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The Checkpoint Simulation

A Tool for Informing Border Patrol Checkpoint Design and Resource Allocation

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***Abstract*—Proper resource allocation at Border Patrol checkpoints is essential for effective and efficient screening. Improper resource allocation can lead to flushing—i.e., allowing cars to pass through a checkpoint without screening—or cost inefficiencies. To better inform resource allocation, we present a prototype simulation that models the major processes of an operational checkpoint. Data for the simulation was collected during extensive site visits to checkpoints on the U.S. northern and southern borders. In a case study, we configure the simulation to model the Tucson Sector, I-19 checkpoint. We found that the checkpoint can handle current traffic demands, but additional screening capacity is needed to accommodate traffic in the next 20 years.**

Keywords—checkpoint simulation; flushing; resource allocation; traffic flow

I. INTRODUCTION

Border Patrol (BP) checkpoints are located on interior U.S. roads as a part of BP's three-tier strategy to interdict and deter illegal immigration, contraband smuggling, and terrorism. Proper resource planning is important for operating existing checkpoints and designing new checkpoints [1]. Allocating too few resources (e.g., planning insufficient lanes at new checkpoints or assigning too few personnel to existing checkpoints) to meet traffic demands may result in suboptimal screening or suspended screening (i.e., flushing). Flushing poses a vulnerability to border security as the adversary may anticipate flushing and bypass the checkpoint during this time [2]. Allocating too many resources will result in underutilized assets and thereby increased costs. Thus, there is a need to develop decision support systems to aid in checkpoint resource allocation based on real and anticipated traffic flows.

To address the need for informed resource allocation, we propose a checkpoint simulation. A simulation refers to a computerized model of the operation of a real-world process or system over time. Simulations have been used in a variety of border contexts [e.g., 3, 4, 5]. However, to our knowledge, no simulation has been created for Border Patrol checkpoints. In this paper, we report on a prototype simulation built in Arena simulation software that models the major checkpoint operations, allowing BP to assess the resources and staffing needed to meet current and future traffic demands. The simulation allows BP to predict how making resource changes to a checkpoint will influence performance measures (e.g., the amount of flushing, wait times, capacity, resource utilization, etc.) before making changes in the real world. This paper will proceed as follows. First, we describe our process of gathering real-world data to develop the checkpoint simulation. We then briefly summarize the simulation and its key components. Finally, we report the results of a case study examining how the I-19 checkpoint in the Tucson Sector, Arizona may be influenced by estimated traffic flow over the next 20 years, given the checkpoint's current infrastructure and resource allocation.

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II. CHECKPOINT MODEL DEVELOPMENT

A simulation is only as a good as the information, assumptions, and data used to create it. Thus, to ensure an accurate representation of the real world and a valid simulation, we conducted a series of rigorous data collections. First, our research team visited 17 operating checkpoints from 5 different sectors on the northern and southern borders to collect data—checkpoints in the Tucson, El Paso, Rio Grande Valley, Swanton, and San Diego sectors (Fig. 1). During these visits, we carefully documented and modeled checkpoint operations. We interacted with BP agents working at checkpoints to verify the accuracy of our models and documentation. A high-level overview of checkpoint operations is shown in Fig. 2. Note that individual checkpoints vary in resources and operations. Our simulation models the processes that the majority of checkpoints have in common; we also documented operational and resource differences between specific checkpoints that would need to be adjusted when modeling a specific checkpoint.

Fig. 1. Summary of Sectors Visited

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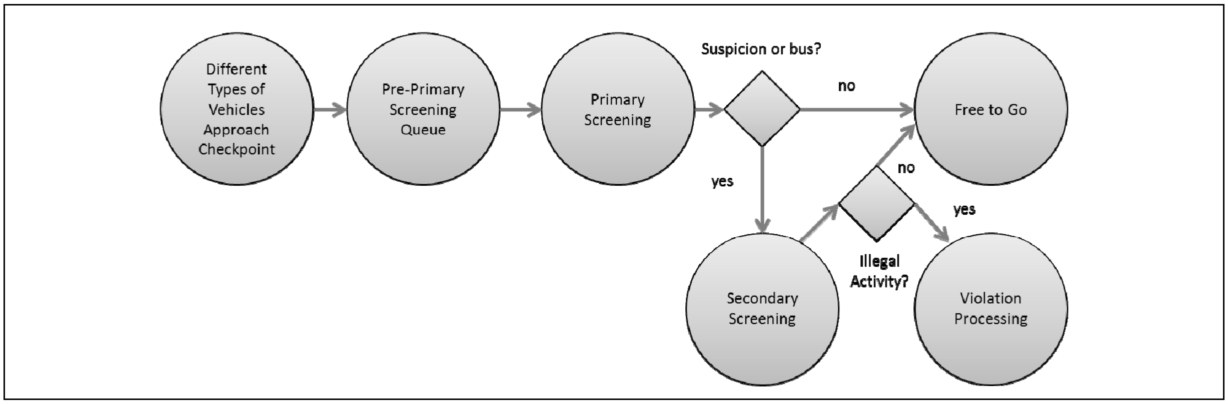

