## itsaustralia () **Summit** 2024

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Integrating Large Language Models for Traffic Incident Severity Classification

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## Background

#### What do we know about traffic accidents?

- Statistics: The annual economic cost of road crashes in Australia was estimated at \$27 billion in 2017 [1]. There were 39,505 hospitalized injuries in Australia in 2021 [2] and 1,194 fatalities in 2022 [3].
- **Impact:** Traffic accidents pose significant challenges to modern transportation systems, affecting traffic flow and public safety.
- **Prediction:** Accurate modelling of traffic accidents is crucial for intelligent transportation systems, for reducing traffic congestion and economic cost associated with accidents. ٠
- Large Language Models (LLMs): recent developments in the field of large language models holds considerable promise for addressing the complexities associated with processing unstructured datasets [3] and potential for enhancing the efficiency of accident modelling.

[1] https://infrastructure.gov.au/roads/safety/,
[2] https://www.officeofroadsafety.gov.au/data-hub/serious-injuries-data
[3] https://www.bitre.gov.au/statistics/safety/fatal\_road\_crash\_database
[4] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N. & Polosukhin, I.
(2017). Attention is all you need. Advances in neural information processing systems, 30.

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## **Traditional vs LLM-based models**

#### **Limitations of Traditional Models:**

- **Strict Accident Report Format:** Models built on structured/tabular data often can't transfer between systems due to using different accident report formats.

- Limited Linguistic Understanding: These models often struggle to capture the nuanced linguistic features present in textual accident reports

#### **Potential of Large Language Models:**

- Flexible Unstructured Accident Report representation: Traffic incident reports and other related text data represent a rich source of information that is often underutilized in traditional predictive models. LLM hold the capability to process this kind of data.

- **Cross-Dataset Transferability:** Potential capability for a development of universally applicable LLM models (transferable across different datasets and reporting formats).

- Multi-modality or recent LLMs (2023): LLM obtain the ability to process image and video data, that may be collected from the crash site.

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### **Existing research: incident severity /duration classification**

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Oliaee, A. H., Das, S., Liu, J., & Rahman, M. A. (2023). Using Bidirectional Encoder Representations from Transformers (BERT) to classify traffic crash severity types. Natural Language Processing Journal, 3, 100007.

In 2021 IEEE 94th Vehicular Technology Conference. IEEE.



## LLMs for accident report embedding



### **Novel Approach: LLMs as a substitute for data preparation**

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# LLM-based data processing pipeline

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Fig. 2. Diagram of the full-text representation and feature extraction

## **Datasets**

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**1. USA Countrywise Traffic Accident Dataset** – subset of 25,000 cases:

This dataset includes detailed information on U.S. traffic accidents, focusing on environmental and lighting conditions.

**2. UK Road Safety Data (2018-2021)** – subset of 20,000 cases: This dataset covers UK traffic accidents, with a focus on infrastructure details like pedestrian crossings and local authority data.

**3. Queensland Road Crash Data** – subset of 25,000 cases: This comprehensive dataset from Queensland includes detailed geographical information, useful for localized analysis.

All the datasets have been evenly sampled for balanced analysis of each severity class.



