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Efficient, Fast, and Fair Voting Through Dynamic Resource Allocation in a Secure Election Physical Intranet

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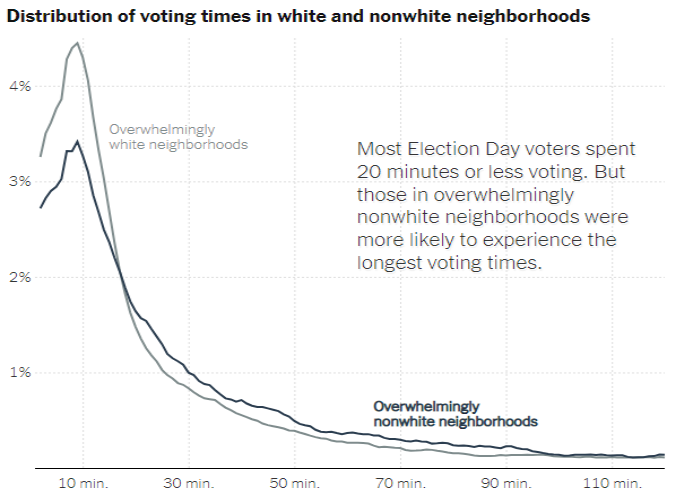
Introduction

Costly, Long, and Unfair Waiting Time During Elections

Source: npr.org/2020/10/17/924527679



Source: nytimes.com/interactive/2021/01/04/upshot/voting-wait-times.html

- The national economic cost of a 10-to-15-minute wait time is approximately $500 million
- Past several general elections: Hours of average waiting times in multiple locations in multiple states
- Long waits are more likely to happen to racial and ethnic minorities and low-income communities

Allocate the right amount of resources to the right location on the right day

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Introduction (contd.)

Efficient, Fast and Fair Allocation

Fixed Population-based Allocations

- Fixed from early voting to the election day
- Mostly based on the number of registered voters and historical plans

Require more resources
- Either under or over-utilized

Cannot handle demand changes
- Voters' behaviors deviate

Fairness is rather neglected
- Reuse unfair plans

Proposed Dynamic Allocations

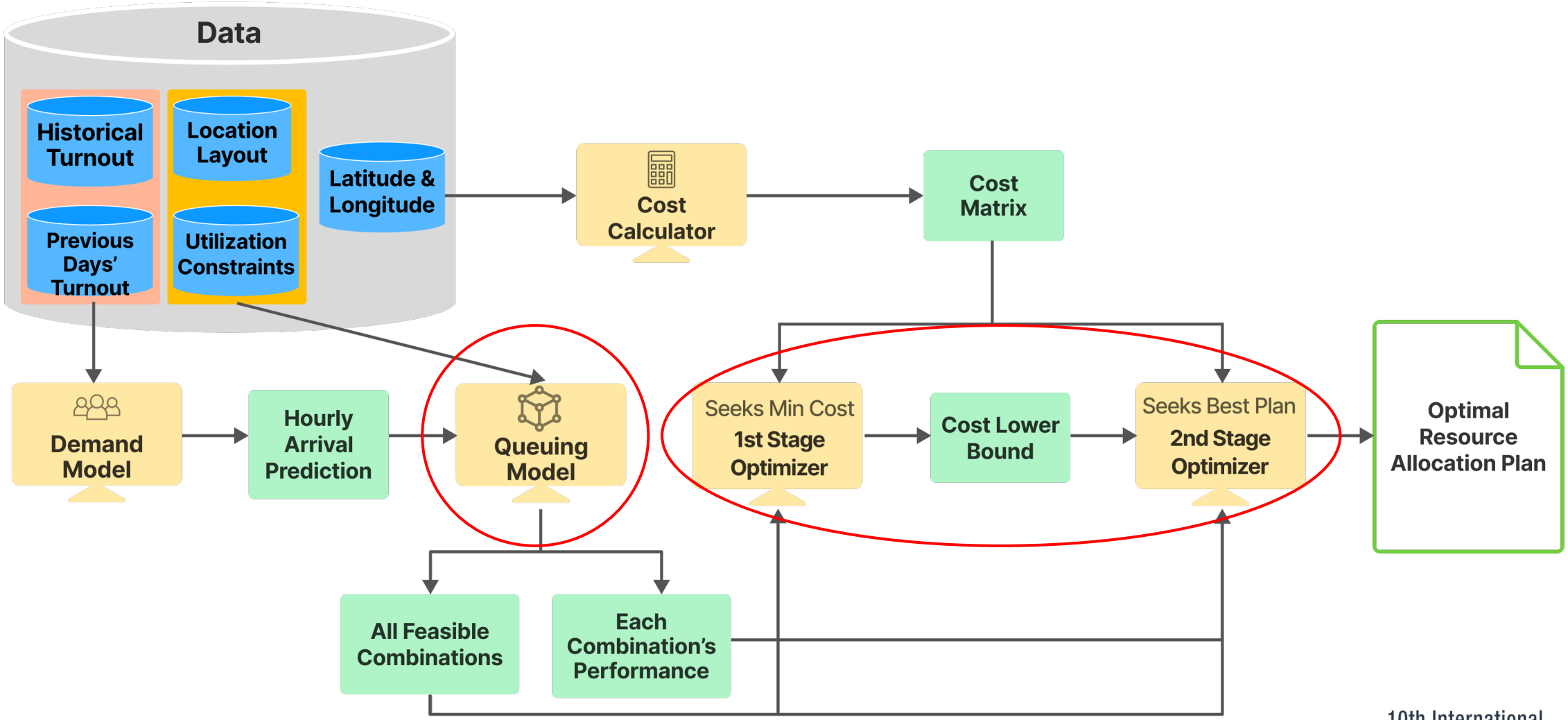
- Dynamic across the entire election period
- Utilize historical data and the current trend

