Convenience or safety system? Crash rates of vehicles equipped with partial driving automation

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Contents

ABSTRACT

Objective: Partial driving automation assists drivers by providing sustained support of steering, speed, and headway. Although these systems are usually discussed as convenience features, consumers sometimes consider them to be safety features. The goal of this study was to assess if partial driving automation reduces rear-end and lane departure crashes beyond safety systems like automatic emergency braking (AEB) and lane departure prevention (LDP), on the limited-access roads and highways where they are designed to be used.

Methods: Analyses examined crash rates of model year 2017–2019 Nissan Rogues and model year 2013–2017 BMW vehicles. Negative binomial regression was used to assess the association of Nissan's partial driving automation system, ProPILOT Assist, and BMW's system, Driving Assistant Plus, with police-reported rear-end and lane departure crash rates on limited-access roads per vehicle mile traveled. Crash rates were also examined on roads with speed limits of ≤ 35 mph, where the systems were expected to have limited functionality and not be used much.

Results: Equipment with BMW's Driving Assistant Plus was not associated with significantly lower crash rates than equipment with LDP alone. Crash rates were lower on limited-access roads for Nissan Rogues with ProPILOT Assist than for those with LDP or AEB alone, but these effects persisted on roads with speed limits ≤ 35 mph. This brings into question if the lower crash rates associated with ProPILOT Assist can be attributed to use of the system, given that it would be activated infrequently on residential roads.

Discussion: There is no convincing evidence that partial driving automation is a safety system that is preventing crashes in the real world. Considering that drivers have been documented misusing these systems, partial driving automation needs to be thought of as a convenience feature and not a safety feature until there is strong support otherwise. Designing partial driving automation with robust safeguards to deter misuse will be crucial to minimizing the possibility that the systems will inadvertently increase crash risk.

Keywords: Level 2 automation; advanced driver assistance system; active driving assistance; adaptive cruise control; driving automation

INTRODUCTION

Partial driving automation systems that provide sustained support of steering, speed, and headway have become increasingly available, with more than half of new vehicle series offering partial driving automation as an optional or standard feature in 2023 (Highway Loss Data Institute 2024). These systems require that the driver remain attentive and intervene when hazards appear or when the automation does not perform as expected. But despite that vehicles with this functionality are not self-driving, sometimes the public and even consumers who use them overestimate their capabilities (Lee et al. 2023; Lin et al. 2018; Mueller et al. 2024; Singer et al. 2022; Teoh 2020).

There is similar uncertainty about the safety benefits of partial driving automation, which is often marketed as a convenience feature but has also been touted by some automakers as improving safety (e.g., Tesla 2023). Some research exists from driving simulators and field operational tests showing that adaptive cruise control (ACC) is associated with positive driving behaviors that would support that the technology can prevent risky situations from developing, such as increased time headways, decreased tailgating, decreased harsh-braking events, and decreased lane changing (Bianchi Piccinini et al. 2014; Kessler et al. 2012; Kummetha et al. 2020; National Highway Traffic Safety Administration 2005; Varotto et al. 2022; Vollrath et al. 2011). Because partial driving automation incorporates ACC, the behavioral benefits of ACC could theoretically still apply when it is combined with lane centering assistance. LeBlanc et al. (2023) reported from a naturalistic field study of Cadillac drivers that hard-braking events were more likely under manual driving or during ACC use than when Super Cruise, GM's partial driving automation system, was engaged under similar environmental conditions.

However, the potential safety benefits of partial driving automaton shrink when considering the types of crashes they would most likely address. The sustained longitudinal control provided by adaptive ACC would be most relevant to front-to-rear crashes, and sustained lateral control from lane centering assistance would most likely affect crashes due to lane departures. But crash avoidance systems that provide transient interventions aimed at these crash types are already effectively preventing them. Forward collision warning (FCW) with automatic emergency braking (AEB) reduces rear-end crash risk by up to 50% (Aukema et al. 2023; Cicchino 2017; Leslie et al. 2021; Spicer et al. 2021). Lane departure prevention (LDP), also known as lane keeping assistance, provides steering input when a driver departs the lane and has shown more modest benefits in preventing single-vehicle run-off-road crashes and other crash types that result from unintentional lane departures (Aukema et al. 2023; Dean and Riexinger 2022; Leslie et al. 2021; Spicer et al. 2021; Sternlund et al. 2017).

Partial driving automation would need to act on a subset of these crash types that crash avoidance systems are not already preventing to reduce crashes over and above already prevalent crash avoidance technologies. Since the lateral and longitudinal support provided by partial driving automation is continuous, it could potentially prevent crash-critical situations from developing where a transient response from a crash avoidance system would not be enough to prevent the crash. There are situations where AEB or LDP have been documented to struggle, such as in roadside departures with a short time-to-collision to a roadside object for LDP (Riexinger et al. 2019) or at high speeds or in encounters with motorcycles and trucks for AEB (Cicchino and Kidd 2024; Cicchino and Zuby 2019). Rau et al. (2015) estimated that the target crash population that could be addressed by partial driving automation would include crashes with “erratic” precrash actions (e.g., with a driver failure to control the vehicle) that would not be prevented by crash avoidance systems. It is unknown, though, how well partial driving automation would control steering, speed, and headway in these situations given that the systems are using similar sensors to AEB and LDP that are subject to the same limitations.

The Highway Loss Data Institute ([HLDI] 2021a, b) performed early evaluations of the changes in insurance claim rates per year the vehicle was insured associated with Nissan’s ProPILOT Assist partial driving automation system on model year 2018–2019 Rogues, and BMW’s Driving Assistant Plus partial driving automation system equipped on model year 2013–2017 vehicles. Both studies examined property damage liability claims, which cover damage the insured vehicle causes to the vehicle or property of others, like would occur in a rear-end crash, and collision claims, which cover damage a driver does to their own vehicle in all crash types. Property damage liability claim rates were a statistically significant 8% lower for Nissan Rogues equipped with FCW and AEB compared with vehicles without those technologies, but adding ACC or partial driving automation was not associated with additional crash reductions. Changes in collision claim rates were small for all technology types.

