Heinz College Policy Innovation Lab

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Project Partner: **North Huntingdon Township, PA**
Project Title: **Landslide Mitigation and Prediction Study**

Project Overview

Landslide risk, frequency, and impact in Southwestern Pennsylvania is worsening. As annual precipitation hits record levels, the growing prevalence of landslides threatens personal property, businesses, and roadways, costing millions of dollars annually in road repairs and other damages.

This project, conducted through Carnegie Mellon University's Fall 2019 Policy Innovation Lab course, endeavored to understand the factors influencing the probability of new landslides in order to advise North Huntingdon Township (NHT) on landslide risk mitigation strategies. The project's output includes two sets of recommendations to the Township—one concerning data collection, sharing, and analysis, the other concerning policy interventions—though much research remains to be completed in future groups' efforts to address this problem.

Summary of Findings

Through background research and stakeholder interviews, the team found that many excellent and innovative efforts to predict or monitor landslides are already underway by experts in the region. This report's recommendations center around (A) better collaboration with those experts so that NHT can benefit from their work and (B) actions and options for better use of data and policy intervention. Highlights of the team's recommendations follow and are explored in greater detail later in this report:

Data Collection

- *Leverage creative data collection opportunities*, such as residential reporting or data mining with engineering reports required from land developers.
- *Use government capacity to obtain and publish datasets* useful for landslide prediction.

Data Sharing

- *Adopt open data principles* for data collection so that staff or external partners are able to easily access and create value from existing data resources.
- *Partner with the Western Pennsylvania Regional Data Center* to tap the existing network of researchers, students, and community members using public data to find innovative solutions.

Policy Intervention

- *Update NHT Subdivision and Land Development Ordinances* (SALDO's) to include additional slope classifications for more adaptive and preventative policy.
- *Convene a landslide advisory group* to engage expertise and resources from across the region in an effort to address landslides in NHT.

- *Establish explicit maintenance priority classifications* to codify levels of response and resource allocation for different degrees of landslide threat or damage.

In addition to the recommendations above, the team has assembled a collection of research and policy resources at the following linked web page. These may be useful to staff or other professionals seeking specific expertise, model ordinances, GIS data, or various insights from this team's research efforts.

Methodology

The project team undertook preliminary research in three phases:

1) **Review of research** and other literature concerning landslides in southwestern Pennsylvania, SALDO/Steep Slope ordinances in NHT and other model municipalities, and other regional efforts to model landslide risk

2) **Exploration of data resources**, including a review of information assets NHT already has access to, a survey of publicly available GIS data useful for landslide risk modeling, and investigation of emerging technologies that may provide innovative opportunities to predict future landslides

3) **"User research"** in the form of in-person or phone interviews with experts, researchers, and other stakeholders whose perspectives could inform policy concerns and opportunities for NHT with regard to landslide prevention and mitigation.

Literature Review

INTEGRATED APPROACH:

Landslides refer to "the failure and movement of a mass of rock, sediment, soil or artificial fill, under the influence of gravity" (Clague, 2013). The ever-increasing incidence of landslides and the associated costs are nudging governments to adopt a proactive approach towards this problem. A proactive approach in the context of landslides not only offers huge costs incentives but also saves lives. The integrated approach to tackle landslides demands a better understanding of the phenomenon and the triggering factors (Martin, 2014).

The integrated approach (Fig.1) to tackle landslides stems from the fact that landslides are an immensely complicated phenomenon, triggered by hard-to-control natural exogenous factors such as rainfall and underlying soil beds. Thus, due to the unpredictable nature of landslides, it is essential to adopt an integrated approach to address both the preventive and the response side of the disaster, apart from successful prediction.

PREDICTION:

Some organizations such as the Norwegian University of Science and Technology in a 2017 study have delved deeper into the question of predicting landslides and how to go about it.