## **Examples of full text representation**

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Description	Example Crash Report
USA Data Set	Accident ID A-7463401, Source Source1, Start Latitude 32.68116, Start Longitude -97.02426, End Latitude
	32.67618, End Longitude -97.03483, Accident extent (miles) 0.704, Description Ramp to I-20 Westbound -
	Accident., Street President George Bush Tpke S, City Grand Prairie, County Dallas, State TX, ZipCode 75052,
	Timezone US/Central, Airport Code KGPM, Temperature (F) 48.2, Humidity (%) 75.0, Pressure (inch) 30.26,
	Visibility (miles) 10.0, Wind Direction South, Wind Speed (mph) 5.8, Weather Condition Mostly Cloudy,
	Junction, Sunrise/Sunset Night, Civil Twilight Night, Nautical Twilight Night, Astronomical Twilight Night,
	Start_Time_hour 22, Start_Time_month 1, Weather_Timestamp_hour 22, Weather_Timestamp_month 11
JK Data Set	accident_index: 2018460317259, accident_year: 2018, accident_reference: 460317259, loca-
	tion_easting_osgr: 556147.0, location_northing_osgr: 165830.0, longitude: 0.241871, latitude:
	51.370065, police_force: 46, number_of_vehicles: 1, number_of_casualties: 1, date: 08/08/2018,
	day_of_week: 4, time: 11:35, local_authority_district: 538, local_authority_ons_district: E07000111,
	local_authority_highway: E10000016, first_road_class: 3, first_road_number: 20, road_type: 6,
	speed_limit: 60, junction_detail: 3, junction_control: 4, second_road_class: 6, second_road_number: 0,
	pedestrian_crossing_human_control: 0, pedestrian_crossing_physical_facilities: 0, light_conditions: 1,
	weather_conditions: 1, road_surface_conditions: 1, special_conditions_at_site: 0, carriageway_hazards:
	0, urban_or_rural_area: 2, did_police_officer_attend_scene_of_accident: 1, trunk_road_flag: 2,
	lsoa_of_accident_location: E01024433
Queensland (Australia) Data Set	Crash_Ref_Number: 28863.0, Crash_Year: 2004.0, Crash_Month: September, Crash_Day_Of_Week: Wednes-
	day, Crash_Hour: 6.0, Crash_Nature: Angle, Crash_Type: Multi-Vehicle, Crash_Longitude: 152.872284325108,
	Crash_Latitude: -27.5455985592659, Crash_Street: Kangaroo Gully Rd, Crash_Street_Intersecting: Mount
	Crosby Rd, State_Road_Name: Mount Crosby Road, Loc_Suburb: Anstead, Loc_Local_Government_Area:
	Brisbane City, Loc_Post_Code: 4070, Loc_Police_Division: Indooroopilly, Loc_Police_District: North Brisbane,
	Loc_Police_Region: Brisbane, Loc_Queensland_Transport_Region: SEQ North, Loc_Main_Roads_Region:
	Metropolitan, Loc_ABS_Statistical_Area_2: Pinjarra Hills - Pullenvale, Loc_ABS_Statistical_Area_3:
	Kenmore - Brookfield - Moggill, Loc_ABS_Statistical_Area_4: Brisbane - West, Loc_ABS_Remoteness:
	Major Cities, Loc_State_Electorate: Moggill, Loc_Federal_Electorate: Ryan, Crash_Controlling_Authority:
	State-controlled, Crash_Roadway_Feature: Intersection - T-Junction, Crash_Traffic_Control: No traffic control,
	Crash_Speed_Limit: 70 km/h, Crash_Road_Surface_Condition: Sealed - Dry, Crash_Atmospheric_Condition:
	Clear, Crash_Lighting_Condition: Daylight, Crash_Road_Horiz_Align: Curved - view open,
	Crash_Road_Vert_Align: Level, Crash_DCA_Code: 202.0, Crash_DCA_Description: Veh'S Opposite
	Approach: Thru-Right, Crash_DCA_Group_Description: Opposing vehicles turning, DCA_Key_Approach_Dir:
	E, Count_Unit_Car: 1.0, Count_Unit_Motorcycle_Moped: 1.0, Count_Unit_Truck: 0.0, Count_Unit_Bus: 0.0,
	Count_Unit_Bicycle: 0.0, Count_Unit_Pedestrian: 0.0, Count_Unit_Other: 0.0
	TABLE III
	EXAMPLE OF FULL TEXT REPRESENTATIONS FOR DIFFERENT DATA SETS