On BMW vehicles in HLDI's (2021a) research, equipment with FCW and AEB was associated with statistically significant reductions of 13% in property damage claim rates and 7% in collision claim rates. BMW vehicles equipped with FCW, AEB, and ACC experienced larger reductions of 25% in property damage liability claim rates, and no additional change in collision claim rates. However, adding the Driving Assistant Plus partial driving automation system to the package of FCW, AEB, and ACC resulted in no incremental benefit. Taken together, these studies suggest that BMW's ACC system may be associated with an additional crash benefit beyond FCW/AEB alone, but that there are not additional crash reductions afforded with the addition of lane centering assistance from partial driving automation.

A limitation of HLDI's research is that they were not able to focus on the crash types or driving environments where partial driving automation would be most likely to exhibit a safety benefit. Partial driving automation is designed for use on limited-access, high-speed roadways, known as freeways and interstates in North America. The technology can be geofenced to only operate in those road environments, and it often cannot be activated at low speeds. These systems have been demonstrated to be used by drivers much more often on limited-access roads or highways than on roads with lower functional classes, even when not geofenced to these environments (Gershon et al. 2021; Orlovska et al. 2020; Reagan et al. 2019; Russell et al. 2018). Crash rates are lower on limited-access roads than on road types with intersections, which have more opportunities for conflict. Moreover, only a small percentage of crashes occur on limited-access roads; for example, in 2021, 26% of all miles traveled in the United States were on interstates, but just 10% of crashes were in those roadways (Federal Highway Administration 2023; Insurance Institute for Highway Safety [IIHS] 2024b). It is, therefore, important to take road environment into consideration when doing a crash analysis involving driver assistance technologies. The potential benefits of the technology can be obscured or even inflated when crashes on other roads are included or when comparing primarily non-highway driving without use of the system with highway driving with the system engaged.

Few evaluations have examined the real-world crash outcomes associated with partial driving automation while limiting the analysis to the commonly intended design domain of highway driving or the rear-end and lane departure crashes that these systems could potentially prevent. Goodall (2024) adjusted Tesla-reported crash rates with Autopilot engaged and only active safety systems engaged to reflect the amount of freeway driving and concluded that crash rates with and without Autopilot engaged were closer than Tesla had publicly reported. Leslie et al. (2022) compared rear-end and lane-departure crash risk on limited-access highways between

GM vehicles equipped and not equipped with Super Cruise and did not report meaningful differences in crash risk between the vehicles.

There is no convincing evidence yet that partial driving automation is reducing crashes in the real world based on this small body of research. This study built on HLDI's (2021a, b) work by examining the crash experience of the Nissan Rogue with ProPILOT Assist and BMW vehicles with Driving Assistant Plus over and above the effects of FCW/AEB and lane departure warning (LDW)/LDP, while limiting crash types to the rear ends and lane departures the systems would be most likely to prevent, occurring on the high-speed, limited-access roads where the systems would be most likely to be activated. Crash rates on roads with speed limits ≤ 35 mph were also examined to assess if results differed on road types where the systems would be less likely to be engaged.

METHODS

Vehicles

Study vehicles were model year 2017–2019 Nissan Rogues and model year 2013–2017 BMW and MINI models that were included in HLDI's research (2021a, b) (full list of BMW and MINI models in Appendix Table A1). Vehicle Identification Numbers (VINs) of vehicles linked to the presence or absence of various driver assistance features were obtained from the manufacturers. Vehicle feature data denoted if a vehicle was equipped with a system only; it was unknown how often drivers used the systems or if they were in use at the time of a crash.

The Nissan Rogue was equipped with FCW/AEB as an optional feature in the 2017 model year and a standard feature in 2018 and 2019, ACC and LDW/LDP as optional features in all model years, and ProPILOT Assist as an optional feature in model years 2018 and 2019. FCW, AEB, and ACC are radar-based systems. FCW/AEB function at speeds above approximately 3 mph, and ACC functions up to 90 mph. LDW/LDP and the lane centering functionality of the partial driving automation system work at speeds of 37 mph and above; lane centering can operate at lower speeds when following a lead vehicle. ACC can be used independently of the lane centering functionality on Nissan Rogues equipped with partial driving automation and is operational at high speeds. LDW and LDP were always packaged together, as were FCW and AEB. LDW/LDP also came packaged with a front crash prevention system that detects pedestrians in all model years and high beam assist in model years 2018–2019.

Additionally, most vehicles were equipped with blind spot detection and some with various parking assistance features.

The systems of interest were optional on BMW vehicles, although the optional Driving Assistant Plus system was not offered on all models. LDW/LDP and Driving Assistant Plus on BMW vehicles were operational at speeds of approximately 40 mph and above, and Driving Assistant Plus was also capable of following lead vehicles at lower speeds. Driving Assistant Plus came packaged with front cross-traffic alert functionality. BMW models may have been equipped with other crash avoidance features, including blind spot detection, curve-adaptive headlights, high beam assist, night vision with pedestrian detection, and parking assistance systems. Like on the Nissan Rogue, LDW and LDP were packaged together on BMW models.

HLDI (2021a) reported that reductions in property damage liability claim rates were twice as large for BMW models equipped with ACC or partial driving automation and FCW/AEB compared with those equipped with FCW/AEB alone, so assessing if this effect would replicate when focusing on rear-end crashes was of interest. However, when investigating the characteristics of BMW's AEB system, it became apparent that the AEB was more capable when it was paired with ACC or partial driving automation. AEB used radar on vehicles without ACC and a combination of radar and a camera when ACC and AEB both were equipped. The fusion AEB system had an increased speed range compared with the radar system; on some models, for instance, the AEB on vehicles without ACC operated at speeds up to 35 mph, while on vehicles with ACC, the AEB operated at the full speed range. It was not possible to attribute differences in crash rates between BMW models equipped with these systems to the contribution of ACC, and rear-end crash patterns associated with FCW/AEB, ACC, and partial driving automation on BMW vehicles were not analyzed because of this confound. AEB functionality did not differ systematically between Nissan Rogue models with and without ProPILOT Assist, nor did LDW/LDP functionality and the partial driving automation system from either manufacturer.

