

DMS does not need to identify cause of impairment to be effective



Introduction

The introduction of the breathalyser in the mid-20th century and its subsequent adoption for scalable roadside enforcement of drunk-driving laws marked a major milestone in traffic safety. It operationalised alcohol-induced impairment as a measurable concentration threshold.

The appeal of setting a fixed chemical concentration value as a proxy for impairment was its generalisability for enforcement and accessibility for public acceptance despite significant variabilities in the exact Blood Alcohol Concentration (BAC) value considered high risk across jurisdictions.

Such accessibility of this approach motivated efforts to extend its applicability to other intoxicants, in particular cannabis. Adoption of the chemical threshold method for cannabis is in part necessitated by the legalisation of its use for medicinal and recreational purposes across growing regions. However, when it comes to a specific chemical threshold that constitutes a significant risk for driving, there's even less of a consensus for cannabis than alcohol.

As a result, adoption of the chemical threshold as a proxy for impairment varies from zero-tolerance to defined per se limits.

In some jurisdictions, detection of minimal presence of the substance through roadside oral fluid testing constitutes an offence irrespective of demonstrable impairment¹, while other regions have specified maximum concentration limit or tiered levels that correspond to low- and high-level offences².

The evidence base for establishing concentration limits for cannabis has proven more complex than for alcohol, in part because blood levels of the primary psychoactive component, tetrahydrocannabinol (THC), demonstrate a weak and inconsistent relationship with driving impairment³.

Consequently, THC cutpoints have been widely challenged as lacking strong scientific credibility as indicators of real-time functional impairment⁴.

These limitations highlight a broader constraint of chemical thresholds as proxies for impairment: chemical presence does not reliably or uniformly translate to a reduction in operational capacity.

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Intoxication vs impairment

In common usage, intoxication and impairment are often treated as interchangeable.

While concentration-based frameworks support legal enforcement and compliance, DMS are preventive technologies designed to mitigate crash risk associated with driver impairment arising from a range of causes.

Realising the safety potential of DMS therefore requires conceptual clarity regarding the distinction between intoxication and impairment to ensure detection logic aligns with crash prevention objectives.

The historical reliance on per se concentration limits in traffic safety has shaped how substance-related risk is conceptualised. In common usage, intoxication and impairment are often treated as interchangeable.

Behaviourally, intoxication is inferred from observable changes in appearance, motor coordination, judgement, or attentional control; making it synonymous with impairment. In technical and regulatory contexts, however, intoxication refers to the measurable presence of a psychoactive substance in the body, typically quantified through blood, breath, or other biomarkers. It is a pharmacological state defined by concentration. Under concentration-based models, intoxication is operationalised as impairment once a predefined threshold is exceeded.

Driver impairment, by contrast, is a state of reduced functional capacity to safely operate a vehicle. It reflects degradation in the perceptual, cognitive, or psychomotor processes required for effective vehicle control within a given environment.

Impairment is therefore a functional construct defined by diminished operational capability.

Furthermore, impaired states may be transient or non-transient⁵.

- Transient impairment involves short-lived reductions in performance, such as momentary lapses in attention. These states are typically situational and reversible, though they may still elevate short-term crash risk. Distraction due to engagement in a secondary task is one such a state that can increase crash risk, and is currently addressed by DMS capabilities.
- Non-transient impairment, by contrast, involves persistent degradation that develops over time and progressively increases crash risk. It is commonly associated with broader homeostatic or neurochemical changes arising from sleep pressure, pharmacological effects of intoxicants, or acute medical and psychological events. In such cases, performance degradation extends beyond isolated lapses and manifests as a systemic change in attentional regulation, perceptual processing, and psychomotor control.

The defining characteristic of driver impairment is its measurable impact on operational capability, not its biological or chemical origin.

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Comparing alcohol and cannabis

Part 1 of this Technical Paper series examined this limitation in the context of alcohol and demonstrated why BAC does not provide a reliable or temporally stable ground truth for real-time impairment detection, owing to the dissociation between pharmacokinetic concentration curves and pharmacodynamic expression of functional impairment.

The present analysis extends that reasoning by examining another widely used intoxicant, cannabis, to illustrate a broader principle: effective DMS do not require causal attribution to reduce crash risk.

The practical importance of this proposition is underscored by epidemiological evidence from real-world crash statistics.