Polling locations will transfer resources to each other during the night based on predictions on what will happen in the future

When?
Which locations?
What resources?
How many?

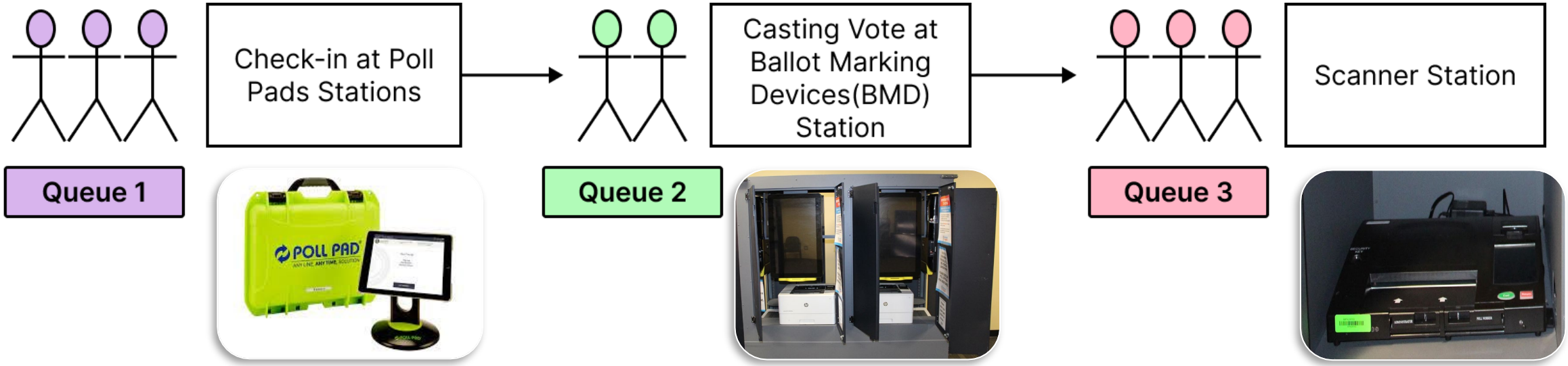
Proposed Dynamic Resource Allocation Framework

Queueing Network + Optimization



Queueing Network Model

Voting Process of Three Steps



Inputs (per location)

- Voters hourly arrival
- Polling location's layout constraint
- Utilization constraint

Queuing model running many times to ensure rigorous results

Outputs

- All feasible resource combinations
- Each combination's performance, i.e., waiting time