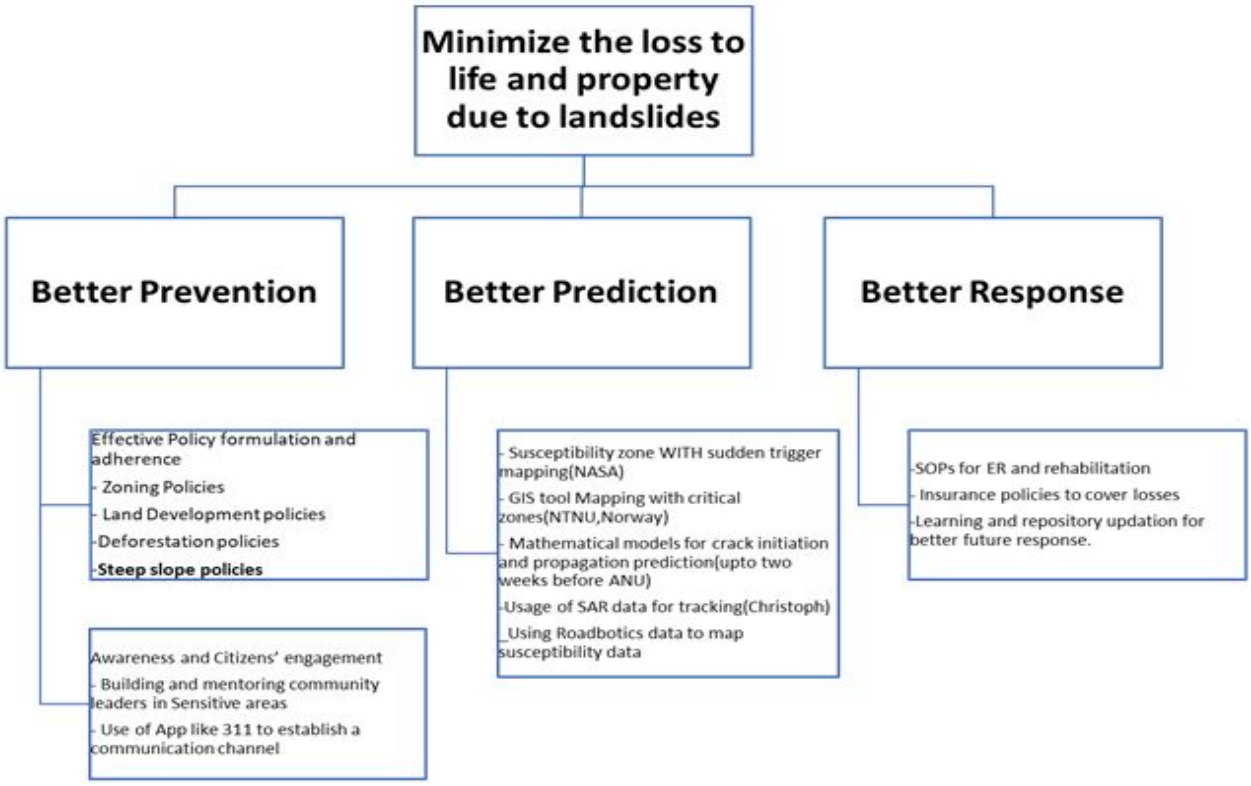


Fig.1: An integrated approach for landslide mitigation

There are several technologies available to predict the landslides; for example, Zhao (Lu, 2018) has identified the following techniques for landslide detection, including inventory mapping, surface deformation monitoring, trigger factor analysis, and mechanisms for inversion.

Another recent development in the prediction of landslides comes from NASA. NASA's Landslide Hazard Assessment for Situational Awareness (LHASA) model (NASA, 2018), with the help of advanced technology, maps areas of unusually high precipitation with regional susceptibility maps. This imposition allows identification of areas with higher likelihood of landslides with an unusual trigger, in this case rain. Some researchers (Tordesillas, 2018) have claimed to be able to predict the landslides as much as two weeks before it actually happens (Matchar, 2018).

PREVENTION:

In order to successfully tackle landslides, an important aspect in addition to prediction is prevention. The steep slope ordinance by counties plays an important role in prevention. The "Steep Slopes" section of the Subdivision and Land Development Ordinance (SALDO) enforces the set of regulation for developmental work in the areas designated as steep slope.

Study of the SALDO used in North Huntingdon Township and six top-performing counties demonstrates that there is a scope to further strengthen the NHT SALDO. The policy recommendations section summarizes the findings of this comparative study, and Appendix 5 provides a user-friendly chart of comparative practices.