In a recent report, 53.4% of drivers involved in a crash and treated for injuries tested positive for at least one psychoactive substance, with alcohol and cannabis being the most commonly detected⁶. This report further highlights the problem of polydrug use, with 62% of alcohol-positive cases also involving another substance.

The high prevalence of alcohol and cannabis, particularly in combination, complicates causal attribution and reinforces the importance of focusing DMS design on functional impairment rather than discrete chemical concentration levels.

From a collision prevention perspective, the relevant variable is the degree of functional impairment, not the specific intoxicant contributing to it. Crash risk increases as operational capability degrades, irrespective of whether that degradation arises from alcohol, cannabis, combined substance use, fatigue, or other causes.

While the underlying mechanism may differ, the safety consequence is mediated through the same pathway: reduced perceptual, cognitive, or psychomotor performance relative to driving demands. Accordingly, effective real-time safety systems need only detect the presence and severity of impairment to align with crash prevention objectives, without requiring precise attribution of its source.

Alcohol intoxication represents the most pharmacologically predictable, extensively studied, and standardised model of substance-related driver impairment. Its relatively stable elimination process, coupled with reliable breath-based detection technology, enabled the development of targeted sensing solutions such as ignition interlock systems.

These technologies are feasible because alcohol is systemically distributed, measurable in expired breath, and supported by broadly accepted concentration thresholds.

Cannabis differs materially in its pharmacokinetic profile, redistribution characteristics, and concentration–impairment coupling. Blood or oral fluid THC levels do not demonstrate the same temporal stability or predictive strength with respect to functional degradation.

Unlike alcohol, there is currently no widely accepted, technically practical, and temporally reliable biomarker that can serve as a single-substance in-vehicle proxy for real-time impairment⁷.

Table 1 compares alcohol and cannabis across dimensions relevant to real-time safety system design, highlighting material differences that affect detection feasibility and reliability.

53.4% of drivers involved in a crash and treated for injuries tested positive for at least one psychoactive substance.

Extending a hardware-bound, substance-specific detection model across multiple drugs would require parallel sensing modalities for each compound, with uncertain linkage to operational capability.

These differences illustrate a broader systems implication: while alcohol may lend itself to concentration-based detection technologies, the diversity of intoxicants and variability in their relationship to functional performance limit the scalability of substance-specific approaches.

For generalised in-vehicle safety systems intended to reduce crash risk across causes, a cause-agnostic framework that directly assesses impairment provides a more robust and extensible solution. This allows for development of intervention strategies that are aligned with risk rather than presumed cause of impairment.

Concentration thresholds remain essential for enforcement, but crash prevention is mediated through functional capability. Across substances and non-substance-related causes alike, it is the severity and time course of impairment, rather than chemical presence, that directly increase collision risk.

Real-time safety systems must therefore prioritise detection of functional impairment and degraded operational performance relative to driving demands.

Driver Monitoring Systems provide a scalable framework for achieving this objective by focusing on functional state, irrespective of the underlying cause.

Table 1.
Properties of Alcohol and Cannabis, and implications for real-time detection.

Dimension	Alcohol (Ethanol)	Cannabis (THC ± CBD)	Implications for DMS
Composition	Single psychoactive compound; % ABV influences absorption rate and timing of peak effect but not mechanism of action	Multiple active cannabinoids; THC:CBD ratio modulates both magnitude and qualitative profile of psychoactive and functional effects	Substance-specific detection requires compound-level specificity; effect heterogeneity complicates concentration-based inference
Physicochemical properties	Hydrophilic; distributes primarily in total body water	Lipophilic; rapidly partitions into fat and peripheral tissues	Lipophilicity contributes to delayed redistribution and prolonged detectability without proportional impairment
Intake and absorption	Oral ingestion; predictable gastrointestinal absorption into bloodstream	Inhaled or orally ingested; route-dependent absorption and onset profiles	Route variability reduces reliability of concentration as a time-locked impairment indicator
Elimination kinetics	Approximately linear elimination across typical ranges	Non-linear kinetics; redistribution from fat stores; prolonged metabolite presence	Blood concentration does not reliably indicate current functional state
Blood concentration-impairment coupling	Moderate population-level correlation with impairment, subject to temporal variability	Weak and inconsistent correlation with acute impairment; high inter-individual variability	Functional state assessment provides more direct alignment with crash risk than biomarker thresholds



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