

A Statistical Review of Road Intersection Dynamics

Data Synthesis for Thesis Research

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1 Fuel Consumption at Intersections

1.1 Intersection Inefficiency Statistics

- The transportation sector is the largest consumer of fuel in the United States [1].
- Road vehicles account for approximately 75% of all transportation energy used in the U.S. [1].
- In a single-vehicle study, 50.36% of total fuel was consumed within the intersection influence area, which only constituted 28.9% of the total distance traveled [2].
- The same study found that 68.5% of the vehicle's running time was spent in the intersection influence area [2].
- In the U.S., drivers spend an average of 10% of their journey time delayed by traffic signals [3].
- The average American driver spends more than 18 seconds idling at each traffic signal [3].
- This aggregates to 8.65 billion hours of vehicle idling at U.S. intersections annually [3].
- This idling and subsequent acceleration/deceleration generates nearly 28 million metric tons of CO₂ emissions annually in the U.S. [3].
- This results in approximately 3.9 million barrels of oil wasted each year in the U.S. due to signal delays [3].

1.2 Expanded Table: Fuel Consumption and Emissions Data

Table 1: Breakdown of Fuel Consumption and Emissions at Signalized Intersections

Metric	Value	Unit	Source(s)
Share of Fuel Consumed at Intersection (single vehicle study)	50.36	%	[2]
Share of Intersection Distance (single vehicle study)	28.9	%	[2]
Share of Intersection Running Time (single vehicle study)	68.5	%	[2]
Share of Intersection Fuel Use from Acceleration/Idling	78.4	%	[2]
Average Journey Time Delayed by Signals (U.S.)	10	%	[3]
Average Idling Time per Signal per Vehicle (U.S.)	418	seconds	[3]
Total Annual Idling Hours (U.S.)	8.65	billion	[3]
Total Annual CO ₂ Emissions from Signal Delay (U.S.)	~28	million metric tons	[3]
Total Annual Oil Wasted from Signal Delay (U.S.)	3.9	million barrels	[3]
Emission Increase due to Signal Influence (CO ₂)	11.52	%	[4]
Emission Increase due to Signal Influence (CO)	16.46	%	[4]
Emission Increase due to Signal Influence (HC)	16.89	%	[4]
Emission Increase due to Signal Influence (NO _x)	15.72	%	[4]

2 Accidents at Intersections

2.1 National Accident Prevalence

- Approximately 2.5 million accidents occur at U.S. intersections annually [5].
- Intersections are involved in 40% of all police-reported crashes [5].
- Intersections account for approximately 25% of all traffic fatalities in the U.S. [6].
- Intersections account for approximately 50% of all traffic injuries in the U.S. [6].
- In 2022, of 42,514 total traffic fatalities, 12,036 (28.3%) were intersection-related [6].
- There are nearly 16 million intersections in the continental U.S. [7].
- Less than 0.01% of intersections qualify as "deadly intersections" (locations with multiple fatal crashes) [7].
- 82% of fatal crashes at these deadly intersections involved at least one high-speed "main artery" (interstate, U.S. highway, etc.) [7].
- 71% of fatal crashes at deadly intersections occur in non-city (rural/suburban) areas [7].

2.2 Expanded Table: U.S. Intersection Fatality Statistics by Control Type (2018-2022)

Table 2: Intersection Fatality Data from NHTSA FARS

Metric	2018	2019	2020	2021	2022
Total Traffic Fatalities	36,835	36,355	39,007	42,939	42,514
Total Intersection Fatalities	10,148	10,273	10,720	11,799	12,036
<i>Unsignalized Intersections</i>					
Fatalities at Unsignalized Intersections	6,801	6,977	7,143	7,752	7,832
Pedestrian Fatalities at Unsignalized	1,036	1,048	877	939	1,033
Bicyclist Fatalities at Unsignalized	220	214	210	260	263
<i>Signalized Intersections</i>					
Fatalities at Signalized Intersections	3,347	3,296	3,577	4,047	4,204
Red-Light Running Fatalities at Signalized	871	856	1,074	1,202	1,272
Pedestrian Fatalities at Signalized	817	848	792	853	983
Bicyclist Fatalities at Signalized	140	152	151	154	182
Ped/Bike Fatalities in Red-Light Running	57	62	58	58	84

Source: Federal Highway Administration (FHWA), data from NHTSA FARS [6].

3 Human Error vs. Other Causes of Accidents

3.1 Causal Factor Attribution

- Human/driver error is the critical reason for 90% to 96% of all vehicle collisions [8].
- A definitive NHTSA study attributed 94% of crashes to drivers, 2% to vehicle malfunctions, and 2% to environmental factors [8].
- Specifically at intersections, 96% of crashes are attributed to driver error [9].

3.2 Table: Breakdown of Crash Causal Factors

Table 3: Primary Causal Factor Attribution in Vehicle Crashes

Primary Factor	Sub-Category	Attributed %
Human / Driver Error		94%
	Recognition Errors (Inattention, distraction)	41%
	Decision Errors (Speeding, misjudgment)	33%
	Performance Errors (Poor control)	11%
	Non-Performance Errors (Sleep, medical)	7%
Vehicle Malfunctions		2%
	Brake Failure	0.5%
	Steering System Failure	0.3%
	Tire Blowouts	0.2%
	Other	1.0%
Environmental Factors		2%
	Poor Weather, Inadequate Signage, Road Design	2%

Source: NHTSA [8].