The partial driving automation systems from both manufacturers available for the model years examined in this study required drivers to keep their hands on the steering wheel. They were not geofenced to particular road types by GPS. Beyond equipment with the special headlight packages mentioned above (high beam assist from both manufacturers; curve-adaptive headlights and night vision with pedestrian detection on BMW models), data were not available on differences in the performance of the base headlights that individual vehicles were equipped with. For example, according to headlight ratings from the IIHS, model year 2017–2019 Nissan Rogues could be equipped with headlights that received the worst rating of poor or with headlights with the second-highest rating of acceptable, but these headlight packages were not linked to vehicles through VINs like other vehicle features were.

Crash data

Police-reported crash data were obtained from 17 U.S. states during 2013 to 2022 (full list in Appendix Table A2). Not every calendar year in this range was included for every state due to availability of data sets or key variables. Data were coded into a common format to standardize across states. Crash involvements potentially preventable by FCW/AEB, ACC, and partial driving automation included when the study vehicle was the striking vehicle in a rear-end crash, and those potentially preventable by LDW/LDP and partial driving automation included when the study vehicle was involved in a single-vehicle crash or same-direction sideswipe crash.

These crash types were examined when they occurred on limited-access roads, which included interstates, freeways, and other expressways. Functional class was determined from geocoordinates when they were available, which were mapped to functional class if they were within 18 meters of a road in the Federal Highway Administration (FHWA) Highway Performance Monitoring System road inventory geodatabase. When geocoordinates were not available or could not be mapped onto a functional class, variables from the state's crash data were used to identify interstates, freeways, and other expressways.

Rear-end crashes were defined by the manner of collision (front-to-rear) and excluded crashes where an involved vehicle was backing. The striking vehicle had an initial point of impact to the front (11-, 12-, or 1-o'clock) and the struck vehicle to the rear (5-, 6-, or 7-o'clock). Single-vehicle crashes were limited to those where the first event reported was ran off the road, crossed centerline or median, collision with a fixed object, or rollover. Same-direction sideswipes were multivehicle crashes defined by the manner of collision. No vehicle involved in single-vehicle or sideswipe crashes that was changing lanes, passing, merging, turning, or backing prior to the crash was included to better capture unintentional lane departures. Although head-on crashes and opposite-direction sideswipes have been included in some studies of the effects of LDW/LDP (Cicchino 2018; Dean and Riexinger 2022; Leslie et al. 2021; Spicer et al. 2021; Sternlund et al. 2017), they were excluded from the current study because limited-access roads are divided by median barriers, which should prevent crossing into the opposite lane of traffic. Leslie et al. (2022) took a similar approach to examining the crash effects of GM's Super Cruise.

Vehicle miles traveled (VMT) data

Odometer readings and dates of readings associated with VINs were obtained by HLDI from CARFAX, a unit of S&P Global. Readings came from multiple sources, such as title transfers, annual inspections, and routine maintenance service. HLDI transformed these readings for vehicles insured with collision coverage in their database into average miles per day by taking the difference between two consecutive mileage readings and dividing by the number of days between them. These data were validated by HLDI (2018) against FHWA's annual VMT estimates.

Miles per day were aggregated by the age (≤ 24, 25–64, ≥ 65 years) and gender of the rated driver on the insurance policy, state, and the make, model, model year, and advanced driver assistance systems of interest. As odometer readings were not available for every VIN, average miles per day were then multiplied by the total number of days vehicles with those characteristics were insured with collision coverage in HLDI's database. This gave an estimate of the total number of miles traveled by state, driver, and vehicle characteristics. The age and gender of the rated driver were unknown for some vehicles, and mileage counts were redistributed in these cases based on the distribution by other characteristics when age and gender were known.

Analyses

Main analyses. The primary analyses used negative binomial regression to examine the association of systems of interest with rear-end crashes or lane departure crashes on limited-access roads per VMT, while controlling for other vehicle technology that may act on those same crash types. Three models were constructed to investigate rear-end crashes with the Nissan Rogue, lane departure crashes with the Nissan Rogue, and lane departure crashes with BMW models.

Vehicle feature data were linked to crash and VMT data by VIN. Crash and VMT data were merged by aggregated state, driver, and vehicle characteristics. Regression analyses included independent variables for state, driver age (≤ 24, 25–64, ≥ 65) and gender, and vehicle model, model year, and technology systems; because the Nissan analyses included a single model (the Rogue), vehicle model was not included in those analyses. When data by state were sparse, state was collapsed into Census regions of the country. The log of VMT was included as an offset term.

All Nissan vehicles equipped with ACC or partial driving automation also had FCW/AEB, and all vehicles from both manufacturers with partial driving automation were also equipped with LDW/LDP. The presence or absence of these technology combinations was indicated by three separate binary variables for FCW/AEB alone, ACC with FCW/AEB, and partial driving automation with FCW/AEB in the rear-end model, and two binary variables for LDW/LDP alone and partial driving automation with LDW/LDP in lane departure models. These variables estimate how crash rates for vehicles equipped with these technologies compare with vehicles without FCW/AEB (in the rear-end model) or without LDW/LDP (in the lane departure models). Comparisons were also made between ACC with FCW/AEB vs. FCW/AEB alone and partial driving automation with FCW/AEB vs. FCW/AEB alone in the rear-end analysis, and between partial driving automation with LDW/LDP vs. LDW/LDP alone in the lane departure analyses, to assess the change in crash rates associated with the driving automation systems over and above the contribution of the crash avoidance technologies.

Models of the Nissan Rogue's crash rates did not control for other vehicle technologies. The Rogue was not equipped with additional systems that would be thought to impact the risk of a rear-end crash. Advanced lighting systems like high beam assist can affect risk of lane departure crashes, and data were available on which Nissan Rogue vehicles were equipped with high beam assist, but it was not included as a covariate since it was almost always packaged with LDW/LDP. The model of lane departure crash rates with BMW vehicles controlled for the presence or absence of high beam assist and curve-adaptive headlights. While data were available on which individual BMW vehicles were equipped with those advanced lighting systems, like with Nissan, the base headlight performance on each vehicle was unknown and could not be accounted for in analyses.

