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Design Integration of Adaptive Safety Systems in Modern Passenger Cars

Aneesh Upasanamandiram Baladevan

Kerala University, Kerala

Corresponding Author Email: aneeshub@gmail.com - ORCID: 0009-0009-4199-8325

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Abstract:
Modern passenger cars are undergoing design integration of adaptive safety systems, which are redefining the nature of automotive safety as no longer being a series of individual instances of feature enhancement, but rather a context-based orchestration of safety. This paper summarizes the interrelationships between sensing and fusion, risk and severity prediction, decision logic, and coupled actuation between crash avoidance and injury mitigation. The focus is put on the effects that uncertainty-conscious triggering, driver and occupant state prediction, and the impact of pre-crash maneuver on the occupancy kinematics have on the effectiveness of adaptive restraint measures. It is also argued in the review that an evaluation method requires real-world effectiveness evidence coupled with scenario-based testing and injury-relevant measures, which require both consistency in the coverage of scenarios between traffic conflicts and occupant outcomes. Some of the challenges involve confirmation of AI-enabled perception when operational variability occurs, interaction of longitudinal/lateral control and restrain performance, and traceability of evidence between simulation and real crash results. The paper comes to a close and identifies future directions towards closed-loop co-design of safety with a dedicated emphasis on posture and occupant-aware protection and scalable validation methods offering plausible safety case to proceed with production deployment.

Keywords-adaptive safety systems; ADAS integration; active–passive safety coordination; sensor fusion; crash severity prediction; scenario-based testing; occupant state estimation; adaptive restraints; uncertainty-aware decision making; passenger car safety

1. Introduction:

In more recent passenger cars, design integration of adaptive safety systems is characterised by the interaction of both crash avoidance (active safety such as AEB, lane keeping, ACC/CACC) and injury mitigation (passive safety such as airbags, belt pre-tensioners and load limiters) in time-critical and uncertain situations. The problem of integration has become more multifaceted with vehicles including multi-modal sensing (camera radar ultrasonic and in-cabin sensing), AI-enabled perception, and predictive control capable of modifying pre-crash kinematics (e.g. braking-induced occupant motion) and hence change restraint effectiveness at impact [1], [2]. This area also aligns well with the general application of AI technology, since most adaptive safety functions rely on learned perception and risk prediction models, and the reliability of these models in the low-frequency safety-critical corner cases is a major obstacle to reliable deployment [1], [3]. Practical research gives high impulses to integration since a number of ADAS functionalities have reported quantifiable crash decrease gains, but gains are contingent on circumstance of functioning, controller design, and human interaction. According to large-scale assessments, low-speed AEB has been identified with decrease in real-world rear-end collisions [4], and lane departure warning/assist has been linked with decrease in lane-departure harm crashes in passenger vehicles [5]. Traffic level studies also show that ACC/CACC is capable of affecting instability and risk of collision based on parameter tuning, delays and penetration rates and can therefore not be considered safe performance based on features presence [6], [7]. Simultaneously, injury research conducted through simulation increasingly points to versions of pre-crash strategies to modify occupant posture and injury mechanisms, indicating the necessity to combine active maneuvers with adaptive restraint measures instead of considering them as two separate subsystems [8]. Key gaps remain. First, coordination gap remains between proactive and passive domains: a car can prevent a great number of crashes, but still, it might be at risk, and without severity prediction that can be accurately predicted, restraint-based strategies are either delayed, too conservative, or introduced inappropriately to the occupant condition [8]. Second, safety design is moving to data-driven perception and driver monitoring, however engineering assurance has to cope with functional inadequacies, dataset constraints and out-of-distribution cases that can cause unsafe behavior without the traditional meaning of fault [1], [3]. Third, end-to-end integration adds to the burden of validation since it must be combined with sensing, decision logic, vehicle dynamics, occupant kinematics, and restraint deployment timings under diversity and uncertainty in scenarios and within industrial cost constraints [9], [10]. The review thus considers peer-reviewed evidence about and ways of combining adaptive safety systems between sensing and actuation with (i) real-world safety effectiveness, (ii) integrated pre-crash and in-crash protection measures, (iii) patterns of system architecture that allow coordination, (iv) verification and validation practices to deploy safety-critical systems.

