On Designing and Operating Voting-by-Mail (VBM) Processes

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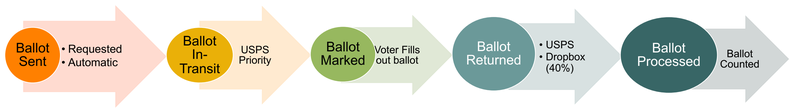
Background

Utilization of Vote-by-Mail (VBM) election infrastructure increased due to the COVID-19 pandemic[1]

25% (2016) ⇨ 46% (2020)

Weaknesses in the VBM processes were revealed with its operation at scale:
- Delays and administrative issues
- Equity in accessibility
- Security concerns associated with timelines
- Cost of election administration

Each part of this process is susceptible to attacks.



- Ballots can be lost in-transit
- Incorrectly filled out\processed
- Susceptible to malicious attacks

Existing VBM Analysis

VBM Performance
- Election Performance Indices (EPI)[2] focuses on rejection rate of returned ballots
- Preparedness of election offices (admin) evaluated
- Proximity of drop box to voter impacts likelihood of voting

Election Security
- An assessment prior to 2020 election[3] details 10 types of risks, increase resources
- In-person voting widely studied for various attack types

Risk Identification
- Attack/fault trees used to model threats and dependencies to VBM process
- Does not address likelihood of events or temporal elements of attacks

Equity Modeling
- Operations research literature addresses equity concerns in the public sector
- To date, ignored within election infrastructure modeling.

Gap: There are vulnerabilities associated with inadequate resource allocation, timelines of VBM procedures, and delays which have not yet been considered.

Mathematical Modeling of VBM Processes

Mathematical modeling approaches to model VBM processes and attacks **allow pre-planning** and i**mplementation of equitable procedures**.

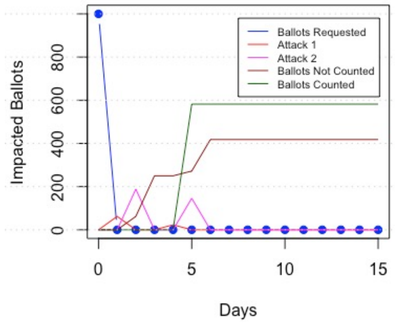
Temporal Analysis of a VBM Process

VBM processes are defined by time-dependent facets:
- Attacks (malicious and non-malicious)
- Mitigating Actions
- Procedure

Using Existing attack trees for threat ID

We propose and expandable discrete-time Markov chain (**DTMC**) model that captures all three components.

A simulation using the DTMC provides insights into temporal threats and mitigation opportunities.



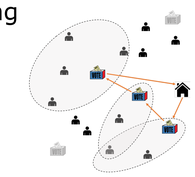
Number of ballots impacted by event (y-axis) on each day of the election period (x-axis)

Dropbox Resource Allocation

Drop boxes serve as voting method when the voter
- Lacks trust in USPS
- Has insufficient time to mail ballot using USPS
- Is located close to a drop box

Identifying locations of **new drop boxes** is non-trivial due to a limited budget.

Three objectives:
1. Minimize collection route length
2. Maximize voter access
3. Minimize cost of locating drop boxes



Management Cost: 6
Voter Access: 7

Management Cost: 13
Voter Access: 9

Informing Policy

With expanded drop box use, it is critical to **investigate and understand the trade-offs** between:

1. Equity: *remove discriminatory practices*
- Equity metrics built into objectives and constraints to equally reflect accepted values[4]
- We model inequitable practices as attacks to the VBM process

2. Security: *correctly marked ballots are counted*
- Compute the likelihood of disruption or malicious attack given various policies.

3. Cost: *effectively allocate resources to conduct elections*
- Externally determine the cost of various policies.

4. Access: *reduce barriers to casting a vote*
- Assess the likelihood for individuals to vote under certain policies.

Applying case studies, we answer the following **policy questions**:
- What is the cost-effectiveness of various mitigations and procedures
- When and where is the VBM process most at risk?
- How and when should resources be used to improve the VBM system?

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