Sensitivity analyses. If partial driving automation and ACC effectively reduce target crash types, the crash reductions associated with the systems should be apparent on the limited-access roads for which they were primarily designed and not on low-speed roads. Sensitivity analyses examined the association of systems with rear-end and lane departure crash rates on non-limited-access roads with speed limits of 35 mph or lower using the same modeling approach as the main analyses. LDW/LDP from both automakers are not operational at these speeds, and partial driving automation is also not operational unless following a lead vehicle. Nissan's ACC system can work at low speeds, but drivers tend to use ACC and partial driving automation much more frequently on limited-access roads than on the local roads where speed limits of 35 mph or less are typical (Reagan et al. 2019).

Run-off-road crash risk is elevated in the dark (McLaughlin et al. 2009) and better headlights have been shown to be associated with lower single-vehicle nighttime crash rates (Brumbelow 2022). Lane departure crash rates during daylight associated with partial driving automation would not be affected by uncontrolled differences in headlight performance between vehicles with and without the system. Analyses of lane departure crash rates on limited-access roads were stratified by light condition to separately examine crashes that occurred in daylight and in dawn, dusk, or dark. Rear-end crash scenarios introduce the additional visibility cue of the leading vehicle's taillights and so were not expected to be as affected by headlight illumination.

VMT estimates were for all miles traveled regardless of location or condition. Thus, VMT estimates were the same in analyses that included common vehicles, even if they examined crashes occurring on different road types or under different light conditions.

RESULTS

Nissan Rogue rear-end crashes

Table 1 lists the number of rear-end crashes and rates per 100 million VMT involving Nissan Rogues with FCW/AEB alone, ACC and FCW/AEB, partial driving automation and FCW/AEB, and none of these systems on limited-access and low-speed roads. In a negative binomial regression model controlling for state, model year, and driver age and gender (Table 2), all three system types were associated with rear-end crash rates that were about half or less of that for Nissan Rogues without a front crash prevention system (FCW/AEB alone: rate ratio [RR], 0.51; 95% confidence interval [CI], 0.36–0.71, $p < 0.001$; ACC and FCW/AEB: RR, 0.46; 95% CI, 0.31–0.67, $p < 0.001$; partial driving automation and FCW/AEB: RR, 0.38; 95% CI, 0.24–0.59, $p < 0.001$). Rear-end crash rates were lower for vehicles equipped with partial driving automation and FCW/AEB than with FCW/AEB alone (RR, 0.74; 95% CI, 0.55–1.00, $p = 0.050$; Figure 1), while the difference between vehicles equipped with ACC and FCW/AEB compared with FCW/AEB alone was not as large (RR, 0.90; 95% CI, 0.69–1.18, $p = 0.436$; Figure 1).

However, Figure 1 indicates that rear-end crash rates were similarly lower among vehicles equipped with partial driving automation and FCW/AEB than among those with FCW/AEB alone on roads with speed limits of 35 mph or less (RR, 0.57; 95% CI, 0.41–0.80, $p = 0.001$). While ACC is still operational at low speeds, and partial driving automation is operational when following a lead vehicle, the expected low use of these features on local roads brings into question if the association of equipment with partial driving automation with a lower rear-end crash rate than FCW/AEB alone can be attributed to use of partial driving automation.

Nissan Rogue lane departure crashes

Nissan Rogue models were involved in 204 lane departure crashes on limited-access roads when equipped with LDW/LDP alone, 69 of this crash type when equipped with partial driving automation and LDW/LDP, and 610 crashes when equipped with none of these systems (Table 3). Without accounting for driver, state, and other vehicle factors, lane departure crash rates on limited-access roads per 100 million VMT were lower among Rogue models equipped with partial driving automation and LDW/LDP than among those equipped with no systems or LDW/LDP alone.

Table 4 summarizes the results of a negative binomial regression model examining the association of these systems with lane departure crash rates on limited-access roads. After controlling for model year, driver age and gender, and state, Rogue vehicles with both partial driving automation and LDW/LDP had a significantly lower lane departure crash rate on limited-access roads than Rogues without LDW/LDP (RR, 0.66; 95% CI, 0.46–0.96, $p = 0.030$), while crash rates for Rogue vehicles with LDW/LDP alone did not differ significantly from those without it (RR, 0.89; 95% CI, 0.67–1.18, $p = 0.405$). Lane departure crash rates were lower for Rogues with both partial driving automation and LDW/LDP than for vehicles with LDW/LDP alone (RR, 0.75; 95% CI, 0.56–1.00, $p = 0.053$; Figure 2).

Similar to the association of partial driving automation with rear-end crash rates, this pattern also persisted on low-speed roads and was additionally more prominent in the dark than in daylight (Figure 2). This suggests that the lower lane departure crash rates associated with being equipped with partial driving automation can again not be attributed to use of the system, since they are present in conditions when the system is unlikely to be operational, and that differences in headlight performance may contribute to the pattern of results because effects are most prominent in the dark. On low-speed roads, lane departure crash rates were significantly lower among vehicles equipped with partial driving automation and LDW/LDP compared with those equipped with LDW/LDP alone (RR, 0.69; 95% CI, 0.51–0.93, $p = 0.016$). Rogues equipped with both partial driving automation and LDW/LDP had significantly lower nighttime lane departure crash rates on limited-access roads than Rogue vehicles without LDW/LDP (RR, 0.47; 95% CI, 0.25–0.88, $p = 0.019$) and with LDW/LDP alone (RR, 0.57; 95% CI, 0.35–0.94, $p = 0.029$).

BMW lane departure crashes

Lane departure crash rates among BMW models with LDW/LDP alone, partial driving automation and LDW/LDP, and no lateral system appear in Table 5. After controlling for state, model and model year, curve-adaptive headlights, high beam assist, and driver age and gender, neither LDW/LDP alone (RR, 0.91; 95% CI, 0.81–1.02, $p = 0.103$) nor partial driving automation with LDW/LDP (RR, 0.81; 95% CI, 0.61–1.06, $p = 0.124$) was associated with significantly lower lane departure crash rates on limited-access roads compared with no lateral assistance system (Table 6); crash rates also did not differ significantly between vehicles equipped with partial driving automation and LDW/LDP compared with LDW/LDP alone (RR, 0.89; 95% CI, 0.68–1.17, $p = 0.398$; Figure 3). There was additionally no significant difference in lane departure crash rates between vehicles equipped with LDW/LDP alone and with partial driving automation and LDW/LDP on roads with speed limits of 35 mph or less or on limited-access roads during daylight or darkness (Figure 3). Lane departure crash rates were significantly lower among BMW vehicles equipped with LDW/LDP alone than without the technologies on limited-access roads in daylight (RR, 0.84; 95% CI, 0.72–0.97, $p = 0.022$), but not in darkness (RR, 1.03; 95% CI, 0.86–1.22, $p = 0.760$).