2. Literature Review

When tested in the real world, the key ADAS functions have been shown to be able to decrease crashes, although observed benefits are dependent on operating design domains, user interaction, and the relevance of the crash types. According to the multi-country insurance and crash research, low-speed AEB is linked with significant crash-end reductions, which proves its usefulness in being a high-impact crash-avoidance system to the prevalent types of conflicts [4]. In addition to rear-end crashes, the concept of lane departure warning/assist is related to the decrease in passenger-car fatal injuries in field studies and showed that lateral control assistance is efficient to apply within appropriate road and surrounding conditions [5]. Additional to these results, police-reported crash statistics specific to LDW-relevant events, indicate the decrease in the single-vehicle, sideswipe, and head-on crash involvement rates, indicating the significance of assessing

ADAS in terms of its role in resolving crash scenarios and not as per its aggregate crash counts [9]. In the case of lane-change conflicts, the involvement in lane-change crashes as reported by police has been found to be lower with blind spot monitoring, supporting the usefulness of maneuver-specific sensing and warning [10]. The effects of ADAS also provide vulnerable road user outcomes; pedestrian-detecting AEB has been assessed on real world crash data and the results have shown alterations in pedestrian crash risks as a factor of system availability, exposure, and the distribution of scenarios [11]. Traffic-safety and control In longitudinal studies of ACC and CACC, longitudinal automation has been found to have a prospective effect on traffic oscillations and risk of rear-end collisions, and depends on controller tuning, delays, and interactions between mixed-traffic conditions instead of universally enhancing traffic safety [6], [7]. On the integration frontier, injury-centered crash studies highlight that pre-crash interventions (e.g. emergency braking) can modify occupant posture and kinematics before impact, which may modify restraint interactions and injury pathways; this drives joint initiatives between active and passive approaches instead of competing feature optimization [8]. Lastly, human factors moderate the safety impact of ADAS in the field, in that, even when the underlying operation is a good one, misuse or disuse may diminish the overall benefit; research on trust in drivers demonstrates that trust is not uniformly distributed across the functions of assistance and across vehicles, meaning that acceptance and perceived reliability may affect real-world use and, therefore, safety performance [12].Collectively, the literature suggests that the current state of passenger-car safety is evolving towards “feature-based safety and on to system-of-systems safety in which integrated architectures, uncertainty management, driver interface, and validation strategy define the effectiveness realized in a wide range of crash types and scenarios [4]-[12].

3. Methodological Foundations for Adaptive Safety Integration

Adaptive safety integration can be organized into methodological layers: **(i) perception and driver/occupant state estimation**, **(ii) risk and severity prediction**, **(iii) coordinated decision/control across active and passive measures**, and **(iv) validation and assessment**. Methodologically, the first layer requires reliable multi-modal inference of driver readiness and occupant status (e.g., posture, belt use, seating configuration) under real-world variability, because downstream decisions depend on whether intervention will be accepted or physically effective; assurance challenges surrounding “performance insufficiency” and foreseeable misuse are increasingly framed within SOTIF-oriented research discussions for automated and AI-heavy functions [13]. In the risk layer, recent injury-severity prediction work shows how near real-time estimates can support pre-crash planning and adaptive restraint activation when a collision is judged unavoidable, enabling decision logic to optimize not only crash probability but also injury outcomes [14]. This motivates a shift from purely avoidance-oriented cost functions to injury-informed motion planning, where decision-making explicitly considers human injury risk as an optimization objective in imminent collision scenarios [15]. At the control layer, a central methodological challenge is the coupling between pre-crash maneuvers and in-crash protection, because braking/steering interventions can change occupant kinematics and restraint timing requirements; simulation-based studies show that AEB combined with pre-pretensioning strategies can alter injury measures in high-severity frontal crashes, reinforcing that coordinated active–passive strategies are necessary rather than independent tuning [8]. Complementary restraint-focused studies indicate that reversible belt pre-pretensioning can reposition forward-leaning occupants during the pre-crash phase, but effectiveness depends on timing and force profiles, which creates explicit design trade-offs between early preparation and unnecessary activation risk [17]. In parallel, "predictive safety" approaches emphasize the methodological importance of incorporating external-sensor information into pre-crash and crash recognition logic to improve restraint activation decisions and timing, effectively tightening the loop between perception and passive safety actuation [18]. For collision avoidance decision-making itself, emergency control research shows that integrated braking-and-steering strategies (often framed via model predictive control or structured decision layers) can improve avoidance capability versus single-actuator approaches, but require careful constraint handling to maintain stability and tire-force feasibility under extreme conditions [19], [20]. These integration methods also depend on reliable evaluation and assurance of AI-enabled components used for perception and risk assessment; peer-reviewed surveys on AI safety challenges highlight that functional insufficiency and dataset/operational limitations can introduce hazards even without classical component failures, reinforcing the need for uncertainty-aware design and verification [13]. Overall, methodological foundations for adaptive safety integration increasingly converge on a closed loop in which sensing uncertainty, injury-aware risk prediction, coordinated active–passive control, and systematic validation co-evolve, because improvements in one layer can be negated by mismatch or unmodeled interaction in another [14]–[20].