## **LLM models**

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Model	Number of pa-	Training Method	Notable Features			
	rameters					
BERT [9]	110 mil	Masked Language Modeling (MLM)	Bidirectional context, Pretrain-finetune dis-			
			crepancy			
BERT-large [9]	345 mil	Masked Language Modeling (MLM)	Bidirectional context, Pretrain-finetune dis-			
			crepancy			
XLNet [10]	110 mil	Generalized Autoregressive Pretraining	Overcomes BERT limitations, Transformer-XL			
			integration			
XLNet-large [10]	340 mil	Generalized Autoregressive Pretraining	Overcomes BERT limitations, Transformer-XL			
			integration			
GPT-2 [11]	1.5 billion	Autoregressive Language Modeling	Large-scale unsupervised, Zero-shot learning			
RoBERTa [13]	125 mil	Optimized BERT (MLM with changes)	Longer training, Removed next sentence pre-			
			diction, Dynamic masking			
RoBERTa-large [13]	355 mil	Optimized BERT (MLM with changes)	Longer training, Removed next sentence pre-			
			diction, Dynamic masking			
ALBERT [14]	18.2 mil	Optimized BERT (MLM with changes)	Sentence Ordering Prediction, Layer-Sharing			
			Architecture, Reduced Memory Footprint			
ALBERT-large [14]	223 mil	Optimized BERT (MLM with changes)	Sentence Ordering Prediction, Layer-Sharin			
			Architecture, Reduced Memory Footprint			
TABLE I						

SUMMARY OF NLP MODELS

### **USA: Performance of LLM models**

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### **Queensland: Performance of LLM models**

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## **Findings**

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We tested 8 large language models (BERT, XLNet, RoBERTa, etc.) combined with 4 different ML models (XGBoost, KNN, etc) across 3 diverse accident data sets from USA, UK, and Australia.

1. Language models can provide performance comparable to traditional machine learning pipeline with manual feature engineering step excluded completely.

2. LLM promise universally applicable accident analysis solutions, unconstrained to reporting format (which can vary across countries/cities).

## Multi-modal LLMs for accident analysis



### **Multimodal Large Language Models**

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2024

2023

#### Multimodal Large Language Models (MLLMs)

are advanced Generative AI systems designed to process and integrate information from multiple types of data, or "modalities," such as text, images, audio, and video.

Zhang, D., Yu, Y., Dong, J., Li, C., Su, D., Chu, C., & Yu, D. (2024). MM-LLMs: Recent Advances in Multimodal Large Language Models.

### Multi-modal LLMs for crash site analysis

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ChatGPT-40 input image





Prompt

Provide a list of

vehicle types

involved

Describe the

location and

road condition

Describe lighting

conditions

The lighting conditions appear to be natural daylight, likely on a cloudy or overcast day. The light is soft and diffused, with no harsh shadows, suggesting the sun is obscured by clouds. This provides even illumination across the scene without strong directional light.

ChatGPT-40 output

Silver Honda Stream - A compact MPV (Multi-Purpose Vehicle).

Beige Nissan Sunny - A compact sedan.

The location is an urban intersection, likely in Japan, as indicated by

the Japanese road markings and license plates. The road surface is asphalt, dry, and well-maintained with clear zebra stripes for a

pedestrian crossing and a visible bicycle lane marking. The road

conditions are good, with no visible debris or hazards.

https://en.wikipedia.org/wiki/Traffic\_collision

## WIP: TrafficIncidentResponseGPT

**TrafficIncidentResponseGPT**, an innovative platform that uses Generative AI to generate <u>incident response</u> <u>plans</u> by utilizing specific traffic <u>incident response</u> <u>guidelines</u> based on <u>incident description</u>.

- Visualized Chain-of-Thought Process: The platform offers transparency by visually presenting the AI's thought process, enabling users to understand how conclusions are drawn.

- **Empirical Evaluation:** The produced response plans are expected to have a formal structure to facilitate validation using decision-making algorithms (currently using TOPSIS) or traffic simulation software.

https://arxiv.org/abs/2404.18550



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## Integration: 1-click Accident Identification & Severity classification

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### TrafficIncidentResponseGPT. Results of guideline synthesis

