University of Illinois Facilities and Services
March 16, 2020

Crowd Management for Quad Day

Weichen Li
PhD Student

Ruifeng She
PhD Student

Xiaojia Shelly Zhang
Assistant Professor

Yanfeng Ouyang
George Krambles Professor

Civil and Environmental Engineering
University of Illinois

Project topic

Event: Quad Day

Planning phase: Spring 2020

Event date: September 2020

Topic: Traffic measurement, estimation, planning, and control for special events

Continuous Traffic Equilibrium

Entering and Exiting Flux

Bounded area with entering and exiting fluxes at given boundaries

- Given entering flux
- Unknown exiting flux

It can be proved that the equilibrium flux $\mathbf{f}(x)$ and cost $u(x)$ are described by the following PDE

$$\nabla \cdot \mathbf{f}(x) = 0, \quad x \in S,$$

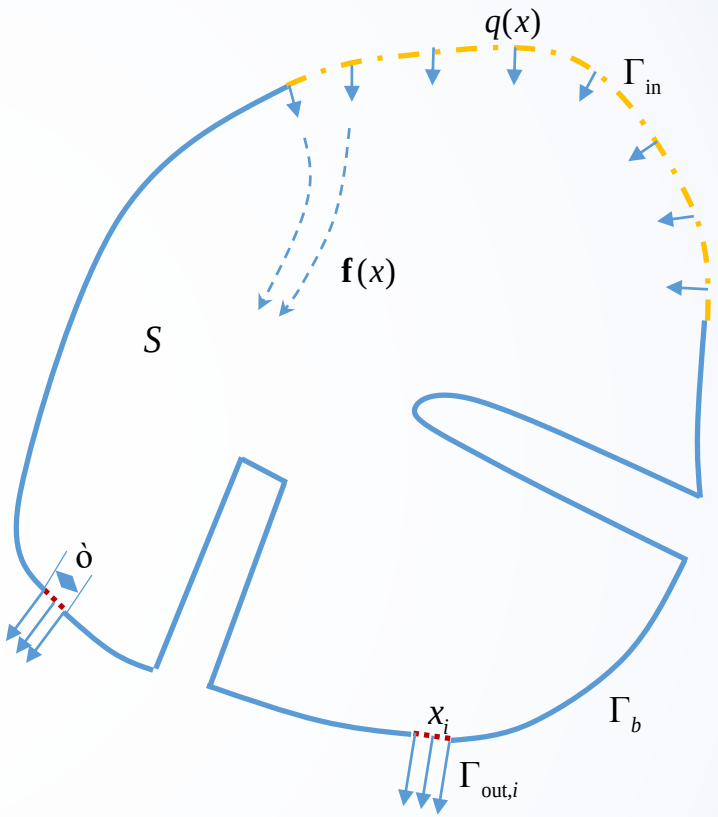
$$c(x, \mathbf{f}(x)) \frac{\mathbf{f}(x)}{|\mathbf{f}(x)|} = -\nabla u(x), \quad x \in S,$$

$$\mathbf{f}(x) \cdot \mathbf{n}_x = q(x), \quad x \in \Gamma_{\text{in}},$$

$$\mathbf{f}(x) \cdot \mathbf{n}_x = 0, \quad x \in \Gamma_b,$$

$$u(x) = C_i(Q_i), \quad x \in \Gamma_{\text{out},i}, 1 \le i \le M,$$

$$\int_{\Gamma_{\text{out},i}} \mathbf{f}(x) \cdot \mathbf{n}_x \, dx + Q_i = 0, \quad 1 \le i \le M,$$



Hughes (2003), Huang et al. (2009)

Optimization Formulation

Objective

$$\min_{\alpha} \quad J = \beta \cdot J_R(\alpha) + (1-\beta) \cdot J_T(\alpha)$$