4. System Architecture for Integrated Adaptive Safety

Adaptive safety systems Design integration The integration of adaptive safety systems in current passenger vehicles is becoming an end-to-end, closed-loop architecture coordinating perception, prediction, decision-making and actuation both in crash avoidance (active safety) and in injury mitigation (passive safety). At the sensing layer, modern systems are based on heterogeneous sensor suites and fusion pipelines (camera-radar-LiDAR-ultrasonic plus vehicle dynamics signals) to enhance resistance to partial observability, adverse weather and transient occlusions; fusion technology reviews typically point to consistency of calibration, time compatibilities and fault tolerance as key determinants of reliable downstream behaviour instead of raw sensor counts alone [23]. Since integration means handing over the responsibility of isolated feature ECUs to distributed decision logic, verification workflows are more and more being focused on not just on detection performance but also fusion-stack correctness even in the presence of realistic timing and failure modes (e.g., degraded sensors, misalignment drift), which drives verification-oriented fusion frameworks and design to focus on system-level rather than component-only metrics [24]. In addition to raw perception, integrated safety architectures need a risk prediction layer, which approximates the probability of collision and (where avoidance is not possible) the severity of crashes and occupant-relevant boundary conditions in real time; prediction of crash-severity based on perception has thus become a crucial enabling module of pre-crash activities such as reversible belt pre-pretensioning, posture control, and restraint priming [25]. System-level integration also demands an explicit arbitration policy, between (i) "avoid if possible" maneuvers (AEB/steering support) and (ii) "mitigate when necessary" maneuvers (restraint adaptation), without prejudice to driver acceptance or to unnecessary intrusive actuation. This arbitration is often achieved by means of hierarchical supervisors that are guarded by uncertainty-conscious triggering logics and situation-specific threshold since irreversible or uncomfortable actions require evidence of risk estimates to be sufficiently confident and time-to-impact to be sufficiently brief [25]. Lastly, actuation integration is also embracing the concept of occupant-conscious adaptation: a posture-specific, seating arrangement, and belt route are examples of in-cabin/occupant state information that are considered as influencing restraint choice; studies of non-standard postures that are likely to arise in mobility scenarios show that posture variations can actually alter injury biomechanics and thus should be made a first-class input to integrated safety decision-making as opposed to a nuisance factor [26].

