An Integrated Data-Driven Approach for Hydroplaning Risk Assessment in Asphalt Pavements Using Crash Narrative and Pavement Surface Texture Data

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Introduction

- Hydroplaning is a critical wet-weather safety phenomenon caused by the interaction between pavement surface conditions, water accumulation, and vehicle dynamics.
- Pavement texture quantified using Mean Profile Depth (MPD), from road profilometer measurements influences surface drainage and water film thickness and thereby hydroplaning susceptibility.
- Crash narratives written by investigating officers contain rich contextual information about road conditions and vehicle behavior not captured by coded crash fields.
- Despite their complementary relevance, crash narratives and MPD data are rarely integrated within a unified analytical framework – creating a significant gap in wet-weather safety research.

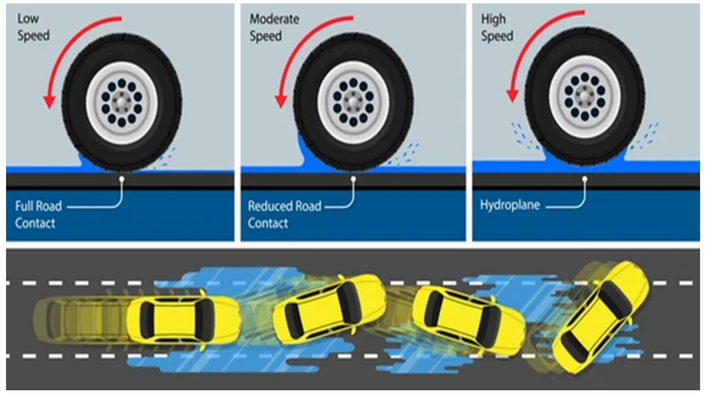

Figure 1. Hydroplaning phenomenon

Research Question

- Can pavement texture alone explain the occurrence of hydroplaning-related crashes ?

Objectives

- Identify hydroplaning-related crashes using crash narratives through keyword-based filtering of wet-weather crashes.
- Integrate crash records with pavement texture data using highway and DFO-based matching.
- Evaluate the influence of pavement texture on hydroplaning occurrence using statistical testing.
- Demonstrate the importance of integrating crash narratives with texture data for improved interpretation of hydroplaning risk assessment.

Dataset Description

- Data sourced from TxDOT Crash Report Information System (CRIS), Austin District FY2024.
- Crash dataset includes:
  - ➢ *Investigator narratives, roadway attributes, GPS coordinates, crash severity,*
  - ➢ *Speed limit, functional classification, roadway surface condition, weather condition.*
- Texture dataset includes:
  - ➢ *Average texture – MPD_{Mean}*
  - ➢ *Minimum texture – MPD_{Min}*
  - ➢ *Maximum texture – MPD_{Max}*
  - ➢ *Distribution of texture – MPD_{Dist}*

Methodology

CRIS Crash Data
- Austin District FY2024
- 2613 wet weather crash records

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Narrative-Based Hydroplaning Identification
- Examine crash narratives
- Apply keyword-based filtering (hydroplane, wet road, skid, loss of control)
- Classify crashes into: Hydroplaning vs Non-hydroplaning (Ground truth)

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Crash-Texture Integration
- Match crashes with pavement texture using Highway identifier and Distance From Origin (DFO)
- Assign MPD metrics to each crash datapoint

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Statistical Analysis
- Descriptive statistics
- Hypothesis testing: Mann-Whitney U test, Kolmogorov-Smirnov (KS) test

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Texture Analysis
- MPD bins analysis

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Final key insight
- Hydroplaning – Multifactor Phenomenon

Results & Discussion

➢ Narrative-based Hydroplaning Identification

- Hydroplaning crashes: 703, which contribute to 26.9% share of wet weather crashes.
- Non-hydroplaning crashes: 1910, which contribute to 73% share of wet weather crashes.