Road construction cost

transportation cost

Constraints

$$\text{s.t.} \quad g = \max(\rho) - \bar{\rho} \leq 0$$

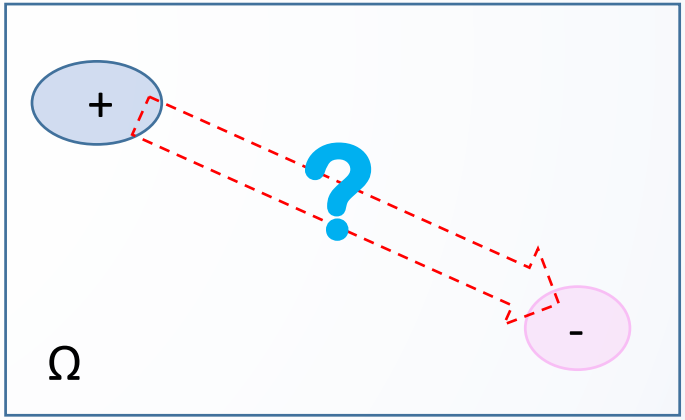
→ Maximum density constraint

$$\underline{\alpha} \leq \alpha \leq 1$$

State equations

$$\text{with} \quad \rho \boldsymbol{u} = -\kappa \nabla \phi$$

