



University of
Pittsburgh

Swanson School
of Engineering

Analysis of Highway Construction Safety Using the Large Language Models

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PITT | **IRISE**

CENTER FOR IMPACTFUL RESILIENT
INFRASTRUCTURE SCIENCE & ENGINEERING

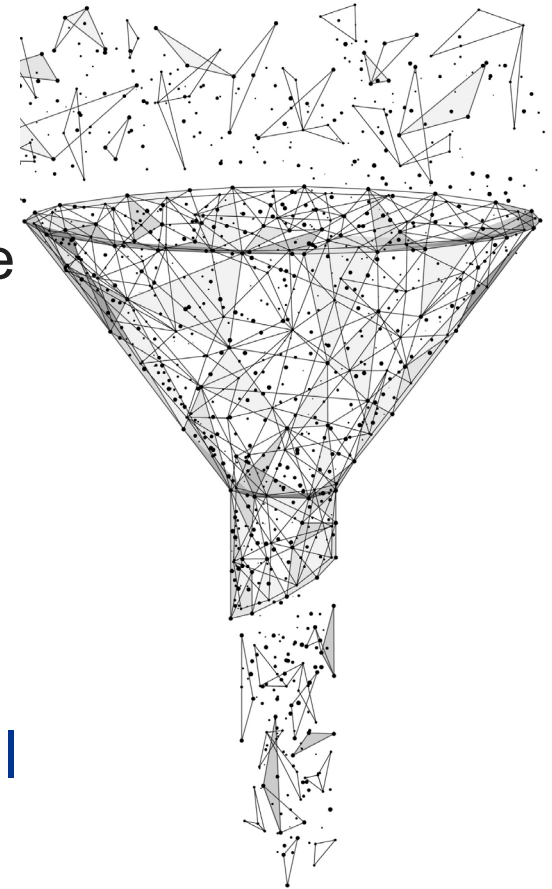
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Smetana, Mason, Lucio Salles de Salles, Igor Sukharev, and Lev Khazanovich. "Highway Construction Safety Analysis Using Large Language Models." *Applied Sciences* 14, no. 4 (2024): 1352.



Construction Industry As a High-Risk Sector

- Approximately 108,000 workers lose their lives at construction sites worldwide each year.
- One out of every ten construction workers in the United States suffers injuries each year.
- Many accidents occur due to road construction.

Zhou Ket al.. Discovering the Research Topics on Construction Safety and Health Using Semi-Supervised Topic Modeling. Buildings. 2023;13.0(5.0);1169. <https://www.mdpi.com/2075-5309/13/5/1169>

Occupational Safety and Health Administration (OSHA) Database

Severe Injury Reports

- Approximately 70,000 incident records occurred between 2015 and 2021 across all industries in the United States.
- 1,032 records correspond to NAICS code 237310 (Highway, Street, and Bridge Construction).

Example incident description – “Final Narrative”