Optimization Model

Lexicographic Optimization for Multiple Objectives

Objectives

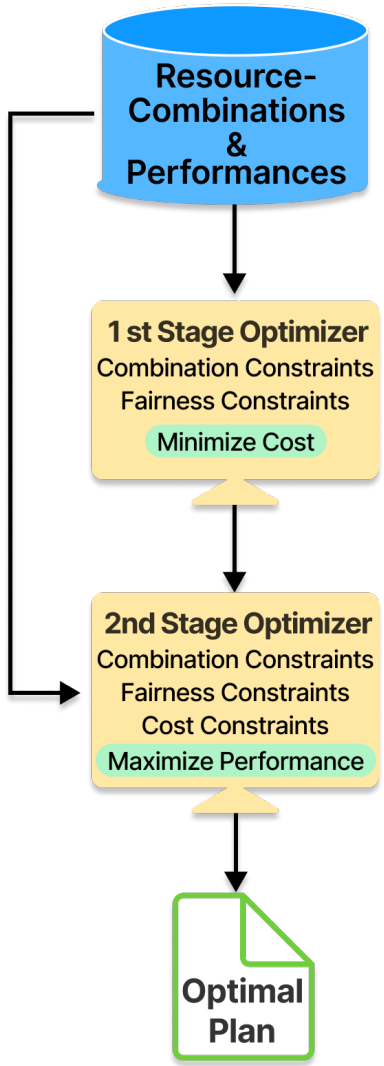
1. Min the total cost (less expensive)
2. Max the total performance (efficient)
3. Min the waiting time gap (fair)

Optimization

- Handle the 3rd objective with constraints
- 1st and 2nd objectives are conflicting and hard to normalize