DISCUSSION

There is still no clear evidence that partial driving automation is a safety system that is preventing crashes in the real world. In the current study, BMWs equipped with a partial driving automation system and LDW/LDP did not have meaningfully lower lane departure crash rates than vehicles equipped with LDW/LDP alone. Nissan Rogues equipped with partial driving automation had lower rear-end and lane departure crash rates on limited-access roads than vehicles equipped with only crash avoidance systems, but this difference persisted on roads with speed limits of ≤ 35 mph where partial driving automation and ACC are less likely to be used. The difference in lane departure crash rates on limited-access roads between Nissan Rogues with and without partial driving automation was larger in the dark than in daylight, which suggests that variations in available headlight systems may have contributed.

Examining the crash effects of driving automation systems that are not always turned on, and that are designed for specific roadway environments, is more of a challenge than investigating the real-world benefits of most crash avoidance systems. A system can’t affect crashes unless it is in use, and in these analyses, it was unknown where and how often drivers were using partial driving automation. There has been great variation observed among systems and individual drivers in how often they choose to use them, even on the limited-access roads where the systems are used the most. For instance, Reagan et al. (2019) observed that drivers with Volvo’s Pilot Assist system in a field operational test had the system turned on during 8% to 20% of miles traveled on limited-access roads on average, depending on the version of the system they had, but this ranged from 0.2% to 65% of miles traveled on limited-access roads among individual drivers. In an examination of telematics data from owners of GM vehicles with Super Cruise, drivers who used the system had it engaged on 40% of miles traveled on average on limited-access roads where the geofenced system could be used (LeBlanc et al. 2023). But Super Cruise was never used at all on 28% of the vehicles that had it, and among the vehicles where it was used, nearly half had Super Cruise turned on during less than 10% of the distance they traveled on Super Cruise-enabled roads. Complicating the relationship between use and crashes is that systems are engaged less often in the presence of certain roadway characteristics, such as increased horizontal curvature, that can increase run-off-road crash risk (Hu et al. 2022; LeBlanc et al. 2023).

Research methods that can account for how often and under what conditions partial driving automation systems are used, such as telematics-based studies of owners or field operational tests, will be important to understanding their effects on crashes when they are engaged. It will also be important to document how these systems impact the larger crash picture. The potential world of crashes that partial driving automation could impact is limited. In 2021, only 6% of police-reported crashes in the United States were run-off-road or same-direction sideswipes resulting from unintentional lane departures, or rear-ends, that occurred on interstate highways (IIHS 2024b). If partial driving automation was used half the time on those roads, it would cut the maximum crash prevention potential in half—and that's before accounting for the contribution of systems like AEB and LDP to preventing these crashes. In insurance data, which has a larger proportion of low-severity claims resulting from incidents like parking lot crashes that are often not police-reportable, the potential for partial driving automation to impact the overall universe of claims is even smaller.

Partial driving automation should be designed to minimize the possibility that the systems will inadvertently increase crash risk. Drivers have been documented performing risky behaviors with the technology, such as engaging in secondary tasks more often than when driving manually without assistance (Dunn et al. 2021; Naujoks et al. 2016; Noble et al. 2021; Reagan et al. 2021) and looking away from the road more often and for longer periods (Dunn et al. 2021; Gaspar and Carney 2019; Morando et al. 2021; Noble et al. 2021). Misuse of driving automation systems is common during safety critical events that occur when they are in use (Kim et al. 2022). Implementing partial driving automation with safeguards that encourage drivers to stay in the loop and alert them when they become disengaged from driving are essential to reducing potential risks (Mueller et al. 2021). Partial driving automation does not monitor the environment for hazards the way a human driver does and can behave unexpectedly, which is why one's crash risk will increase if they are distracted by secondary tasks and not prepared to take over steering or braking when the situation requires it. Because the safety benefits of partial driving automation are not yet clear, it is also necessary for LDP and AEB systems to remain turned on when partial driving automation is engaged (IIHS 2024a).

Some crash avoidance systems on the Nissan and BMW vehicles performed as expected. FCW/AEB was associated with a 51% reduction in rear-end crash rates on limited-access roads, which is very similar to U.S. multi-automaker estimates on AEB effects on all roads of 49%–50% (Aukema et al. 2023; Cicchino 2017). LDW/LDP were associated with reductions of 9% on BMW models and 11% on the Nissan Rogue in lane departure crash rates that were not statistically significant, but that are of similar magnitude to the modest 7%–12% reductions in these relevant crash types that have been found for these systems in U.S. studies (Aukema et al. 2023; Cicchino 2018; Leslie et al. 2021; Spicer et al. 2021). The estimate for BMW's LDW/LDP system was larger (16% reduction) and statistically significant during daylight. Some road departure scenarios where LDW/LDP would be expected to be less likely to help prevent a crash, such as when the driver is impaired or avoiding a crash with an animal, occur more often in the dark than during daylight (Hossain et al. 2023), which could have contributed to BMW's better performance during daylight.

LDP needed to be turned on with every trip in the Nissan Rogue, which likely impacted its use and effectiveness. Only about half of drivers keep LDP turned on even when it retains its prior setting at ignition (Reagan et al. 2018), so it would be expected that use would be lower than average on the Rogue. Nissan's LDW system did retain its prior setting at ignition, but most crash studies that have examined both LDP and LDW have reported greater effectiveness for LDP (Aukema et al. 2023; Dean and Riexinger 2022; Spicer et al. 2021). The increase in crashes associated with high beam assist on BMWs was identical to what was seen in HLDI's (2021a) examination of insurance claims with these vehicles, but was unexpected given crash benefits associated with this system from another automaker (Leslie et al. 2021).

