Quarterly Report – Public Page

Date of Report: *4th Quarterly Report – September 30, 2024*

Contract Number: *693JK32310007POTA*

Prepared for: *DOT-PHMSA*

Project Title: *An Integrated Knowledge Graph Model for Geohazard Monitoring Data*

Prepared by: *University of Wyoming*

Contact Information: *Dr. Minou Rabiei, mrabiei@uwyo.edu*

For quarterly period ending: *September 30, 2024*

1: Items Completed During this Quarterly Period:

- Secured the licenses for the required software and cloud storage.
- The questionnaire and industry interview questions were reviewed and approved by the TAP.
- Transformed the collected data into standardized format.

The following activity is ongoing (50% done) and will be completed during the 4th quarters.

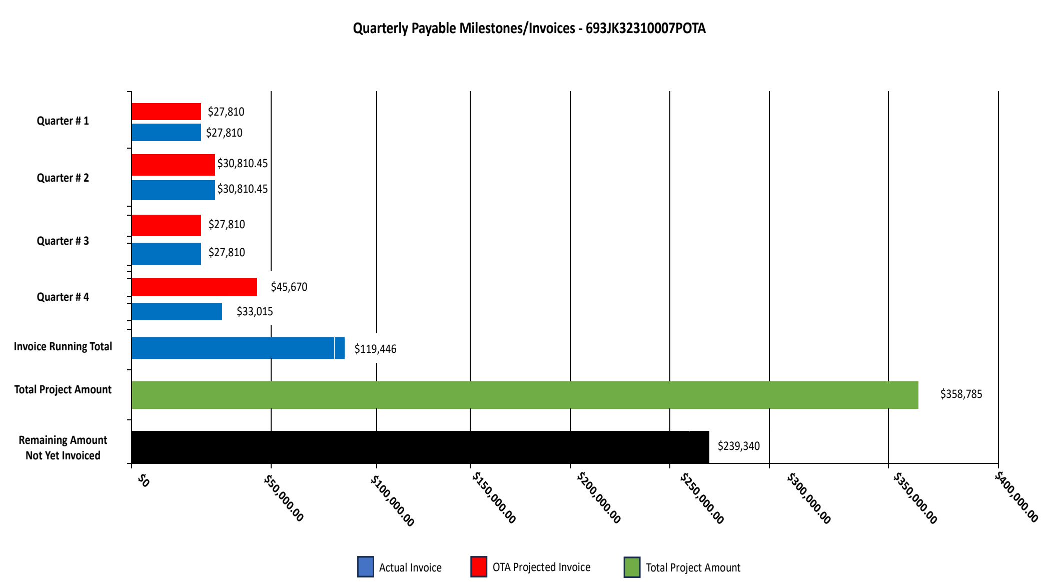
- Design and develop ontology and semantic model

2: Items Not-Completed During this Quarterly Period:

- Design and develop ontology and semantic model

  The design and development of the ontology and semantic model are still in progress. The delay in completing this task is primarily due to the large size and complexity of the collected data, which requires conversion into a tabular format for effective processing by Neo4j. Additional time is needed to restructure it for compatibility. This conversion is essential to ensure that the ontology and semantic model can be accurately represented and processed within the graph database, which is critical for the project's next steps.

3: Project Financial Tracking During this Quarterly Period:



4: Project Technical Status

Item 13, Task 1: Get the licenses for the required software and cloud storage - *List of acquired software and licenses*

Narrative: After evaluating various options, we have decided to use Neo4j as the primary platform for building our knowledge graphs. Neo4j's robust graph database capabilities and efficient handling of complex relationships make it an ideal choice for developing and managing the ontology and semantic models required for the project. Its compatibility with large datasets and ability to handle sophisticated querying and visualization align with our project goals, ensuring scalability and flexibility in the analysis and representation of the data.

Item 14, Task 3: Transform the collected data into standardized format - *Documentation on the necessary data standardization activities*

Narrative: Following detailed discussions with stakeholders, we have decided to focus the project on landslide data to ensure it remains realistically achievable, as covering all types of geohazards would overextend the scope. By concentrating on landslides, we can optimize resource use and deliver a more detailed analysis within the project's timeline.