EventDate	Employer	Address	City	State	Zip	Latitude	Longitude	Primary	Hospital	Amputated	Inspected	Final Narrative	Nature	Part of	Event	Source	Second Source	Second Source
1/28/2015	Traffic Control Services, LLC	3682 Irish Valley Road	ELYSBURG	PENNSYLV	17824	40.85	-76.53	237310	1	0		At approx	111 Fractures	5189 Multiple l	2412 Pedestrian	840 Highway vehicle, motorized, unspecified		
3/9/2015	New Enterprise Stone & Lime	3247 Pennington Road	TYRONE	PENNSYLV	16686	40.68	-78.18	237310	1	0		An employee	1972 Soreness,	513 Lower leg	4111 Slip on surface	562 Bodily motion	9273 Ice, sleet, snow	
3/11/2015	Golden Triangle Construction	8555 Old Stubenville	IMPERIAL	PENNSYLV	15126	40.45	-80.24	237310	1	0		An employee	1972 Soreness,	510 Leg(s), un	6220 Struck by	4133 Beams-unattached metal		
3/30/2015	Trumbull Corporation	38 Denny Estates	PITTSBURGH	PENNSYLV	15238	40.53	-79.82	237310	1	0	1050737	An employee	10 Traumatic	9999 Nonclassifi	4336 Other fall	9999 Nonclassifiable		
4/22/2015	JD Eckman, Inc.	Rt 23 Pickering Creel	PHOENIX	PENNSYLV	19453	40.14	-75.51	237310	1	0	1058681	An employee	1972 Soreness,	510 Leg(s), un	6241 Struck by	6391 Guardrails	3211 Backhoes, trackhoes	
4/28/2015	Granna Brothers Stone and Asphalt	PA Turnpike Mile Marker	HOLLIDAY	PENNSYLV	16648	40.43	-78.37	237310	1	0		An employee	10 Traumatic	9999 Nonclassifi	20 Transport	840 Highway vehicle, motorized, unspecified		
8/6/2015	E.J. Breneman, L.P.	Lake Dr	NESQUEHEEN	PENNSYLV	18240	40.85	-75.84	237310	1	0		An employee	133 Puncture	512 Knee(s)	433 Other fall	3252 Asphalt and concrete paving machine:		
8/13/2015	NEW ENTERPRISE STONE & LIME COMPANY, INCORPORATED	Turnpike I76 Carlisle	CARLISLE	PENNSYLV	17013	40.21	-77.19	237310	1	0		An employee	111 Fractures	582 Foot (feet)	4333 Other fall	631 Bridges, dams, locks		
8/18/2015	GREGORI CONSTRUCTION & ENGINEERING, INC	355 Perryopolis Road	BELLE VERE	PENNSYLV	15012	40.11	-79.81	237310	1	0	1094585	An employee	111 Fractures	5830 Ankle(s) a	4334 Other fall	631 Bridges, dams, locks		
8/24/2015	Russell Standard Corporation	3580 Wheelertown Farm	WATERFORD	PENNSYLV	16441	41.9	-79.93	237310	1	0	1109170	On August	1839 Fractures	38 Multiple t	2410 Pedestrian	8429 Truck-motorized freight hauling and unloading		
8/28/2015	Trumbull Corporation	PA Turnpike Milepost 4	PITTSBURGH	PENNSYLV	15232	40.45	-79.93	237310	0	1		An employee	1311 Amputati	4429 Finger(s),	642 Compress	6551 Girders, beams, structural steel		
9/3/2015	John J. Dougherty & Son, Inc.	The Navy Yard, 1200	PHILADELPHIA	PENNSYLV	19112	40	-75.15	237310	1	0		On Septe	160 Intracran	111 Brain	4210 Fall on surface	660 Floors, walkways, ground surfaces, unloading		
9/19/2015	HRV Conformance Verification Associates	JV522 Wilten Road	LIGONIER	PENNSYLV	15658	40.24	-79.22	237310	1	0		An employee	132 Cuts, lacer	135 Jaw, chin	429 Fall on surface	6630 Ground, unspecified		
10/5/2015	Golden Triangle Construction Company	Route 50 & Penn Dot	BRIDGEVIEW	PENNSYLV	15017	40.34	-80.11	237310	1	0		An employee	1972 Soreness,	899 Multiple t	2729 Nonroad	8619 Off-road equipment	69 Structures and supports	

An employee sustained a serious leg injury while he was attempting to dismount a CAT paving machine. The employee was in the process of dismantling the equipment, slipped and suffered a puncture to the knee from a bolt protruding on the machine. The employee was hospitalized and required surgery.

OSHA <https://www.osha.gov/severeinjury>

Event type

Activity source

Occupational Safety and Health Administration (OSHA) Databases: Categorical Variables

Four Major Categories Coded – OIICS Manual (OSHA)

["NatureTitle"] - Nature of Injury or Illness

503 Unique Codes | 58 Specific to NAISC Code

["Part_of_Body_Title"] - Part of Body Affected

166 Unique Codes | 82 Specific to NAISC Code

["SourceTitle"] - Source of Injury or Illness

1407 Unique Codes | 230 Specific to NAISC Code

["EventTitle"] - Event or Exposure

342 Unique Codes | 160 Specific to NAISC Code

There are over 175,000,000 combinations just for highway construction—too specific!

