Three Operations Management Problems in Criminology

Lawrence M. Wein

Graduate School of Business, Stanford University

RECENT TOPICS

PTSD in returning troops (*Mgmt Science, NY Times*)

Allocating blood for transfusions (*Transfusion*)

Space debris (*Advances in Space Research*)

Screening for childhood obesity (*Obesity, Mgmt Science*)

Allocating interventions to reduce childhood mortality (*PNAS*,…)

Verifying biometrics for social inclusion (*PLoS ONE*)

Crime

Fecal transplantations (*Microbiome, PLoS ONE*)

THREE OPERATIONS MANAGEMENT PROBLEMS IN CRIMINOLOGY

Operations management: match the supply of goods and services with the demand

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- Demand = inmates and suspects
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Problems 2+3: Solve violent (gun and sexual) crimes

- Supply = investigative capacity (and $)
- Demand = criminal evidence (ballistic images and SA kits)
- Maximize investigative hits subject to capacity constraint

Assessing Risk-based Policies for Pretrial Release and Split Sentencing in Los Angeles County Jails

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Management Science & Engineering Dept, Stanford University

PLoS ONE 2015, *NY Times* 2015

BACKGROUND

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Two primary options for reducing jail overcrowding:

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- Split sentencing: sentence split between jail time and mandatory supervision (for low-level felons)

Correctional system uses risk-based tools to predict likelihood of recidivism and appearing in court

- Based on criminal history and demographic information
- Moderately predictive (AUC of ROC = 0.7)

RESEARCH PROBLEM

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Use data from LA County jail system

PROCESS FLOW

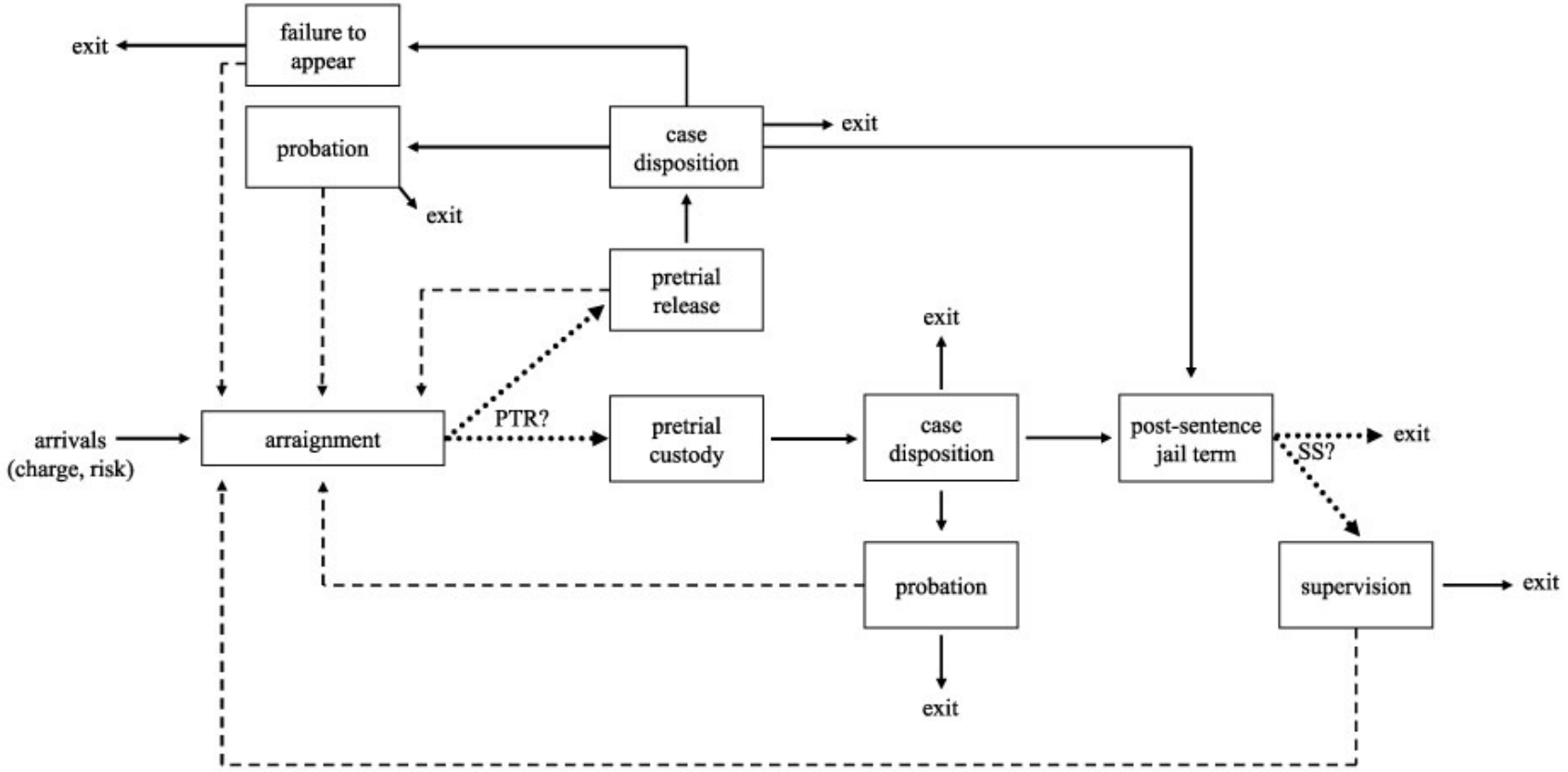

Fig. 1

Two classes: felony charges and non-felony charges

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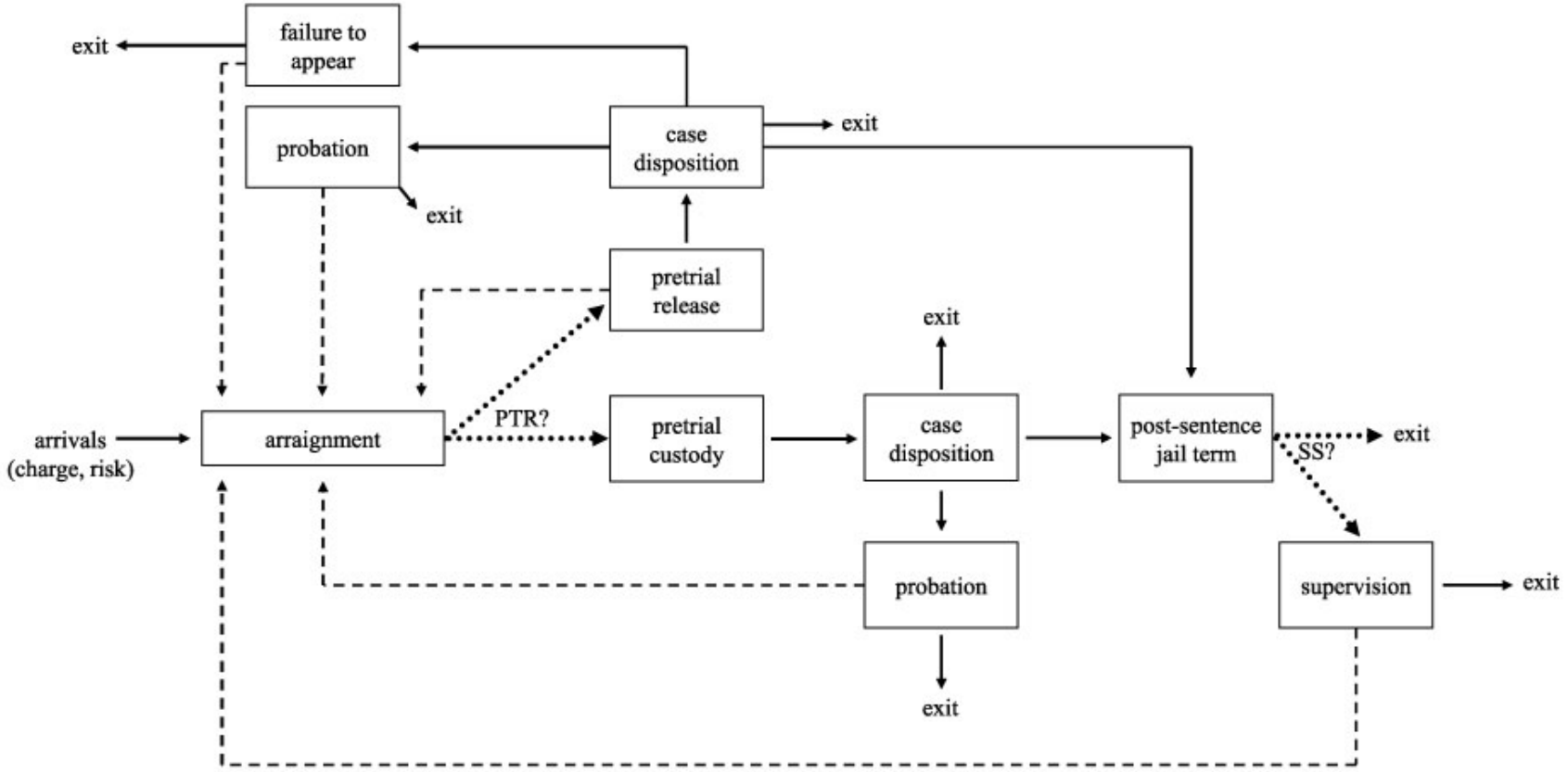

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Recidivists: Risk does not change

Charge is the same for PTR, new for supervision

Detained for PTR, released w.p. 0.1-0.2 for supervision

DATA & PARAMETER ESTIMATION

Jail capacity	19,000	LA County (JFA Institute, ACLU So CA)
Arrival rate	193/day new 350/day total	LA County, 2008-2012
Time delay from arrest to arraignment	2 days	LA County 2008 (Vera)
Charge proportions	44.2% felony 55.8% non-felony	LA County 2008 (Vera)
Risk tools	CSRA (3 risk levels) for recidivism COMPAS (aggregated to 3 levels) for FTA	

DATA & PARAMETER ESTIMATION

Risk proportions	17.0% low 28.1% medium 54.9% high	CDCR 2014
Time to recidivism for each risk level	Fig. 1 of Appendix	CDCR 2014
Failure to appear	0.117 low risk 0.178 medium risk 0.178 high risk	Broward Co, FL
Time from arraignment to disposition	128 days for non-felony, released 8 days for non-felony, custody 191 days for felony, released 53 days for felony, custody	LA County, 2008 (Vera)

DATA & PARAMETER ESTIMATION

Disposition probabilities	dismissed probation jail prison Table 4	Vera (2011) Judicial Council CA
Post-sentence jail terms	felony vs. non-felony release vs. custody Table 4	Vera (2011) CCJCC (2012)
Length of probation	0 -3 yr non-felony 1-5 yr felony	
PTR in LA County	felony vs. non-felony risk level	Vera (2011) BJS (2010)

POLICIES ASSESSED

Pretrial Release for Non-felony	Pretrial Release for Felony	Split-sentencing for Felony
0 - no one	0 - no one	no one
1 - only low risk	1 - only low risk	only low risk
2 - low and medium risk	2 - low and medium risk	low and medium risk
3 - everyone	3 - everyone	everyone

Table 1: The 64 policies are all combinations of one option from each of the three columns. The numbers in the pretrial release columns are used in Fig. 3 to refer to these policies.