User Research

In order to better understand the problem from the perspectives of those affected by (or invested in addressing) landslides, the group conducted interviews with various experts and stakeholders. Interviews followed the guidelines and goals established in the team's user research planning document, and key insights from each interview are included below.

(Interviewee names are omitted to maintain privacy. However, their organization names are included, should reviewers of this report wish to follow up with any listed agency.)

Interview #1 - Roadbotics

This agency has successfully developed technology for mapping and classifying the condition of cracks in a given municipality's roadways, enabling targeted maintenance and planning. This technology has the potential to expand to landslide prediction; however, the agency faces obstacles in implementation: in order to accurately predict landslide prone areas (or even to accurately classify possible landslide predictors using computer vision), a model requires tens of thousands of pre-labeled images and the certainty of a "before" and "after" label.

This interview's most actionable insights:

- Although landslide classification and prediction are difficult machine learning problems to solve, the integration of new, creative prediction variables may add considerable power to the model. For example, existing before-and-after landslide area photos from this agency's work with NHT roadways reveal that less conventional signs may presage future landslides--these may include taut powerlines, leaning telephone/utility poles, bulging retaining walls, changes in tree angulature, leaning gravestones, and more.
- Using a set of known landslide points, NHT could use Roadbotics images (in addition to Google Street View images, if desired) to review slide sides before and after a landslide event.
- Researchers would benefit immensely if municipal governments can find creative ways to gather granular geographical data. In particular, soil and rock information collected on site prior to home building could serve as rich predictive variables for a landslide model

Interview #2 - University Professor (Prior Experience with Landslide Research and Environmental Policy)

This individual discussed the extent of prior work completed in the area of landslide prevention in Southwestern Pennsylvania, particularly the often-referenced Pomeroy Report, which documents historic landslide points and Pittsburgh Red Bed Soils, among other leading factors.

This interview's most actionable insights:

- Many parties with many areas of expertise have been working to address landslides for many years. Parties seriously interested in collective wisdom around landslide prevention should consider working together with: geologists, academic engineering experts/professors, journalists, state transportation officials, PDEP employees, etc.
- Human activity influences the majority of landslides. Although this reflects poorly on past decisions to build in risky areas, it suggests that policy interventions around constructions practices may in fact be very effective in preventing landslides

Interview #3 - Real Estate Developer (~40 years' experience building in SWPA)
This interview provided insight to the approach developers take when building in areas with steep slopes. The interviewee self-identified as more conscientious about risky building than other developers and may not necessarily be a fully representative viewpoint; however, their concerns and consideration are likely shared by many developers in the area. Although risk mitigation specifically for developers is not this project's main objective, the group has concluded through the literature review and other interviews that a substantial proportion of landslides are due to human activity—particularly disturbance of hillsides through new construction—and therefore any practices that reduce landslide risk for developers also, by extension, reduce risk of landslides that may damage township roads and endanger citizens.

This interview's most actionable insights:

- Many developers' chief concern with regard to landslide prevention is avoiding "grey clay soils" (same type as modeling clay), which are often deep beneath the surface and less discussed in the literature than the typical "Pittsburgh red bed" soils.
- Two real estate development trends will increase landslide risk in the coming years:
    - Most flat, low-risk territory has been developed already, pushing a higher and higher volume of new development to areas with steeper slopes and greater landslide risk.
    - Many experienced developers who understand and take precautionary measures to mitigate landslide risk in SWPA are retiring. New players entering the market may be inexperienced and are increasingly coming from outside the region, making them less likely to be aware of and careful with the risks of building on steep slopes
- Some challenges arise from mistrust between developers and soil engineering firms. Although the interviewee chooses to hire two or even three firms to inspect building sites in steep areas to cross-vet safety approvals, many developers (a) do not choose to undertake this expense as a cautionary measure and (b) do not know what to look for in their engineers. Both shortcomings may lead to insufficient information regarding the safety of a development site.
- Developers would use and benefit from the information contained in inspection reports for nearby properties. For example, knowledge that nearby properties sit above grey clay or red bed soil deposits might dissuade developers from building in a particularly risky area. Importantly, the interviewee expressed they would be willing to share inspection

reports from their own engineering reports with other developers, especially in return for access to the same information from them.