Traditional Descriptive Statistics



- Heavy dependence on numerical data
- Database contains large amount of textual information
- Descriptive statistics may be limited to few columns and existing OSHA coded classifications
- Look to find other means of analyzing such data...

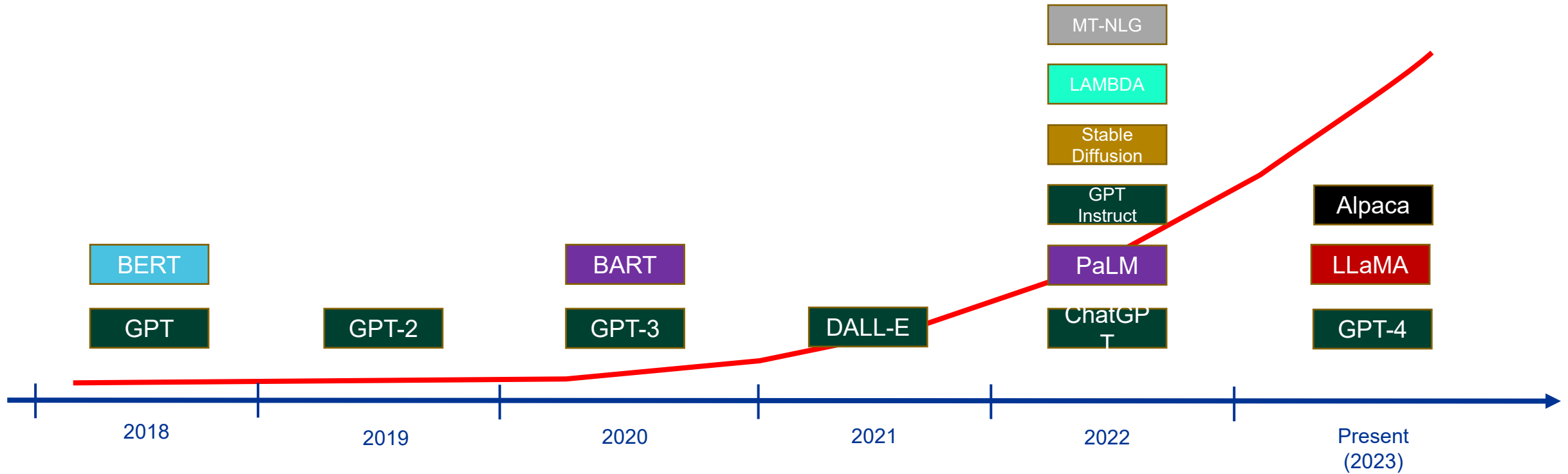
All States:

- **90.2 % of cases resulted in hospitalization**
- **17.5 % of cases resulted in amputation**

Pennsylvania:

- **88.2 % of cases resulted in hospitalization**
- **12.9 % of cases resulted in amputation**

AI Large Language Models (LLM) – History



LLM Data Analysis – Embeddings

Final Narrative

Employee sustained 2nd and 3rd degree burns on 8 to 11% of the employee's back. The wind blew a torch flame around the back side of steel that was being cut and under protective gear, catching the employee's street clothes on fire underneath.