Fig. 2. High-Level Overview of Checkpoint Operations

Next, we collected screening times, hourly traffic counts, and daily projected traffic flow data. Hourly traffic counts and daily projected traffic flow were obtained from BP and the Department of Transportation. We recorded screening times using stopwatches at operating checkpoints, including the I-19 checkpoint in the Tucson Sector, for a case study (reported in the next section). Because different types of vehicles take different lengths of time to screen (e.g., in general, it takes a semi-truck longer to start/stop and be screened at a checkpoint than a sedan), we recorded how long it takes to screen different types of vehicles in primary screening and secondary screening. Analyzing this data using an ANOVA, we found that primary screening times for vehicles can be statistically separated into two different groups. These groups exclude buses and commercial livery vans because they are automatically sent to secondary screening at the checkpoints we visited. Group 1 includes semi-trucks and pickup-trucks with trailers. Both semi-trucks and pickup-trucks with trailers took statistically the same amount of time to screen in primary screening ($f = .203$, $p = .657$, df=23, m=26.46 seconds, sd = 15.670 seconds). Group 2 included all other vehicles (sedans, pickups with no trailers, non-livery vans, SUVs, and others) screened in primary screening. These vehicles took statistically the same amount of time to screen in primary screening (f=1.485, p=.219, df=280, m=6.28 seconds, sd = 6.36 seconds). However, vehicles in Group 1 took significantly longer to screen than those in Group 2 ($f = 160.880$, $p < .001$, df= 304).

For modeling secondary screening, we recorded how long it takes on average to screen a vehicle in secondary screening (for buses, vans, group 1 vehicles, and group 2 vehicles) for various tasks (e.g., check immigration documents, run a vehicle through a backscatter machine, etc.). We also recorded the number of agents needed to screen a vehicle in secondary screening. For example, in our sample, it took 10.5 minutes on average to screen a car in secondary screening (sd = 4.95 minutes). On average, it took three agents to screen a vehicle when using a backscatter machine in secondary screening (1 agent to drive the car, 1 agent to operate the backscatter machine, and 1 agent to stay with the car's owner). On average, it took 120 seconds to perform a backscatter screening. Table 1 summarizes key screening times in primary and secondary screening.

TABLE 1. SCREEN TIME OBSERVATIONS MADE DURING SITE VISIT

Screening Area	**Vehicle Group**	**Time to Screen Mean (m) and Standard Deviation (sd)**
Primary	Group 1	m = 26.46 seconds sd = 15.67
Primary	Group 2	m = 6.28 seconds sd = 6.36 seconds
Secondary	All Groups	m = 10.5 minutes sd = 4.95 minutes

Using the models and data collected during site visits, we created a checkpoint simulation model using Arena simulation software—a standard for process simulation. Per our analysis, buses, vans, semis (including pickup-trucks with trailers), and cars (including all other vehicles) are modeled separately to capture both the differences in screening times and screening rules (Fig. 3). Depending on a checkpoint's specific rules, vehicles are allowed to go to any primary screening lane queue (the one with the shortest queue), or certain vehicles are required to go to specific lanes (e.g., some checkpoints request semi-trucks go to a specific lane). If a lane queue gets longer than a specified value (unique to each checkpoint), it will automatically start flushing. If the vehicle is a bus or van (if applicable at the specific checkpoint), or the vehicle arouses suspicion (K9 hit, agent suspicion, etc.), the car is sent to secondary screening.