Other Items, Task 2: Comprehensive literature review on factors affecting landslides.

1. **Land Use:**

Land use significantly impacts landslide susceptibility, especially in mountainous regions where human activities like construction, agriculture, and deforestation disrupt the natural landscape. Construction and urban development, including excavation and slope modification, weaken the stability of slopes and alter drainage patterns, leading to higher landslide risks. Similarly, farming, particularly on steep slopes, increases soil erosion and destabilizes the terrain, while excessive irrigation can saturate the soil, making it prone to failure. Deforestation exacerbates these risks by removing vegetation that stabilizes soil, increasing runoff and erosion.

2. **Elevation:**

Elevation plays a crucial role in landslide risk evaluation due to its influence on various environmental and anthropogenic factors that contribute to slope instability. At higher elevations, the intensity of human activities tends to decrease due to difficult accessibility and challenging terrain, which often leads to less direct modification of the landscape, such as construction or deforestation. However, in regions where human activities, such as mining or road building, occur at higher altitudes, the impact on slope stability can be severe because the steep slopes are more prone to erosion and slope failure.

Vegetation type and coverage also vary significantly with elevation. In lower elevation areas, there is typically denser vegetation, which helps stabilize the soil by reducing erosion and anchoring the land with root systems. As elevation increases, vegetation becomes sparser and less capable of holding the soil in place, making slopes more susceptible to landslides. Furthermore, certain vegetation types, such as alpine grasses or shrubs, offer less protection against landslides compared to forests at lower elevations, where trees can provide significant soil reinforcement.

Rainfall patterns are another critical factor influenced by elevation. Higher elevations tend to receive more precipitation, especially in the form of orographic rainfall, where moist air is lifted by the terrain and cools, releasing rain. Increased rainfall at higher altitudes can saturate soils, reducing their cohesion and triggering landslides. Waterlogged soil experiences heightened pore water pressure, diminishing the friction that stabilizes slopes. On the other hand, lower elevations may experience less rainfall but may still be vulnerable to landslides due to intense human activity and land use changes.

In conclusion, elevation affects landslide susceptibility by influencing human activity intensity, vegetation coverage, and atmospheric conditions, particularly rainfall. These factors collectively make elevation a significant consideration in landslide risk assessment, as the stability of slopes is closely tied to the interactions between natural forces and human-induced changes that vary with altitude.

3. **Land Cover:**

Land cover plays a critical role in determining landslide susceptibility by influencing various factors related to slope stability. It affects the hydrological functioning of hillslopes, such as how rainfall is absorbed, how water infiltrates the soil, and how runoff is generated. These changes impact soil saturation levels, which can weaken slope stability and increase the risk of landslides. Additionally, different land cover types influence soil shear strength, with vegetation generally enhancing stability through root systems that help anchor the soil, while areas with sparse or no vegetation may have reduced soil strength, making them more prone to instability. The dynamic nature of land cover, which can change rapidly due to human activities or natural events, means that the relationship between land cover and landslide risk can evolve over time. Therefore, regular monitoring and historical analysis of land cover changes are essential for accurately assessing and managing landslide risks.

4. **Roads**

The distance from roads impacts landslide susceptibility primarily through the influence of road construction and maintenance activities on slope stability. Road construction often involves significant excavation and modification of the mountain terrain, which can weaken the underlying rock and soil structures. This excavation exposes slopes to weathering and erosion, making them more vulnerable to landslides, particularly during heavy rainfall. The presence of roads can also alter natural drainage patterns, increasing runoff and soil saturation, further compromising slope stability. Consequently, areas closer to roads are generally at a higher risk of landslides due to the disruption and destabilization caused by road-related activities.

5. **Hydrographic Features and Watersheds:**

The distance from water bodies, such as rivers, streams, lakes, or coastal areas, is a critical factor in determining landslide susceptibility due to the erosive forces water exerts on the surrounding landscape. Water systems, particularly those with significant surface runoff or flowing water, can gradually weaken and destabilize the underlying rock and soil through processes like scouring and erosion. As surface runoff from rainfall or snowmelt converges into streams and rivers, it gains the power to erode the banks, remove sediments, and carve through soft rock, progressively undermining the stability of the nearby slopes.