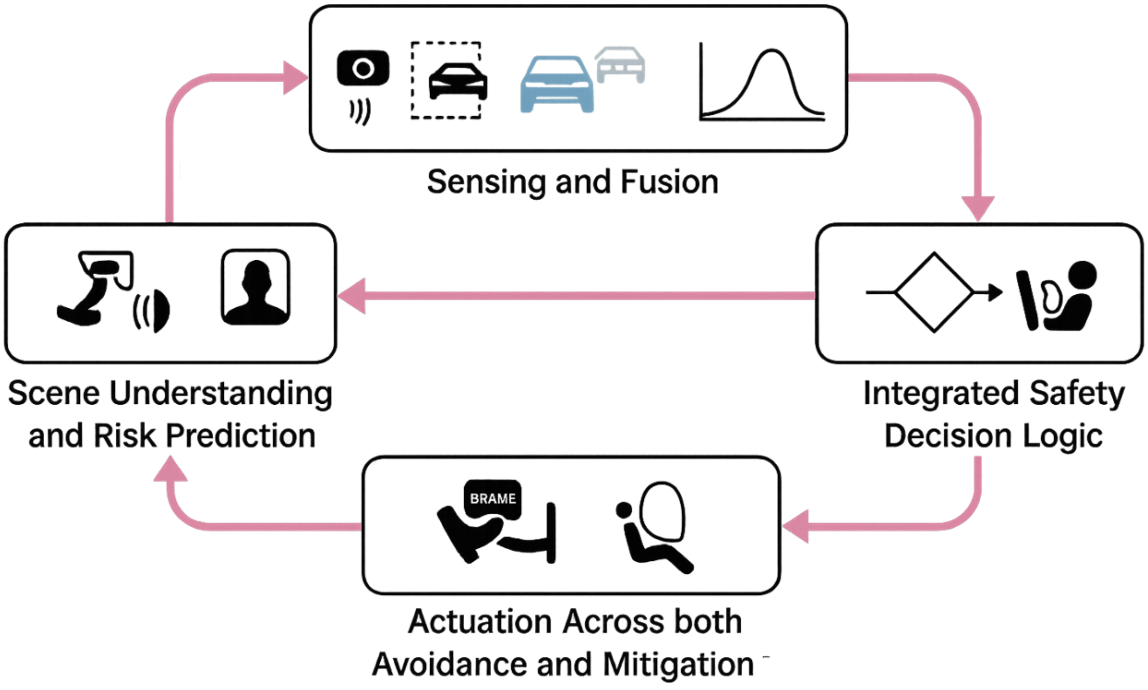

Figure 1: End-to-End Architecture Pipeline for Integrated Adaptive Safety

5. Evaluation Metrics and Scenario Coverage for Integrated Safety

Integrated adaptive safety demands assessment procedures that can simultaneously capture success of avoidance, change of impact condition and injury consequences- under identical scenario definition. To avoid this, event-based endpoints (collision/no-collision) are also required but still too few, as the behaviors of near-misses, and the aggressiveness of interventions, can differ significantly across controllers with the same number of crashes; the literature on surrogate safety assessment thus emphasises the necessity of conflict-based measures (e.g. time-to-collision, post-encroachment time, deceleration rate to avoid crash) and, most importantly, the inability to derive plausible crash-conflict relationships to avoid over-optimistic conclusions based In the case of integrated systems, the identical situation has to be considered in both (a) collision avoidance and (b) the ability to hit other objects (collision) and (c) the ability to miss collision (pre-crash maneuvers) but (d) changed delta-v, impact configuration, occupant posture, belt loading, and forecasted injury. This methodologically assumes a step further than feature scorecards to multi-objective measures that equalize safety benefit and side effects like instability, unnecessary harsh braking or posture changes that increase restraint interaction. The structure of scenario coverage should also avoid blind spots: scenario-based testing systems in traffic safety and automated-driving assurance typically formalize the level of scenario abstraction (logical vs. concrete scenarios) in order to systematically cover the variations in parameters (initial speeds, friction, cut-in geometry, sensor visibility, driver response) and maintain traceability to actual crash typologies in the real world [27]. Since coupled external hazards (between the system and occupant response) the ability of integrated systems to couple external hazards implies that diversity (in-cabin) should also be added to scenario libraries (including in-cabin diversity (seating posture, occupant size distribution, and belt fit), as occupant arrangement can alter injury outcome despite similar crash pulses [28].Practically to do rigorous integrated evaluation, however, it is needed that: (i) traffic-conflict measures of how close was the failure, (ii) maneuver-quality measures of smoothness, stability, and intervention timing, (iii) crash-configuration measures when impacts are not eliminated, and (iv) injury-related measures based on validated occupant models or injury risk functions - which are mapped uniformly across scenario abstractions [26]-[28].