The limitations of this analysis highlight the challenges of examining the crash effects of driving automation. In addition to not knowing how often the automation was used, the VMT data used as an exposure measure could not be separated by road type. If drivers with partial driving automation tend to drive a larger percentage of their miles on limited-access roads, for instance, this analysis would underestimate the effects of equipment with the system on limited-access roads and underestimate it on roads with lower speed limits. Crash counts were small in analyses of partial driving automation, which could have precluded statistical significance. It is also important to note that the systems that were investigated were early designs and do not represent the current partial driving automation systems offered by Nissan and BMW.

These results emphasize the benefit of conducting complementary analyses to collect converging evidence when examining the crash effects associated with vehicle features. It would have been easy to conclude that the Nissan Rogue's partial driving automation system was reducing crashes if performance only on limited-access roads was examined. It's unknown why Rogues with partial driving automation were associated with lower crash rates under multiple conditions. In addition to uncontrolled differences in headlights or exposure on limited-access roads, as previously mentioned, differences in the driving habits of owners who chose to purchase the optional system could have contributed. Some evaluations of crash avoidance systems have included this converging evidence by incorporating multiple methods of exposure or crash types that shouldn't be affected by the technology of interest (e.g., Aukema et al. 2023; Cicchino 2017; Cicchino 2022; Cicchino 2023a; Cicchino 2023b; Leslie et al. 2022; Leslie et al. 2021; Teoh 2021), which increases confidence that results can be attributed to the systems. Examining the crash effects of partial driving automation requires careful attention to the environments where this technology is most often used and consideration of the types of crashes it could conceivably prevent. To date, early research, including this study, has not reported conclusive evidence that partial driving automation is a crash prevention system. Future research that incorporates system use will be key to understanding safety effects, but even then, the maximum crash prevention potential of a system that is operated primarily on limited-access roads is not large. Partial driving automation needs to be thought of as a convenience feature, and not a safety feature, unless there is strong evidence otherwise.

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TABLES

Table 1. Nissan Rogue rear-end crash rates per 100 million VMT by equipment with vehicle technology and road type.

Condition	No system		FCW/AEB		ACC + FCW/AEB		Partial driving automation + FCW/AEB	
	Crashes	Rate	Crashes	Rate	Crashes	Rate	Crashes	Rate
Limited-access roads	525	15.9	422	11.7	107	10.7	73	8.9
Low-speed roads	597	18.1	432	12.0	121	12.1	54	6.6

Note. VMT estimates do not differ by road type.

Table 2. Negative binomial regression model results of Nissan Rogue rear-end crash rates per VMT on limited-access roads.

Predictor	Rate ratio	95% CI	*p*
FCW/AEB alone (vs. no FCW/AEB)	0.51	(0.36, 0.71)	<0.001
ACC + FCW/AEB (vs. no FCW/AEB)	0.46	(0.31, 0.67)	<0.001
Partial driving automation + FCW/AEB (vs. no FCW/AEB)	0.38	(0.24, 0.59)	<0.001
Model year 2017 (vs. 2019)	0.71	(0.49, 1.02)	0.072
Model year 2018 (vs. 2019)	0.99	(0.78, 1.27)	0.963
Driver age < 25 (vs. 25–64)	2.47	(2.23, 3.01)	<0.001
Driver age 65+ (vs. 25–64)	0.50	(0.39, 0.64)	<0.001
Driver gender male (vs. female)	1.40	(1.19, 1.65)	<0.001

Note. For brevity, state is not shown.

Table 3. Nissan Rogue lane departure crash rates per 100 million VMT by equipment with vehicle technology, road type, and light condition.

Condition	No system		LDW/LDP		Partial driving automation + LDW/LDP	
	Crashes	Rate	Crashes	Rate	Crashes	Rate
Limited-access roads	610	10.0	204	11.2	69	8.5
Low-speed roads	641	10.6	211	11.5	64	7.8
Limited-access roads, daylight	367	6.0	123	6.7	48	5.9
Limited-access roads, dawn/dusk/dark	242	4.0	81	4.4	21	2.6

Note. VMT estimates do not differ by road type or light condition.

Table 4. Negative binomial regression model results of Nissan Rogue lane departure crash rates per VMT on limited-access roads.

Predictor	Rate ratio	95% CI	*p*
LDW/LDP alone (vs. no LDW/LDP)	0.89	(0.67, 1.18)	0.405
Partial driving automation + LDW/LDP (vs. no LDW/LDP)	0.66	(0.46, 0.96)	0.030
Model year 2017 (vs. 2019)	0.70	(0.50, 0.97)	0.034
Model year 2018 (vs. 2019)	0.82	(0.61, 1.11)	0.199
Driver age < 25 (vs. 25–64)	2.36	(1.93, 2.89)	<0.001
Driver age 65+ (vs. 25–64)	0.52	(0.40, 0.68)	<0.001
Driver gender male (vs. female)	1.50	(1.28, 1.76)	<0.001

Note. For brevity, state is not shown.

Table 5. BMW crash rates in lane departure crashes per 100 million VMT by equipment with vehicle technology, road type, and light condition.

Condition	No system		LDW/LDP		Partial driving automation + LDW/LDP	
	Crashes	Rate	Crashes	Rate	Crashes	Rate
Limited-access roads	3,601	10.8	430	9.2	72	7.8
Low-speed roads	3,213	9.6	419	9.0	63	6.8
Limited-access roads, daylight	2,120	6.3	237	5.1	41	4.4
Limited-access roads, dawn/dusk/dark	1,463	4.4	193	4.1	31	3.4

Note. VMT estimates do not differ by road type or light condition.