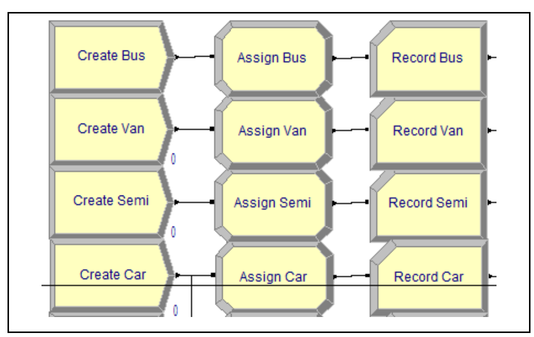

Fig. 3. The simulation begins with creating different vehicles that take different times / procedures to screen

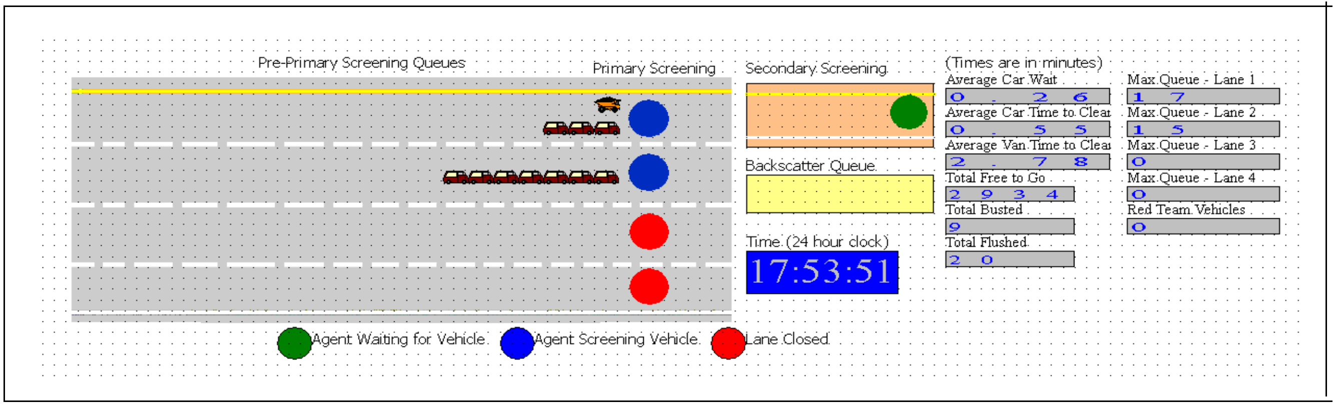

Fig. 4. Key statistics in the management dashboard including a visual representation of queues in primary and secondary screening, average wait time, average time for a car and van to clear screening, , total cars that went through the checkpoint (excluding those caught for a violation) (total free to go), total vehicles that had a violation and were caught (total busted), total number of vehicles flushed, max queue lengths, and the total number or red teaming vehicles that passed through the checkpoint.

Secondary screening can involve multiple tasks depending on the specific nature of a checkpoint, including, but not limited to, agent inspection and backscatter machine screening. The number of inspection areas and other resources (e.g., agents, backscatter machines) are modeled in the simulation. At the end, a car is either released (free to go) or processed for a violation. Key operational statistics resulting from the simulation are reported in our management dashboard (Fig. 4), and Arena outputs a number of statistics, including:

- Average wait time
- Average time to clear
- Total vehicles processed
- Total arrests
- Total flushing
- Queue length for each lane

Arena *schedules* are used to model hourly traffic arrival times and agent staffing. For example, there are peak traffic times and low traffic times daily. The simulation accounts for these fluctuations in traffic levels by specifying a distribution of traffic for each hour of the day using arrival schedules. Likewise, checkpoints do not always have the same number of agents on duty. Rather, during peak times, more agents may be needed to run additional lanes in primary and secondary screening. Agent work schedules are specified in Arena using the scheduling functionality.

III. I-19 Case Study and Analysis: Year 2029

We configured our checkpoint simulation to model the Tucson Sector I-19 checkpoint in Arizona by making the following customizations:

- We entered a current traffic count (provided to us by BP) and used the year 2029 average annual daily traffic (AADT) projected estimates from the Arizona Department of Transportation (ADOT) as a comparison [6].
- We adjusted the resources to match the I-19 checkpoint at the time of this study (number of lanes, lane operating schedules, agent schedules, backscatter machines, number of secondary inspection areas, etc.).
- We timed how long it takes to screen different types of vehicles at the I-19 checkpoint in primary screening and secondary screening.
- I-19 has a unique characteristic in that it starts flushing cars if the queue reaches a natural hill in the road (to help ensure the safety of oncoming cars).