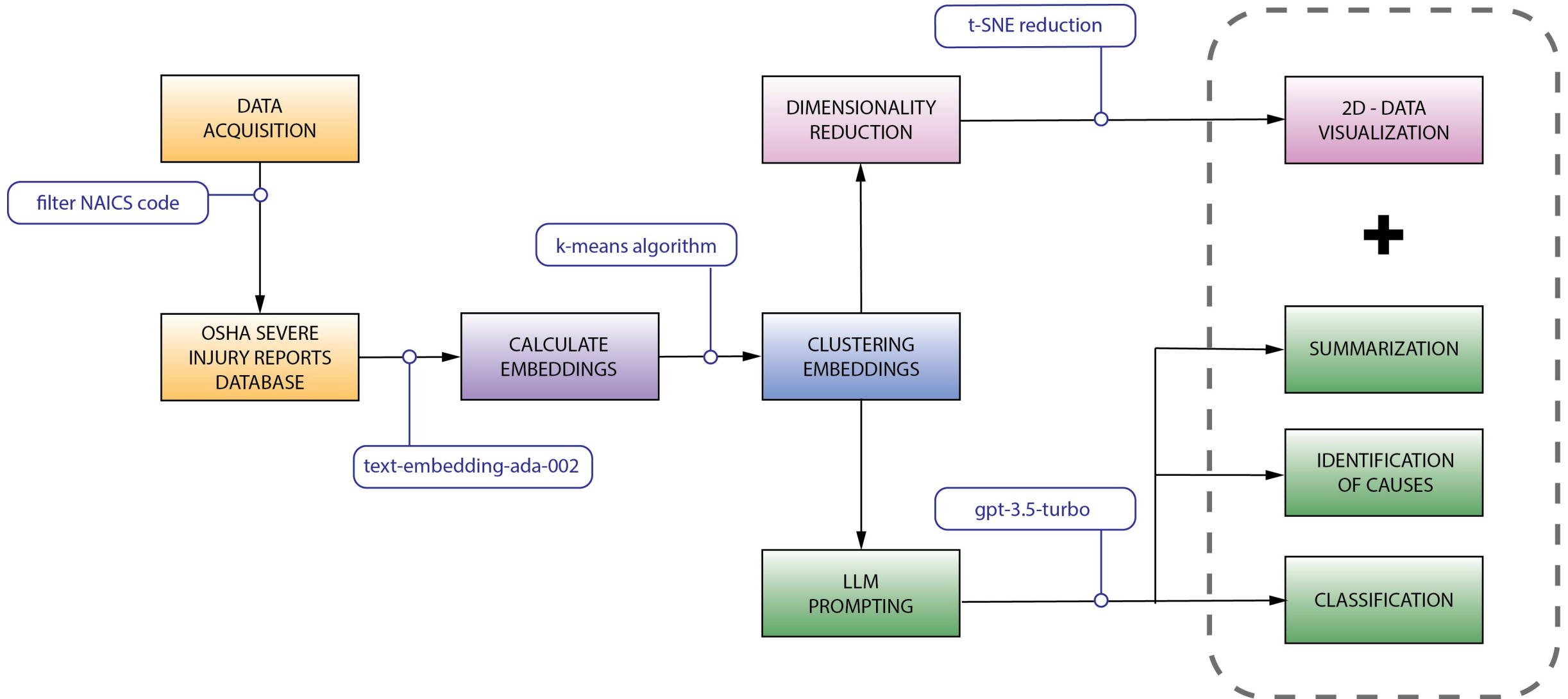
Tokenizer Model: `c100k_base`

Employee sustained 2nd and 3rd degree burns on 8 to 11% of the employee's back. The wind blew a torch flame around the back side of steel that was being cut and under protective gear, catching the employee's street clothes on fire underneath.

