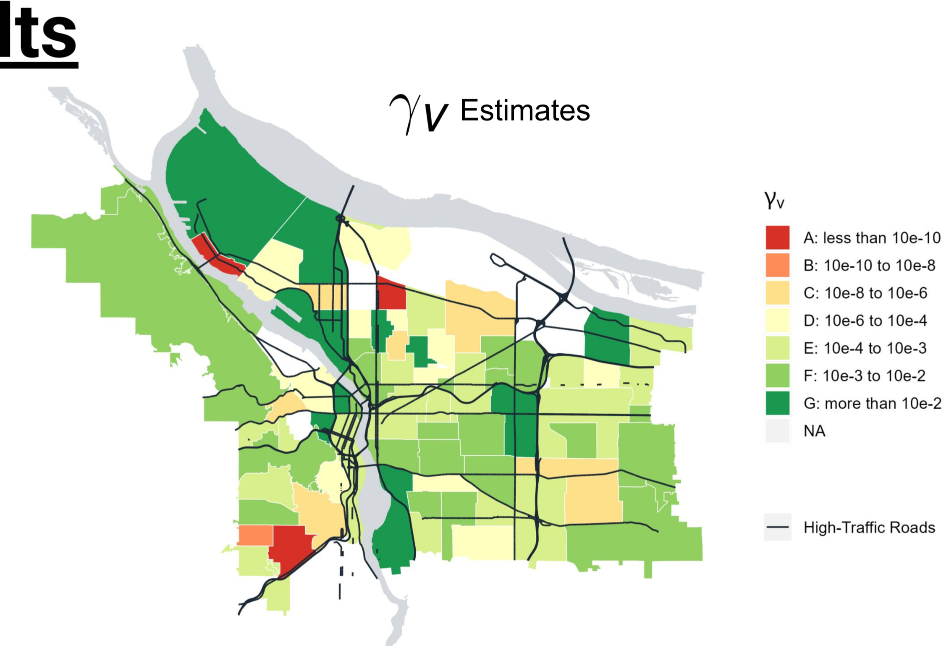
**Variables (Classes of Population)**

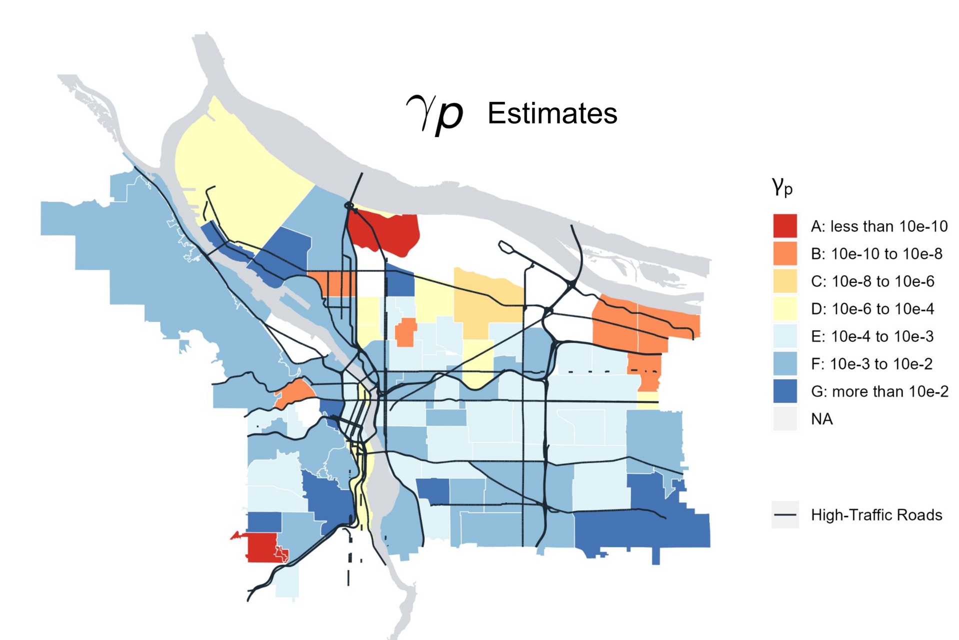
- S(t) is the number susceptible individuals.
- P(t) is the number offenders.
- V(t) is the number victimized individuals.
- O(t) is the number police presence.
- C(t) is the number of reported crimes.
- t is the time in months.