➢ Mann-Whitney U Test

- Compares MPD values between hydroplaning and non-hydroplaning crashes.
- Evaluates difference in central tendency (median/rank).
- Considered hypothesis:
  H_0: MPD values are the same for hydroplaning and non-hydroplaning crashes,
  H_1: MPD values are different between the two groups.

Table 1. Mann-Whitney U test results

MPD metric	Hydroplaning	Non-hydroplaning	p - value	Significance
MPD_{Mean}	0.63	0.63	0.89	Not significant
MPD_{Max}	0.87	0.89	0.42	Not significant
MPD_{Min}	0.41	0.42	0.95	Not significant

✓ **Key insight:** At the network-level, MPD is statistically indistinguishable between crash groups – all p > 0.05. This suggests that texture alone does not provide insights on hydroplaning occurrence.

➢ Kolmogorov-Smirnov (KS) Test

- Non-parametric test comparing entire MPD distributions.
- Evaluates differences in distribution shape, spread, and cumulative behavior.
- Considered hypothesis: H_0: MPD_{Dist} is the same for both groups, H_1: MPD_{Dist} is different.

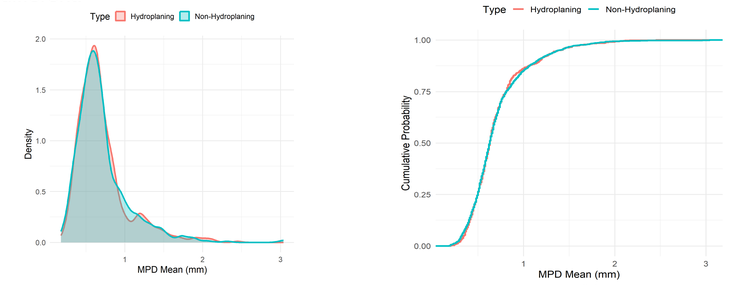

Figure 2. Comparison of MPD Distributions for Hydroplaning and Non-Hydroplaning Crashes: (a) Density Distribution of MPD (b) Empirical Cumulative Distribution Function

✓ **Key insight:** Strong overlap in density and ECDF plots confirms similar MPD distributions for both hydroplaning and non-hydroplaning crashes.

➢ Texture Analysis

- MPD bin analysis was performed to examine hydroplaning distribution across texture ranges.
- Majority of crashes in both groups occur in 0.4-0.79 mm MPD bins.

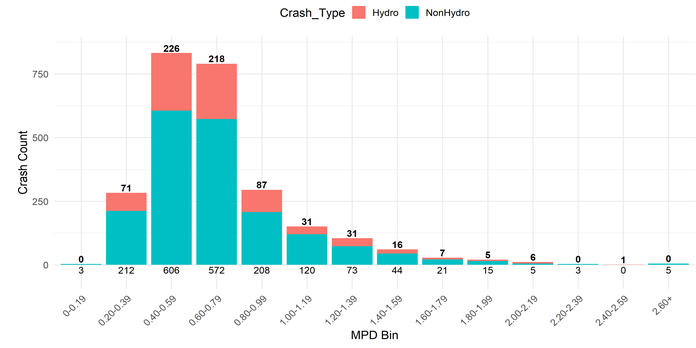

Figure 3. MPD bin analyses for hydro and non-hydro crashes

✓ **Key insight:** Hydroplaning is distributed across all MPD ranges without a distinct texture threshold.

➢ Role of Crash Narratives

- Hydroplaning directly identified using text-based crash narratives.
- Captures both wet surface and loss of control conditions.

✓ **Key insight:** Provides context beyond texture and traditional coded crash variables.

Conclusions

- No statistically significant difference was observed in MPD values or distributions between hydroplaning and non-hydroplaning crashes.
- Hydroplaning crashes remained consistent across texture ranges, with no distinct MPD threshold.
- Statistical analyses results also confirmed strong overlap between hydro and non-hydro groups.

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