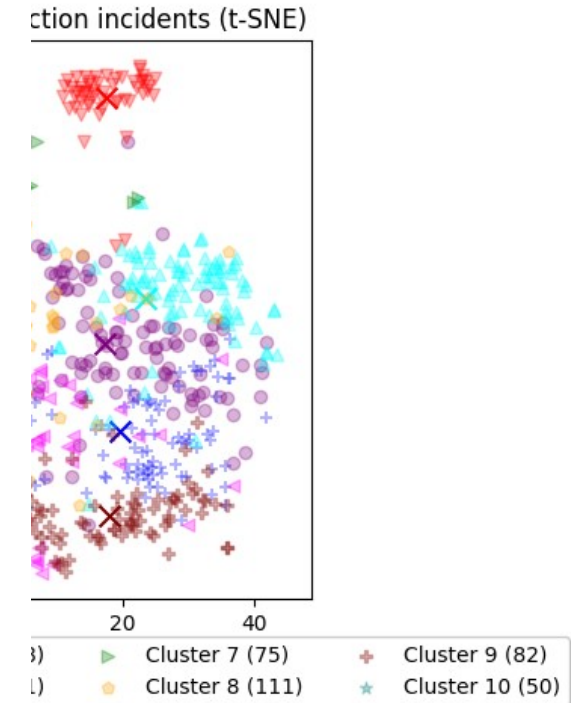
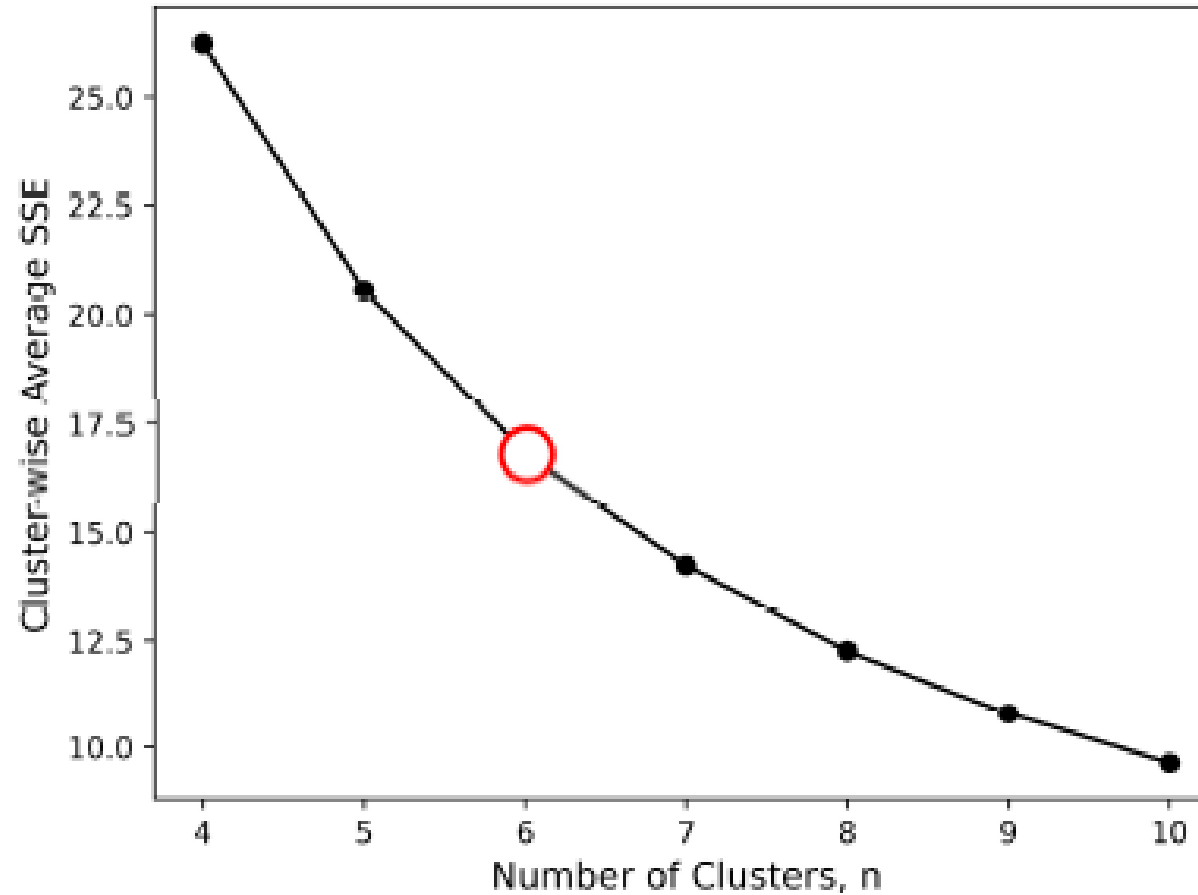
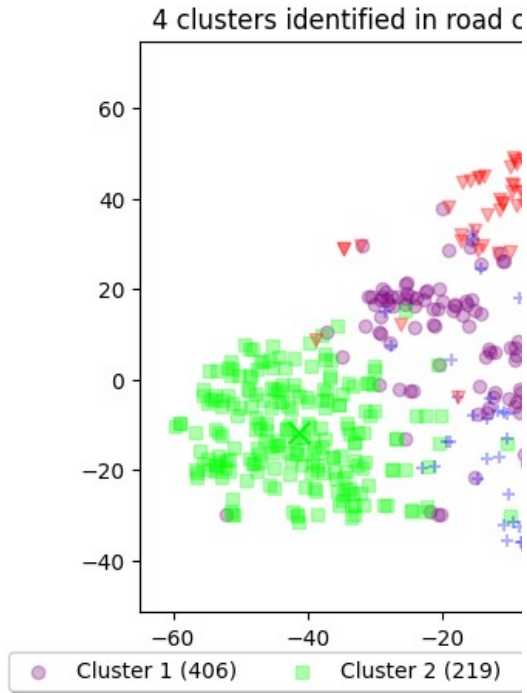
Embedding Model: `text-embedding-ada-002`

