

Influence of Vehicle Characteristics on Driving Events Based on a Naturalistic Driving Experiment

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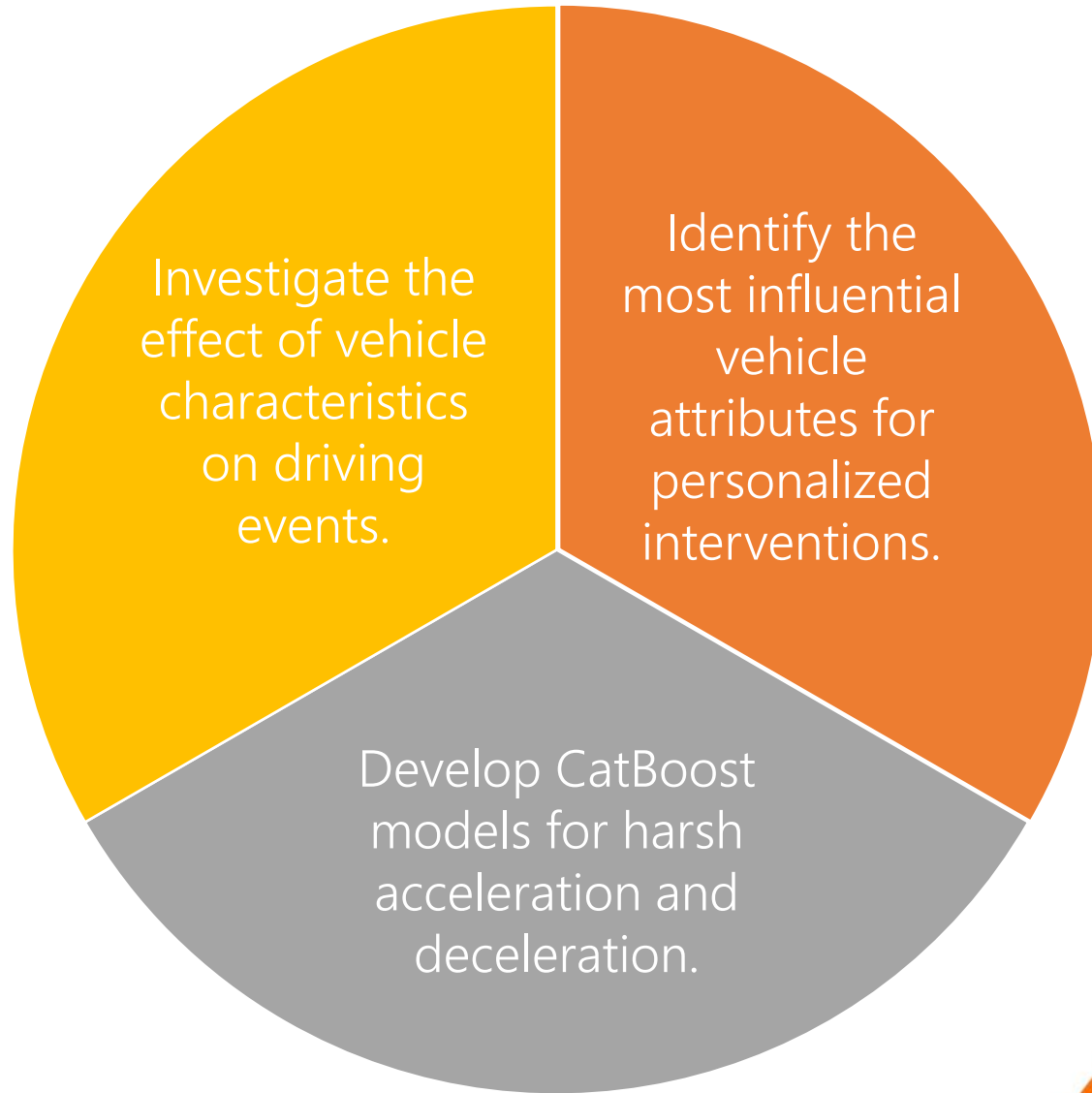


Motivation

- Human factors contribute to the majority of road crashes.
- **Vehicle characteristics** also influence driving behaviour.
- However, their impact on aggressive driving events remains **insufficiently explored**.
- Understanding these effects can support **personalized safety interventions**.
- Which **vehicle characteristics** contribute the most to harsh acceleration and deceleration events?