This continuous erosion process affects the geological structure, creating zones of weakness where landslides are more likely to occur. Areas closer to water systems, especially in steep terrains, are more vulnerable to slope failure because the constant flow of water can cause the loss of soil cohesion and the removal of supporting material at the base of slopes, leading to a higher risk of landslides. Over time, the combined effects of natural erosion and water-induced destabilization accelerate the development of landslide-prone conditions, particularly after periods of heavy rain or flooding.

Additionally, the fluctuating water levels in rivers, lakes, or reservoirs can increase landslide risks by creating cycles of saturation and drying. Saturated soils lose strength due to increased pore water pressure, which reduces friction and weakens the bonds holding soil particles together. This phenomenon, especially prevalent in areas near water, makes nearby slopes more prone to collapse. Thus, the distance from water bodies is a key parameter in assessing regional landslide hazards, as proximity to active water systems directly correlates with increased susceptibility to both the initiation and development of landslides.

6. Soil moisture:

Soil moisture significantly impacts landslide susceptibility by influencing the stability of slopes through several mechanisms. As rainfall intensity and duration increase, more water infiltrates the soil, which adds weight and elevates pore water pressure. This increased pressure reduces the soil's internal friction and shear strength, making it more prone to failure. Water infiltration can also create a lubricated sliding plane within the soil, particularly when it reaches impermeable layers, further destabilizing the slope. Additionally, high moisture levels decrease soil strength by lowering matrix suction, which is crucial for maintaining soil cohesion. Prolonged saturation can lead to weathering, breaking down soil structure and further reducing stability. Thus, increased soil moisture leads to greater instability and a higher risk of landslides, especially during periods of heavy or extended rainfall.

7. Precipitation:

Precipitation has a profound impact on landslide susceptibility by affecting both pore water pressure and soil shear strength. When rain falls on slopes, it infiltrates the soil, increasing the pore water pressure within the soil layers. This rise in pore water pressure reduces the frictional resistance between soil particles, effectively lowering the soil's shear strength. As a result, the soil becomes more prone to failure under the force of gravity, leading to an increased risk of landslides.

In regions with high or intense precipitation, such as those experiencing heavy rainfall, rainstorms, or continuous rain, the risk of landslides is notably higher. The accumulated water not only saturates the soil but can also cause rapid changes in soil moisture content. This saturation makes the soil heavier and more unstable, especially on steep slopes. Additionally, prolonged or excessive rainfall can lead to increased runoff, which can erode the base of slopes and further destabilize the land.

8. Vegetation Index:

The stability of a slope is closely linked to vegetation cover, and the Normalized Difference Vegetation Index (NDVI) is a key tool for assessing this relationship. Vegetation enhances slope stability through several mechanisms primarily involving its root systems. The roots of plants and trees bind soil particles together, which increases the soil's shear strength and helps prevent erosion. This process, known as soil consolidation, stabilizes the slope by reinforcing the soil structure and reducing its susceptibility to failure. As vegetation density increases, the stabilizing effects become more pronounced. Dense vegetation provides greater root mass, which leads to more effective soil consolidation and better protection against slope instability. The root networks of vegetation create a natural reinforcement of the soil, making it more resistant to the forces that could trigger landslides, such as rainfall or seismic activity.

NDVI is utilized to quantify the degree of vegetation cover by measuring the difference between the reflectance of near-infrared and red light, which varies with the amount of chlorophyll and overall plant health. Higher NDVI values indicate more vigorous and dense vegetation, reflecting a greater degree of soil stabilization. By analyzing NDVI data, researchers can assess how variations in vegetation cover impact slope stability and predict landslide risk more accurately.

In a nutshell, NDVI provides a quantitative measure of vegetation density, which is crucial for evaluating slope stability. By strengthening soil shear capacity through root systems, vegetation plays a critical role in reducing landslide risk, and NDVI helps in monitoring and managing this important stabilizing factor.

5: Project Schedule

The project is about one month behind schedule.