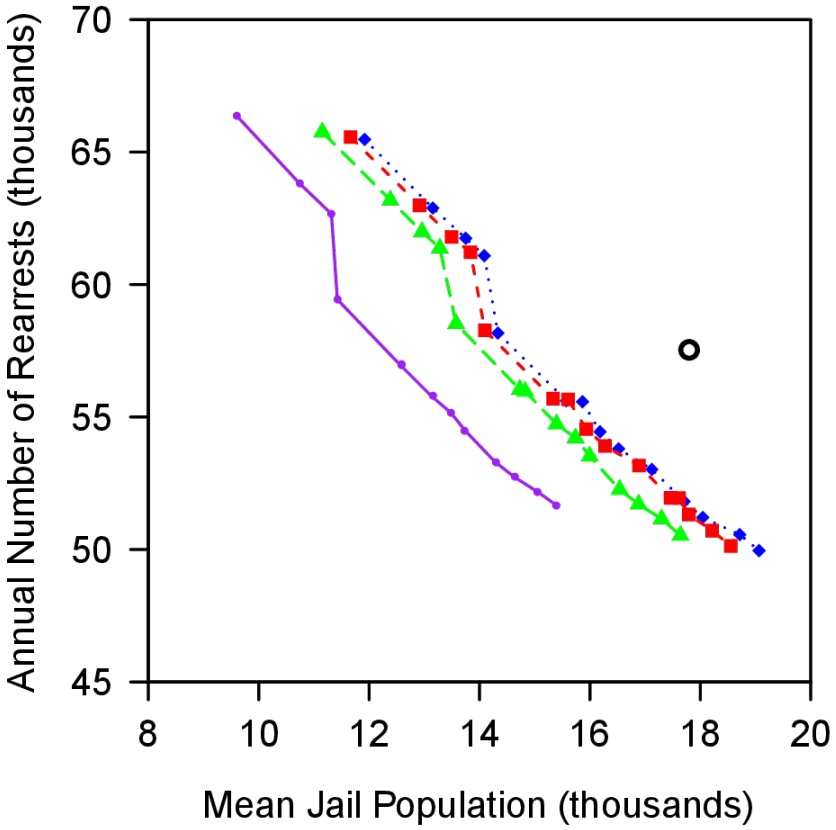
TRADEOFF CURVES

Split Sentencing: everyone

low + medium

low

(a) none



RISK RATIO

Risk ratio for each type of decision:

- Pretrial release for felon
- Pretrial release for non-felony
- Split sentencing for felony

In each case:

- Release someone for a certain amount of time and incur recidivism risk during that time
- Reduce jail population for a possibly different amount of time

Risk ratio = # of days released / # jail days saved

Risk ratio = 1 for split sentencing

KEY INSIGHT

Decision	Mean Increase in Recidivism Exposure (Days)	Mean Reduction in Jail-Days	Risk Ratio
pretrial release of non-felony	128	8	16.0
pretrial release of felony	191	53	3.6

Numerator = time from arraignment to case disposition if pretrial release

Denominator = time from arraignment to case disposition if pretrial detention

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Why are risk ratios so large for pretrial release?

PTD gets higher priority in court queue

PTR less apt to plea bargain quickly

STUDY LIMITATIONS

Data

Pretrial Release vs. Pretrial Detention

Model Boundaries

DATA LIMITATIONS

Recidivism risk is the same for:

- Pretrial release (Broward County, FL = LA?)
- Probation
- Supervision

Recidivism model and risk profile are based on pre-alignment state parolees

Pre-Proposition 47 (reclassifying drugs + theft) and pre-AB 1468 (requiring split-sentencing)

PTR VS. PTD

The following depend on whether PTR or PTD:

- Time until case disposition (longer for PTR)
- Court outcomes (less guilty for PTR)
- Post-sentence jail terms (shorter for PTR)

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If PTR decisions are partially based on data not included in our model (e.g., judges set higher bond if they view acquittal as unlikely) then we are overestimating the benefits of PTR

Since our results imply that SS is more effective than PTR, this assumption is conservative

MODEL BOUNDARIES

We assume exogenous delay until case disposition

- Court processing capacity
- Prosecutor behavior

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In addition, risk models (e.g., CSRA, COMPAS) may be reinforcing cumulative disadvantage of Black defendants

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- Don’t use SS in lieu of PTR (PTDs aren’t guilty yet!)
- Because 45% of inmates are felons

CONCLUSIONS

International New York Times | http://nyti.ms/1S0i1YN

The Opinion Pages | OP-ED CONTRIBUTORS

One Way to Reduce Jail Populations

By LAWRENCE M. WEIN and MERICCAN USTA OCT. 23, 2015

PRISON reform is getting a big bipartisan pitch. Republicans and Democrats have professed their desire to do something, and earlier this week, more than 130 police chiefs, prosecutors and sheriffs said they would push for alternatives to arrests.

CONCLUSIONS

In LA County, split-sentencing is key to achieving substantial improvement in public safety vs. jail population tradeoff

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Risk ratios explain first-order effects

- Due to courts prioritizing PTD over PTR and/or
- PTR less apt to plea bargain

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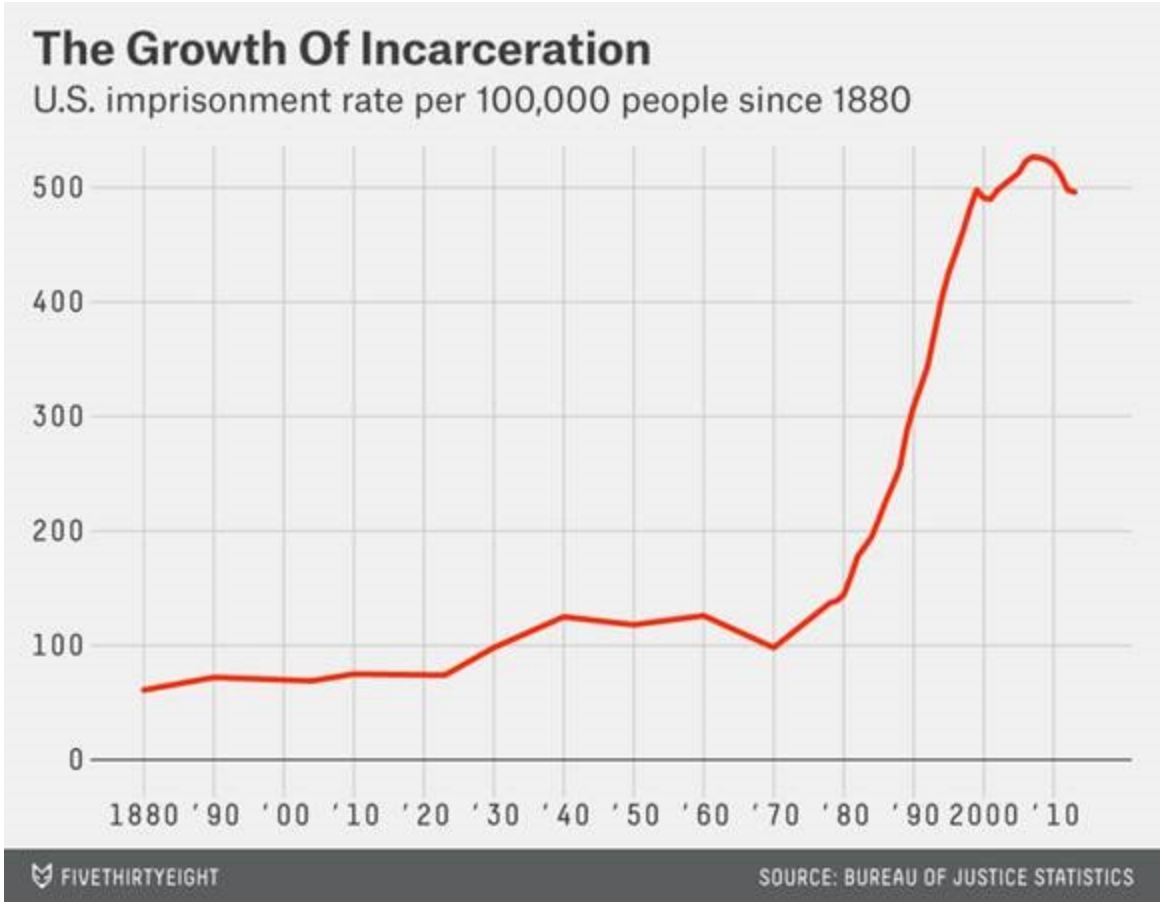
Impact of AB 1468

- May 2014: <1% of eligible felons get SS
- February 2015: 37.7% of eligible felons get SS

CONCLUSIONS



Over half of recent US incarceration drop due to CA

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Where to live on tradeoff curve:

Reduced detention costs ($40k/yr) vs.
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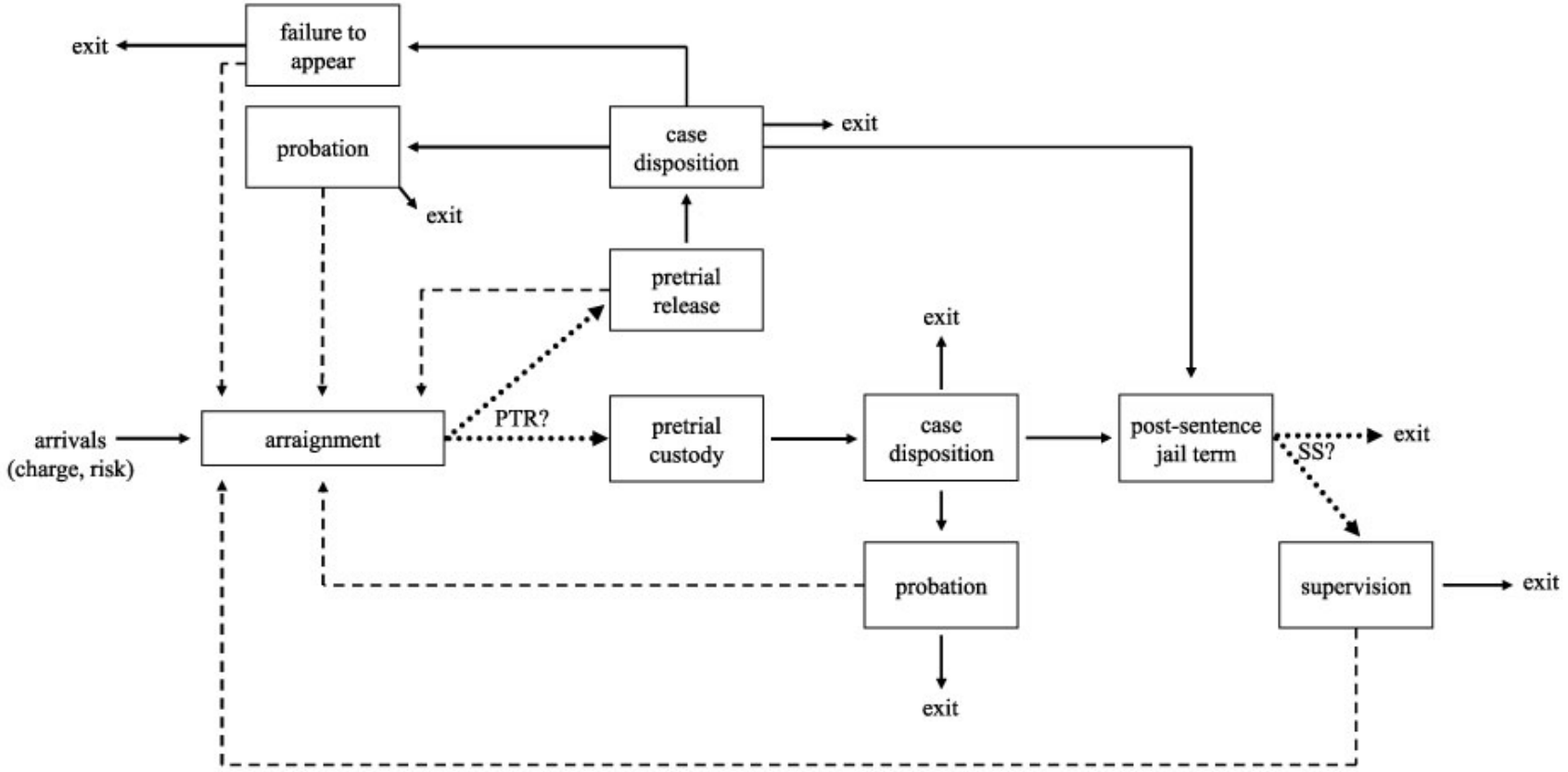
50% return from more incarceration vs.
160% from more police
156-300% from more drug treatment