Objectives



The i-DREAMS project

➤ 13 Project partners:

[Universiteit Hasselt](#), [National Technical University of Athens](#), [Loughborough University](#), [Technische Universität München](#), [Kuratorium für Verkehrssicherheit](#), [Delft University of Technology](#), [University of Maribor](#), [OSeven Telematics](#), [DriveSimSolutions](#), [CardioID Technologies](#), [European Transport Safety Council](#), [POLIS Network](#), [Barraqueiro Transportes S.A.](#)

➤ Duration of the project:

36 months (May 2019 – May 2022)

➤ Framework Program:

[Horizon 2020](#) - The EU Union Framework Programme for Research and Innovation - Mobility for Growth

iDREAMS



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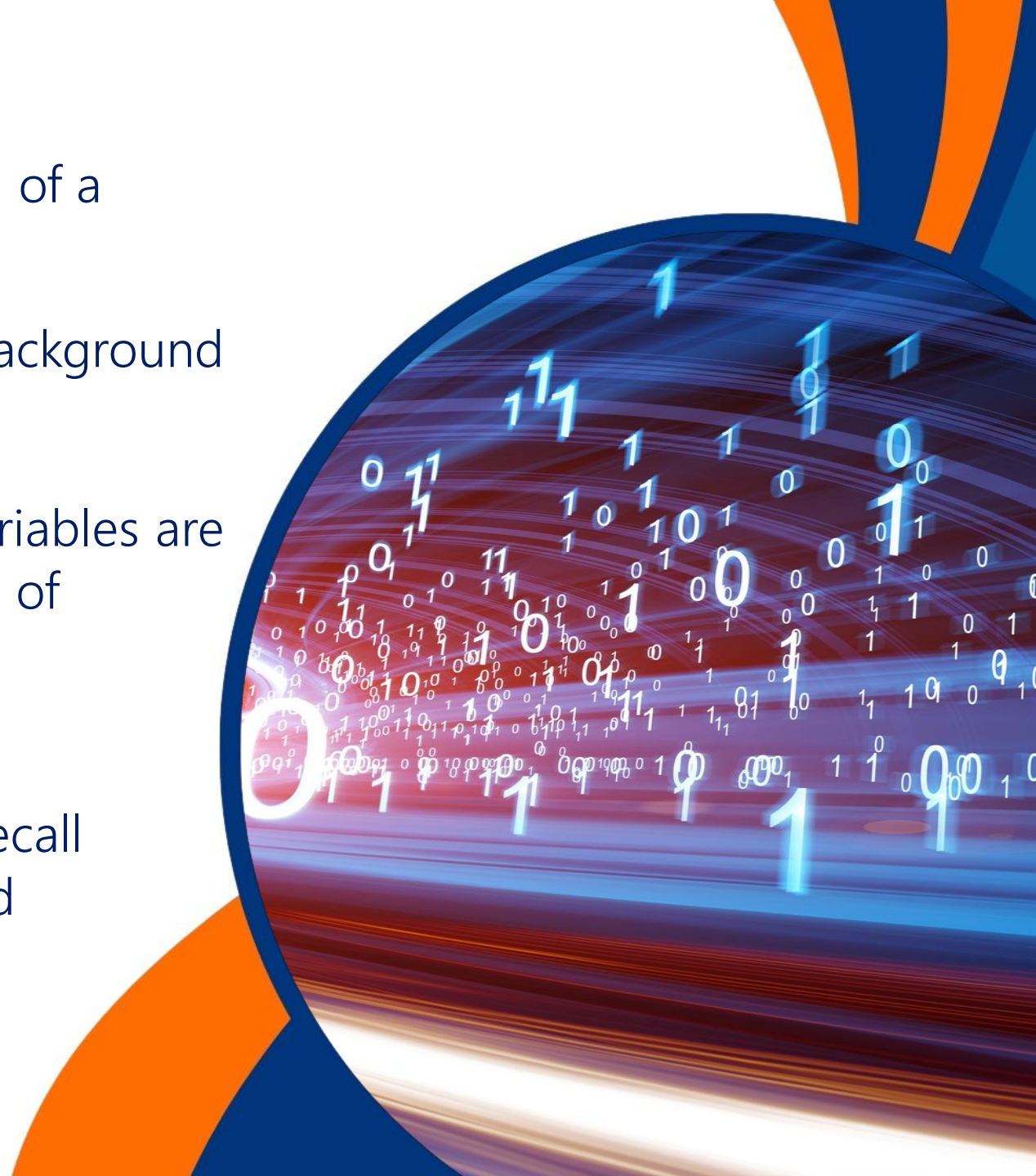