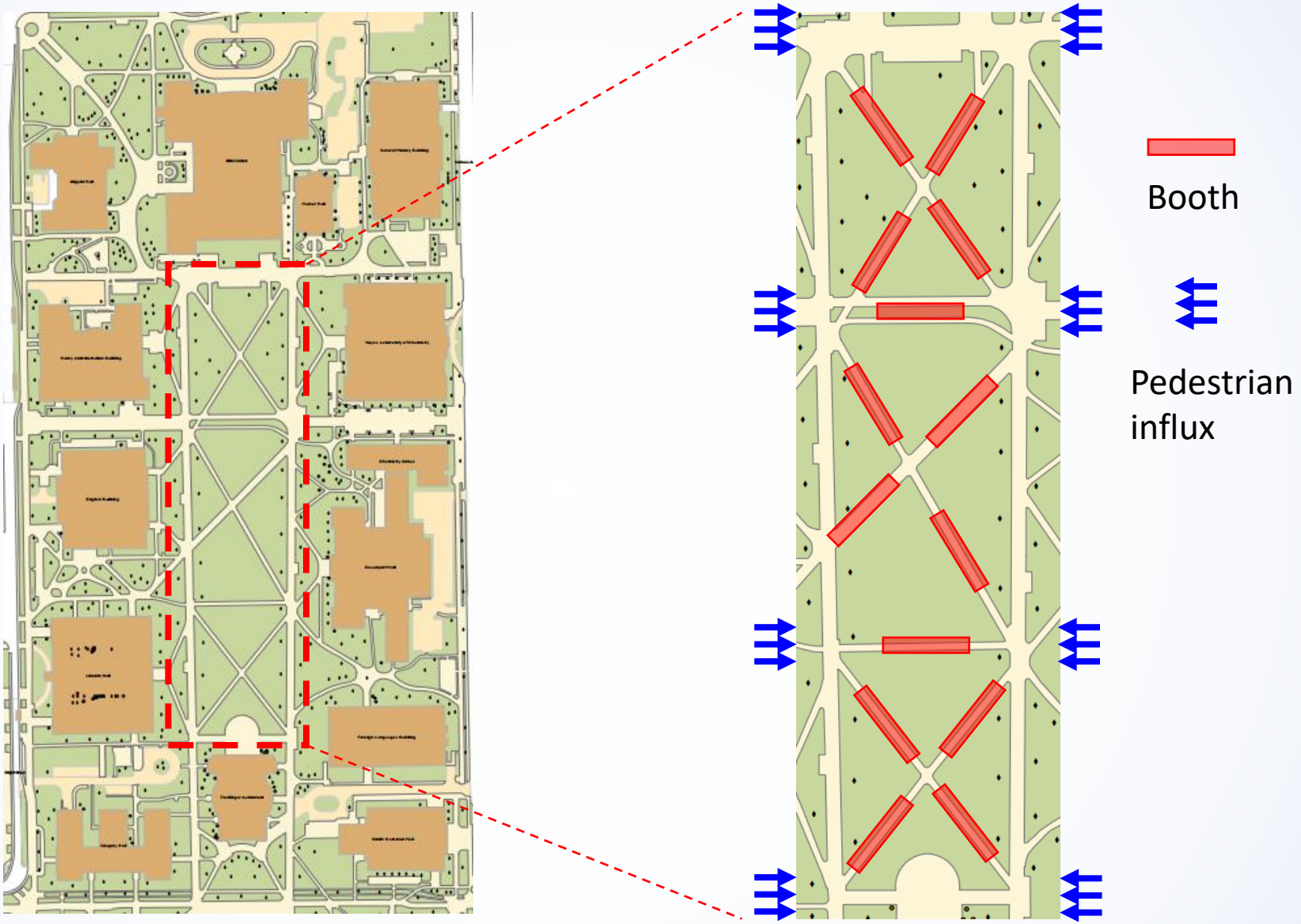
$$-\text{div}(\kappa \nabla \phi) = q$$



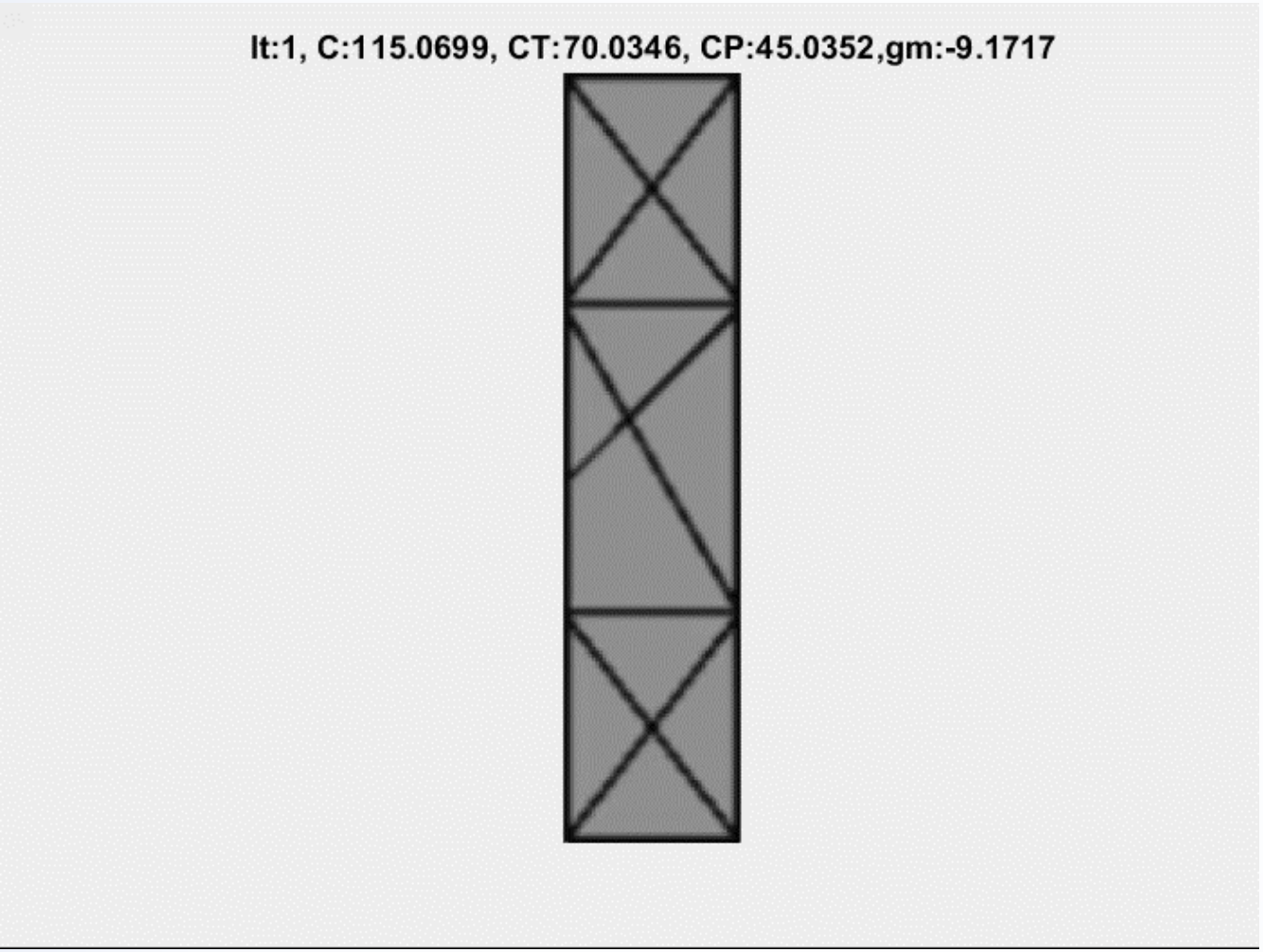
- **Pavement optimization**
- **Barrier distribution**

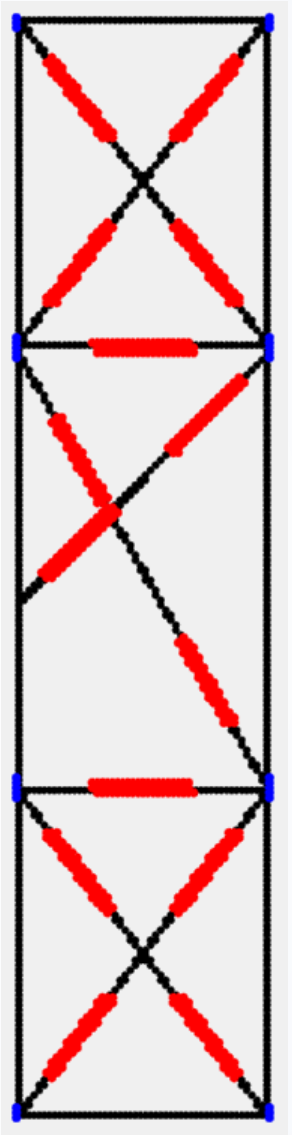
Pavement Upgrade Design Optimization for Quad Day (Macroscopic)