Using this model, we ran four different scenarios through the checkpoint simulation. First, we ran the baseline model using the provided traffic counts (from BP), current resources, and current operating schedules (e.g., fewer lanes are open at night vs. during rush hour) (Scenario 1). Second, we ran the projected year 2029 traffic flow through the checkpoint simulation (from ADOT) using the existing infrastructure and operating schedule (Scenario 2). Third, we ran the 2029 traffic flow estimates and adjusted the operating schedule so that all three lanes were continuously open (Scenario 3). Finally, we ran the 2029 traffic flow estimates and added a fourth lane (all continuously operating) to the simulation (Scenario 4). For each scenario, we calculated the average car wait time, the max car wait time, and the percentage of vehicles screened. Table 2 summarizes the results of the simulation runs.

TABLE 2. SIMULATION RESULTS

Scenario	**AADT**	**Avg. Car Wait Time (minutes)**	**Max. car Wait Time (minutes)**	**Percentage Screened (not flushed)**
1	8,540*	.40	2.79	99.9%
2	28,000**	1.69	4.41	44.3%
3	28,000**	.75	2.58	59.1%
4	28,000**	.28	1.93	62.3%

* Current traffic counts provided by BP
** Arizona Department of Transportation 2029 estimate

IV. Discussion

The results of our simulation show potential for informing resource allocation. First, our results suggest that the I-19 checkpoint operations can handle the current traffic counts provided by BP (99.9% of vehicles were screened; low average and max wait times). However, the simulation also suggests that additional resources or more efficient processes are needed to meet future traffic demands. We found that under the current operating conditions, only 44.3% of traffic would be screened using projections from 2029. In addition the average and max weight times were approximately 2-3 times longer. Continually operating all lanes would result in a 59.1% screening rate; and adding an additional lane would increase the screening rate to 62.3%. These statistics suggest that future checkpoint operations should consider deploying more efficient screening technologies (e.g., license plate scanners, biometric identification, automated screening solutions, or fast-lanes) to accommodate future traffic flow.

V. Assumptions

The results of the simulation are dependent on several assumptions. For example, scenarios that use the 2029 traffic projections assume that several factors are the same as the observed 2012 values (collected by our research team), including:

- The same proportion of vehicle types arriving at the checkpoint (group 1, group 2, buses, and vans)
- Proportionally the same vehicle arrival schedule (some times of the day are busier than others)
- The same mean and standard deviations of screening times
- The same percentage of vehicles get sent to secondary screening
- The same permanent infrastructure (for Scenarios 1, 2, and 3 only)
- The same personnel schedule (for Scenarios 1 and 2 only)

VI. Future Research and Development

We now outline several opportunities for future research and further development of the simulation.

Additional Validation

Future research should validate the results of our simulation by comparing the projected outcomes (wait times, vehicles flushed, etc.) to actual outcomes and adjust the simulation accordingly. Based on our preliminary observations at checkpoint visits, the results shown in the simulation are consistent with real world checkpoint operations.

Real Time Interventions

Any modifications to checkpoint operations in the simulation must be made between simulation runs. Having to stop the simulation, make a change, run the simulation, and compare the results can be time consuming. Ideally, we would incorporate the capability to let users modify the simulation in real-time. For example, if a manager were running the simulation, he or she could close a primary screening lane and observe the impacts of that change. This could be done easily from a graphical user interface in which dragging and dropping a barricade into a lane of traffic would be possible.

Data Integration

The current simulation has traffic flow and agent resource scheduling already incorporated. Any changes to traffic flows or resource scheduling have to be done inside the simulation itself. In the future, it may be possible to link the simulation to real-time data sources allowing the simulation to be updated.

Circumention Zones

One purpose of checkpoints is to increase egress time by denying fast routes of egress, e.g. freeways and state roads. This often causes smugglers to circumvent or go around the checkpoint. Importantly, adequate resources must be allocated to these circumvention zones to apprehend this illegal activity. Adding circumvention zones to the simulation to inform this research allocation may be beneficial.

VII. Conclusion

Proper resource allocation is essential for effective and efficient checkpoint operations. This paper presents a prototype checkpoint simulation that models the major processes of an operational checkpoint. The simulation can be customized to model the idiosyncrasies of individual checkpoints. In a case study of the Tucson Sector I-19 checkpoint, we found that the checkpoint can handle current traffic demands, but additional screening capacity is needed to accommodate traffic in the next 20 years.

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