SIMPLIFIED QUEUEING MODEL



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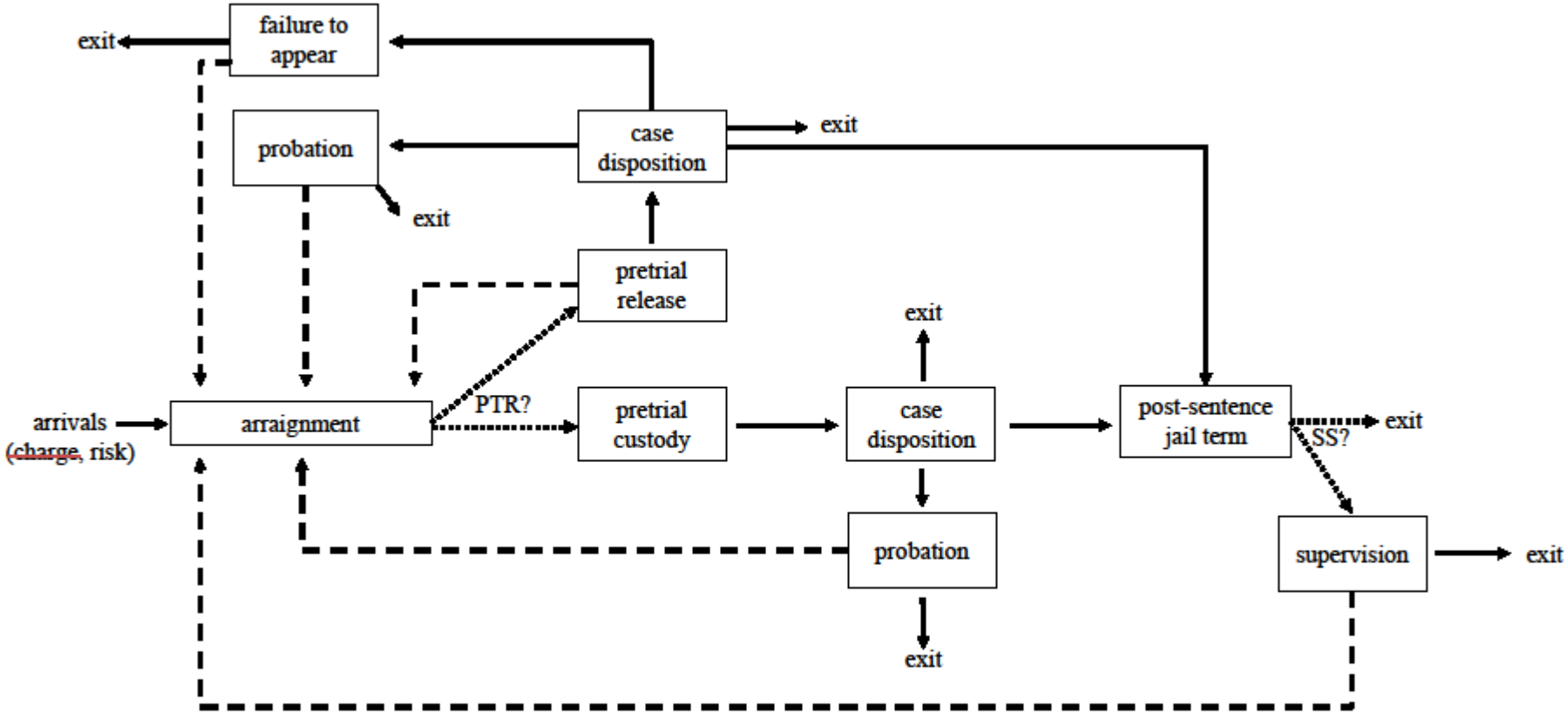

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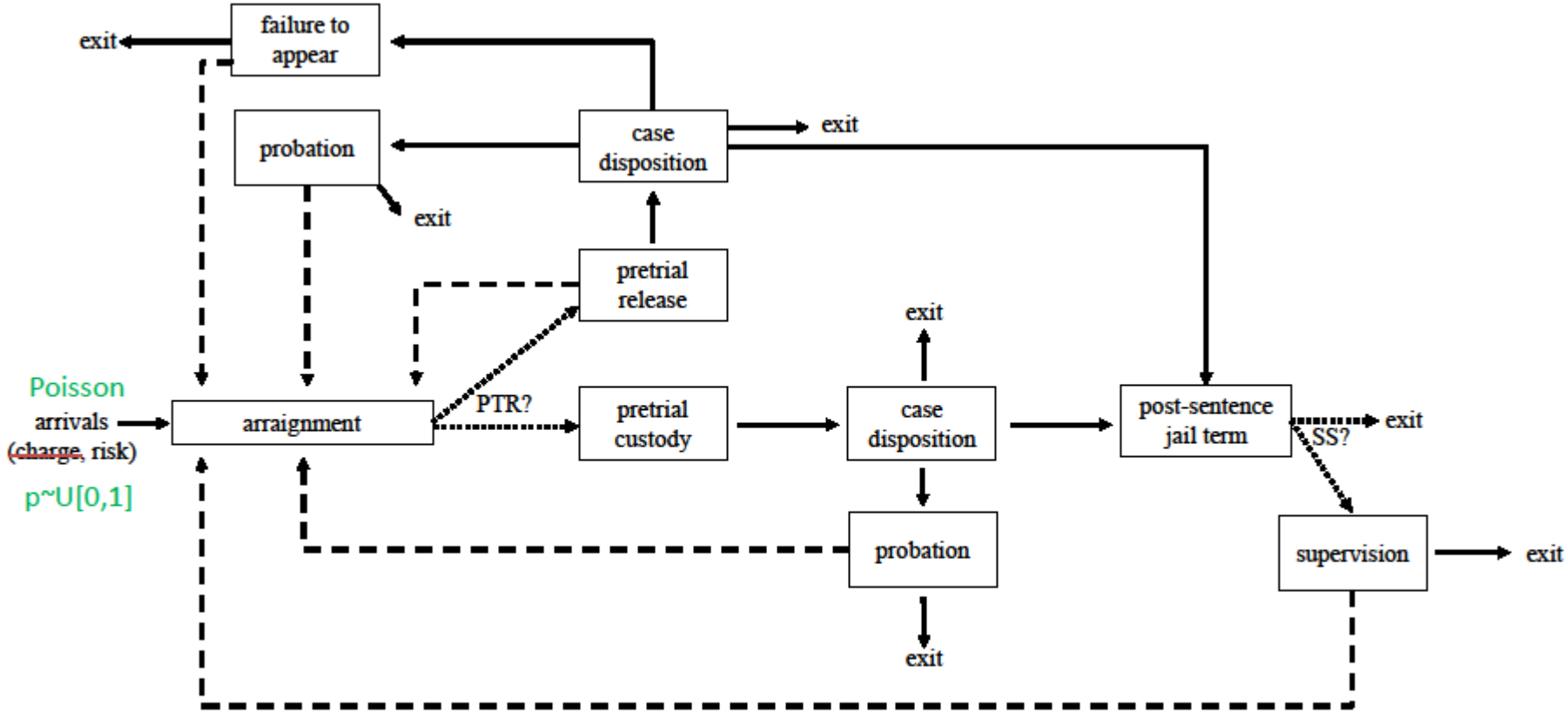

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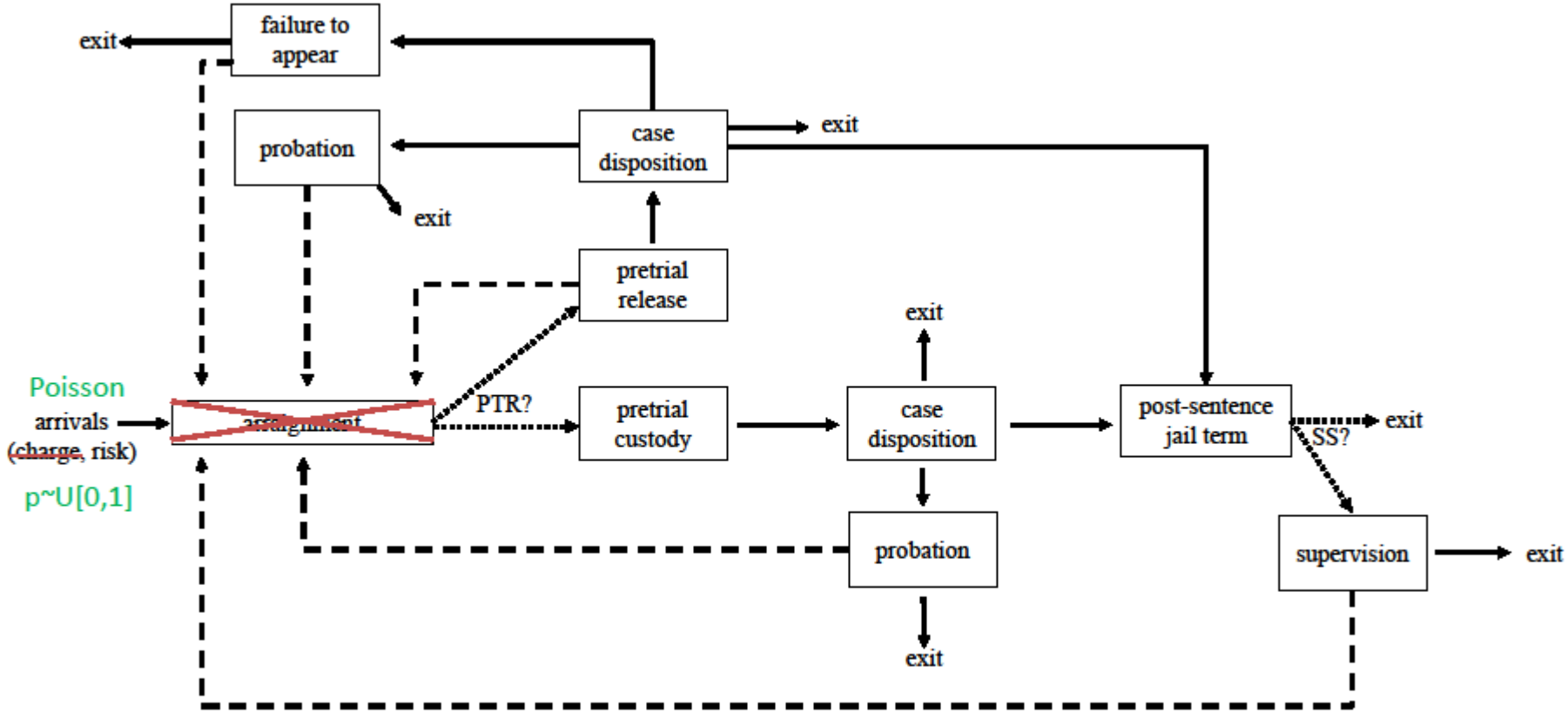