Quad Day Layout



Modeling and optimization



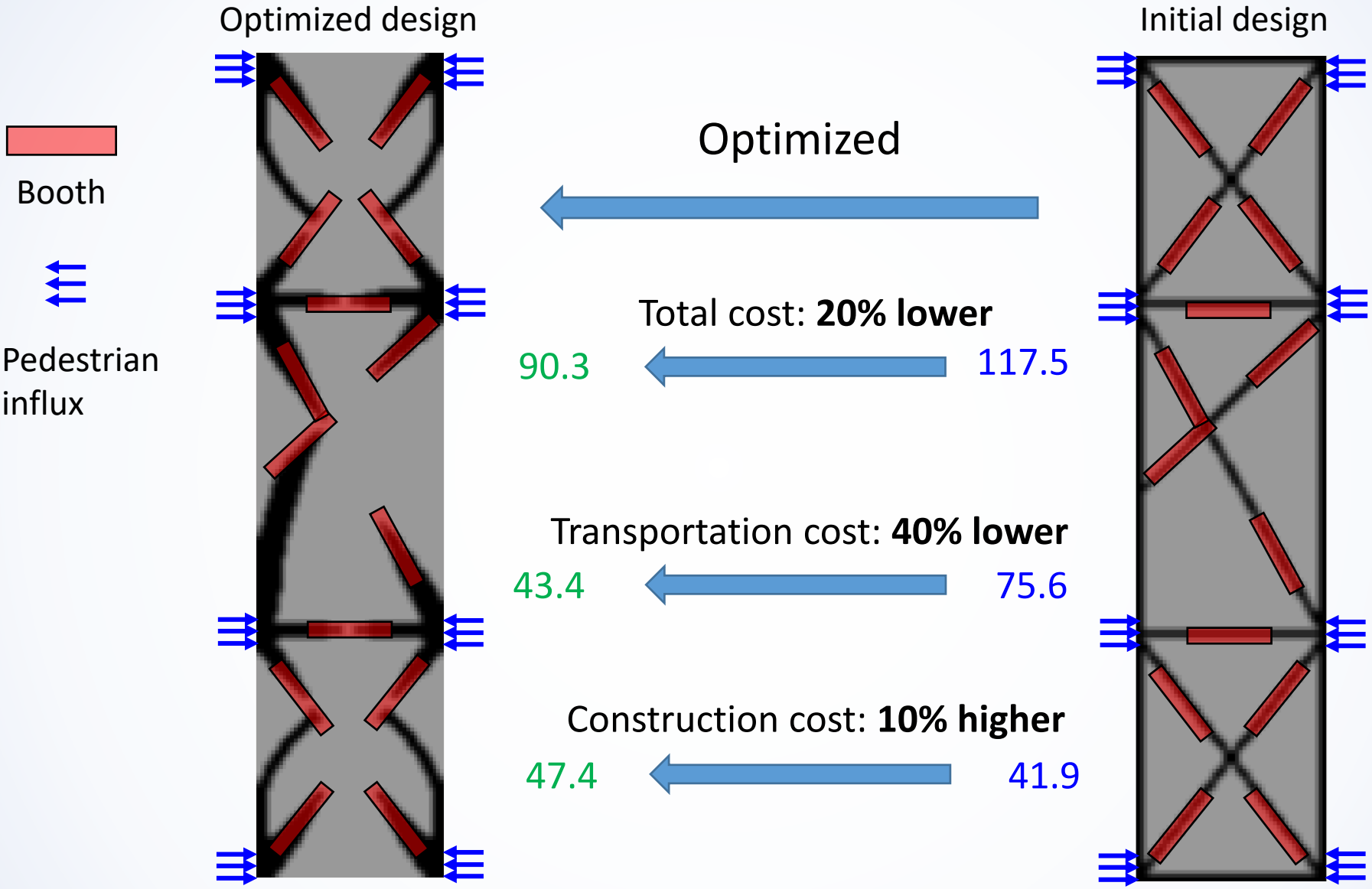


Booth

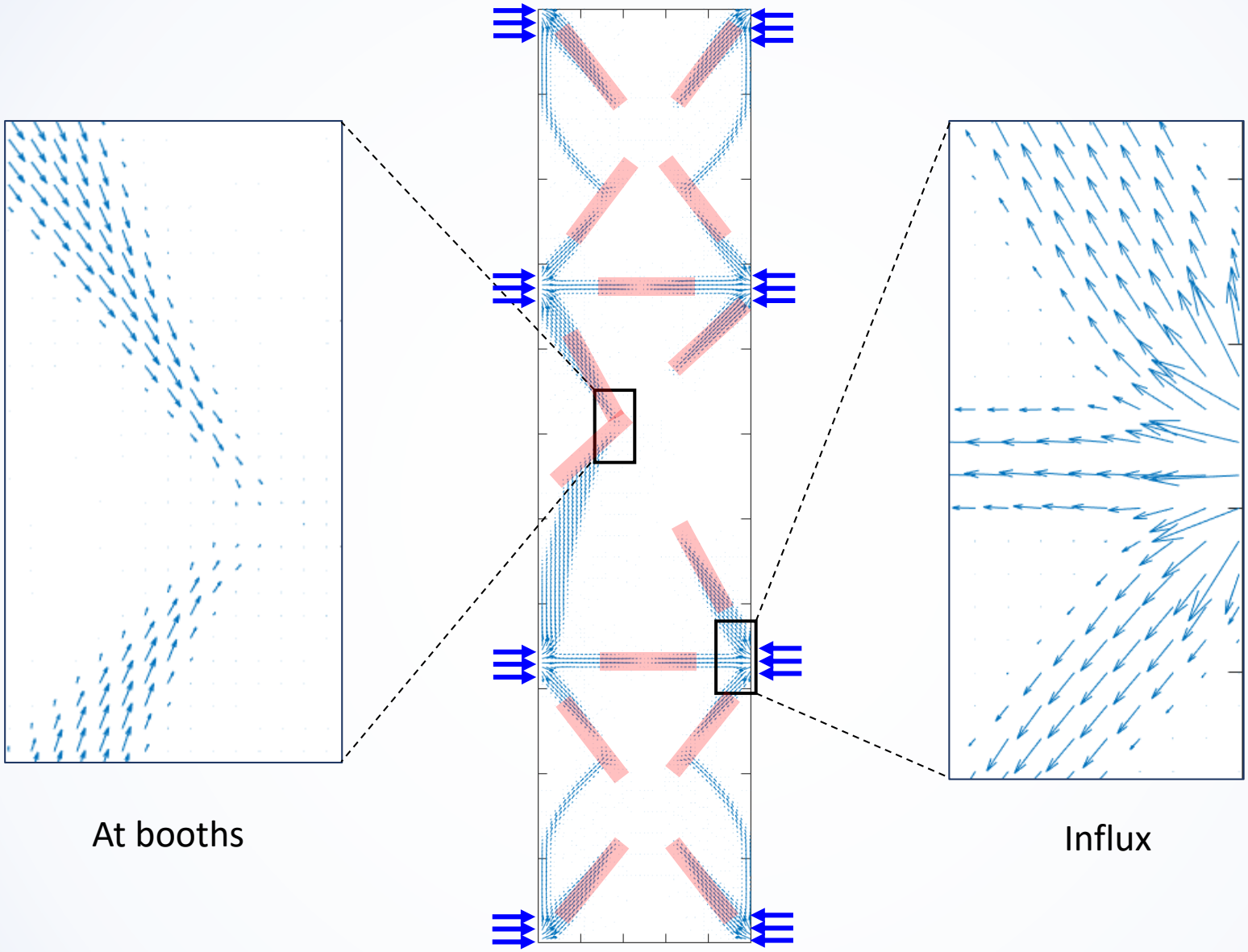
Pedestrian influx

Existing pavements

Cost reduction