[0.010815243236720562, 0.005784206558018923, 0.029783211648464203, -0.04413306340575218, -0.034592922776937485, 0.007544904015958309, 0.0014790853019803762, 0.001152051379904151, ... , -0.014376279897987843]

LLM Data Analysis – Processing

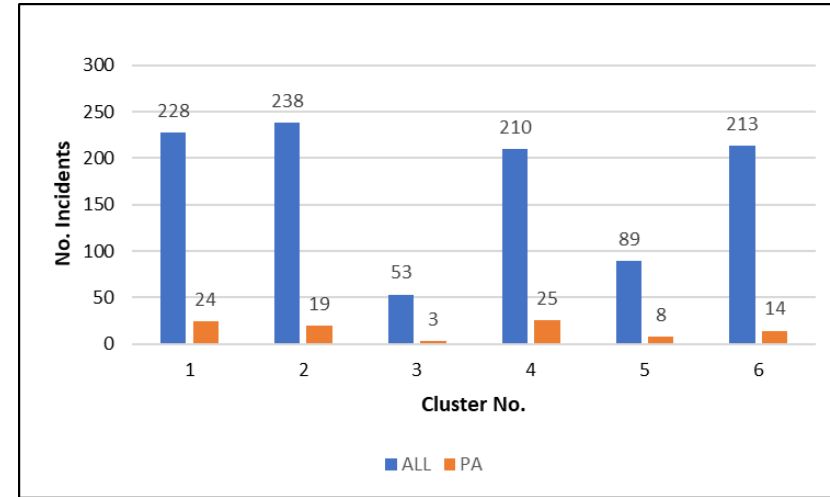
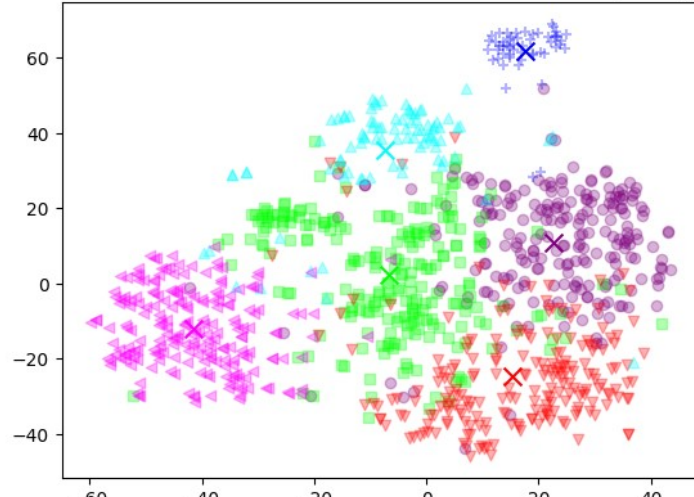


LLM Data Analysis – Clustering



LLM Data Analysis Results– 6 Clusters

6 clusters identified in road construction incidents (t-SNE)