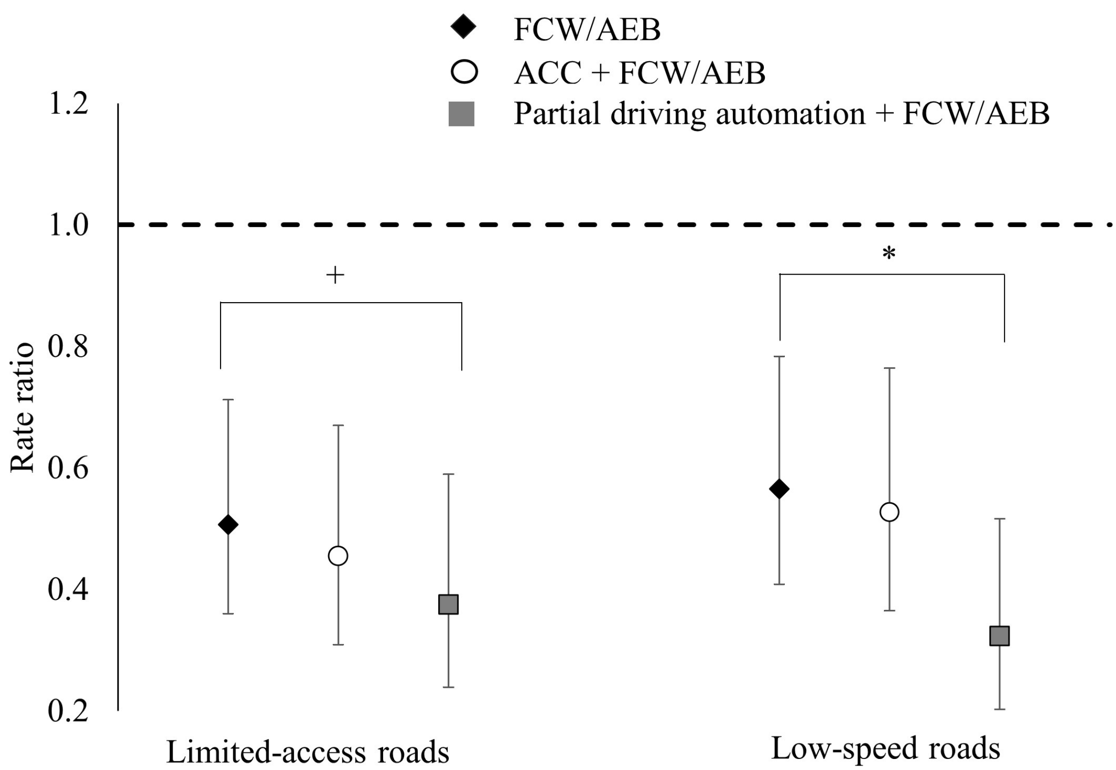
Table 6. Negative binomial regression model results of BMW lane departure crash rates per VMT on limited-access roads.

Predictor	Rate ratio	95% CI	*p*
LDW/LDP alone (vs. no LDW/LDP)	0.91	(0.81, 1.02)	0.103
Partial driving automation + LDW/LDP (vs. no LDW/LDP)	0.81	(0.61, 1.06)	0.124
Curve-adaptive headlights (vs. none)	0.97	(0.88, 1.08)	0.605
High beam assist (vs. none)	1.17	(1.04, 1.31)	0.010
Model year 2013 (vs. 2017)	1.30	(0.91, 1.17)	0.636
Model year 2014 (vs. 2017)	1.02	(0.90, 1.15)	0.754
Model year 2015 (vs. 2017)	1.02	(0.90, 1.15)	0.802
Model year 2016 (vs. 2017)	1.03	(0.91. 1.17)	0.663
Driver age < 25 (vs. 25–64)	3.57	(3,29, 3.87)	<0.001
Driver age 65+ (vs. 25–64)	0.46	(0.39, 0.53)	<0.001
Driver gender male (vs. female)	1.62	(1.51, 1.73)	<0.001

Note. For brevity, state and model are not shown.

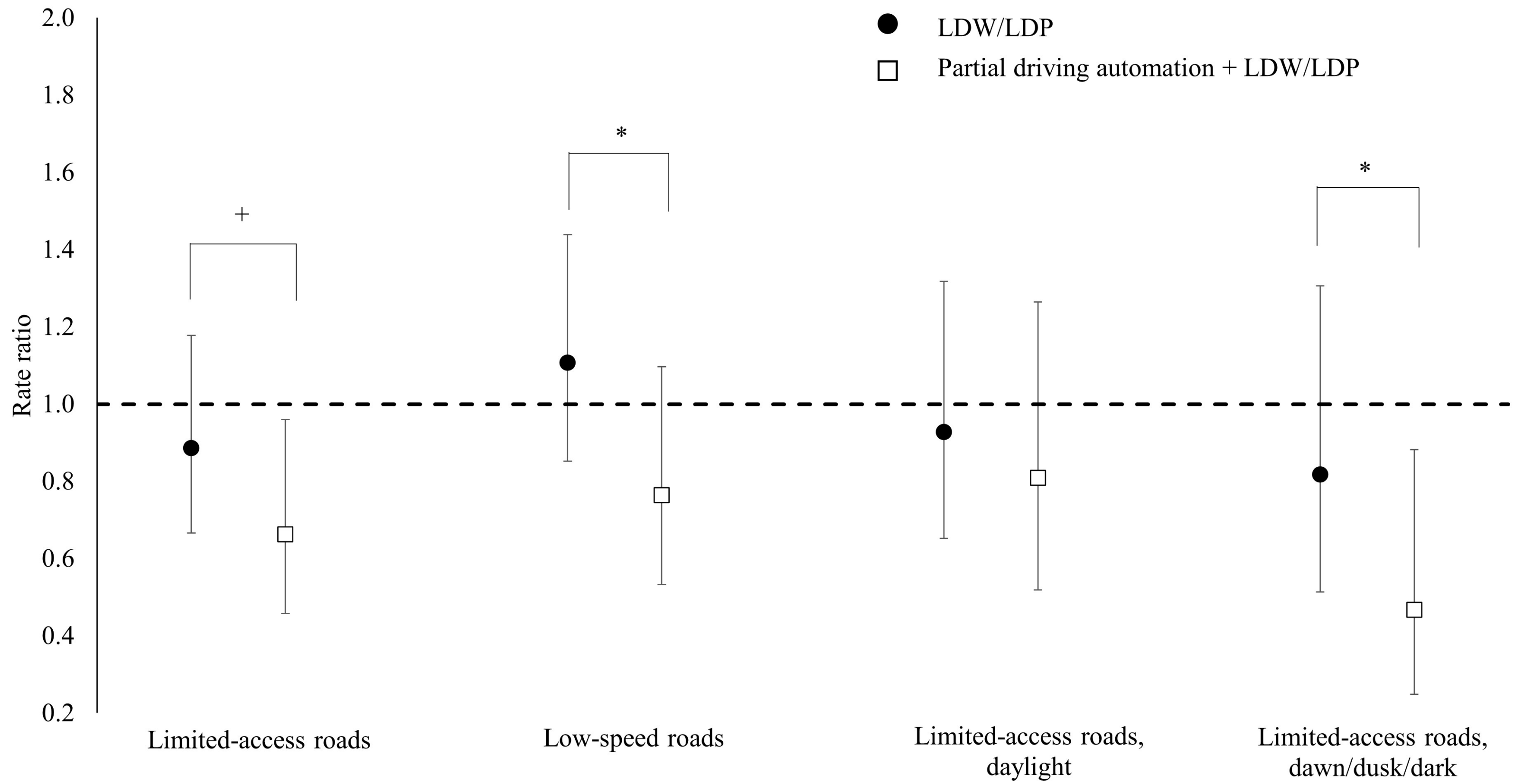
FIGURES

Figure 1. Association of FCW/AEB, ACC, and partial driving automation on Nissan Rogue vehicles with rear-end crash rates from negative binomial regression models.