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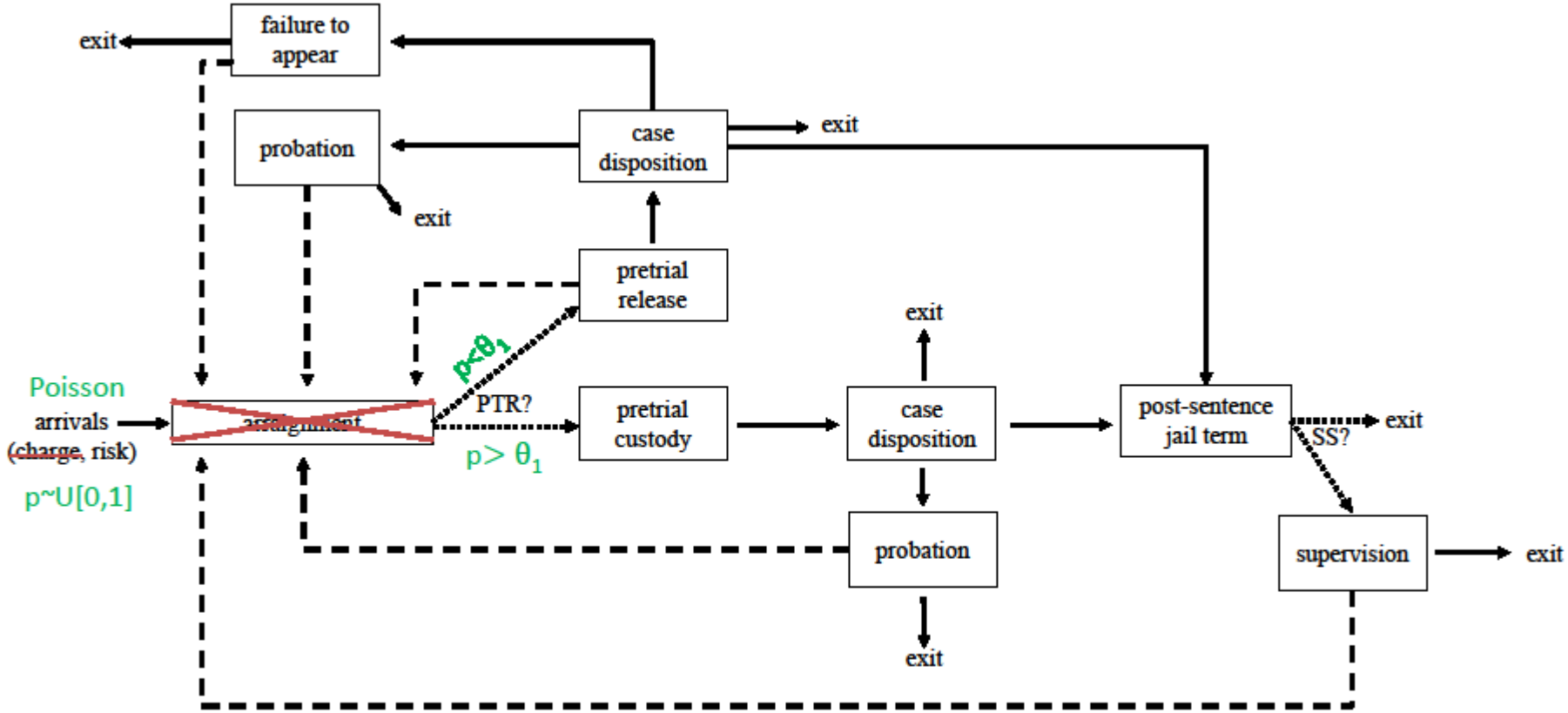

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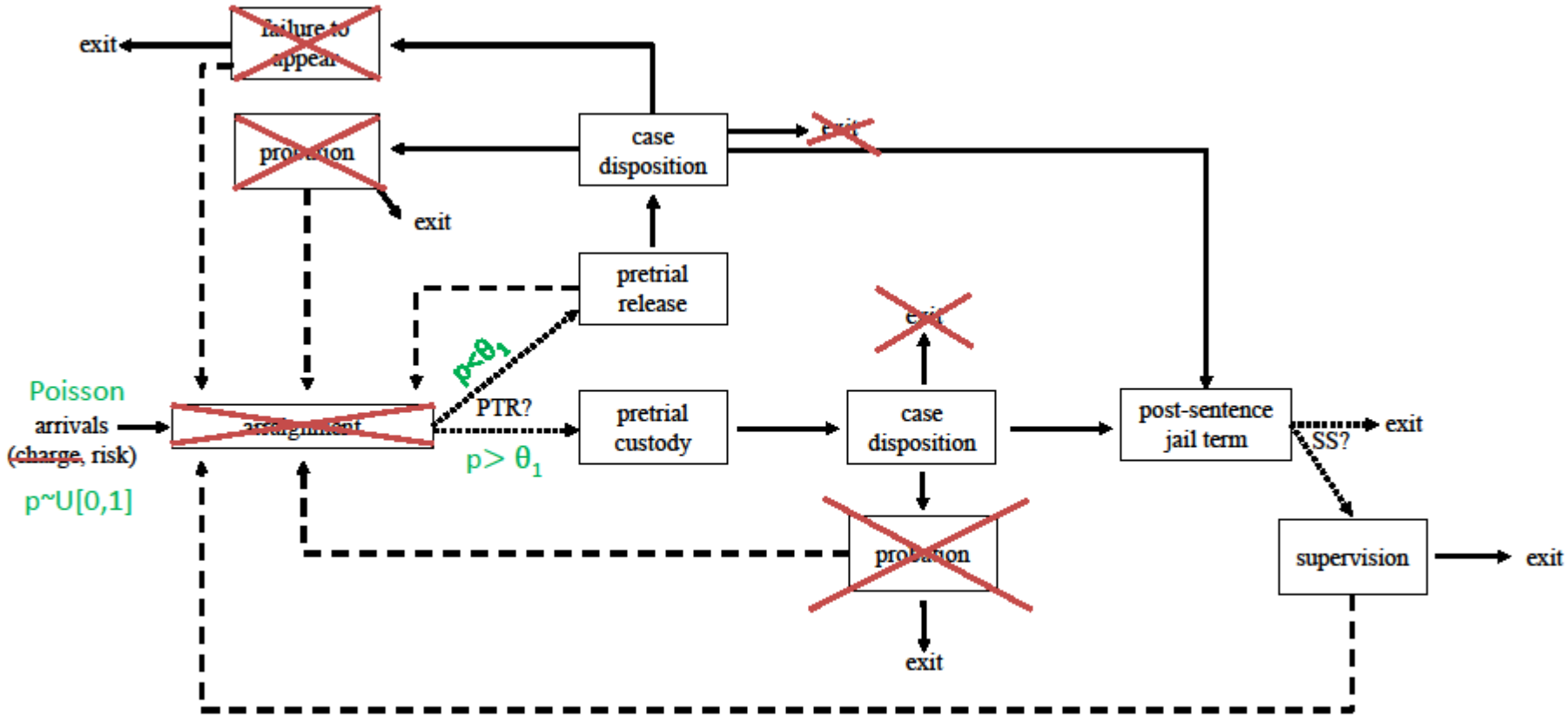

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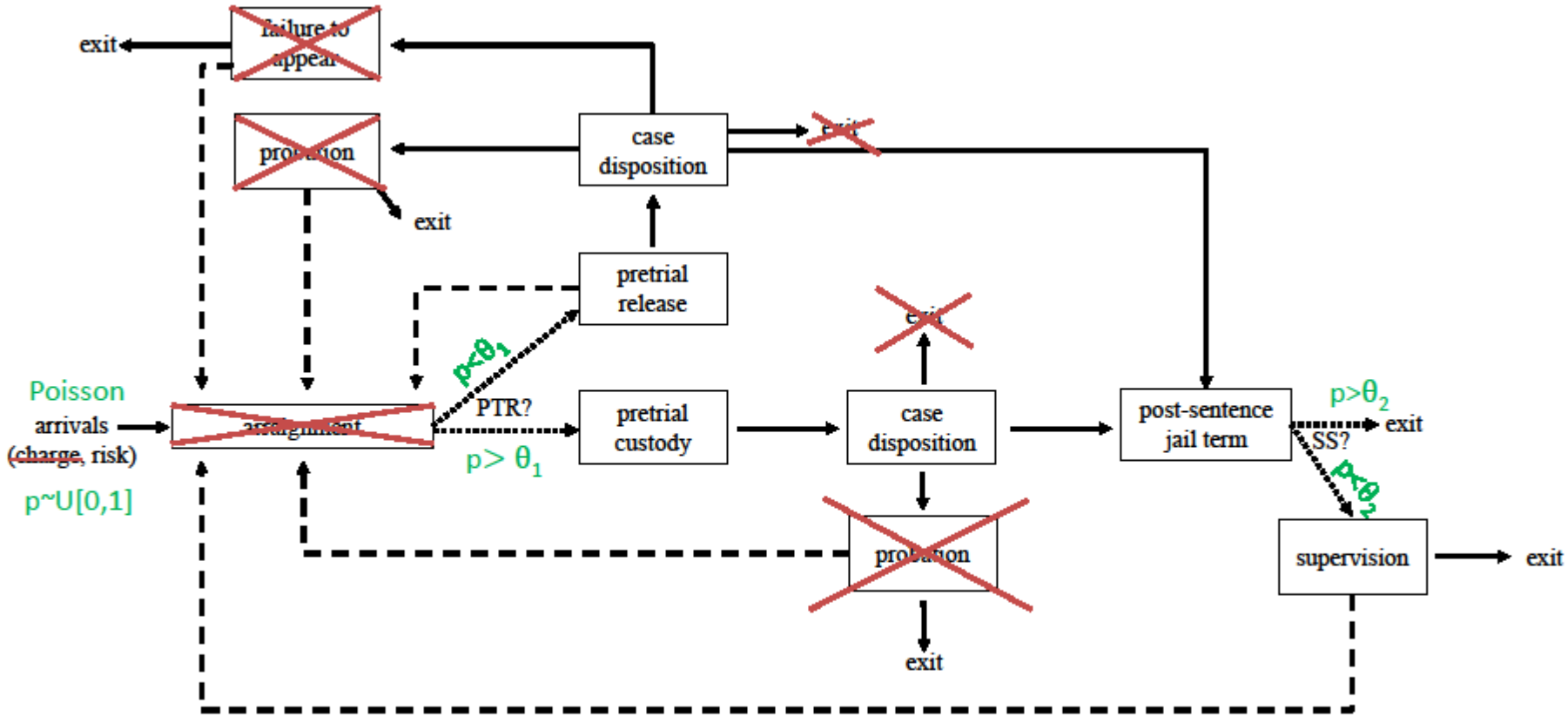

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Master, Reiman, Wang and Wein

Continuous-class M/M/c/c loss system

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Vary θ_1, θ_2 to sweep out crime vs. jail population tradeoff curve

Vary α and γ to see effect of AUC on tradeoff curve

Optimizing Ballistic Imaging Operations

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Journal of Forensic Sciences 2017

BALLISTIC IMAGING SYSTEMS

Collect cartridge casings and bullets from crime scenes
Take 2-D or 3-D images and put in database

FIGURE 2-2 Breech face markings and firing pin impressions for three ammunition types and two firearm brands.
NOTE: S & W = Smith & Wesson.
SOURCE: Adapted from Tulleners (2001:Fig. 3-4).

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National system in place (NIBIN)

- Single vendor (Forensic Technology) for hardware and software
- Top-10 list sent to human examiner
- Used inconsistently (and locally) in U.S.
- Cartridge casings used more than bullets

Background

Immense variability in U.S.:

- Some cities enter all of their spent cartridges into NIBIN and generate many hits
- Other cities enter few cartridges and generate few hits
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Stockton, CA processes all of its cartridges

- This uncensored view allows us to predict hit performance if Stockton was capacity constrained

Research Questions

Assumption: city doesn't have budget to process (enter into NIBIN and search for hits) all cartridges

Q1: If I enter more cartridges, how many more hits will I get?