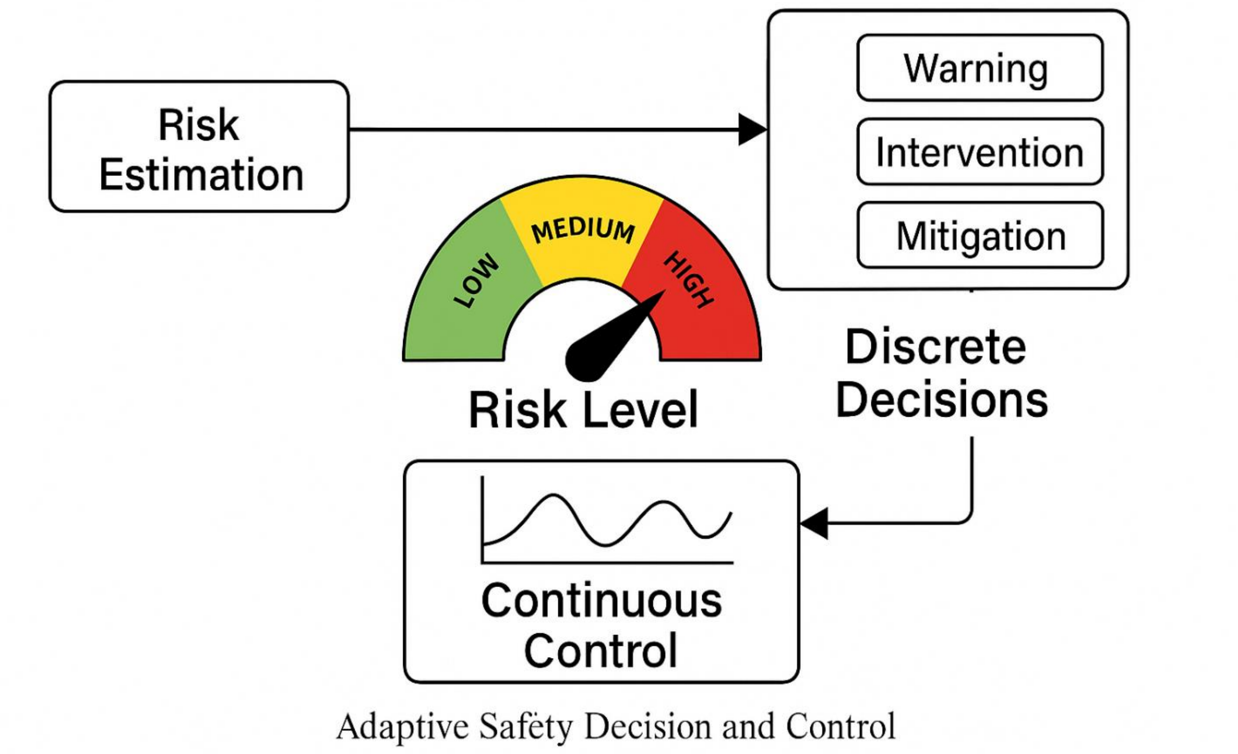

Figure 2. Metric Taxonomy Map

6. Data-Efficient Design and Validation Strategies

Due to the time and cost requirements of full-scale real-world collection of evidence to support integrated adaptive safety, data efficiency has become a fundamental constraint of engineering to influence contemporary validation strategy. At perception and prediction layers, data-efficient sub techniques comprise targeted dataset creation (coverage of uncommon-yet-important edge cases), controlled domain-shift testing, and scenario mining to make sure that sampled models are trained over the domain of operation and not on convenient samples. Scenario-based testing is also much less prevalent at the system-validation layer, where the combinatorial explosion of potential traffic interactions is often mitigated by describing the logic scenario families, and sampling representative concrete instantiations; a formal model of scenario definition that supports explainable coverage arguments and minimizes the risk of validation becoming simply an unstructured set of demonstrations [27]. To enable combined pre-crash functionality, work in the perception-based prediction of crash severity is directly framed as a scenario-based process, where real crash data is used to obtain representative catalogs which are then used in the virtual testing to reduce physical test load without the need to trace back to actual collisions in the real-world [25]. Passive-safety adaptation is also sought more with the use of data efficiency through simulation-based optimization. As an example, the adaptive restraint design-guided by machine learning has been shown to be able to tune restraint settings in the context of occupant anthropometry diversity population-based simulations has shown a route to understanding the design trade-offs prior to making it costly to hardware-iteration-commit [22]. Throughout the integration pipeline these approaches come together into the same idea namely, effective safety development requires the focus on information-rich situations (rare conflicts, short time-to-impact, occlusions, non-standard postures) and strategic use of simulation to determine where real-world testing is producing the most marginal reduction in uncertainty about safety performance [25], [27], [22].

