Problem A   Sand transport in water flow

Sediment deposition is one of the most important problems that the designer of reservoirs try to solve in their engineering practice. The amount of reservation of the reservoir with heavy sediment deposition will decrease till the efficient storage capacity is full filled with the deposited sediment, which makes the reservoir loss its function.

In order to investigate the mechanism of sediment transportation, a trail is conducted in laboratory, and the result is recorded in an video, which is given in an attachment file （videoplayback.mp4）. In this video, we can find the speed of sediment transportation is related to the velocity of the water flow, the level difference between the upstream and downstream, and the height of the obstacle.

Please construct your mathematical model to answer the following questions:

(1) Modelling the relationship between the velocity of sand transportation and the depth of the water flow, the velocity of the current over and through the bed of sand;

(2) Find the minimal depth of the water and the minimal velocity of the current flow over the bed of sand;

(3) Find the equilibrium between sand transportation velocity and the depth and the velocity of the water flow, which make the sand transportation at a stable velocity;

(4) Make a simulation with your model and provide the resulted video to describe the equilibrium state of the sand transportation system similar to the video provided in this project.

Problem B   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 (https://storymaps.arcgis.com/stories/4df2b76ade6a4171a5ccbed80bf47ceb), 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 (Sidewalk Design Criteria), 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?

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 (see: SID_memo.pdf) . 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.

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* 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.

Problem C   The impact of the use of electronic RMB

Digital Currency /Electronic Payment (DC/EP), issued by the People's Bank of China, has been piloted in many parts of the country. In the future, more enterprises and individuals at home and abroad will use Electronic RMB. Please build some models and answer the following questions:

（1） The use of electronic RMB can reduce the operating cost of cash and reduce the spread of diseases. Please establish some mathematical models to calculate the income from the above two aspects.

（2）   The use of electronic RMB by the Central bank requires certain equipment support and cultivation of users' usage habits. Considering the acceptance level of users, please establish a mathematical model to predict the issuing speed of electronic RMB.

（3）   The electronic currency of the central bank can achieve controllable anonymity, ensuring the anonymity of both parties and anti-money laundering, anti-terrorist financing and anti-tax evasion. Please analyze the impact of the use of e-RMB on the growth of national fiscal revenue.

Establish a model to analyze the impact of electronic RMB on the acceleration of RMB internationalization and foreign trade settlement.

Problem D   Control of COVID-19 and Economic Development

It has been nearly a year since the outbreak of COVID-19, and there is still no sign of being controlled throughout the world. So far, people have found that the most effective means is still the traditional isolation measures. However, isolation has a huge impact on people's lives, and has also greatly affected the economic development of various countries. According to the economic data released by the United Nations, all countries have fallen into different degrees of economic recession.

The development of the new outbreak has also aroused the enthusiasm of scientists all over the world for virus transmission and control research, and further extended to economic, social and even political aspects. Some scholars have studied the economic impact of virus transmission and control.

Please build a mathematical model based on the public dissemination of information and economic information (other necessary information is also encouraged), and discuss the following issues:

(1) What is the relationship between the severity of the epidemic and the economic recession in different countries? Please select at least 20 countries and explain the

correctness of your conclusion.

(2) Different industries are affected by the epidemic situation because of the differences in production and experience. Please select different industries to establish models and draw your conclusions.

(3) Write a short article to explain the relationship between the epidemic situation and economic development as well as industry development, so as to provide advices for the future behavior of people and governments.

Problem E: Spread and Development of Metropolitan Areas

After the Second World War, American metropolitan areas developed rapidly. One of the important characteristics of American metropolitan areas is the low-density sprawl of suburbs. The traditional view is that the suburbs are the best place to raise a family and can provide people with a clean and healthy living place. However, with the disorderly spread of metropolitan areas, the suburbs have not only failed to provide people with a healthy lifestyle, but have produced a series of environmental, social and economic problems. Your task is to choose a major U.S. city as the object, find the data yourself, and analyze the following subproblems:

(1) What is the increase in private cars brought about by the development of the metropolitan area of the city?

(2) What are the adverse effects of the development of the metropolitan area of the city on the health of citizens? If calculated in U.S. dollars, how much loss would it cause?

(3) What are the development prospects of the city's metropolitan area in the next five years?

(4) What impact does the development of the metropolitan area of the city have on farmland protection and food security?

(5) Based on the above research, make your suggestions.