### Walking on the side: a very concrete problem

### 走在一边：一个非常具体的问题

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.

人们越来越喜欢步行的社区，但是没有高质量的人行道就没有步行能力。 人行道通常由一系列混凝土板制成，经常因树根生长，地面反复冻融，其他土壤侵蚀过程（例如死根腐烂而“沉降”）或过重的重量而受损。 伊萨卡市已经维持了成功且积极的人行道改善计划，但是您团队的建议可能会被用来进一步完善它。

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.

请从下面列出的4个子问题中选择3个。 除了详细的稿件外，请为伊萨卡市人行道项目经理John Licitra先生写一份一页的摘要，以总结您的研究结果。 在概述模型的假设和限制时，请小心。 请记住，政策制定者可能不知道（通常不需要知道）所有技术细节，但是在使用模型做出任何政策决定之前，应该掌握有关模型中不确定性程度的足够信息。

1. **Priority score for blocks:** The City has a limited budget (roughly $865K/year) for all sidewalkrelated activities (surveys, repairs, & new construction). This is certainly insufficient to cover all the needs and makes it necessary to prioritize based on
2. population density;
3. proximity to schools, bus stops, governmental buildings;
4. number of complaints;
5. 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.

1. 街区的优先级评分：纽约市对于所有与人行道有关的活动（调查，维修和新建）的预算有限（大约$ 865K /年）。这肯定不足以满足所有需求，因此有必要根据以下因素确定优先次序：
2. 人口密度；
3. 靠近学校，巴士站，政府大楼；
4. 投诉数目；
5. 混凝土板的物理状况。会根据几项要求定期评估后者，包括满足《美国残障人士法案》（ADA）\*的要求。特别是：
6. 平板不应破碎；
7. 每块平板至少应宽4英尺；
8. 相邻平板之间的界面处的垂直位移不得超过½英寸；
9. 每块平板的行驶坡度（即平行于道路的方向）与道路坡度的偏差不应超过2％；
10. 每块楼板的交叉坡度（即垂直于道路的方向）应至少为1％（允许排水），最大为2％（符合ADA）。

该城市已经有一种算法可以计算每个城市街区的优先级分数，但是他们会很高兴考虑您的想法以进行改进。当前版本使用基于（a）-（c）的特设公式，并且对该块内所有楼板的最大不符合（1）-（5）程度。您的版本应考虑平衡这些标准时可能要进行的取舍。

**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.

B）最优合同：目前，每年都会选择最高优先级的块，并由赢得公开招标过程的承包商进行维修。 一名施工人员每小时的费用约为400美元，平均每周可处理275线性英尺的人行道。 但是，将设备移至遥远的站点大约需要4个小时，这会带来额外的交通复杂性，每次过渡都会增加大约1000美元的成本。 为了减少这种转换成本，您能否建议一种算法，以优先处理将由同一承包商处理的附近街区组？

\*符合ADA的路缘和人行道坡道的可用性是另一个重要考虑因素。 但是为简化问题，我们要求您假设所有坡道均已存在并且不需要任何维修。

**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.

C）最佳维修程序：未损坏但违反（3）-（5）的平板可能需要维修而不是更换。 两种基本的修理程序是起毛和割毛。 升高会改变整个平板的坡度和位置； 它的平均成本为每平方英尺平板$ 5.13。 切割涉及去除平板的顶部切片，使其新表面具有不同的坡度和高度。 此过程的平均成本为每线性英尺平板16美元，但仅在移除最多2英寸时可用。 更换一块完整的平板平均每平方英尺需要22美元。 建议一种算法，该算法将块上所有板的位置和坡度作为输入，并找到最佳的修复策略-在确保满足上述要求的同时，将成本降至最低。

**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.

D）预测未来需求：人行道改善计划由伊萨卡市业主支付的费用提供资金。 人行道计划5年前开始时，最初的重点是积压前几年未解决的真正紧急维修问题。 希望它能很快进入下一阶段，业主支付的费用既包括常规维护/修理费用，也包括新人行道的建造费用。 但是，由于成本上升和收入稳定，该计划的有效性正在逐渐下降。 将来还有另外两种情况会加剧这种情况。 首先，城市中人行道的总长度不断增加，最终将导致每年需要维修的平板数量增加。 其次，气候变化性的增加也可能增加每个冬季的“地面冻结然后解冻”的平均次数，从而导致混凝土板起伏/开裂的机会增加。

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.

为了保持该计划的有效性，其预算将需要随着时间的推移而增长。 要求您的团队预测未来25年的预算增长。