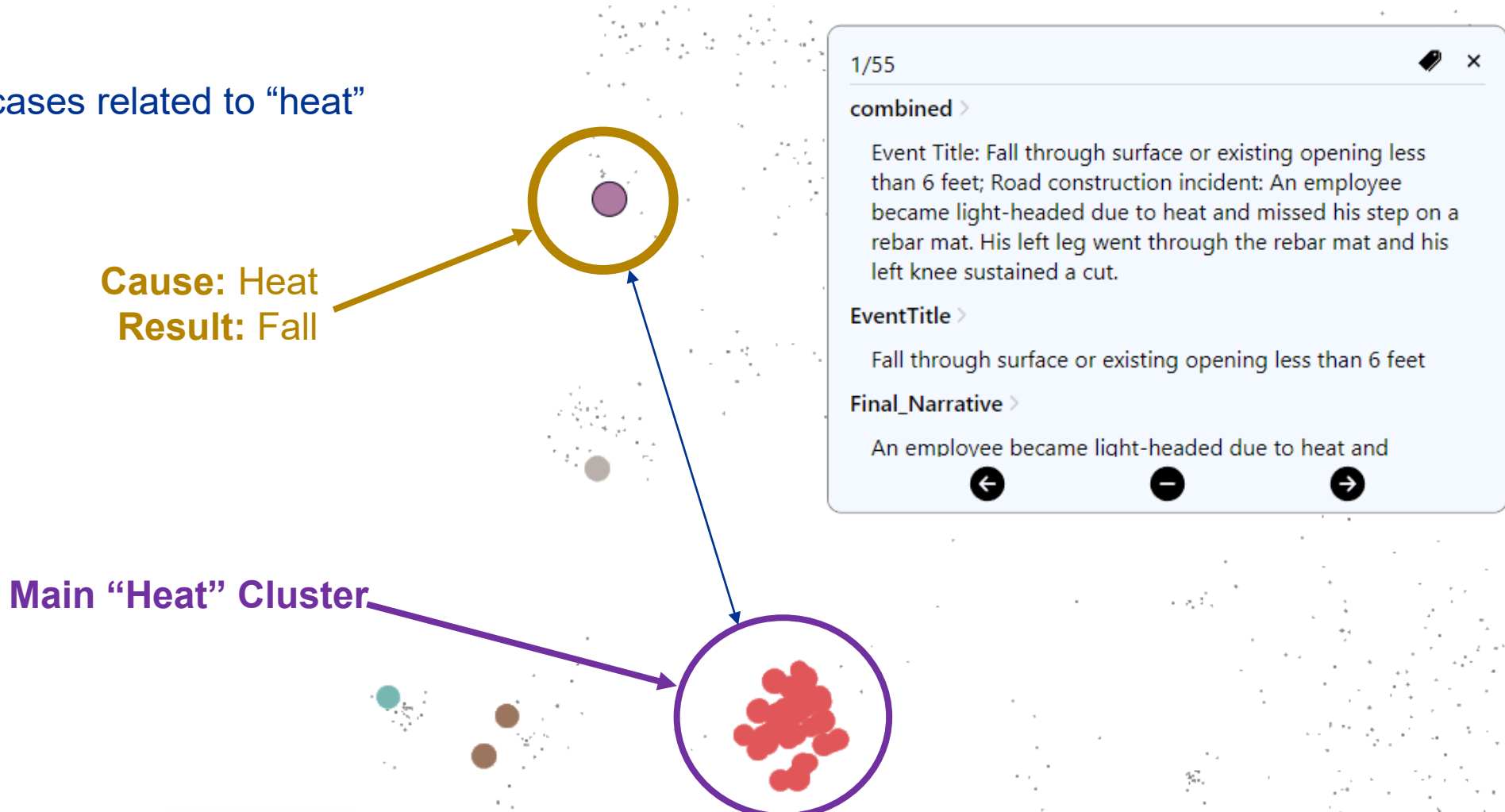
- Struck by vehicle / traffic incidents
- Struck by object / caught in machinery
- Heat-related illness
- Falls / struck by falling objects
- Burns / electrical shock
- Finger and hand injuries

Cluster	Region			
	ALL		PA	
1	228	22.1 %	24	25.8 %
2	238	23.1 %	19	20.4 %
3	53	5.1 %	3	3.2 %
4	210	20.4 %	25	26.9 %
5	89	8.6 %	8	8.6 %
6	213	20.7 %	14	15.1 %
Σ Total	1031	100 %	93	100 %

LLM Performance – Nomic

Example

- Identified cases related to “heat”



Future Work: AI Safety Officer Assistant

AI-powered large language model (LLM) tool to assist safety officers and other related personnel

Key Features:

Daily Work Planner: Provides safety-focused insights for specific daily work activities

Incident Reporting Tool: Assists in generating high-quality incident narratives through clarifying questions

Future Work: AI Safety Officer Assistant