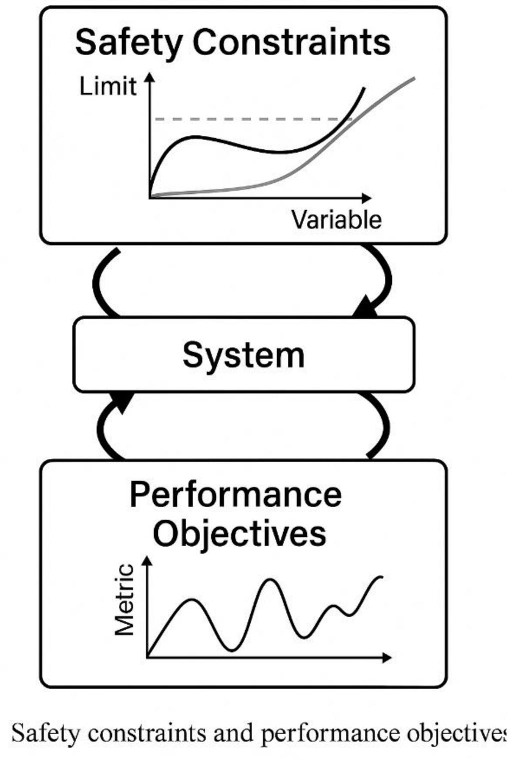

Figure 3: Safety constraints and performance objectives

7. Key Challenges and Research Gaps

There are still a number of research gaps that restrict plausible design incorporation of adaptive safety in manufacturing passenger vehicles. One, uncertainty-sensitive coordination is challenging: integrated systems have to make decisions to intervene, to intervene to which degree, to switch between avoidance focus and mitigation focus, but risk prediction is uncertain by nature, not only by occlusions, sensor noise, but also changing intent of other road users. Perception-based crash-severity prediction validation strategies specifically emphasize the need to provide both performance evidence of and safety argumentation under standards-consistent conditions that to be released on safety, a high average accuracy must be provided, as to motivate irreversible or intrusive pre-crash conduct [25]. Second, variation in sensing stacks and fusion implementations is a contributor to integration fragility: fusion reviews point to calibration, synchronization, and failure management as ongoing technical challenges, and verification-oriented fusion projects reveal that system correctness can be lost in insidious ways in the presence of timing jitter and partial sensor degradation [23], [24]. Third, scenario coverage is still a bottleneck to dominate: even mature proxy measures demonstrate that even without a universally agreed upon guiding framework, the majority of studies of the mapping of surrogate safety scenarios indicates that further efforts are required to bridge the gap between observed conflicts to the likelihood and severity of a crash, primarily to address the edge cases that the adaptive systems are most focused on [26]. Fourth, the occupant variability has been inadequately represented in a variety of integrated validation studies; side-impact studies of non-standard sitting postures have shown that posture variation under the conditions of modern mobility can have a substantial effect on occupant response, suggesting that posture and belt-fit diversity should be considered in integrated safety claims, which are currently modeled using only nominal seated postures [28]. Lastly, even evidence integration itself is an area of weakness: scenario catalogs, simulations, and actual data are typically loosely coupled, and it is difficult to make traceable, system-level safety claims that are not only saying that something is beneficial, on average, but also more constrained and possessing failure modes within a certain family of scenarios [25], [27].

8. Future Research Directions

The direction of future effort is believed to revolve around closer integration of risk prediction, maneuver planning and restraint adaptation in a closed loop safety activity. This would be applied at the architecture level, with sensor fusion and prediction stacks co-designed with clear interfaces to safety arbitration (e.g. calibrated uncertainty outputs and time-steady risk paths), aligned with sensor-fusion reviews identifying robustness and fault management as critical to safety-critical deployment [23]. On the validation level, scenario-based methods are predicted to transform the scenario enumeration to scenario governance: formal scenario models may be employed to not only choose tests but also to sustain traceability in between real-world crashes, logical scenarios definitions, and concrete simulation instances, which makes it possible to build cumulative evidence and not limited evaluations [27]. To achieve integrated pre-crash mitigation, further research into crash severity prediction and its validation will continue to extend to quantifying end-to-end benefit (how the quality of prediction translates into quantifiable injury reduction under realistic triggering policies), since the nature of this research area is that the current severity-prediction validation efforts are being triggered by the necessity to obtain findings that demonstrate irreversible benefits [25]. Also occupant-friendly approaches will expand beyond anthropometry to cover posture and seating-configuration forecast, inspired by the safety-science discoveries that occupants can change posture significantly to alter their response and risk of injury [28]. Lastly, optimization of adaptive restraints with learning-based approaches is a direction towards the concept of personalized safety, but it also points to further research requirements in constraint management, explainability, and stable evaluation across a wide range of different occupants, including the value of scalable simulation-to-validation pipelines that maintain physical plausibility and enhance design with improved throughput [22].