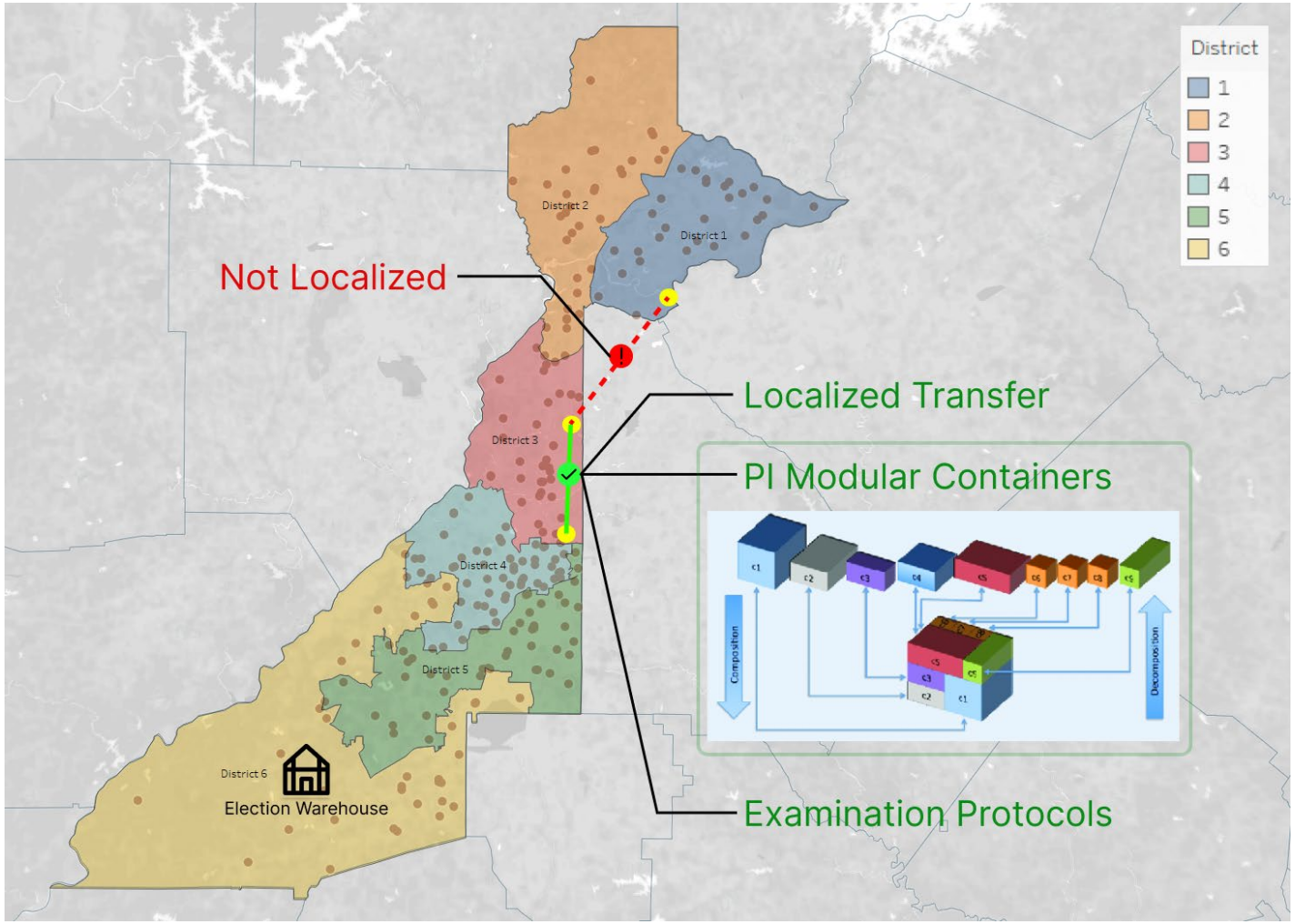
⇩

Two-stage Lexicographic Optimization



Proposed Secure Election Physical Intranet (SEPI)

Containerization, Localized Transfers, and Examinations



Proposed SEPI (contd.)

SEPI in Practice

SEPI Territory

- Define a SEPI Territory where all transactions are limited to, such as a county

Containerization

- Machines are stored and moved within **PI containers** and **connectors** during transfers

Localized Transfers

- Encourage transfers between polling locations in a **localized range** contained by the defined SEPI territory, i.e., in the same city or the same commission district

Examination

- After transfers, examine all resources **extensively** with **standardized procedures**

Methodology Execution

- Election practitioners are encouraged to run our proposed methodology **at the end of every early election day** for the most **updated transfer plan**

Case Study

Presidential Election 2020, Fulton County, Georgia

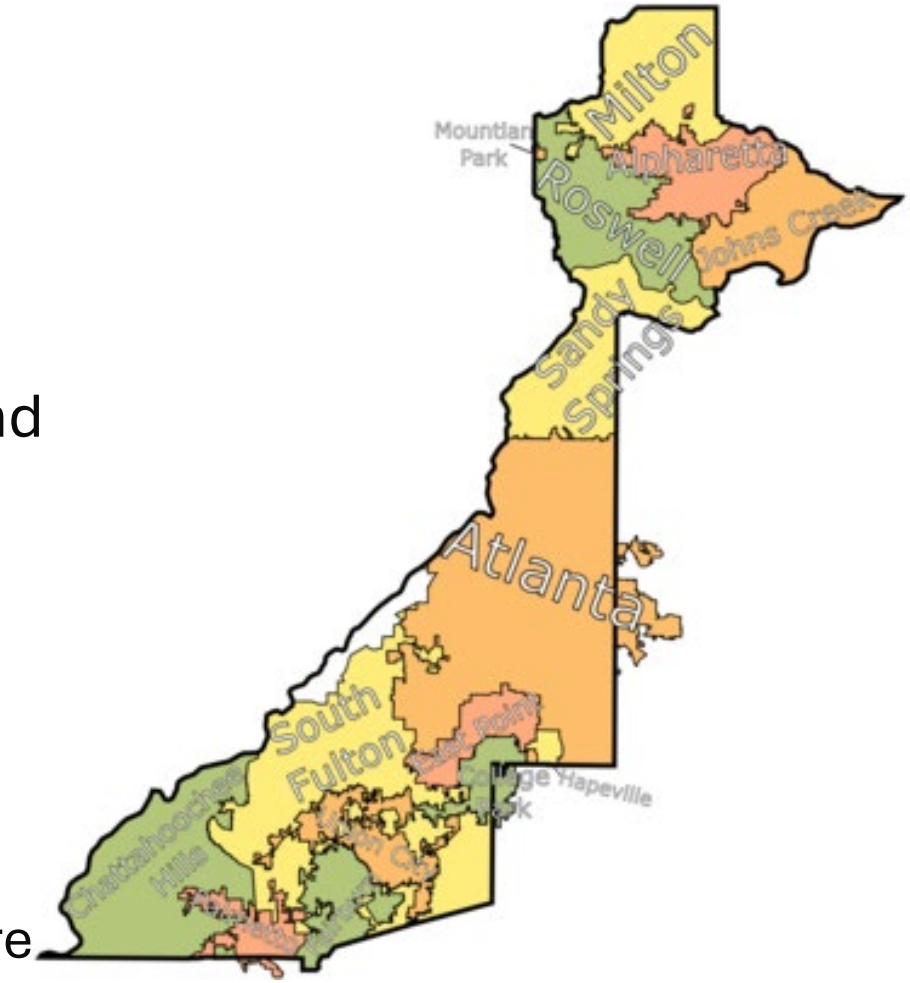
Two Testing Scenarios:

- High Early Voting (75%)
- Low Early Voting (45%)

Comparison Between **Fixed** Allocation and **Dynamic** Allocation on:

- 99.7% Rigorous Waiting Time
- Average Resource Utilization Rate
- Required Resources

Identify **Critical** Polling Locations that Require **More Resources** and/or **Expansions**

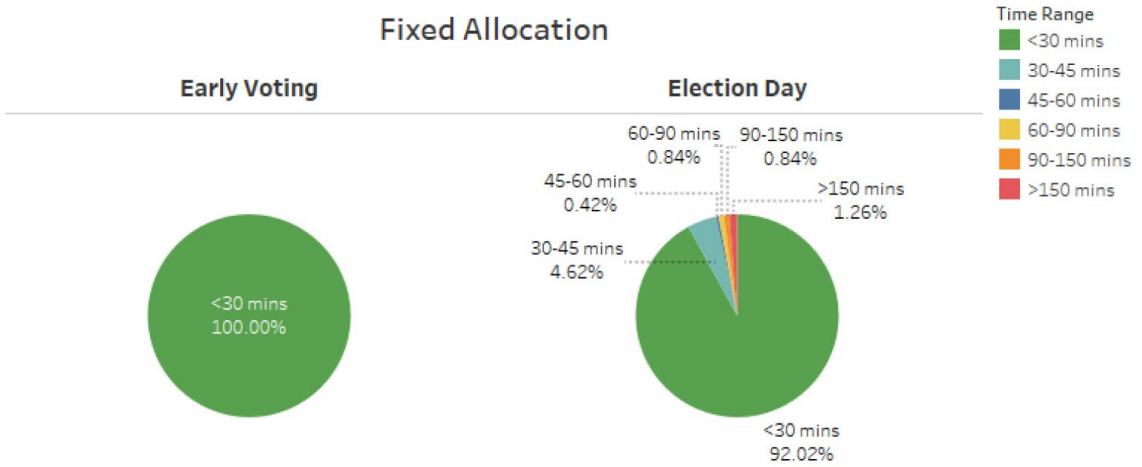


Source: https://en.wikipedia.org/wiki/Fulton_County,_Georgia

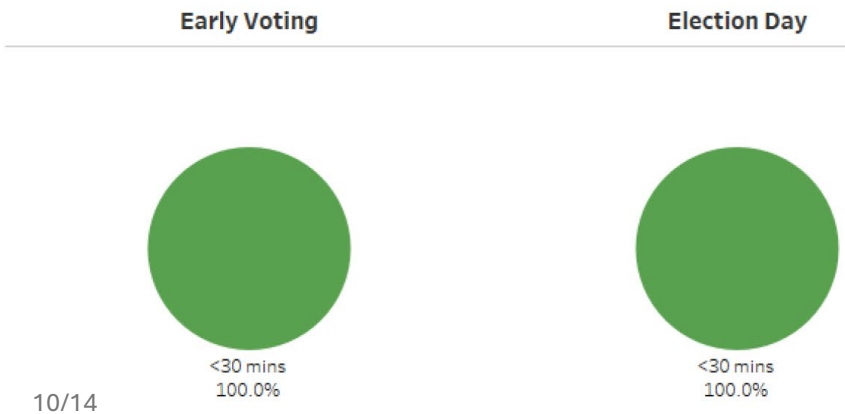
99.7% Rigorous Waiting Time

High Early Voting: 99.7% Rigorous Waiting Time Ranges by Locations

Fixed Allocation

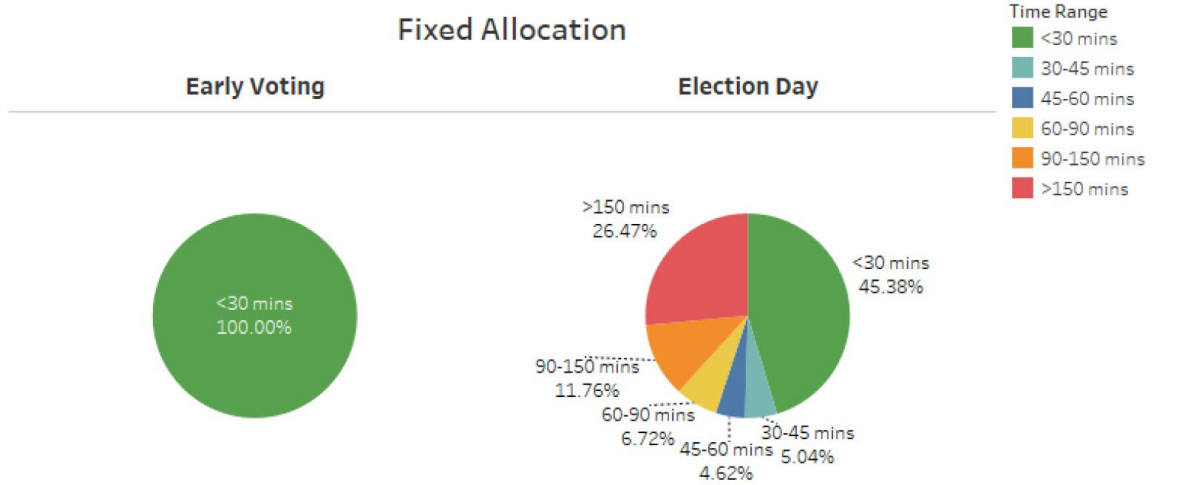


Dynamic Allocation

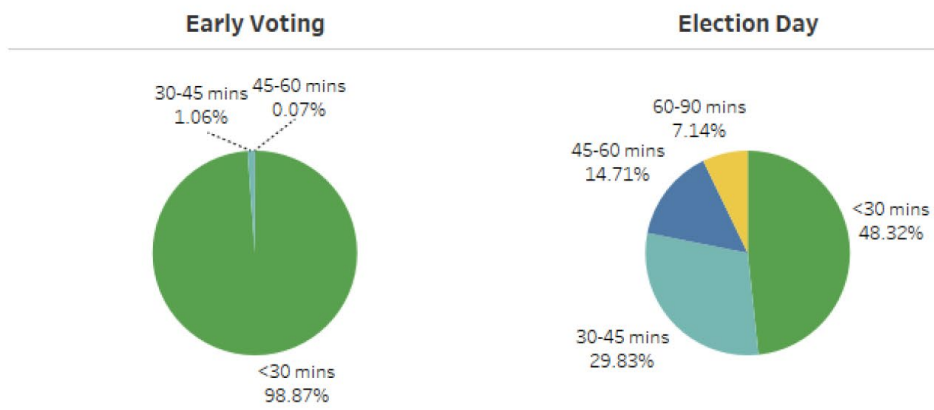


Low Early Voting: 99.7% Rigorous Waiting Time Ranges by Locations

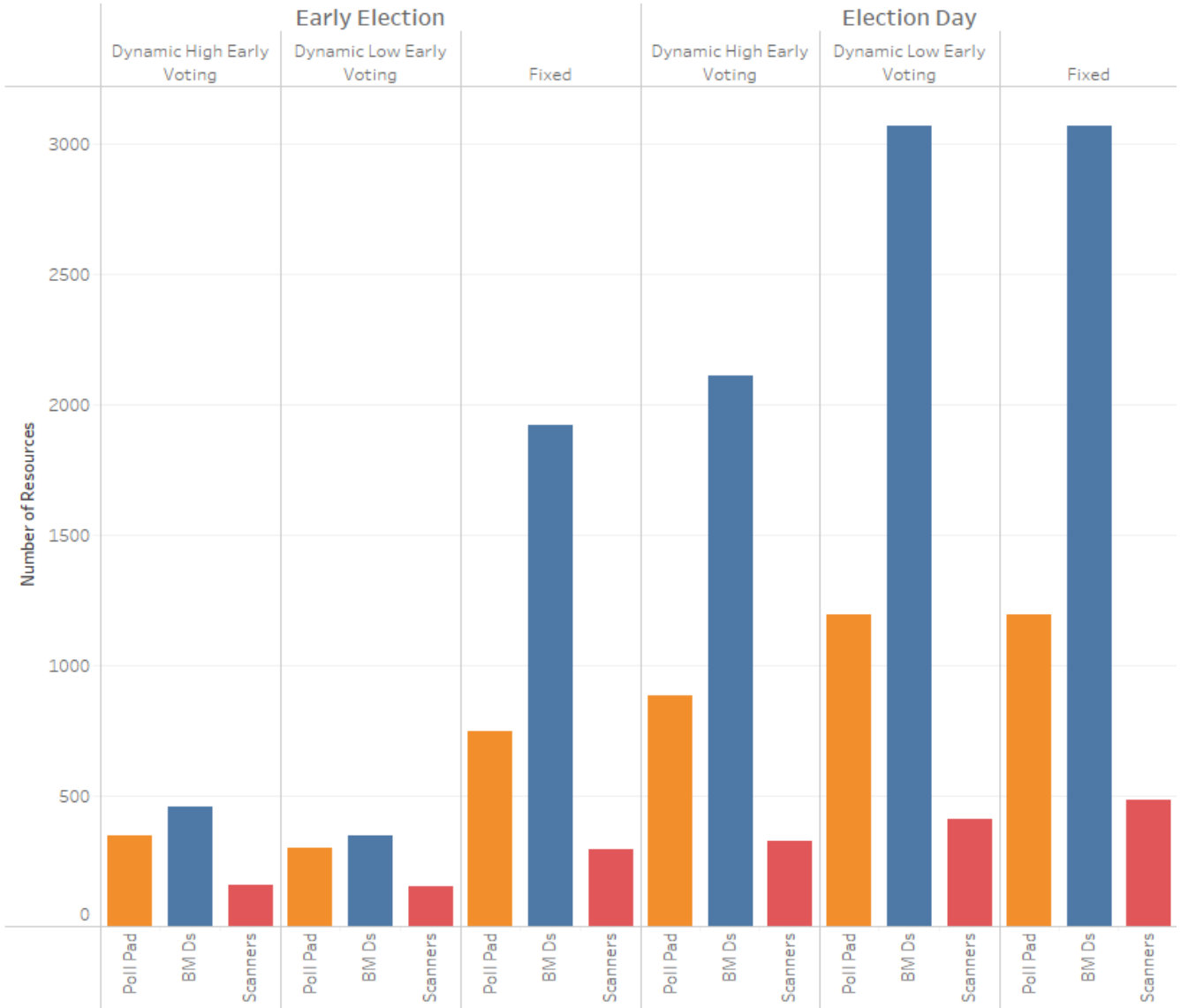