3.3 Table: Common Driver Behaviors in Severe Intersection Crashes

Table 4: Contributing Factors in Fatal & Serious Injury Intersection Crashes (Texas, 2017-2021)

Contributing Factor	Percentage of Crashes
Failure to Yield Right of Way	33%
Speeding	23%
Disregarded Signal or Light	22%
Distracted Driving	16%
Impaired Driving	14%

Source: Texas Strategic Highway Safety Plan [10].

4 Autonomous Vehicles (AV) Statistics

4.1 On-Road Incident Overview

- Total AV-related incidents reported to NHTSA (2019 - June 17, 2024): 3,979 [11].
- Of these, 496 incidents resulted in an injury or fatality [11].
- Total fatalities reported in AV-related incidents: 83 [11].
- Approximately 10% of reported AV incidents involve an injury, and 2% involve a fatality [11].

4.2 Table: AV Incidents by Manufacturer (June 2021 - June 2024)

Table 5: NHTSA Reported Incidents by Company (U.S. Market)

Company	System Type	Number of Incidents
Tesla, Inc.	ADAS	2,146
Waymo LLC	ADS	415
General Motors, LLC	Both	219
Cruise LLC	ADS	187
Transdev Alternative Services	ADS	159
Honda	ADAS	155
Subaru of America, Inc.	ADAS	92
Zoox, Inc.	ADS	75
Toyota	Both	63
Ford Motor Company	Both	58

Source: NHTSA data compiled by Craft Law Firm [11].

4.3 Table: Performance Data for Other International Manufacturers

Table 6: Notable Incidents and Safety Data for Select Manufacturers (Non-NHTSA)

Company	Model(s)	Data Point / Incident Summary
Xiaomi	SU7	Reported a high-profile fatal crash in China (March 2025) with ADAS engaged, resulting in 3 fatalities. This led to a recall of over 110,000 vehicles to update the software. [12, 13]
	SU7	In a Chinese state media ADAS test, the SU7 passed in 1 of 6 scenarios. [14]
BYD	SEAL, DOLPHIN	Awarded 5-star safety ratings from Euro NCAP, with high scores for adult (89%) and child (87%) occupant protection. [15]
	Denza Z9GT	In a Chinese state media ADAS test, failed in 3 of 6 scenarios. [14]
	Song Pro DM	In a Chinese state media ADAS test, passed in 0 of 4 scenarios. [14]

Sources: Various news reports and safety assessments, not comparable to NHTSA aggregate data.

4.4 Table: Expanded Comparative Crash Statistics: AV vs. Human

Table 7: Crash Typology and Safety Performance			
Metric	AVs (ADS)	Human Drivers	Source(s)
<i>Overall Crash Rate</i>			
Crashes per Million Miles*	9.1	4.1	[16]
<i>Crash Type Distribution (% of Total Crashes)</i>			
Rear-End Collisions	~54-64%	28.3%	[16]
Side-Swipe Collisions	20.8%	17.5%	[16]
Broadside/Intersection Collisions	5.7%	25.8%	[16]
Collisions with an Object	3.8%	4.6%	[16]
Pedestrian Collisions	0%	16.3%	[16]
<i>Waymo Performance vs. Human Benchmark (Reduction in Injury-Causing Crashes)</i>			
Overall Serious Injury or Worse	-91%	Benchmark	[17]
Overall Any Injury Reported	-80%	Benchmark	[17]
V2V Intersection Crashes	-96%	Benchmark	[17]
Pedestrian Crashes	-92%	Benchmark	[17]
Cyclist Crashes	-78%	Benchmark	[17]
Motorcycle Crashes	-89%	Benchmark	[17]

*Note: Raw crash rate is subject to significant underreporting bias for human-driven vehicles [17].

4.5 Table: ADAS Safeguard Ratings for Select US & European Manufacturers

Table 8: IIHS & Euro NCAP Assisted Driving System Ratings		
Manufacturer	System	Overall Rating
<i>IIHS Partial Automation Safeguard Ratings (2024) [18, 19]</i>		
Lexus	Teammate with Advanced Drive	Acceptable
General Motors	Super Cruise	Marginal
Nissan	ProPILOT Assist with Navi-Link	Marginal
Ford	BlueCruise	Poor
Tesla	Autopilot / FSD (Supervised)	Poor
Mercedes-Benz	Active Distance Assist DISTRONIC	Poor
BMW	Active Driving Assistant	Poor
Volvo	Pilot Assist	Poor
<i>Euro NCAP Assisted Driving Gradings (2024-2025) [20, 21]</i>		
Mercedes-Benz	Driving Assistance Package Plus	Very Good
Tesla	Autopilot	Moderate
Volvo	Pilot Assist	Moderate

4.6 Table: AV Disengagement Statistics (California, 2023)

Table 9: Disengagements for Vehicles with Safety Drivers (Dec 2022 - Nov 2023)

Manufacturer	Miles Driven	Total Disengagements	Driver-Initiated	System-Initiated
Total (All Companies)	5,801,675	6,570	5,501 (84%)	1,040 (16%)
Waymo	3,669,962	212	191	21
Apple	N/A	3,194	2,391	803
Ghost Autonomy	N/A	1,034	976	58
aiMotive	N/A	708	687	21
Motional	N/A	593	593	0
Bosch	N/A	314	159	155
Qualcomm	N/A	197	197	0

Source: California DMV Disengagement Reports [22]. Note: This data is specific to the California testing program and does not include global operations.

References

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