Interview #4 - Regional Landslide Task Force Appointees
This interview with two members of a task force established to address landslides in a neighboring county revealed the extent to which effective work has already been completed for the region by other parties. A division of the Southwestern Pennsylvania Commission (SPC) has dedicated resources and expertise to reducing damage to state transportation assets through better planning for and response to landslides. The group has assembled an extensive list of useful GIS resources and has engaged a professional GIS consulting firm to design landslide susceptibility maps for the SWPA region.

This interview's most actionable insights:

- Useful GIS layers for slide risk modeling can be found from:
    - PASDA
    - USGS
    - SSURGO (through Dept. of Agriculture)
- SPC plans to run their model against different tiers of their transportation network hierarchy (i.e. what are the slide-prone points along (a) interstate highways, (b) state routes, (c) local roadways) to create a taxonomy of intervention points.
- SPC's/Geodecisions' landslide vulnerability modeling approach was inspired by the Minnesota Department of Transportation's efforts outlined in this report.
- **Top insight:** A landslide risk map for NHT (or, at least, many of the layers for it) have already been developed by SPC. The next step would be for both parties to establish contact for information sharing.

Data Strategy Recommendations

The project team divided strategy recommendations into two main parts: Data Collection and Data Dissemination. The team also designed a data collection/analysis process strategy for landslide prediction research, which can be used in NHT.

Data Collection :

- **Citizen Sharing**: Create a pathway for citizens to share observed information about landslide risk with municipal leaders.
- **Road Imaging**: Continue partnership with Roadbotics to gather and review imagery for slide-prone areas.
- **Regional Model Sharing**: Partner with Southwestern Pennsylvania Coalition to gain access to landslide risk modeling already completed for the area.
- **Pre-Development Inspection**: Standardize format for geological inspection required prior to land development, and collect the resulting geological information in a consolidated database.
- **Hard-to-Find Public Data**: Leverage government funding or staff time to collect

advanced electation (LIDAR) and land movement (SAR) data for NHT, and make this available to the public.

Data Dissemination

- **Data Hub:** Collate landslide-related data and submit to open data portal such as WPRDC. This will provide external partners the opportunity to expand their criteria for analysis.
- **Open Data Principles:** Public institutions have immense opportunity to leverage their data by providing access to researchers, non-profits, and businesses. Where possible, data sets should be made public to encourage innovation and adoption of new analytical approaches.
- **Pursue New Methods of Collection:** New and emerging data collection technologies are rapidly developing. For example, Christoph Mertz and Roadbotics are working to tune their imaging algorithms to map treelines to observe changes over time, and NASA is mainstreaming capabilities to produce hyper-detailed topographical change maps.

Data Collection/Analysis Process Strategy for Landslide Prediction Research

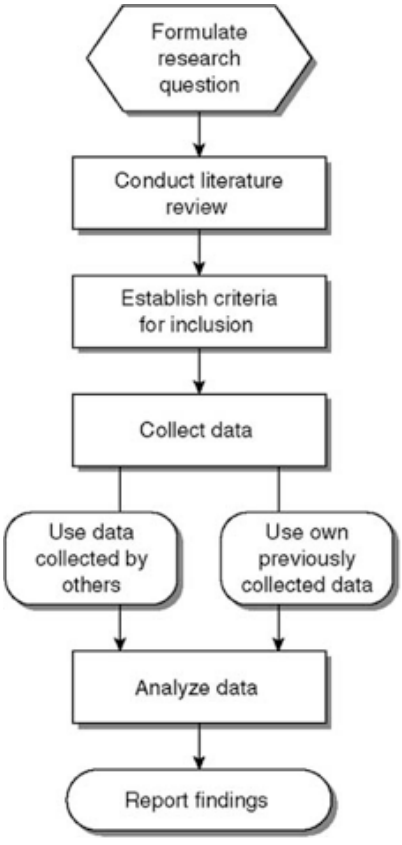


Figure1. Data Collection& Aanalysis Process

As a process model for data collection and analysis, we recommend (a) formulating research questions, (b) conducting literature reviews from multiple sources, (c) establishing criteria designs, (d) collecting data (GIS, Climate, etc.), (e) analyzing the data (Modeling), and (f) reporting findings.