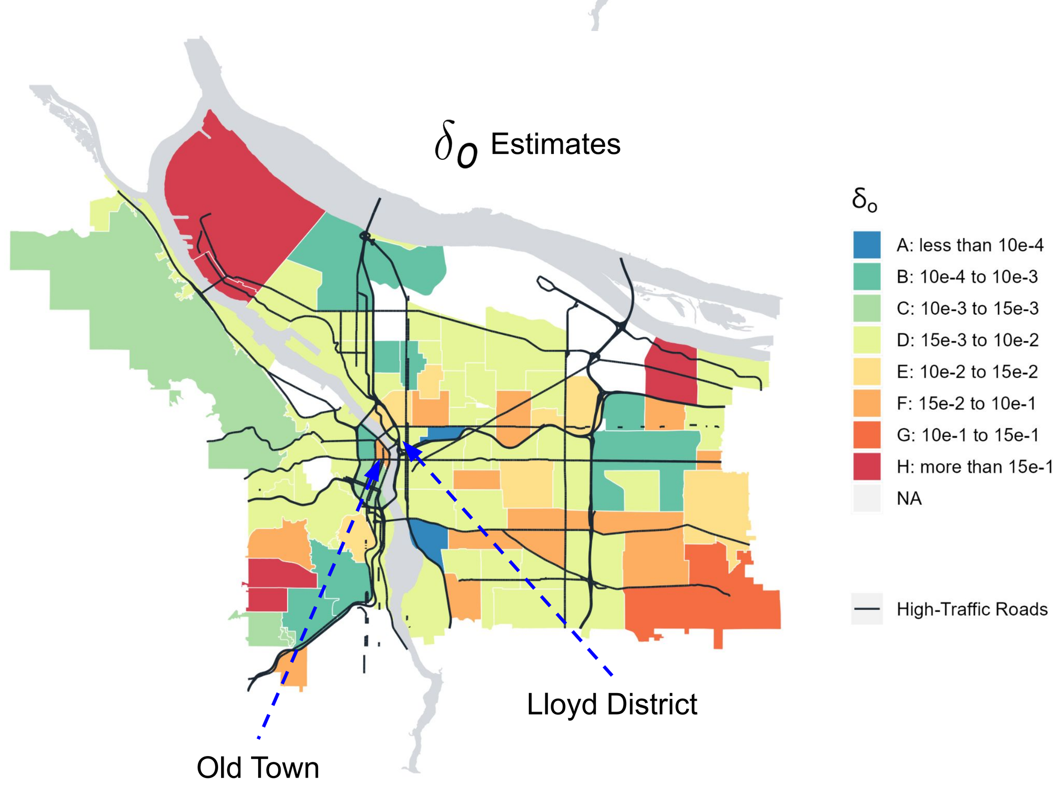
**Parameters of Interest (3/13 Parameters).**

- $\gamma_V$ is the rate at which victimized individuals interact with the police, that includes an encounter or submitting a police report.
- $\gamma_P$ is the rate at which offenders interact with the police that includes an arrest or an encounter.
- $\delta_O$ is the rate at which official crime reports are processed after an encounter with the police.

## Results





The fiscal year spans from July to June for the years 2015 through 2023.

## Acknowledgements

This project was funded by the Summer Undergraduate Research Experience (SURE) at the University of Portland.

## References & Details

Details about the model (equations, data, and fitting), and all references are available online.

## Data Sets

- → Portland Police Bureau - Open Data
  - ◆ Public monthly offence totals
  - ◆ Public dispatched calls for service
- → Portland Maps - Open Data
  - ◆ Neighborhood boundaries
  - ◆ Streets
- → Population Research Center at Portland State University
  - ◆ Neighborhood profiles
  - ◆ 2010 and 2020 census population estimates

## Methodology

- → Model Assumptions
  - ◆ SPV individuals are homogeneously well mixed.
  - ◆ OC are in one compartment separate from SPV.
  - ◆ Total population is not constant in time.
  - ◆ Offence reports were categorized by crime types but - as a start for this model - we assume all crimes are the same.
  - ◆ Dispatch calls were categorized by crime types but - similar to offence reports - we assume all dispatch calls are the same.
- → Solution to the System of Differential Equations
  - ◆ The numerical solver was LSODE, Livermore Solver for Ordinary Differential Equations.
  - ◆ LSODE was used because the formulated system of ODE is a stiff system.
  - ◆ The initial value problem starts with initial values taken from the initial time point of the data.
- → Fitting the Model into the Monthly Data
  - ◆ Maximum likelihood estimation (MLE) was used to estimate the parameters.
  - ◆ The likelihood function was a Poisson random variable, assuming Poisson distributed errors.
  - ◆ Nelder-Mead optimization was used to find the parameters that yielded the maximum likelihood.

## Conclusions & Future Work

- → The completed objectives of this project was:
  - ◆ the data was successfully combined,
  - ◆ a base model was formulated, and
  - ◆ the model parameters was successfully fitted per neighborhood with reasonable results.
- → The model follows an average trend of the police dispatches and crime reports.
- → The data revealed non-linear patterns in each fiscal year that the model failed to capture.
- → Our future work involves adapting the model to include various crime types while considering economic and social factors.