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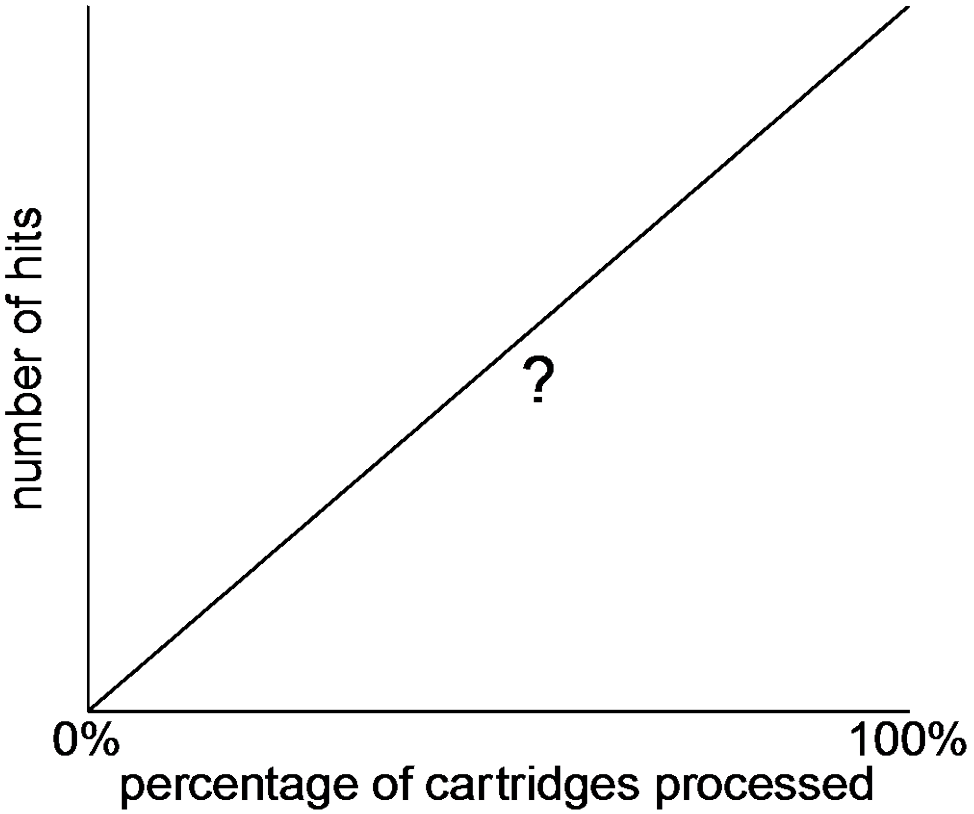

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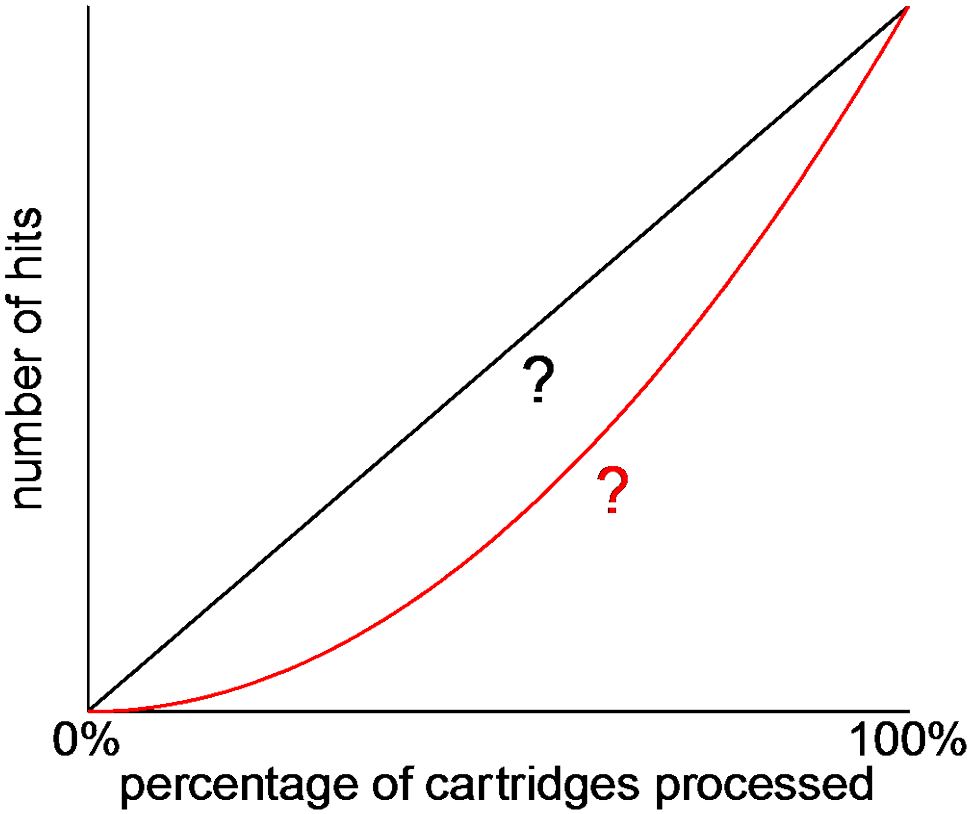

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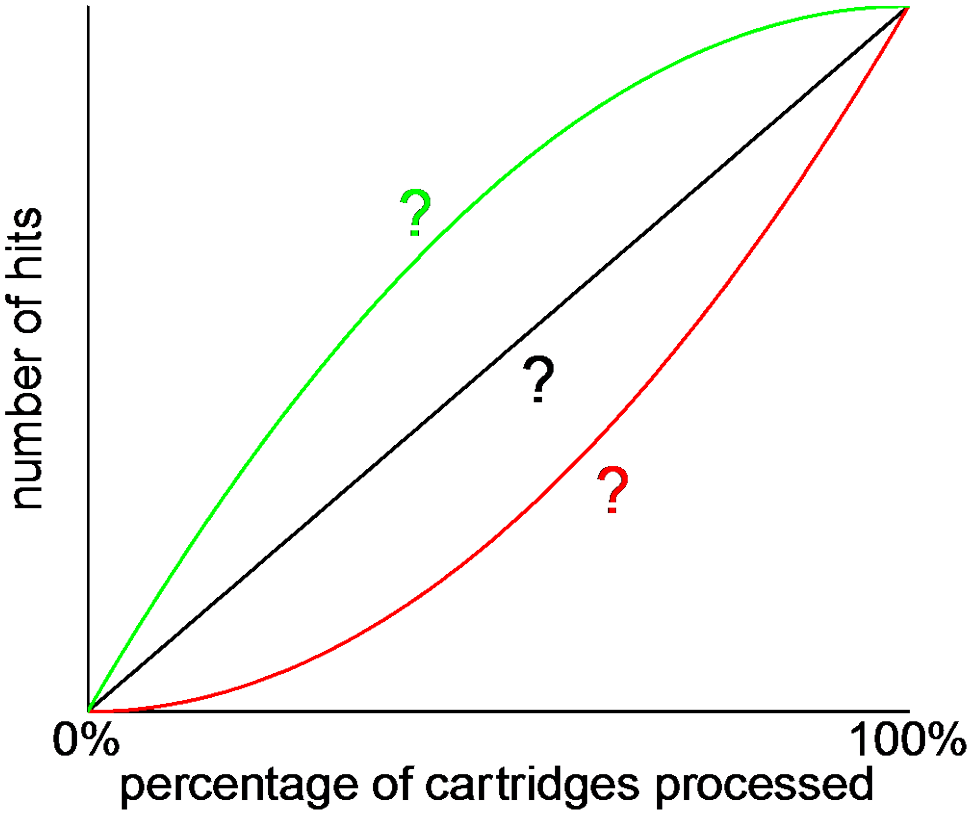

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- Homicides vs. non-homicides?
- Certain cartridge types?

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Q3: Of cartridges that I do plan to process, which of those waiting in my in-box should I process next?

- Goal: maximize useful (before criminal case closes) hits
- First-come first-served (FCFS) vs. last-come first-served (LCFS)

Stockton CA

Population ~ 300,000

Second most violent city in CA in 2012

Brought processing in house in 2012-13

< 2012: used State Lab

> 2012: hired firearms technicians (including co-author) to enter cartridges into NIBIN and look for high-confidence candidate hits

- hired part-time contract examiner to confirm hits
- were able to clear backlog and process all new cartridges

Stockton Data

Data file of NIBIN entries:

- 6703 NIBIN entries during 2010-2015
- NIBIN entry characterized by
  - 6 crime types: evidence: homicide, ADW, other
    test-fires: homicide, ADW, other
  - 12 cartridge types: 11 common types and
    52 rare types combined into “other”
  - Known: date of event, date of NIBIN entry, date of process completion (looking for hits)

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Data file of high-confidence hits:

- 964 hits during 2013-2015
- crime type and cartridge type of new cartridge
- crime type and cartridge type of matches in database

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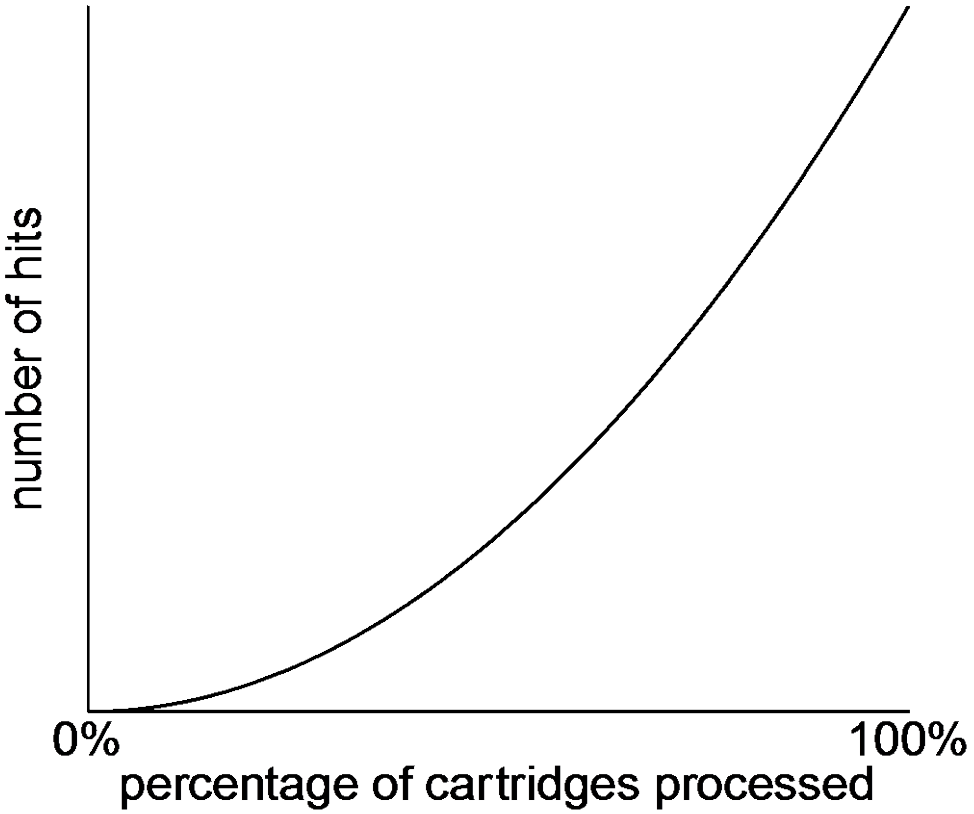

