Walking on the side: a very concrete problem

People are increasingly attracted to walkable neighborhoods, but there is no *walkability* without high quality sidewalks. Typically made as a sequence of concrete slabs, sidewalks are often damaged by tree roots growth, repeated freezing & thawing of the ground, other soil erosion processes (e.g., "settling" when dead roots decay), or excessive weight loads. The City of Ithaca already maintains a successful and active Sidewalk Improvement Program, but your team's recommendations might be used to enhance it further.

Please choose any 3 of the 4 subproblems listed below. In addition to your detailed manuscript, please write a one-page executive summary of your results for Mr. John Licitra, The City of Ithaca Sidewalk Program Manager. Please be careful in outlining the assumptions and limitations of your model. Remember that policymakers may not be aware (and often don't need to be aware) of all the technical details, but should have enough information about the amount of uncertainty in the model before using it to make any policy decisions.

A) Priority score for blocks: The City has a limited budget (roughly $865K/year) for all sidewalk-related activities (surveys, repairs, & new construction). This is certainly insufficient to cover all the needs and makes it necessary to prioritize based on (a) population density; (b) proximity to schools, bus stops, governmental buildings; (c) number of complaints; (d) and the physical condition of concrete slabs. The latter is periodically evaluated based on several requirements, including those needed to comply with the Americans with Disabilities Act (ADA)*. In particular, (1) the slabs should not be broken; (2) each slab should be at least 4 feet wide; (3) the vertical displacement at the interface between adjacent slabs should never exceed ½ inch; (4) the *running* slope (i.e., in the direction parallel to the road) of every slab should not differ from the slope of the road by more than 2%; (5) the *cross* slope (i.e., in the direction perpendicular to the road) of each slab should be at least 1% (to allow for drainage) and at most 2% (to comply with the ADA).

The city already has an algorithm for computing a priority score for *each city block*, but they will be glad to consider your ideas for improving it. The current version uses an ad hoc formula based on (a)-(c) **and** the degree of non-compliance to (1)-(5) maximized over all slabs within that block. Your version should consider possible trade-offs involved in balancing these criteria.

B) Optimal contracts: Currently, the highest priority blocks are selected each year and repaired by a contractor who wins the public bidding process. A construction crew costs about $400/hour and can handle on average 275 linear feet of sidewalk per week. However, moving equipment to a faraway site takes about 4 hours, causes additional traffic complications, and each transition adds approximately $1,000 to costs. To reduce this transition cost, can you suggest an algorithm for prioritizing *groups of nearby blocks* that will be handled by the same contractor?

* Availability of ADA-compliant curb & sidewalk ramps is another important consideration. But to simplify the problem, we ask you to assume that all ramps are already present and don't require any repairs.

C) Optimal repair procedures: Slabs, which are not broken but violate (3)-(5), might be repaired instead of replaced. The two basic repair procedures are *raising* and *cutting.* *Raising* changes the slope & position of the entire slab; it costs on average $5.13 per square foot of the slab. *Cutting* involves removing a top slice of the slab, making its new surface have a different slope and elevation. This procedure costs on average $16 per linear foot of the slab, but it is only usable when removing at most 2 inches. Replacing a full slab costs on average $22 per square foot. Suggest an algorithm that takes as input the position & slope of all slabs on a block and finds the optimal repair strategy – minimizing the cost while ensuring compliance with the above requirements.

D) Projecting future needs: The Sidewalk Improvement Program is funded by the fees paid by property owners in the City of Ithaca. When the Sidewalk Program started 5 years ago, it was initially focused on a backlog of truly urgent repairs unaddressed in previous years. The hope was that it would soon move to the next stage, with fees paid by property owners covering both the regular maintenance/repairs and the construction of new sidewalks. But the effectiveness of the program is slowly decreasing due to its rising costs and flat revenues. Two more circumstances will exacerbate this in the future. First, the growing total length of sidewalks in the city will eventually result in a larger number of slabs that need to be repaired every year. Second, the increasing variability of the climate might also increase the average number of "ground freezing & then thawing" episodes per winter season, resulting in a higher chance of heaving/cracking for concrete slabs.

To keep this program effective, its budget will need to grow over time. Your team is asked to project these budget increases over the next 25 years.