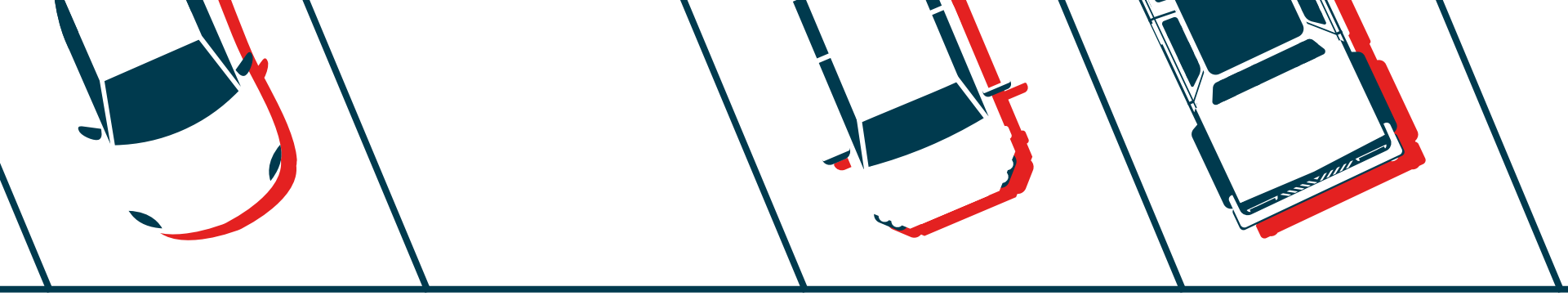

PARKING LOT SIMULATION

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PROBLEM ADDRESSED

- Parking Facilities face strong demand variability over time, with peak periods causing **congestion and off-peak periods leading to underused capacity**
- Static Pricing and simple access rules may **fail to adapt** to these dynamics which can cause **lost revenue**
- Strategies like **Dynamic Pricing** or **Reservations** are risky to deploy directly because they might **cause unintended and unexpected consequences**

Therefore, there is a need for a **controlled, realistic evaluation framework** to study how different parking management strategies affect system performance before real-world implementation

PROJECT OBJECTIVES

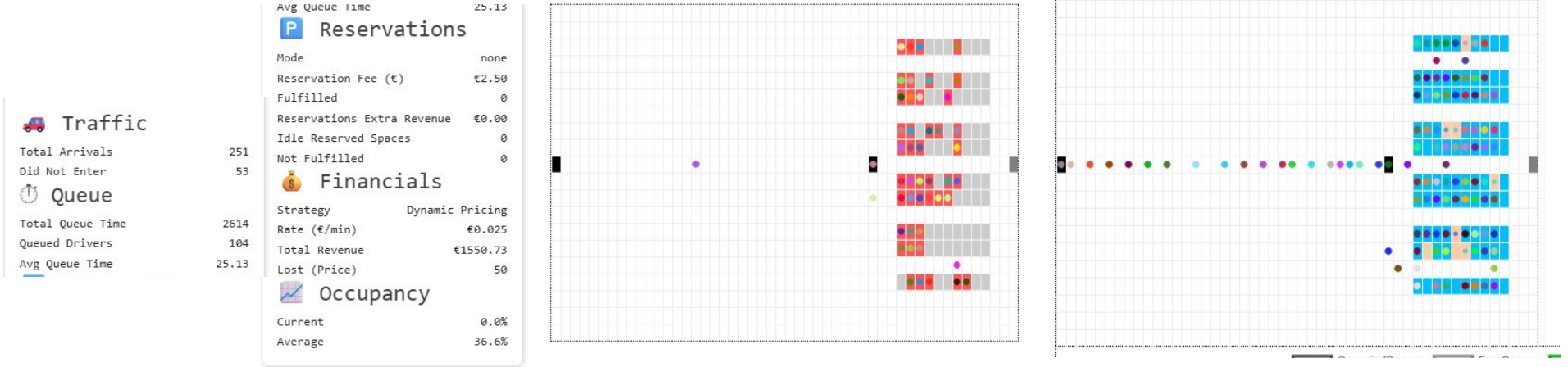
- Model a private parking lot using an **agent-based simulation**
- Simulate **realistic driver behavior** and parking lot mechanics: arrivals, queueing, parking duration and willingness to pay
- Evaluate and compare **parking management strategies**: static pricing, reservation-based access, and dynamic pricing
- Measure **key metrics**
- Provides a **decision-support tool** to test policies safely before deployment

METHODOLOGY

- Agent-Based simulation in **Mesa** with discrete time steps
- **Spatial grid representation**: entry/exit gate, queue lane and multiple parking rows
- **Stochastic demand model**: dependent arrival probability to model peak/off-peak traffic or budget decisions, parking durations sampled from mixture distribution
- **Driver state machine:** ARRIVING → APPROACHING_GATE → (WAITING_AT_GATE) → DRIVING_TO_SPOT → PARKED → EXITING → EXITED
- Measure Key Outcomes: **occupancy, revenue, rejected demand and queue time**
- **Simulate time** from 6 A.M. to 10 P.M.