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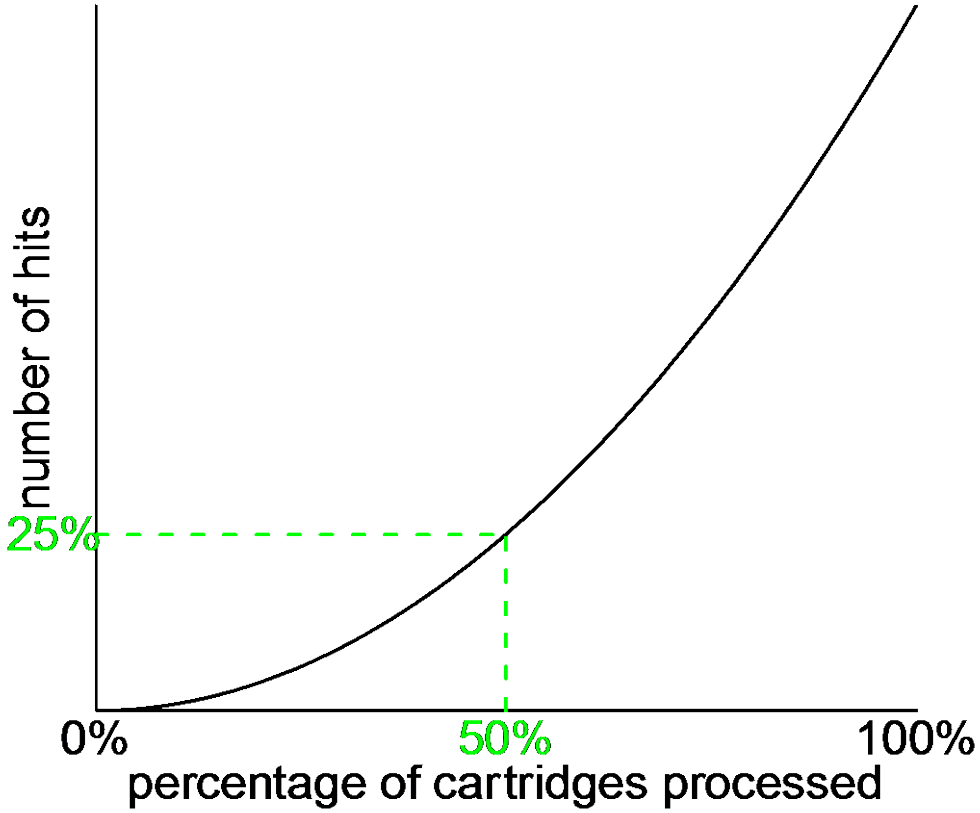

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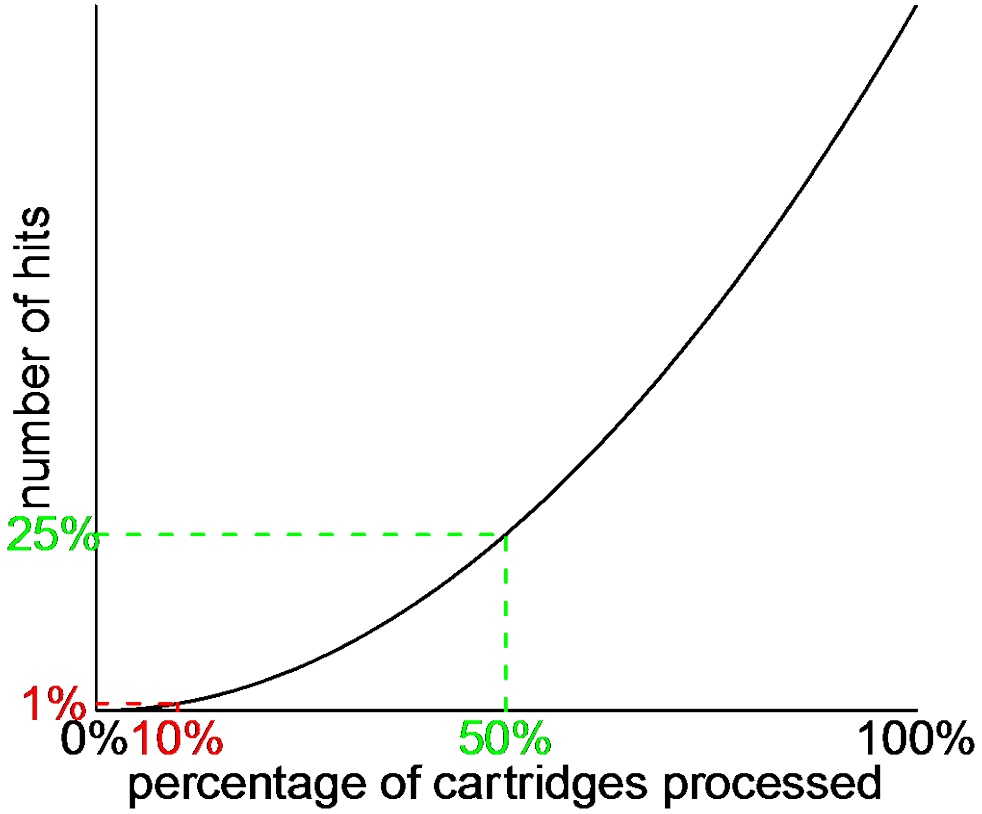

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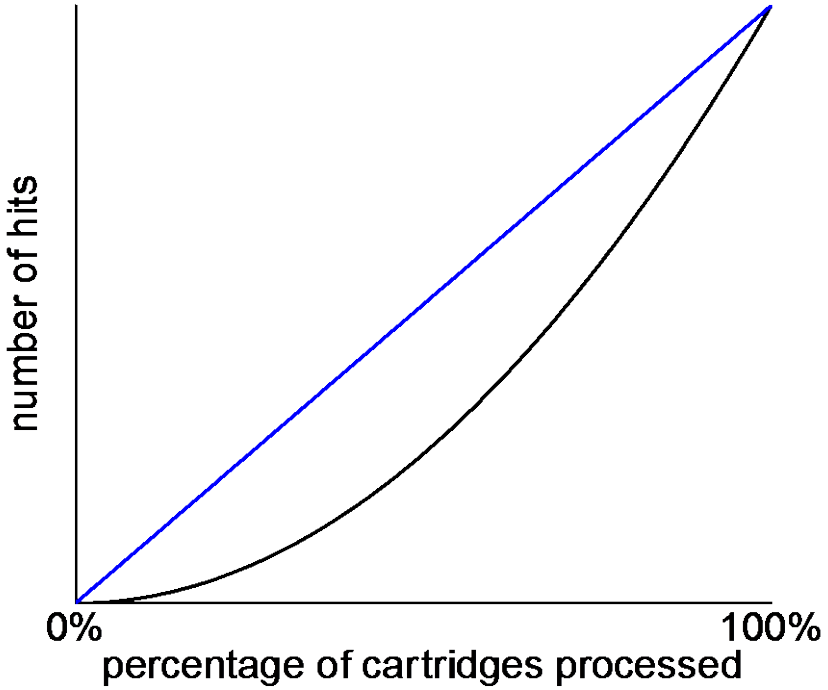

In every other manufacturing and service operation (e.g., supermarket, car factory), this relationship is linear

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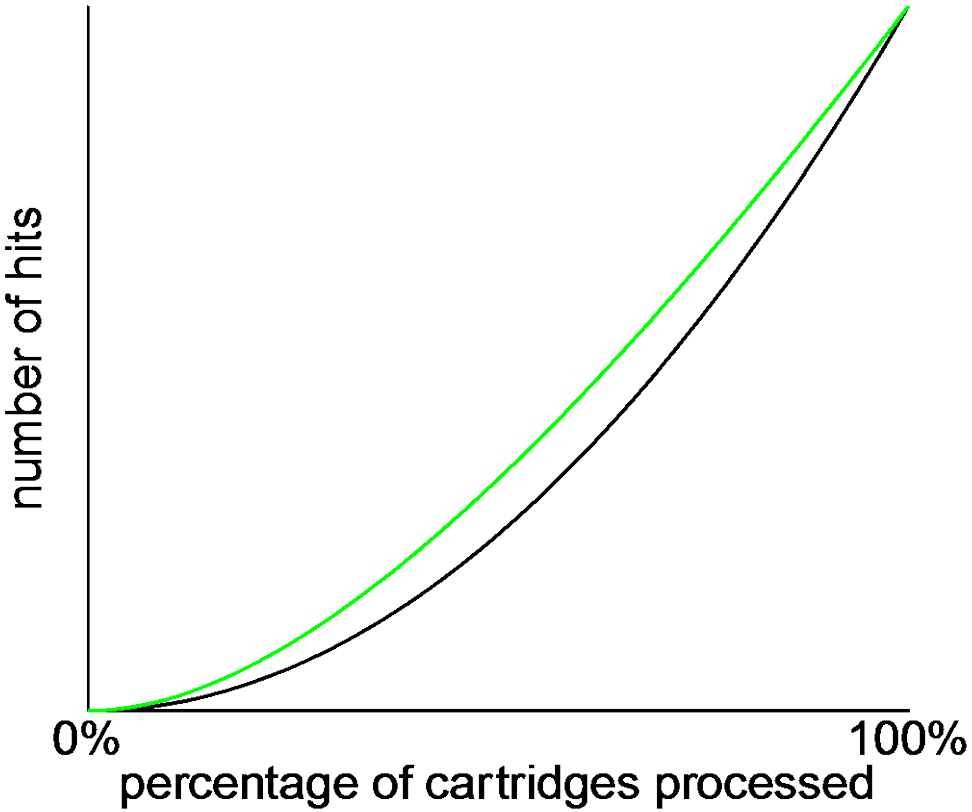
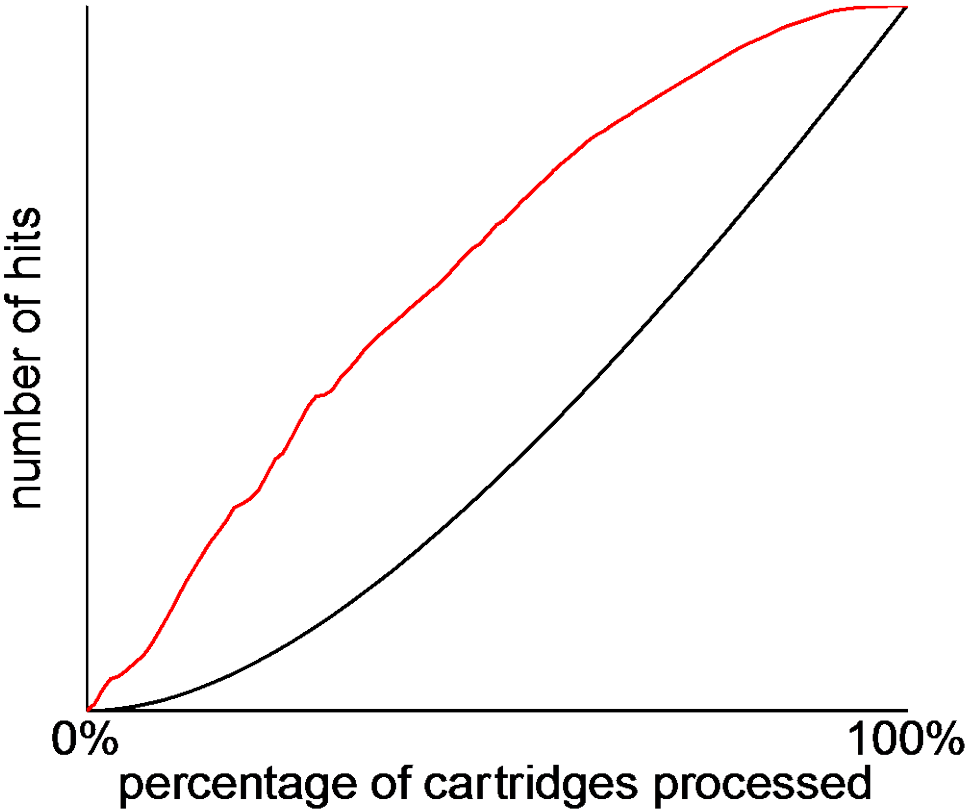
In fact, of arriving cartridges that had at least one hit, the average number of hits was 1.92.



Research Question 2: What to Process?



- Normalized AUC = 0.62 for optimal allocation policy
  = 0.38 for no-priority policy
- Optimal allocation policy more than doubles the number of hits compared to No-Priority Policy, when 50% of cartridges are processed
- But optimal policy is complicated. Are there simple policies close to optimal?