9. Conclusion

Adaptive safety systems Design integration of adaptive safety automotive systems is shifting road safety out of the maintenance focus of individual features, to coordinated safety orchestration of sensing, prediction, control, and occupant protection. The emerging architectures need multi-sensor fusion, scenario-based risk/crash severity prediction, and arbitration logic that supports avoidance and mitigation management coupled with uncertainty and driver acceptance management [23], [25]. Assessment is also gradually moving beyond the simple crash-count endpoints to multiple-level evidences of surrogate safety metrics, scenario based coverage arguments and injury-relevant outcomes- and recognizes that the field of evaluation remains incompletely cohesive in crash-conflict relations, and context and circumstantially sensitive to the application of surrogate metrics [26]. With the rise in occupant variability and non-standard postures, posture-aware considerations are becoming more and more important to plausible integrated safety claims, since the interaction of the response of the occupants and restraints may vary dramatically with varying seating arrangements [28]. Data-efficient, scenario-based validation and simulation-driven adaptive restraint design provide practical pathways to accelerate development, but the strongest remaining needs are traceable system-level assurance, uncertainty-aware coordination, and rigorous integration of scenario libraries with real-world evidence [25], [27], [22].

References:

[1] Gulino, M.-S., Di Gangi, L., Sortino, A., & Vangi, D. (2021). Injury risk assessment based on pre-crash variables: The role of closing velocity and impact eccentricity. *Accident Analysis & Prevention, 150*, Article 105864. https://doi.org/10.1016/j.aap.2020.105864

[2] Ramírez-Moreno, M. A., Domínguez-Morales, J. P., García-Domínguez, M., Martínez-Blanco, M. R., & Jiménez-Fernández, Á. (2019). A comprehensive survey of driving monitoring and assistance systems. *Sensors, 19*(11), 2574. https://doi.org/10.3390/s19112574

[3] Sun, C., Zheng, S., Ma, Y., Chu, D., Yang, J., Zhou, Y., Li, Y., & Xu, T. (2021). An active safety control method of collision avoidance for intelligent connected vehicle based on driving risk perception. *Journal of Intelligent Manufacturing, 32*, 1249–1269. https://doi.org/10.1007/s10845-020-01605-x

[4] Fildes, B., Keall, M., Bos, N., Lie, A., Page, Y., Pastor, C., Pennisi, L., Ohlin, M., Thomas, P., & Tingvall, C. (2015). Effectiveness of low speed autonomous emergency braking in real-

world rear-end crashes. *Accident Analysis & Prevention, 81*, 24–29. https://doi.org/10.1016/j.aap.2015.03.029

[5] Sternlund, S., Strandroth, J., Rizzi, M., Lie, A., & Tingvall, C. (2017). The effectiveness of lane departure warning systems—A reduction in real-world passenger car injury crashes. *Traffic Injury Prevention, 18*(2), 225–229. https://doi.org/10.1080/15389588.2016.1230672

[6] Li, Y., Li, Z., Wang, H., Wang, W., & Xing, L. (2017). Evaluating the safety impact of adaptive cruise control in traffic oscillations on freeways. *Accident Analysis & Prevention, 104*, 137–145. https://doi.org/10.1016/j.aap.2017.04.025

[7] Li, Y., Wang, H., Wang, W., Xing, L., Liu, S., & Wei, X. (2016). Evaluation of the impacts of cooperative adaptive cruise control on reducing rear-end collision risks on freeways. *Accident Analysis & Prevention, 98*, 87–95. https://doi.org/10.1016/j.aap.2016.09.015

[8] Östh, J., Brolin, K., Carlsson, A., Forman, J., & Pipkorn, B. (2022). Effects of automated emergency braking and seatbelt pre-pretensioning on occupant injury risks in high-severity full-frontal crashes. *Frontiers in Future Transportation, 3*, 883951. https://doi.org/10.3389/ffutr.2022.883951

[9] Cicchino, J. B. (2018). Effects of lane departure warning on police-reported crash rates. *Journal of Safety Research, 66*, 61–70. https://doi.org/10.1016/j.jsr.2018.05.006

[10] Cicchino, J. B. (2018). Effects of blind spot monitoring systems on police-reported lane-change crashes. *Traffic Injury Prevention, 19*(6), 615–622. https://doi.org/10.1080/15389588.2018.1476973

[11] Cicchino, J. B. (2022). Effects of automatic emergency braking systems on pedestrian crash risk. *Accident Analysis & Prevention, 172*, 106686. https://doi.org/10.1016/j.aap.2022.106686