Streets for Life
#Love30

Background

Definition, development, testing and validation of a context-aware '**Safety Tolerance Zone**':

- raw **time-series** sensor data and driver background data are transformed into **indicators**
- **operator capacity and task complexity** variables are used for a multi-dimensional assessment of driving context and crash risk prediction
- appropriate driver comfort related interventions take place in **real-time** to recall driver back into a safe area if needed and guidance is given **post-trip** to improve driving behavior



i-DREAMS Experiment

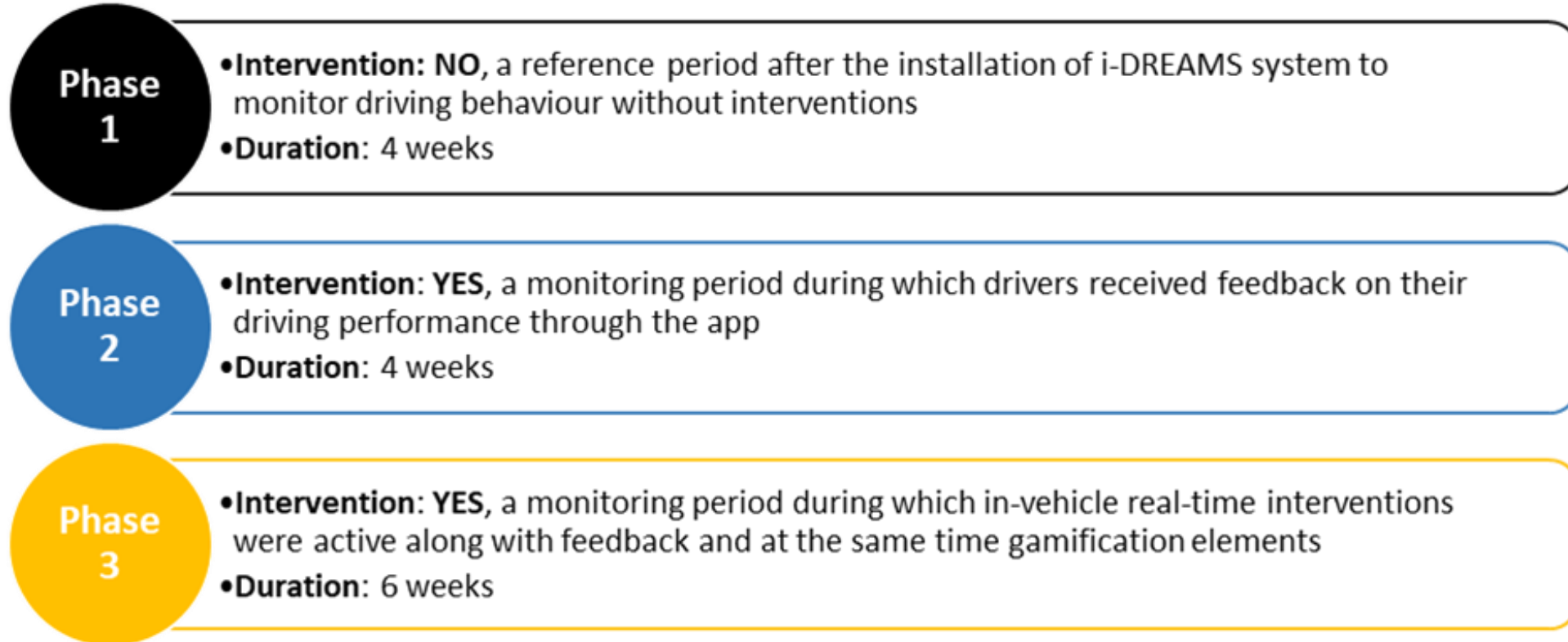


Table 1. Phases of the STZ.