Pedestrian flow on the optimized pavement

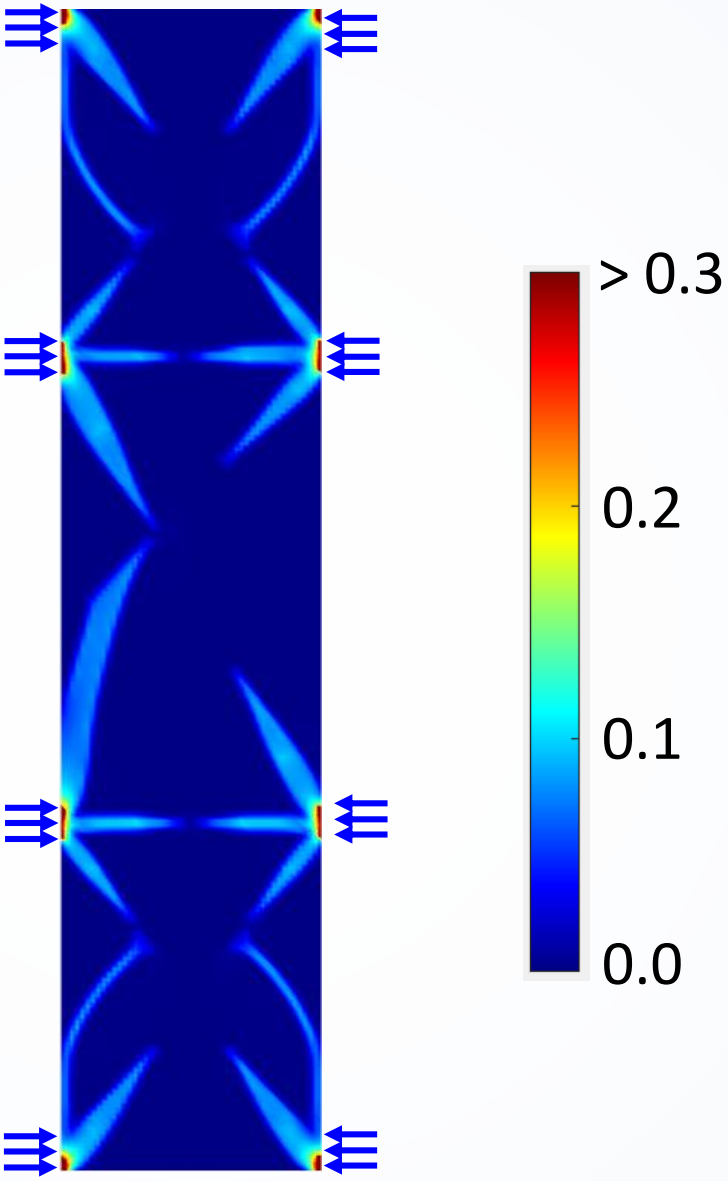


At booths

Influx

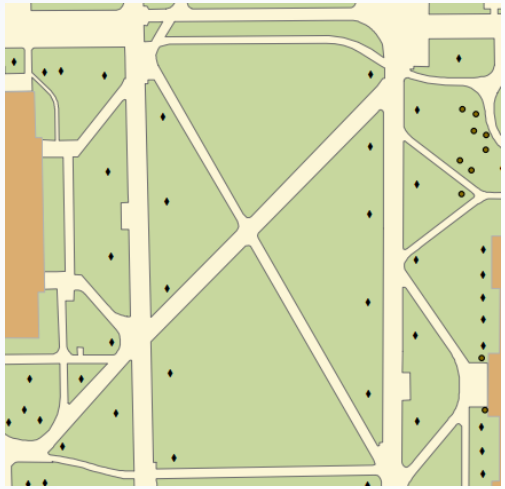
Pedestrian density (persons / sq ft)