[12] Kidd, D. G., Cicchino, J. B., & Reagan, I. J. (2017). Driver trust in five driver assistance technologies following real-world use in four production vehicles. *Traffic Injury Prevention, 18*(sup1), S44–S50. https://doi.org/10.1080/15389588.2017.1297532

[13] Li, H., Huang, Y., & Chen, Z. (2024). A survey on an emerging safety challenge for autonomous vehicles: Safety of the intended functionality (SOTIF). *Engineering*. https://doi.org/10.1016/j.eng.2023.10.011

[14] Wang, Q., Gan, S., Chen, W., Li, Q., & Nie, B. (2021). A data-driven, kinematic feature-based, near real-time algorithm for injury severity prediction of vehicle occupants. *Accident Analysis & Prevention, 156*, 106149. https://doi.org/10.1016/j.aap.2021.106149

[15] Wang, Q., Zhou, Q., Lin, M., & Nie, B. (2022). Human injury-based safety decision of automated vehicles. *iScience, 25*(7), 104703. https://doi.org/10.1016/j.isci.2022.104703

[16] Mishra, E., Mroz, K., & Lubbe, N. (2023). Repositioning forward-leaning passengers by seatbelt pre-pretensioning. *Traffic Injury Prevention*. https://doi.org/10.1080/15389588.2023.2239408

[17] Grotz, B., Straßburger, P., Huf, A., & Roig, L. (2021). Predictive safety—Perception-based activation of pre-crash systems. *ATZ Worldwide, 123*, 18–25. https://doi.org/10.1007/s38311-020-0601-6

[18] Han, Y., Kim, J., & Lee, S. (2023). Decision making for collision avoidance systems considering a following driver model. *International Journal of Automotive Technology, 24*, 1093–1106. https://doi.org/10.1007/s12239-023-0035-4

[19] Zhang, Y., Liu, H., & Chen, L. (2024). Combined steering and braking collision avoidance control method based on model predictive control. *International Journal of Automotive Technology, 25*, 521–535. https://doi.org/10.1007/s12239-024-00044-4

[20] Zhang, X., Zhang, J., & Wang, Y. (2022). Emergency collision avoidance strategy for autonomous vehicles based on steering and braking. *Scientific Reports, 12*, 22327. https://doi.org/10.1038/s41598-022-27296-3

[21] Sun, W., Liu, J., Hu, J., Jin, J., Siasoco, K., Zhou, R., & McCoy, R. (2023). Adaptive restraint design for a diverse population through machine learning. *Frontiers in Public Health, 11*, 1202970. https://doi.org/10.3389/fpubh.2023.1202970

[22] Yeong, D. J., Velasco-Hernandez, G., Barry, J., & Walsh, J. (2021). Sensor and sensor fusion technology in autonomous vehicles: A review. *Sensors, 21*(6), 2140. https://doi.org/10.3390/s21062140

[23] Elgharbawy, M., El Badawy, A., Azim, M., Kim, S., & Kim, K. (2019). A real-time multisensor fusion verification framework for advanced driver assistance systems. *Transportation Research Part C: Emerging Technologies, 104*, 193–209. https://doi.org/10.1016/j.trc.2019.05.003

[24] Putter, R., Neubohn, A., Leschke, A., & Lachmayer, R. (2023). Predictive vehicle safety—Validation strategy of a perception-based crash severity prediction function. *Applied Sciences, 13*(11), 6750. https://doi.org/10.3390/app13116750

[25] Arun, A., Haque, M. M., Bhaskar, A., Washington, S., & Sayed, T. (2021). A systematic mapping review of surrogate safety assessment using traffic conflict techniques. *Accident Analysis & Prevention, 157*, 106016. https://doi.org/10.1016/j.aap.2021.106016

[26] Weber, H., Bock, J., Klimke, J., Roesener, C., Hiller, J., Krajewski, R., Zlocki, A., & Eckstein, L. (2019). A framework for definition of logical scenarios for safety assurance of automated driving. *Traffic Injury Prevention, 20*(sup1), S65–S70. https://doi.org/10.1080/15389588.2019.1630827

[27] Negro Marne, A., Down Alonso, J., Vázquez de Prada Martínez, J., Fernández Peña, M. T., & Díez Marín, M. (2023). Sitting posture influence in autonomous vehicles for the evaluation of occupant safety in side impact. *Safety Science, 159*, 106002. https://doi.org/10.1016/j.ssci.2022.106002