Especially for data analysis, after step (c) is done, establish criteria for inclusion, we recommend (d) locating summarized data collected for various landslide research purposes, and (e) analyzing data (descriptive, modeling, evaluation) before the final step, (f) regularly reporting findings.

In the data gathering and recording stages of secondary data analysis, we recommend establishing a set size of study, research design, quality controls, and so forth, for the data to be included. Next, search data archives for data meeting their criteria. These data, frequently subsets of larger data sets, can be transported into any data analysis environment. Then, establish variables, which will sometimes require combining other variables or constructing new variables. Once the secondary data have been analyzed, secondary researchers can compare their findings with findings of primary researchers and report their findings.

Policy Recommendations

Through background research, review of best practices and model ordinances, and interviews with various stakeholders, the team developed a list of recommended policy intervention areas for reducing landslide risk. Although no one action will solve all landslide problems, each of the following items may serve as the foundation for potential follow on research through other projects conducted by the Township. Policy recommendations are divided into four categories—ordinances, coalition building, standards of service, and site inspection—and are characterized below:

- **Subdivision and Land Development Ordinances (SALDOs)**
  - Categorize slopes in terms of the degree of severity (e.g. moderately steep, very steep, prohibitively steep) to allow stricter regulation for steeper slopes (view more detailed recommendations in Appendix 5)
  - Limit the usage percentage or disturbance area for the regions with steep slopes (e.g. 30% for moderately steep slope and 15% for very steep)
  - Create a Storm Management Plan, apart from the drainage and terracing requirements currently in place.
  - Limit the change in the topography and its slope due to construction, prohibiting slopes to increase from earlier levels.

- **Coalition Building**
  - Convene a Landslide Advisory Group to merge disparate efforts being pursued independently at the regional, neighboring county, and researcher levels. Greater cooperation on this issue would streamline planning and data collection processes, adequately scope risk and prediction models, and pool resources and data archives to prevent duplicative work.

- **Standard of Service Taxonomy**
  - Develop standard of service priority categories for roadway maintenance, using existing landslide risk modeling classifications
  - Consult regional expert resources to assign NHT interventions to each classification of risk/severity (see sample taxonomy)

- **Site Inspection Standards**
  - Require minimum liability insurance coverage for engineering firms conducting site inspection prior to building on steep slopes. Although the Township is not responsible for landslides occurring strictly on personal property, tighter requirements for pre-development inspection reports will improve the quality of assessments conducted by developers and their engineers prior to construction.
  - Specify engineering firm portfolio/experience requirement in current Steep Slopes ordinance, for the same purpose stated above.

Appendices

1. Digital Table of Contents → Link Here
2. Presentation to Commissioners → Link Here
3. Presentation to Policy Innovation Lab → Link Here
4. Project Overview and Sprint Summaries → Link Here
5. Existing vs. Model SALDO Steep Slope Ordinances:

S.No	RECOMMENDATION	WHY	EXISTING	OPTIONS	BENCHMARKED COUNTY
1	Categorization of slopes in terms of degree of severity	Different categories allow different regulations with stricter norms for very steep slope	25% slope or 15% slope with poor soil	• Moderately steep(8-15) • Very Steep (15-25) • Prohibitively Steep(>25)	Edgmonton, Franklin Township, Kennet. Lower Millford goes upto four categories
2	Varied Disturbance Limit in different slope categories	As a precaution, the areas with steeper slope should limit usage	NA	DISTURBANCE Limit no more than 30% of moderately steep slope be built upon or Similarly, no more than 15% for very steep slope	Kennet Township, Franklin
3	To have a separate Storm Water Management Plan apart from drainage plan	During the storms, water often breaches the threshold	Drainage and terracing	Storm Water Management plan at the time of development	Franklin
4	Conditional use hearing mails to the neighbors residing adjacent to the new areas of construction	Allows the neighbors to suggest protective measures for construction	NA	Sending hearing mails to permanent owners in the adjacent areas.	Lower Millford, Franklin
5	No change in existing topography which results in a slope greater than the predevelopment condition within prescribed limit	To maintain slope integrity	NA	no change in existing topography which results in a slope greater than the predevelopment condition may be located within 50ft area of site	Kennet, Lower Millford , Franklin

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