STZ level	Driving Phase	Description	Interventions
1	Normal driving phase	Crash risk is minimal	no real-time interventions were necessary
2	Danger phase	Risk of crash increases as internal /external events occur	a visual warning like a message is presented
3	Avoidable crash phase	Crash is very likely to occur if no preventative action taken by driver	a more intrusive instruction signal (e.g., visual warnings like flashes and auditory warnings like beeps) is provided



Data selection

Vehicle characteristics:

- Vehicle age
- Brand
- Model
- Engine capacity
- Horsepower
- Gearbox
- Fuel type

Experiment phase:

- Baseline
- Post-trip
- Gamification

Safety Promoting Goalsse	Performance Objectives	Severity Level	Events per 100 km					
			Baseline Phase		Post-trip Phase		Post-trip & Gamefication Phase	
			Mean	STD	Mean	STD	Mean	STD
Speed Management	Speeding	Medium	7	15	6	14	6	13
		High	25	33	24	32	21	29
Vehicle Control	Acceleration	Medium	3	10	4	13	2	9
		High	1	11	2	9	2	9
	Deceleration	Medium	6	15	6	14	5	13
			3	11	3	11	3	9
Driver Fitness	Distraction	n/a	23	60	23	57	17	48
Distance (km) per trip		n/a	9	15	8	15	10	18
Duration (min) per trip		n/a	17	15	17	14	18	15

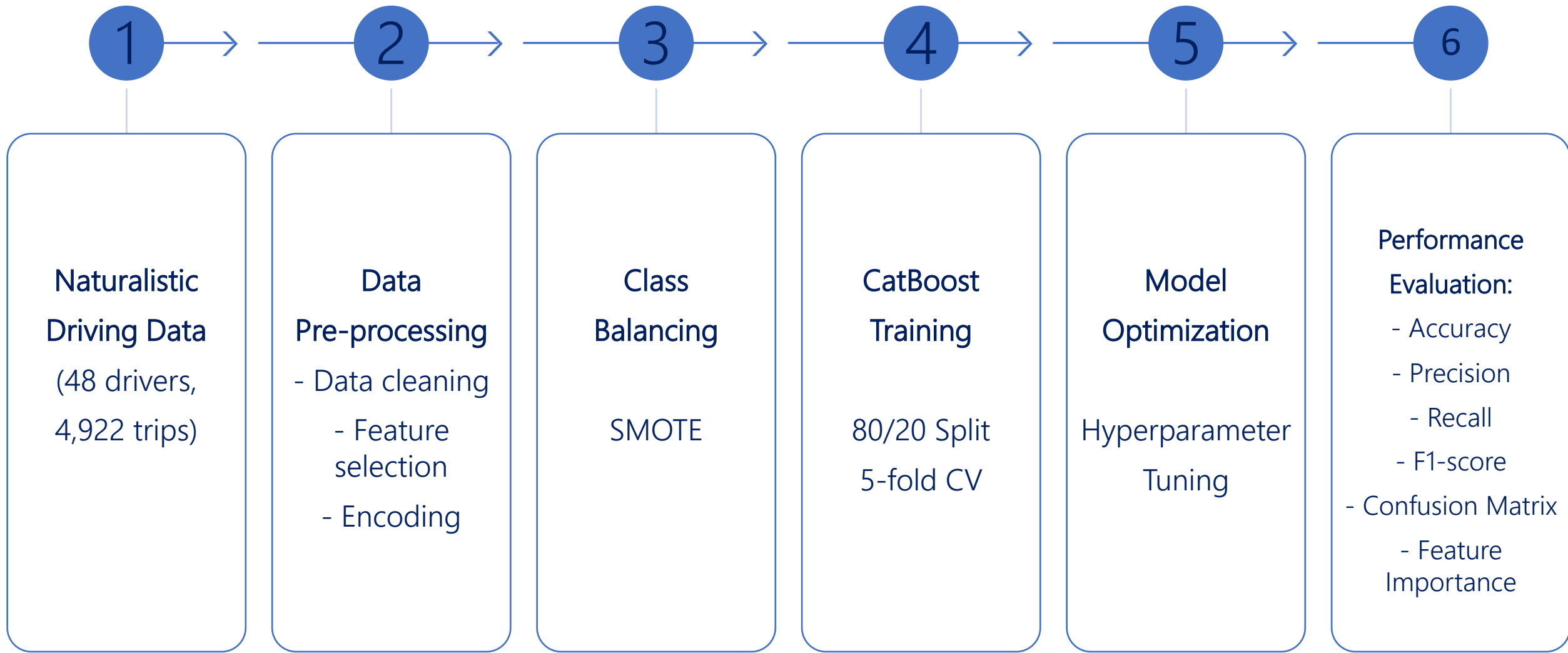
Table 1. Descriptives of events per 100 km for SPG and PO