Fixed Allocation



Dynamic Allocation



Required Resources



Resource Utilization

Table 1: Fixed Allocation and Dynamic Allocation's Average Utilization in High Early Voting

	Early Voting			*Election Day*		
	Poll Pads	*BMDs*	*Scanners*	*Poll Pads*	*BMDs*	*Scanners*
Fixed	10.2%	11.1%	6.5%	44.4%	47.6%	28.6%
Dynamic	24.8%	51.1%	12.7%	60.3%	68.2%	43.0%

Table 2: Fixed Allocation and Dynamic Allocation's Average Utilization in Low Early Voting

	Early Voting			*Election Day*		
	Poll Pads	*BMDs*	*Scanners*	*Poll Pads*	*BMDs*	*Scanners*
Fixed	6.4%	6.9%	4.1%	68.2%	73.0%	43.9%
Dynamic	16.3%	39.5%	8.0%	72.0%	75.2%	53.2%

Examples of Critical Polling Locations

Table 3: Examples of Locations that Require More Resources on Election Day in Low Early Voting

	Fixed				*Dynamic*			
	Poll Pads	*BMDs*	*Scanners*	*Est. WT (mins)*	*Poll Pads*	*BMDs*	*Scanners*	*Est. WT (mins)*
Abernathy Arts Center	5	11	2	90-150	6	17	2	<30
Collier Park RC	3	6	1	45-60	3	9	1	<30
Johns Creek High School	5	14	2	60-90	6	16	3	<30
Morningside ES	6	18	3	60-90	9	19	4	<30

Conclusion

Future Research

Determine Polling Locations

- Smartly and effectively determine a limited number of polling locations with resource allocation plans, especially in regions with less compact populations

Voter Turnout Prediction

- Predict voter turnouts considering multiple factors, such as weather and media

Allocate Polling Workers

- Conduct fast allocation of polling workers in response to unpredicted emergencies, i.e., someone is sick and cannot show up

Thank You!