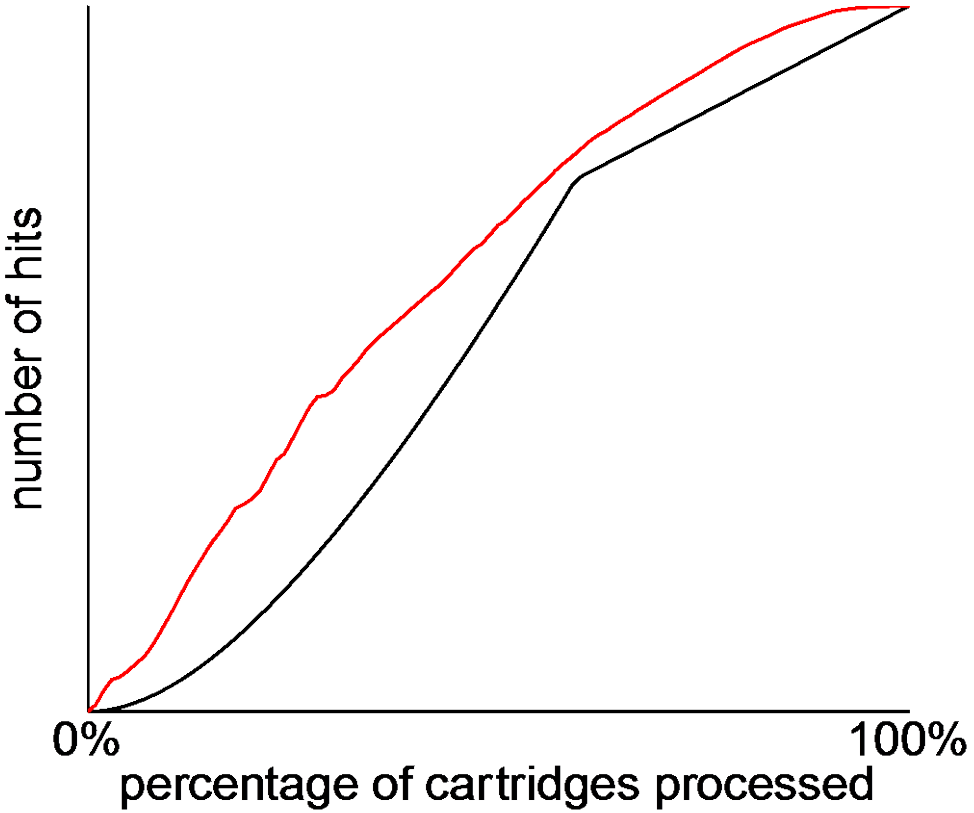
Evidence-Priority Policy

- Give all evidence priority over all test-fires

- Within evidence, do not prioritize among 3 crime types and 12 cartridge types

- Within test-fires, do not prioritize among 3 crime types and 12 cartridge types

Evidence-Priority Policy



Evidence-priority policy is near optimal when we process 60% of cartridges (60% of all cartridges are evidence)

Otherwise, it can be quite suboptimal (due to quadratic curve)

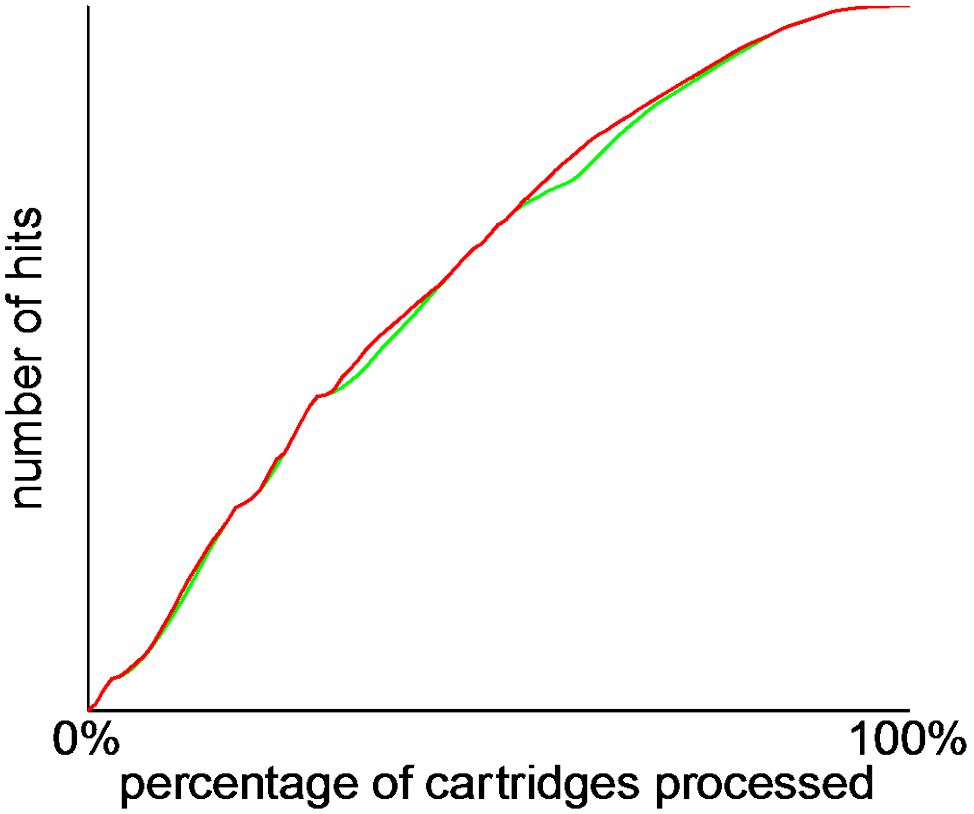
A Better Policy

- Give all evidence priority over all test-fires

- Within evidence
  group by cartridge type
    => this changes quadratic curve into 12 smaller curves
  rank cartridge types by their hit probability
  prioritize higher-ranking cartridge types above lower types

- Within test-fires
  prioritize by their hit probability

Evidence-Priority + Cartridge-Grouping Policy



This policy is nearly optimal!

This policy can be used even with no data:

just guess the ranking of cartridge types

Two Possible Concerns

1) Will criminals game the system by changing to an unprocessed cartridge type?

It seems unlikely, given:

- system's lack of transparency
- criminals in Boston did not switch to revolvers after IBIS implementation (Braga and Pierce 2004)

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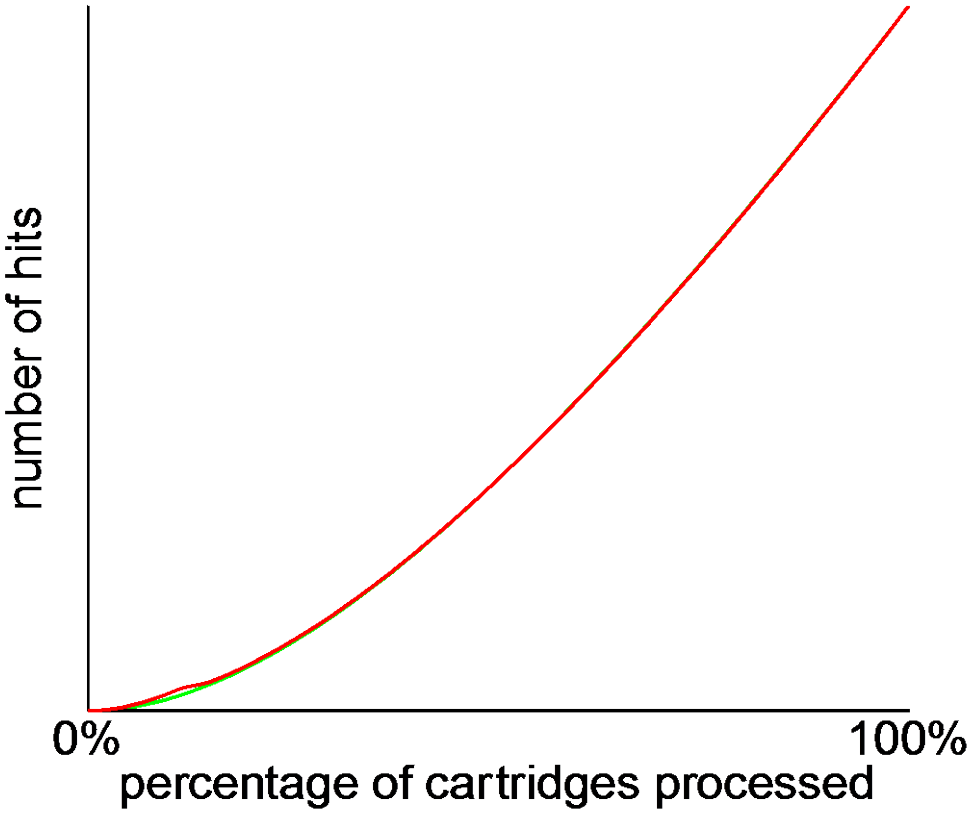
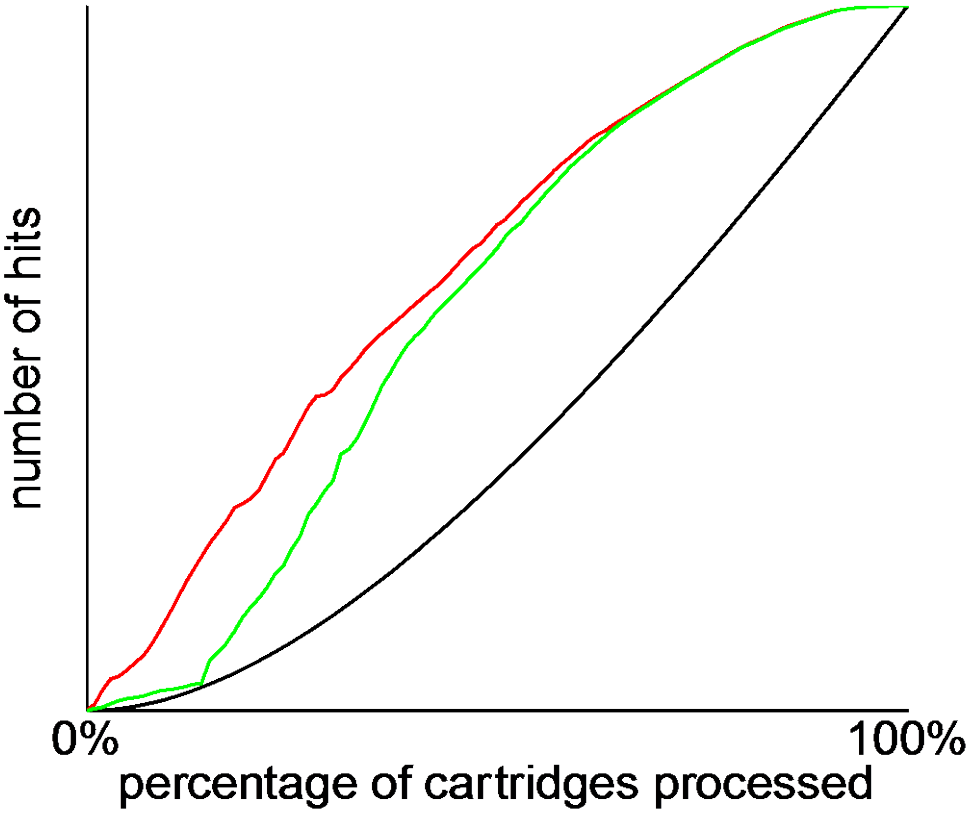
2) What if we want to give priority to homicide cartridges?

Homicides-First, No-Priority Policy



Homicides have same hit rate as non-homicides

Homicides-First, Optimal Policy



Policy: is like No-Priority Policy if < 14% of cartridges processed
catches up between 14 and 44% of cartridges processed
close to optimal if > 44% of cartridges processed

Maximize Useful Hits

Method: Compare waiting times (hit search date – event date)
under FCFS and LCFS to
case closing times (case closing date – event date)

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of solved cases:
46.3% < 1 day
31.5% 1-7 days
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Results: Proportion of useful hits = 51% (FCFS) vs 57%(LCFS)
This modest improvement does not offset severe inequity

Conclusion

When processing capacity is limited:

- The number of hits increases with the capacity in a complicated way
- Cities that enter few cartridges may be underestimating the performance of ballistic imaging systems
- A simple allocation policy can increase the number of hits
    - Give evidence priority over test-fires
    - Within evidence, group by cartridge type
- Prioritizing homicides reduces number of hits only if < 40% of cartridges are processed

Given a capacity allocation policy, LCFS increases usefulness of hits by only 5% compared to FCFS, and should not be used due to its perceived inequity

Analyzing Approaches to the Backlog of Sexual Assault Kits in the U.S.