Driving events:

- Harsh acceleration
- Harsh deceleration



Methodology

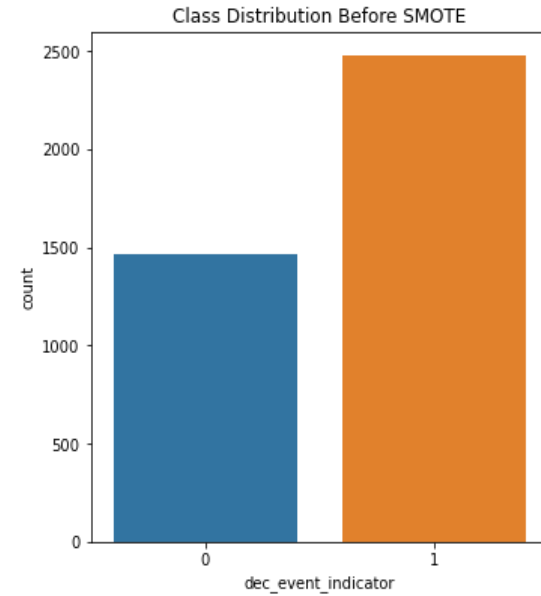
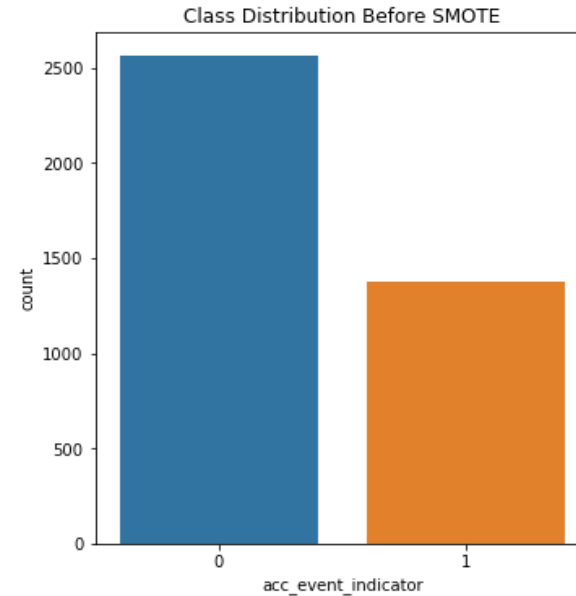


CatBoost Model

Why CatBoost?:

- Native handling of categorical variables
- Robust to heterogeneous datasets
- High predictive performance
- Resistant to multicollinearity
- Provides interpretable feature importance

Class Imbalance for the acceleration event



Class Imbalance for the deceleration event

Model Optimization and their Hyperparameters optimized:

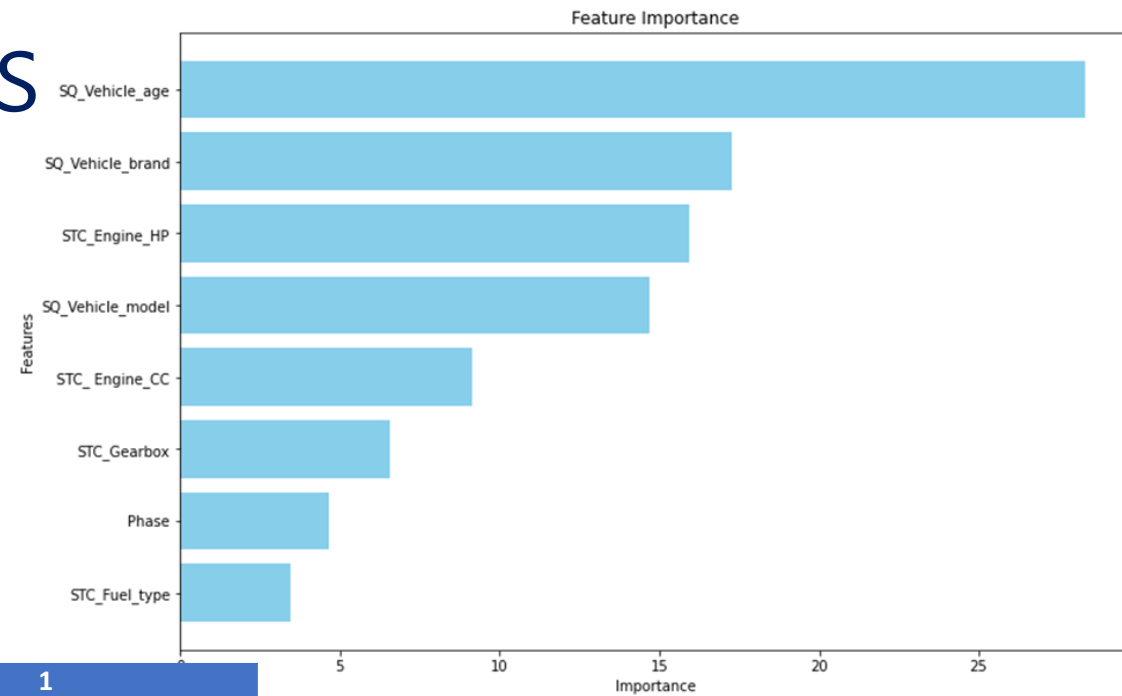
- Learning rate
- Number of iterations
- Tree depth
- L2 regularization
- Border counts
- Class weights using 5-fold Cross Validation

Hyperparameter	Examined range	Optimized Value for Harch Acceleration events	Optimized Value for Harch Deceleration events
Learning rate	0.01 - 0.29	0.1	0.1
Iterations	150 - 450	150	450
Depth	3 - 11	3	11
L2 Leaf Reg.	1-10	10	1
Subsample	0.4-0.99	0.4	0.4
Border Count	32-128	32	128
Class Weights	{0: 0.5, 1: 10}	{0: 1.0, 1: 0.785}	{0: 1.0, 1: 0.5}
Random State	Fixed at 42	42	42



Results- Acceleration Events

- Vehicle age clearly dominates the model, indicating that **older vehicles** are **associated with a higher likelihood** of harsh acceleration events.
- Vehicle performance characteristics, particularly **engine capacity and horsepower**, also play an important role.
- The intervention phase has a smaller but still noticeable effect.



	0 (No acc. events)	1 (acc. events)	
precision	0.76	0.61	0.73
recall	0.83	0.50	0.72
f1- score	0.79	0.55	0.72
Accuracy			0.70
Macro avg	0.68	0.68	0.68
Weighted avg	0.71	0.71	0.71

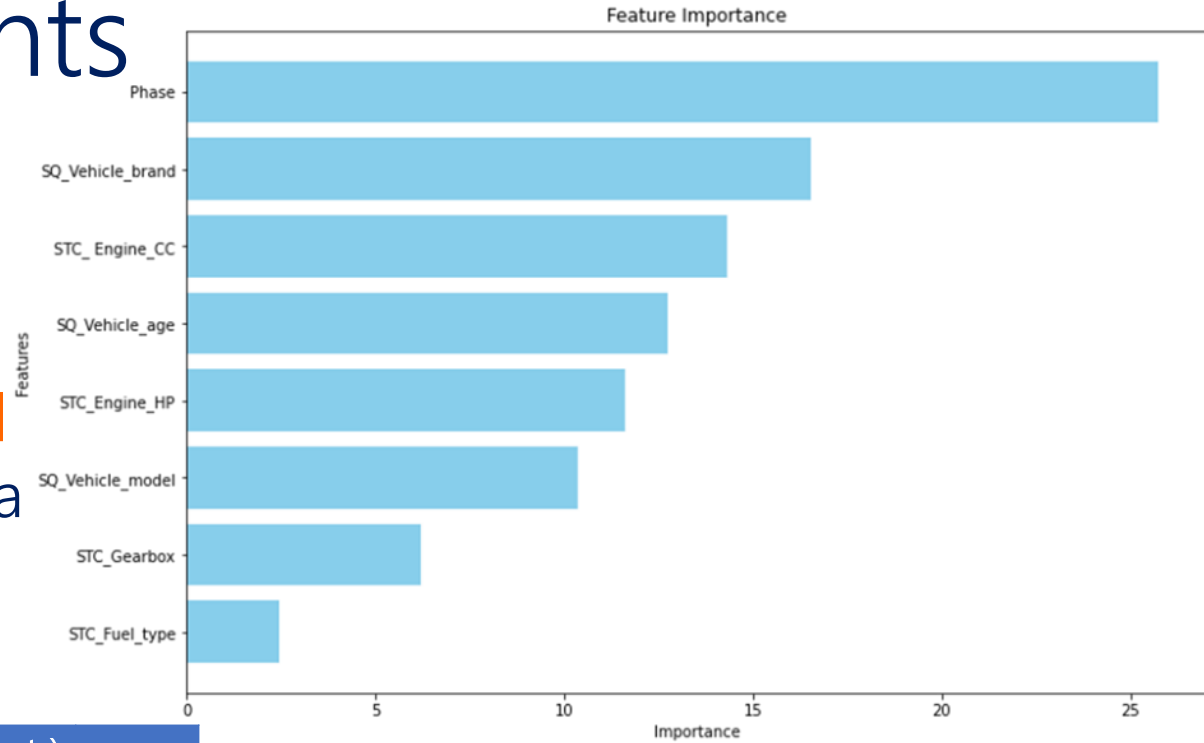
	Predicted No acc. events	Predicted acc. events
Actual Non Acc. Events	538	109
Actual Acc. Events	170	168