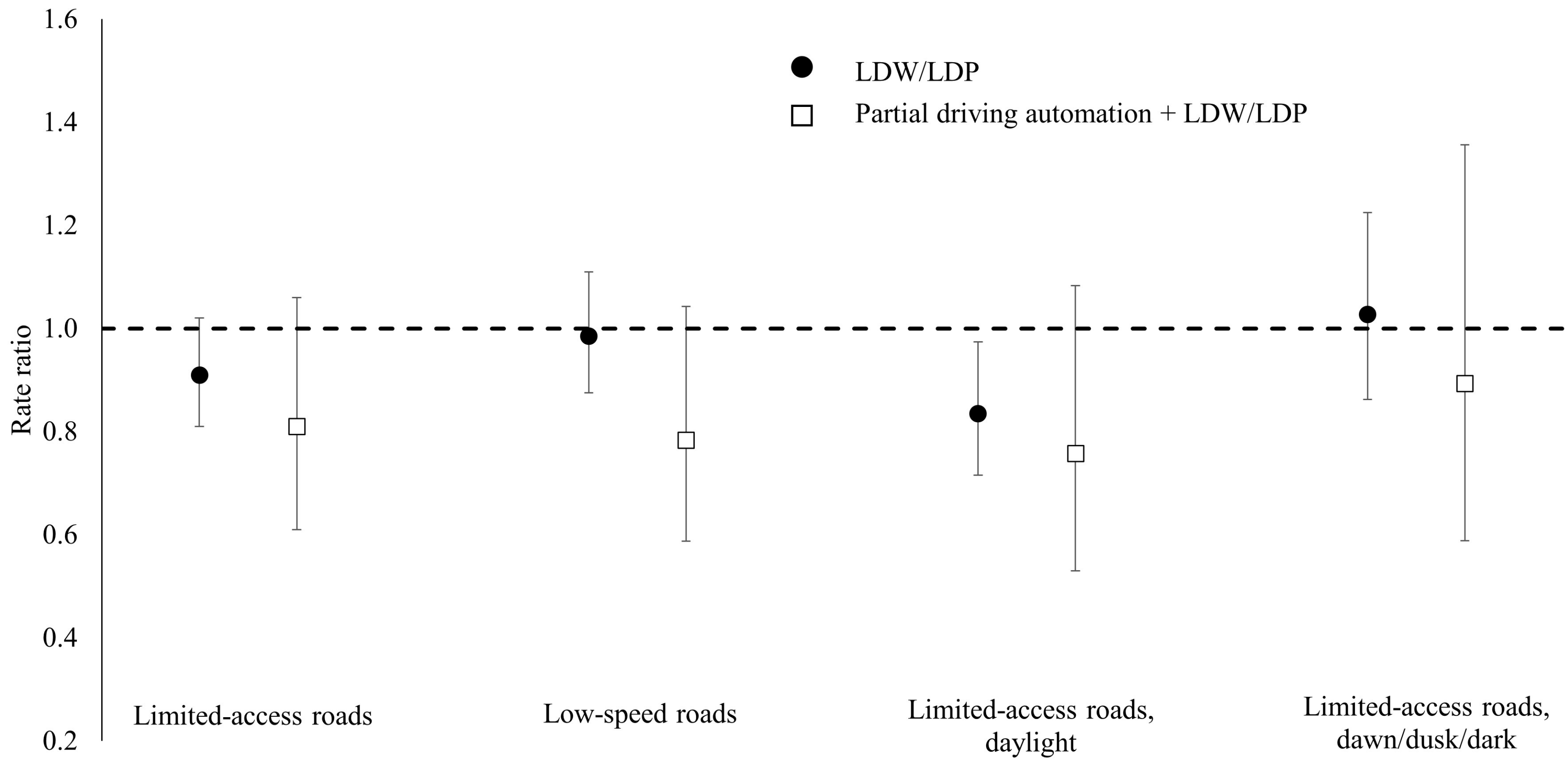
Note. Error bars indicate 95% confidence intervals. *p < 0.05, +p < 0.10

Figure 2. Association of LDW/LDP and partial driving automation on Nissan Rogue vehicles with lane departure crash rates from negative binomial regression models.



Note. Error bars indicate 95% confidence intervals. *p < 0.05, +p < 0.10.

Figure 3. Association of LDW/LDP and partial driving automation on BMW vehicles with lane departure crash rates from negative binomial regression models.



Note. Error bars indicate 95% confidence intervals.

APPENDIX

Table A1. BMW models included in the study.

Make	Model	Model year range
BMW	2 series	2014–2017
	3 series	2013–2017
	4 series	2014–2017
	5 series	2013–2017
	5 series GT	2013–2017
	6 series	2013–2017
	X1	2013–2017
	X4	2015–2017
	X5	2013–2017
	X6	2013–2017
MINI	Clubman	2016–2017
	Cooper	2013–2017
	Countryman	2013–2017

Table A2. States and years of police-reported crash data included in the study.

State	Calendar year range
CT	2017–2022
FL	2013–2021
GA	2019
KS	2013–2021
LA	2013–2021
MD	2014–2022
MI	2013–2021
MN	2013–2021
MO	2015–2021
NC	2015–2019
NE	2013–2019
NJ	2013–2020
OH	2017–2022
PA	2013–2017
TN	2019
TX	2013–2020
WI	2018–2021