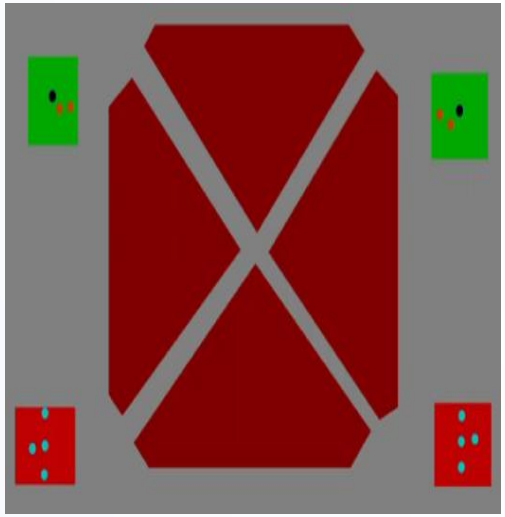
Total influx:
50 persons / s



Simulation on Quad Layout Alternation (Microscopic)

Illustration on layout alteration





It WILL be crowded:

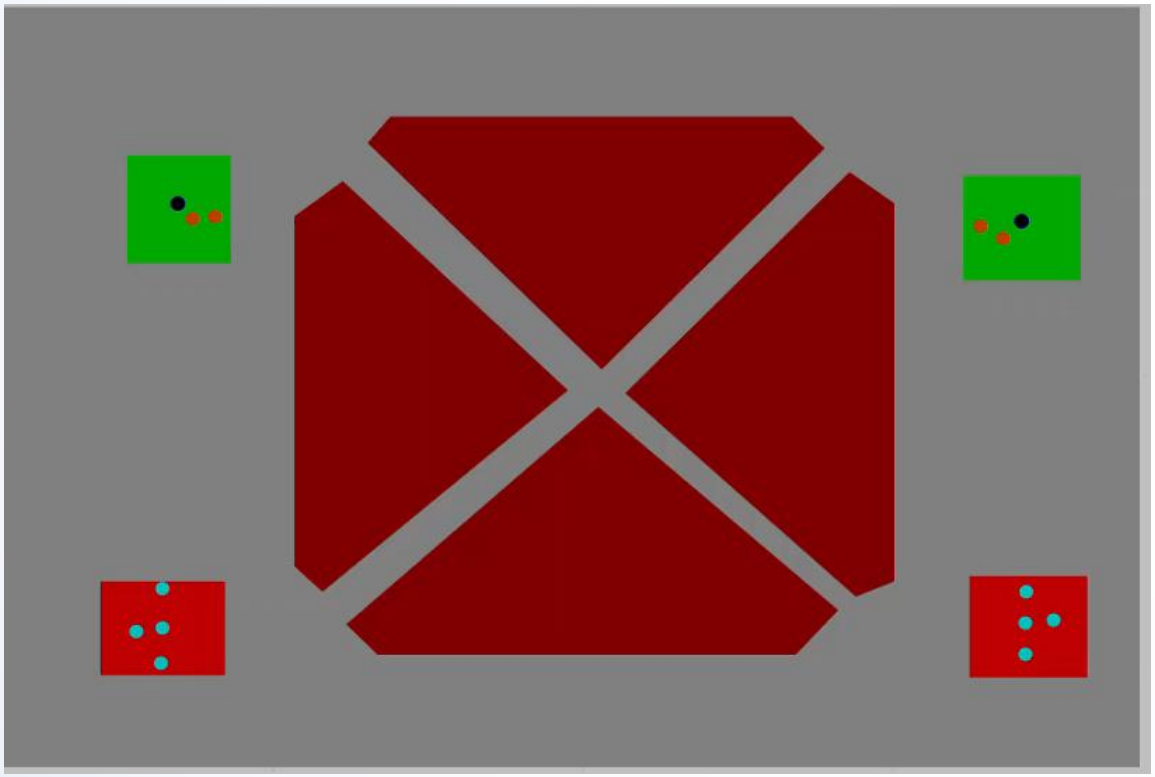
- Intersections – bottleneck with counterflow
- Multiple access/exit points
- Walkway narrowed when booths are present

Simulation

- Pedestrians generated at sources (green) and destinations at sinks (red)
- Continuous inflow of 2 pedestrians per second per source
- Walkway width about 2 m
- Free-flow speed of 2 m/s (for adult male; the crowd consists of adults, teenagers, children, etc.)
- Route decision at entrance by fixed ratio (2/3 shortest path, 1/3 willing to detour)