Hyperparameter	Examined range	Optimized Value
1	Vehicle Age	28.323
2	Vehicle Brand	17.258
3	Horsepower	15.928
4	Vehicle Model	14.700
5	Engine CC	9.158
6	Gearbox Type	6.543
7	Phase	4.646
8	Fuel type	3.440



Results- Deceleration Events

- Unlike acceleration, deceleration behaviour appears to be **influenced primarily by the intervention phase**.
- This suggests that the **post-trip feedback and gamification** implemented in i-DREAMS had a stronger impact on braking behaviour than on acceleration patterns.



- Behavioural interventions** have a **stronger influence on harsh deceleration** than vehicle characteristics.

	0 (No dec. events)	1 (dec. events)	
precision	0.50	0.66	0.59
recall	0.46	0.69	0.60
f1- score	0.48	0.67	0.60
Accuracy			0.60
Macro avg.	0.58	0.58	0.58
Weighted avg.	0.59	0.60	0.60

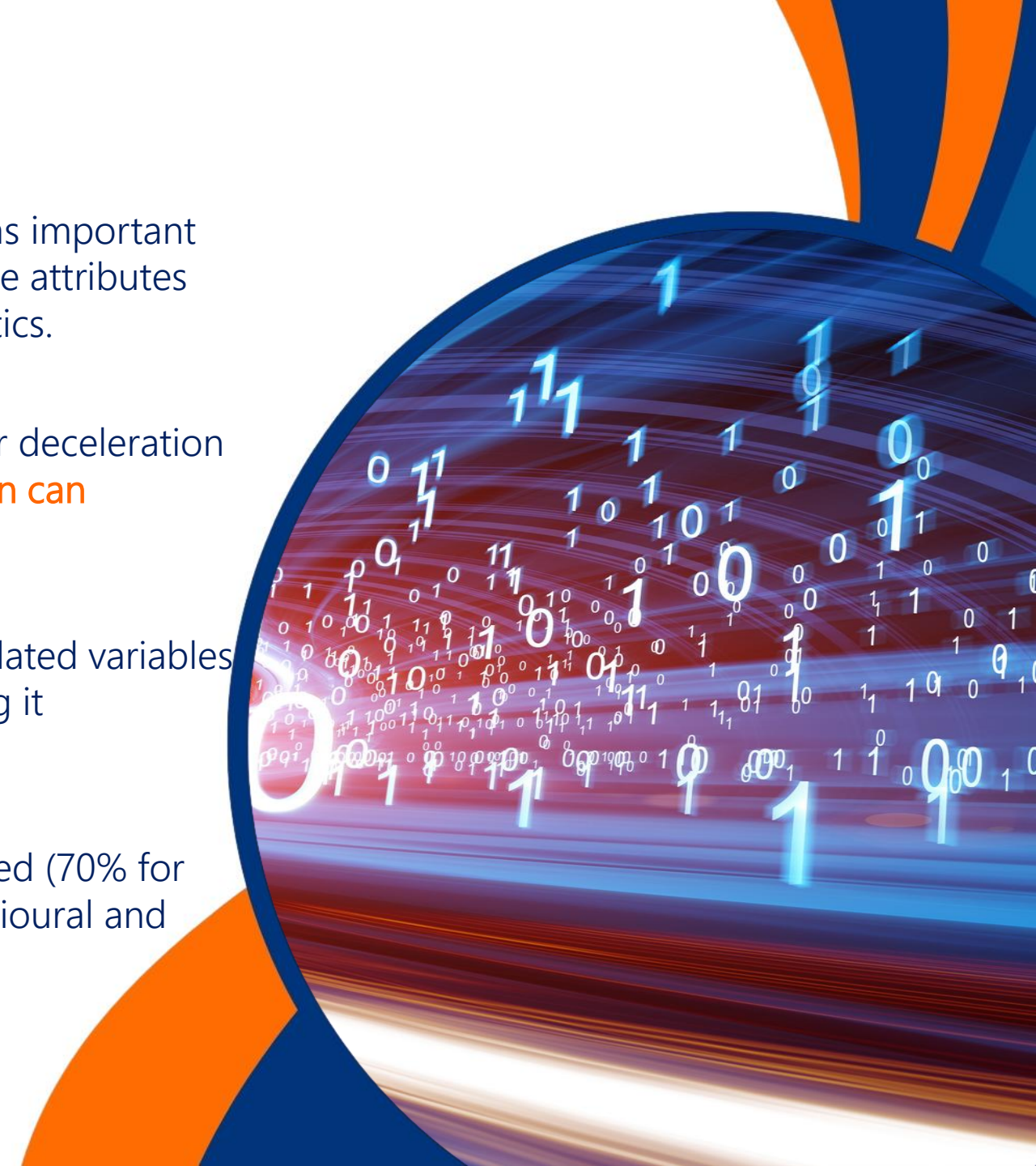
	Predicted No acc. events	Predicted acc. events
Actual Non Acc. Events	183	211
Actual Acc. Events	185	406

Hyperparameter	Examined range	Optimized Value
1	Phase	25.730
2	Vehicle Brand	16.547
3	Engine CC	14.330
4	Horsepower	12.727
5	Vehicle Age	11.615
6	Vehicle Model	10.374
7	Gearbox Type	6.221
8	Fuel type	2.452



Discussion

- 1. Vehicle characteristics matter.**
Vehicle age, engine capacity and horsepower emerged as important predictors of harsh driving events, suggesting that vehicle attributes influence driver behaviour beyond individual characteristics.
- 2. Behavioural interventions are effective.**
The prominence of the experiment phase, particularly for deceleration events, indicates that post-trip feedback and gamification can positively influence driving behaviour.
- 3. CatBoost proved suitable.**