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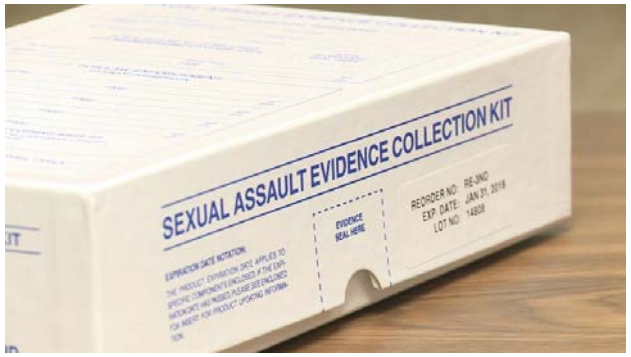
Journal of Forensic Sciences 2018

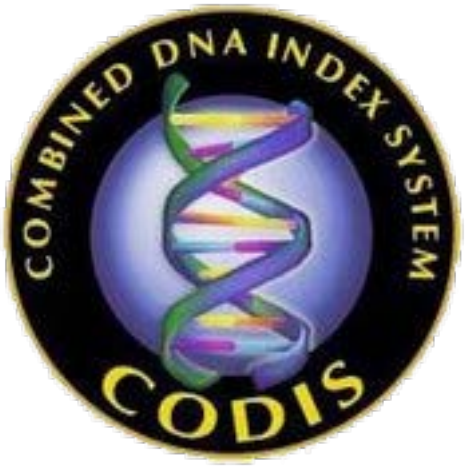
cnn.com 2018

BACKGROUND



Sexual Assault Kit

DNA profile



CODIS database

Conviction

BALLISTIC IMAGING VS. SA KITS
Similarities

Both have huge backlogs:

~400,000 untested sexual assault kits in the U.S.

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Both compare current crime with database of past crimes:

NIBIN = ballistic imaging database

CODIS = criminal DNA database

BALLISTIC IMAGING VS. SA KITS Differences

1) Ballistic imaging has different (nonmatching) caliber types
   Two (possibly matching) SA types: stranger vs. nonstranger

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   Two (possibly matching) SA types: stranger vs. nonstranger

2) Gun crimes only hit each other in NIBIN
   Sexual assaults can hit other types of crimes in CODIS

RESEARCH QUESTIONS

Should a city process its entire backlog?

If a city can process only part of its backlog, which specific sexual assault kits (SAKs) should it process?

- key issue is stranger vs. nonstranger SAKs

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NIJ funded backlog studies in four cities:

Detroit (Campbell 2016) recommends processing all SAKs

- Odds ratio of hits for stranger (vs. nonstranger) SAKs = 1.78 < 2.50
- Takes extra time to sort backlog into stranger vs. nonstranger SAKs

LA (Peterson 2012) recommends focusing on stranger SAKs

- LA hit rates are qualitatively similar to Detroit's
- Stranger SAKs led to more arrests, charges and convictions

DATA AND APPROACH

Data: Detroit tested 1595 (from 2002-2009) out of 11,219 SAKs in its backlog

Approach:

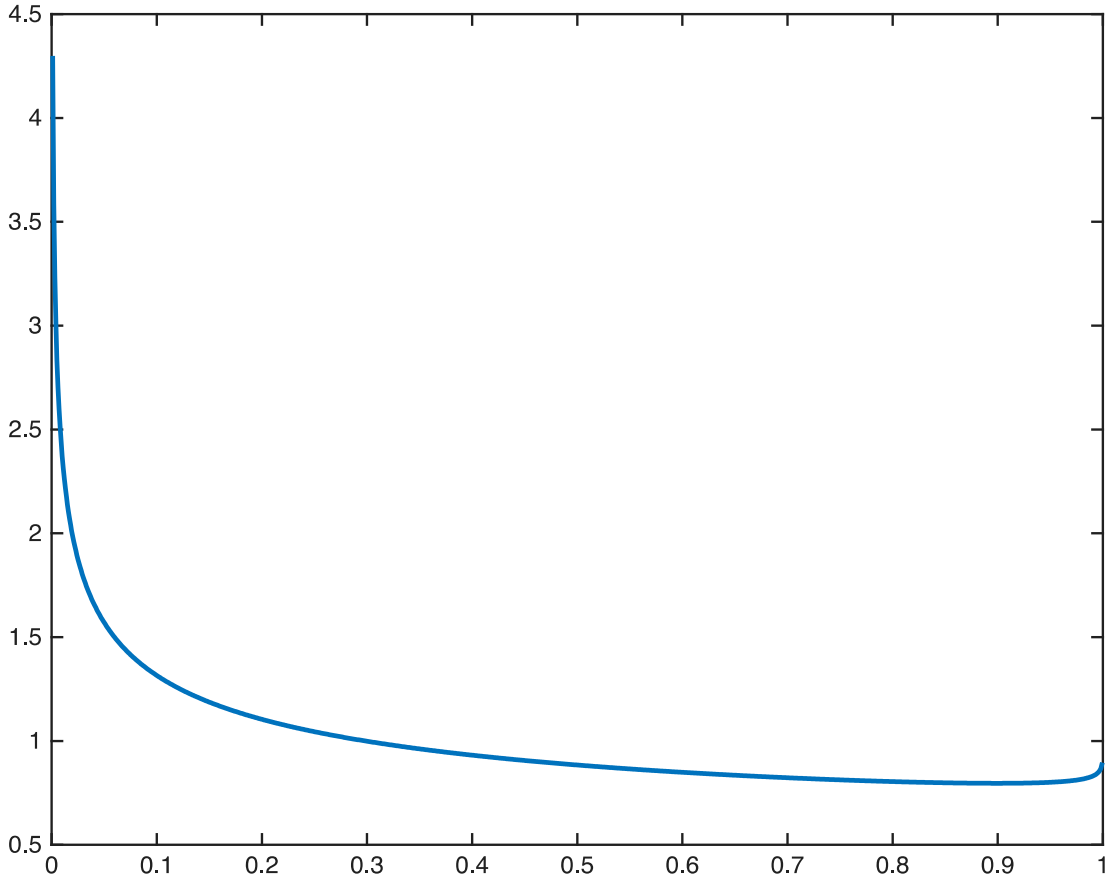
- Develop probabilistic model for observed backlog results
- Use MLE to estimate 10 parameters from Detroit data
- Six-step argument to recommend testing all SAKs

MODEL AND PARAMETER VALUES

Each offender in backlog has specialization s ~ beta distribution

- s = 1/0: offender commits only stranger/nonstranger SAs
- s = 0.5: offender does not specialize

ESTIMATED BETA DISTRIBUTION



More specialized nonstranger offenders than stranger offenders

MODEL AND PARAMETER VALUES

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- s = 1/0: offender commits only stranger/nonstranger SAs
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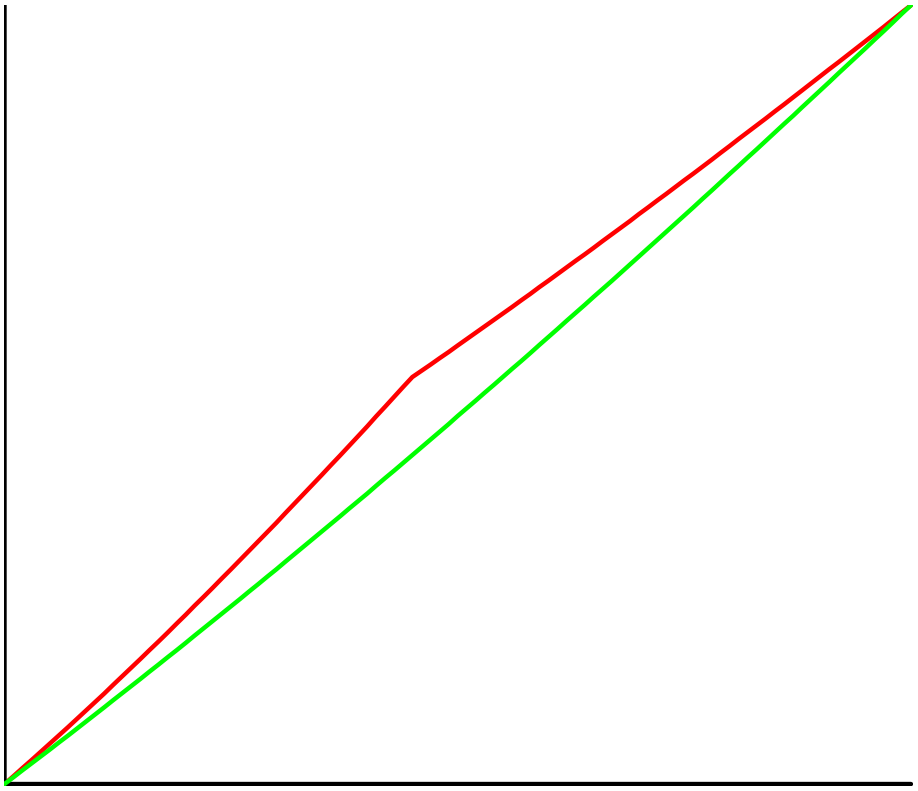
Specialization s impacts each offender's:

- DNA recovery rate (0.53 vs. 0.46)
- # of additional crimes in CODIS + backlog (1.84 vs. 0.88)
- Proportion of these crimes with recoverable DNA that are SAs (0.40 vs. 0.14)
- Proportion of these SAs that are in backlog (0.74 vs. 0.39)

SIX-STEP ARGUMENT TO TEST ALL SAKs

1) Prioritizing stranger SAKs offers a modest improvement
    - Normalized AUC = 0.527 vs. 0.482

MAIN RESULTS



Normalized AUC: stranger SAK priority policy = 0.527

no-priority policy = 0.482

SIX-STEP ARGUMENT TO TEST ALL SAKs

1) Prioritizing stranger SAKs offers a modest improvement
   - Normalized AUC = 0.527 vs. 0.482

2) Sorting cost:
   - Δ AUC drops from 0.045 to 0.034 when you incorporate the extra (3%) cost required to sort the backlog into stranger vs. nonstranger SAKs

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4) Conservative cost-benefit analysis of testing all SAKs is favorable:
   - $1641 in testing and downstream costs averts $133,484 in SA costs
   - Ignores other benefits:
     - Costs averted from nonsexual crimes
     - Populate CODIS so as to solve and deter future crimes
     - Increase the number of victims who report SAs
     - Retribution and reduced trauma for victim, and exoneration of falsely accused

DETAILS OF COST-BENEFIT ANALYSIS

c = cost per averted SA = $435,319
r = active offender rate = 7.1/yr
L = lifetime of offender ~ exp(mean = 28 yr)
C = time until first conviction ~ exp(mean = 7 yr)
A = age of SAKs in backlog (Detroit data as of 2015)

Payoff = cost of averted SAs
= c r E[max{0, min{L,C} - A} | C > A]
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= 0.491 x 0.644 x 0.037 = 0.012

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= 0.491 x 0.644 x 0.037 = 0.01

Testing a SAK is a favorable, high-risk, huge-payoff lottery!

STEPS 5 AND 6

5) A counterargument: stranger SAK hits have higher probative value than nonstranger SAK hits

	Offender Hit	Forensic Hit
Stranger SAK	198 cold hits	13 linked crimes
Nonstranger SAK	196 new offender info	12 cold hits

STEPS 5 AND 6

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	Offender Hit	Forensic Hit
Stranger SAK	198 cold hits	13 linked crimes
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6) Marginal cost-benefit analysis of testing nonstranger SAKs

- Conservatively assume convictions can only arise from cold hits

=> cost-effectiveness of testing nonstranger SAKs = cost-effectiveness of adding police officers