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Scenario ID	Incident Type	Severity	Location	Action	Equipment/Technology Re- quired
1	Vehicle Break- down	Low	Highway/Freeway Lane	<ul> <li>Deploy Incident Response Ve- hicle</li> <li>Temporary lane closure</li> <li>Use VMS to warn drivers</li> </ul>	- Service Patrol Vehicle - Variable Message Signs (VMS) - Traffic Cones or Barriers
2	Minor Two-Car Collision	Moderate	Urban Arterial	<ul> <li>Notify Police &amp; EMS if needed</li> <li>Quick clearance policy</li> <li>Use VMS &amp; social media</li> </ul>	<ul> <li>Police/EMS Vehicles</li> <li>Quick Clearance Equipment (e.g., tow truck)</li> <li>Variable Message Signs</li> <li>Social Media Platforms</li> </ul>
3	Major Multi- Vehicle Crash	High	Highway/Freeway	<ul> <li>Full or partial lane closures</li> <li>Divert traffic to detour routes</li> <li>Activate EOC</li> </ul>	<ul> <li>Police/EMS/Fire Services</li> <li>Emergency Operations Center (EOC) Activation</li> <li>Detour Signage</li> </ul>
4	Hazardous Ma- terial Spill	High	Near Urban Area	<ul> <li>Full road closure</li> <li>Mandatory evacuation if necessary</li> <li>HazMat Team dispatch</li> </ul>	- HazMat Team - Road Closure Signage - Emergency Alert System (EAS)
5	Overturned Truck	Moderate	Highway On-ramp/Off- ramp	<ul> <li>Partial ramp closure</li> <li>Speed limit reduction in area</li> <li>Deploy tow truck and cleanup crew</li> </ul>	- Tow Trucks - Cleanup Crew - Speed Limit Signs
6	Pedestrian Acci- dent	High	Urban Crosswalk	<ul> <li>Full closure of affected lanes</li> <li>EMS priority dispatch</li> <li>Investigative procedures</li> </ul>	- EMS Vehicles - Police Investigation Unit - Temporary Signage
7	Wildlife on Road	Low	Rural Road	<ul> <li>Temporary speed limit reduc- tion</li> <li>Use VMS to warn drivers</li> <li>Wildlife control dispatch</li> </ul>	- Variable Message Signs - Wildlife Control Services
8	Infrastructure Failure (Bridge)	Very High	Bridge	- Full bridge closure - Long-term detour setup - Structural assessment	- Structural Engineering Team - Permanent Detour Signage - Media Briefing Equipment
9	Snow/Ice Con- ditions	Variable	Major Roadways	- Speed limit reduction - Deploy snow plows/salt trucks - Use VMS and radio to inform	- Snow Plows/Salt Trucks - Variable Message Signs - Radio Broadcast System
10	Fog/Visibility Issues	Variable	Highway/Freeway	- Speed limit reduction - Flashing lights to warn drivers - Use VMS to advise caution	- Variable Message Šigns - Highway Flashing Lights

#### Comparison of model performance for incident response plan generation (action weights estimated using TOPSIS, comparison of binary action vectors performed Euclidean distance estimation)

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7	Table 13: Model comparison results with average differences						
		GPT-4	GPT-40	Gemini 1.5 Flash	Gemini 1.5 Pro	Manual solution	Act Deploy Incident
	A-4259643 A-5128843 A-4227983 A-4888575 A-5968770 A-6137133	$ \begin{array}{c c} 1.81 \\ 4.96 \\ 4.54 \\ 4.16 \\ 3.22 \\ 0.75 \\ 2.75 \\ 0.75 \\$	$\begin{array}{c} 2.77 \\ 3.10 \\ 2.13 \\ 2.77 \\ 2.13 \\ 1.57 \\ 2.62 \end{array}$	4.30 4.96 4.44 4.63 4.96 4.96	5.16 $4.97$ $4.97$ $4.96$ $4.45$ $4.77$	$\begin{array}{c} 2.77 \\ 4.96 \\ 4.24 \\ 3.63 \\ 3.45 \\ 1.93 \\ 2.70 \end{array}$	Temporary I Use VMS to Notify Poli Quick Clear Use VMS & Full or Partial Divert Traffic to Activat
	A-4428281 A-4732415 A-6060568 A-3996497	$\begin{array}{c} 2.77 \\ 0.75 \\ 4.63 \\ 0.75 \end{array}$	$3.63 \\ 3.57 \\ 1.61 \\ 2.57$	$\begin{array}{c} 3.70 \\ 4.22 \\ 4.63 \\ 4.01 \end{array}$	$\begin{array}{c} 4.44 \\ 4.63 \\ 4.96 \\ 5.16 \end{array}$	2.70 2.84 4.63 2.15	Total Ra
	Average Difference	0.68	1.16	1.15	1.52	0.00	GPT-4



Manual Solution [001101111

#### Our goal: 1-click Accident Identification & Modelling & Resolution

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## Thank Youl

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