Illustration on layout alteration

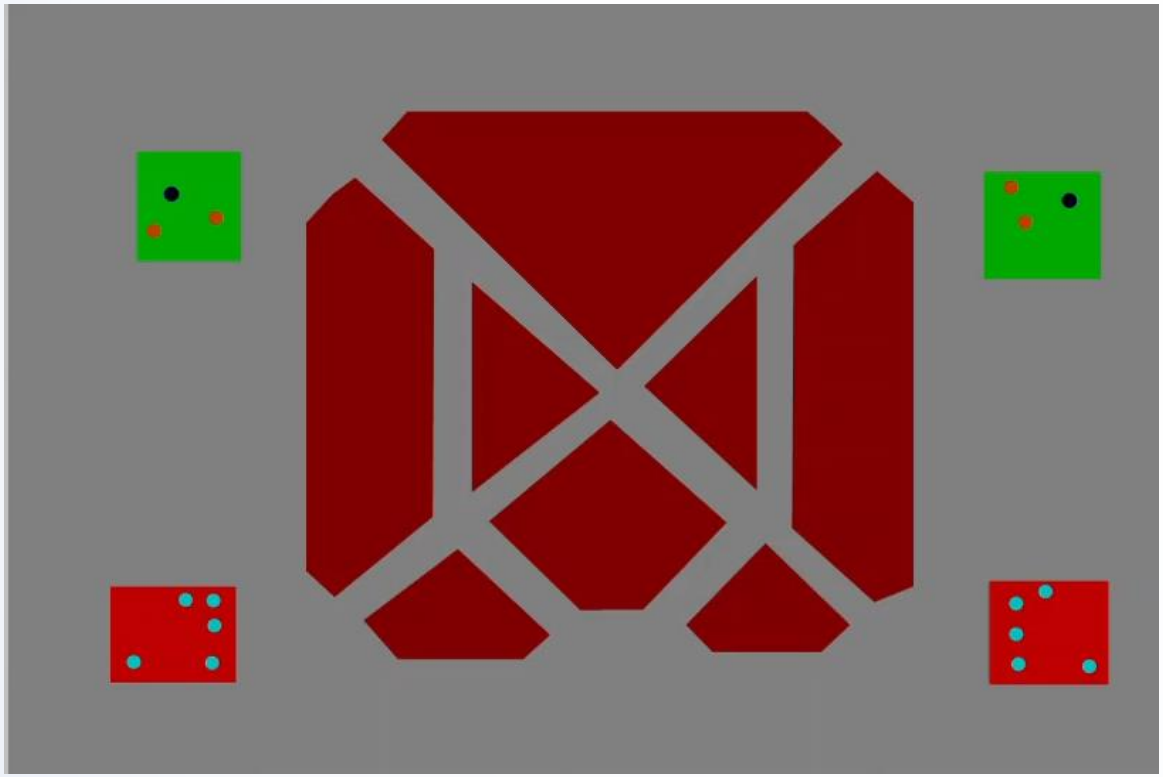
Do-nothing



- Gridlock occurs at intersection
- Queues propagate backwards
- In reality, the case is more severe with reduced link capacity while students linger around booths