CatBoost successfully handled heterogeneous vehicle-related variables while providing interpretable feature importance, making it appropriate for behavioural safety applications.
- 4. Driving behaviour is multifaceted**
Although acceptable predictive performance was achieved (70% for acceleration and 60% for deceleration), additional behavioural and environmental factors are required to fully explain risky driving events.



Conclusions

1. Vehicle characteristics significantly influence aggressive driving behaviour.
2. Vehicle age is the strongest contributor to harsh acceleration events.
3. The intervention phase is the dominant factor affecting harsh deceleration behaviour.
4. Machine learning can successfully identify behavioural patterns from naturalistic driving data.
5. Vehicle-related information should be incorporated into personalized driver support and intervention systems.



The combination of vehicle characteristics and behavioural interventions **provides valuable information for designing next-generation personalized road safety systems.**



Future Work

- Richer data integration
- Driver demographics and psychological traits
- Driver state (fatigue, distraction, workload)
- Weather conditions
- Traffic density, Road geometry
- Advanced AI models, Explainable AI (SHAP), Ensemble learning
- Deep Learning architectures
- Real-time prediction models
- Personalized interventions
- **Develop adaptive intervention strategies co-considering:** Driver profile, Vehicle profile, Driving context, Real-time behaviour

Towards
context-aware
and vehicle-
aware intelligent
safety systems.



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