PROPOSED APPROACH

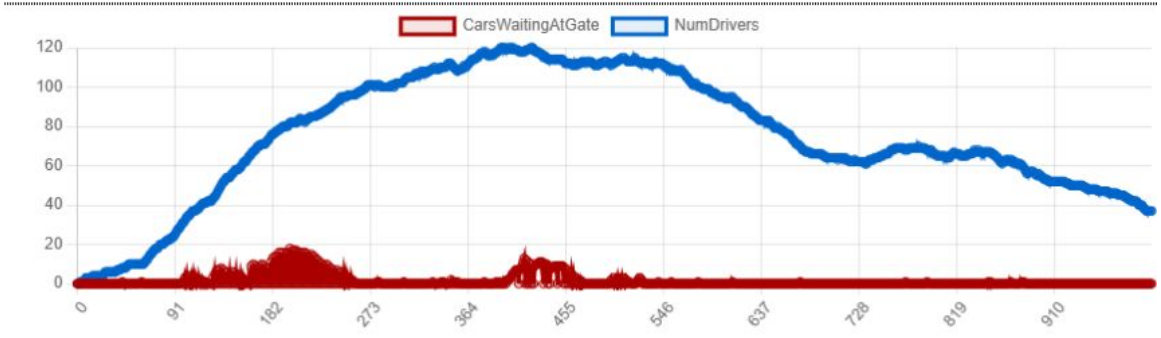
- **Baseline (static pricing)** with capacity-based admission
- **Reservations** where, for an increased fee, Drivers can reserve a parking spot for a specific duration (small chance of no-shows for realism)
- **Dynamic Pricing** in which price is updated based on the occupancy of the parking lot. When prices are lower, more Drivers want to enter the park, when the prices are higher, less Drivers want to park at the parking lot.



RESULTS AND DISCUSSION - STATIC STRATEGY

- Total Revenue: 1454$
- Average Queue Time: 14.47
- Rejected Demand:9 from long queues
- Average Occupancy: 60.6%

Stable performance, decent occupancy and low congestion



RESULTS AND DISCUSSION - RESERVATIONS STRATEGY

One: Additional Lane for Reservation Entry Only

Two: Only one Lane

Strategy One and Two

- Total Revenue: 1483$ 1503$
- Average Queue Time: 38.32 53.48
- Rejected Demand (long queue): 25 28
- Average Occupancy: 62.1% 61.3%

- More reservations➡ less normal spots and “protected” reservation spots ➡ bigger queues
- One gate: people who reserve still have to stay in line
- Two gates: yield good revenue and occupancy and decreases queues

RESULTS AND DISCUSSION - DYNAMIC PRICE STRATEGY

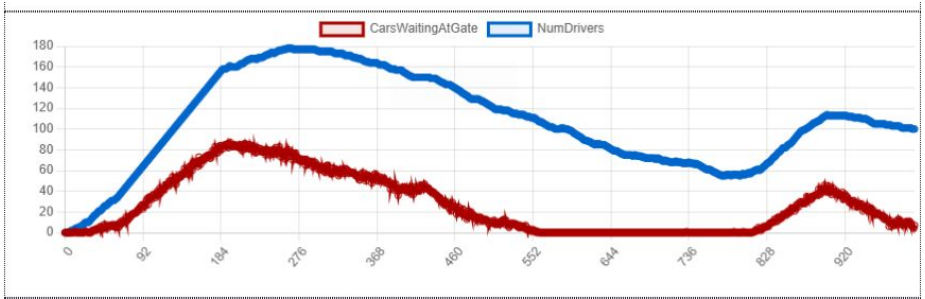
One: Low prices increases demand slightly

Two: Low prices increases demand significantly

Strategy One and Two

- Total Revenue: 1275$ 1510$
- Average Queue Time: 140.36 137.94
- Rejected Demand (long queue): 69 (price) + 23 (queue) 55 (price) + 27 (queue)
- Average Occupancy: 59.0% 64.1%

Two



- Only worth it if low prices can increase demand significantly
- More attractive prices when occupancy is low ➡ more demand ➡ higher occupancy rate
- Extremely high queue times and rejected demand may discourage future use by clients
- Higher revenue for second strategy but relies on attracting much bigger demand

RESULTS AND DISCUSSION

Revenue does not correlate linearly with occupancy. Highest occupancy occurs under dynamic pricing (Two), but static pricing achieves **competitive revenue** with much **lower congestion** ➡ maximizing occupancy alone is not an optimal objective

Reservation must be coupled with **separate access lanes** rules to be effective, which is often difficult to do in real-life

Demand elasticity is the **critical factor** for dynamic pricing success

Dynamic pricing and reservation strategies **increase waiting times** ➡ infrastructure changes that allow queue-aware admission are paramount

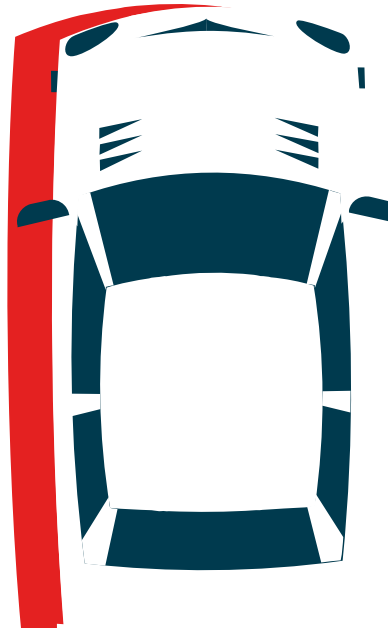
CONCLUSIONS & FUTURE WORK

Conclusions

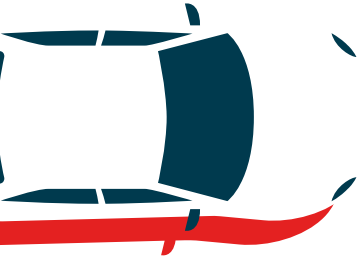
- Static pricing offers the **best trade-offs** between revenue and congestion, although **other strategies can outperform it** in pure revenue and occupancy rate
- All strategies are constrained by a single entry bottleneck, limiting policy-only solutions

Future Work

- Evaluate **infrastructure layouts** such as multiple gates or priority access
- Extend demand modelling with **learning or memory effects** (users reacting to past congestion)
- Calibrate **willingness-to-pay** and **arrival patterns** using real-world data



THANK YOU!



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