Illustration on layout alteration

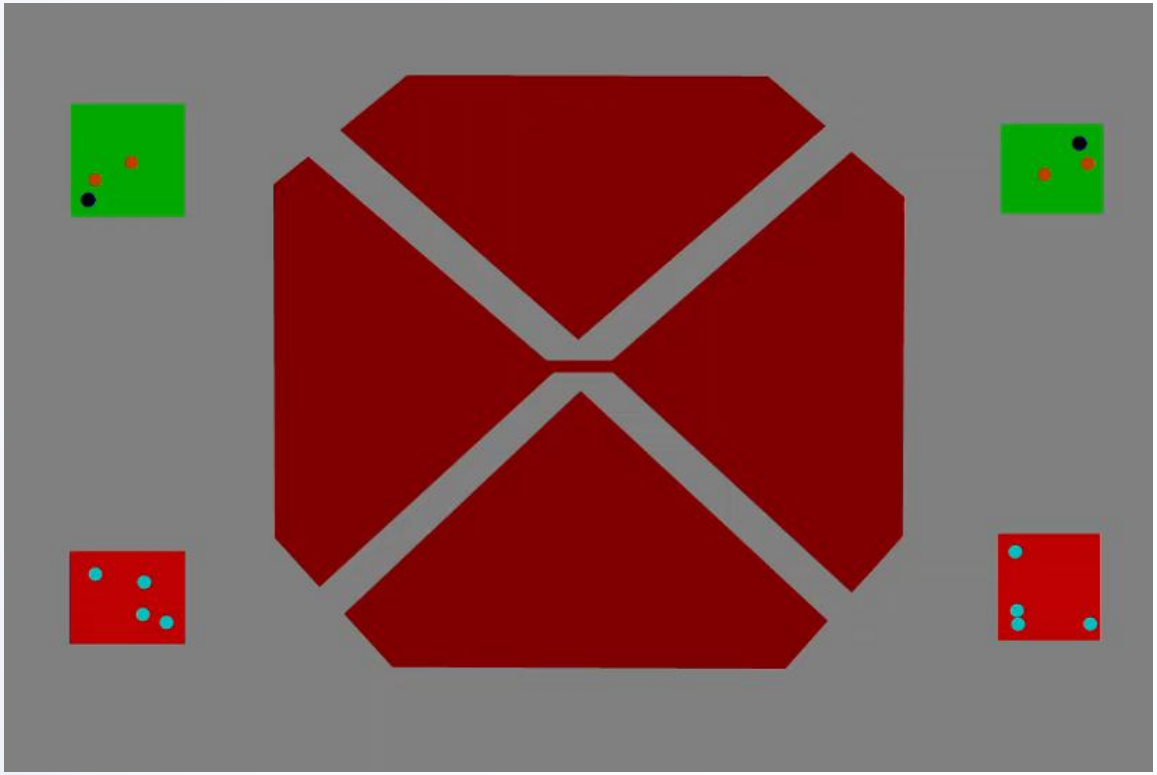
Add Paths



- Adding some walkable paths provides pedestrians with options to detour around bottlenecks.
- It ‘spreads out’ flow concentration.

Illustration on layout alteration

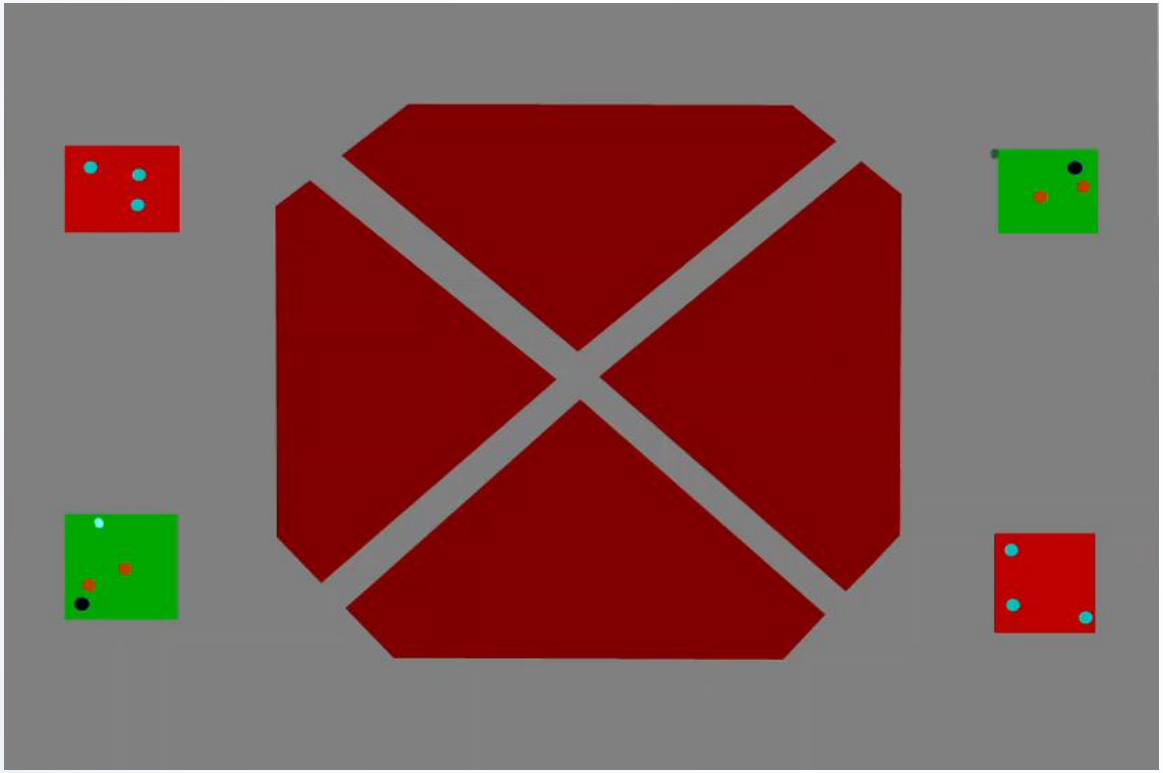
Add Barriers



- Barriers cut some of the pedestrians' desired paths.
- Carefully placed barriers redirect a portion of the crowds, avoiding gridlock at the cost of longer travel distance.

Illustration on layout alteration

Re-organize Origin/Destination



- Suppose the location of entrances, exits and booths can be holistically designed, and the pedestrians are provided with such information.
- The origin-destination decisions may be regulated, such that counterflow is reduced or avoided.
- Pedestrian distance traveled can be reduced beforehand.

Illustration on layout alteration

Performance statistics

Case	Maximum density $(\#\ \mathrm{ped}/m^2)$	Maximum queue length $(\#\ \mathrm{ped})$	Average speed (m/s)	Evacuation time - 60s input (s) Delay (Abs)
Do-nothing	4 (max)	>30	0.13	>600 (>600)
Add Paths	3.65	7	1.59	52.3 (179.0)
Add Barriers	3.82	2	1.52	60.7 (187.4)
Reorganized O-D	3.21	0	1.78	0 (126.7)

- More options for us to consider:
  - Enforce one-way traffic via channels
  - Inflow management
  - Others?

Questions

Questions

- What adjustment to the Main Quad is feasible?
  1. Putting new temporary pavements?
  2. Adding Barriers/guiding facilities?
  3. Moving some booths to the lawn?
  4. Managing incoming traffic?

- Which booths have more/less weight?