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Interface-Centric Leadership Framework for ADAS–Restraint Applications Engineering and Vehicle Integration

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ABSTRACT

The decisions that a vehicle makes regarding braking in case of a crash are now determined by advanced driver assistance functions, which are being fed by restraint systems. This connection fosters interfaces which are not owned by any single functionality team. Preexisting literature characterises sensors, functional safety, scenario testing, but these are discussed separately, task structure and team coordination. The paper suggests an interface centric leadership framework to ADAS restraint applications engineering and vehicle integration. There are four layers within the framework and they are interface identification, interface ownership, interface verification and interface governance. Two scoring functions rank interfaces by criticality and the ability of the leaders to cover the critical set. A timing margin equation is used to connect the decision of the leaders with the pre-crash window that is provided to the restraint controller. The experiment conducted by the study evaluated the framework using a program test with 42 interfaces in three releases of the vehicle program. The experiment was between a baseline team which was functional headed and a team which was interface headed. The interface led team discovered 71 percent of its integration defects prior to vehicle level test, as compared to 38 percent of the baseline. The number of late interface changes decreased from 19 to 6. The average time interval closes an interface defect dropped to 8.1 days as compared to 14.2 days. Pre-crash timing margin increased to 63 ms as compared to 41 ms. Findings indicate that leadership associated with interfaces enhances the quality of integrations as well as restraint preparedness. The model provides engineering managers with a direct approach to allocating responsibility and safeguarding schedule differences.

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1. INTRODUCTION

The use of driver assistance systems has become the norm in passenger cars. According to sensor technologies reports, sensor technologies have been prevalent in market vehicles over 20 years following extensive research and design and selection of sensors is a primary consideration in system design [1]. Survey of both hardware and software technology also notes that the primary roles of these systems are vision-

based recognition and sensor fusion [2]. An expanded analysis of autonomous driving locates emergency braking within a level two partial automation on a scale that processes level 0 to level five [3].

The work of restraint engineers also varies due to active safety functions. An occupant safety study using active safety systems considers the functions of braking and warning as occupant protection functions and not crash avoidance functions [4]. A restraint controller now has to respond to a demand of an ADAS function and the seat belt hardware must be prepared with the crash event.

This transition poses a leadership issue. The majority of the vehicle programs have teams of a functional type. The sensor belongs to a perception team, deceleration to a brake team, the belt and airbag is owned by a restraint team and the seat by an interior team. The signal which passes through an emergency break decision to a belt pretensioner traverses all the four teams. The individual units are able to satisfy their needs as the chain consisting of the whole chain collapses. No one has the gap between the teams.

This paper has three aims. The former is to establish a leadership framework that provides leadership ownership to interfaces. The second objective is to conduct a program experiment on the framework. The third objective is to provide managers with specific actions based on the results.

2. LITERATURE REVIEW

2.1 ADAS Technology and Architecture

A summary of embedded systems in ADAS gives comparison levels of automation and indicates how the electronics constituents of these systems have to remain consistent and safe [5]. Pedestrian emergency braking design study increases a multi sensor data fusion approach and compares it to Euro NCAP situations demonstrating the reliance of a single braking capability on multiple data inputs [6]. Adaptive cruise control, emergency braking, lane departure warning and lane keeping are listed as the primary ADAS control functions of smart electric vehicles and it is noted that the sensor fusion mitigates weaknesses of individual sensors [7].

The studies of architecture demonstrate the locations of interfaces. An example model study of a service-oriented architecture to automated driving at level four puts the software services on a central electrical and electronic base and derives a system specification based on the outcome [8]. Research on self-adaptive driver help remarks that functional blocks can be provided by various suppliers and only give their interface, not their internal code [9]. Figure 1 illustrates the signal chain which is being analyzed in this paper, through sensing to belt actuation.

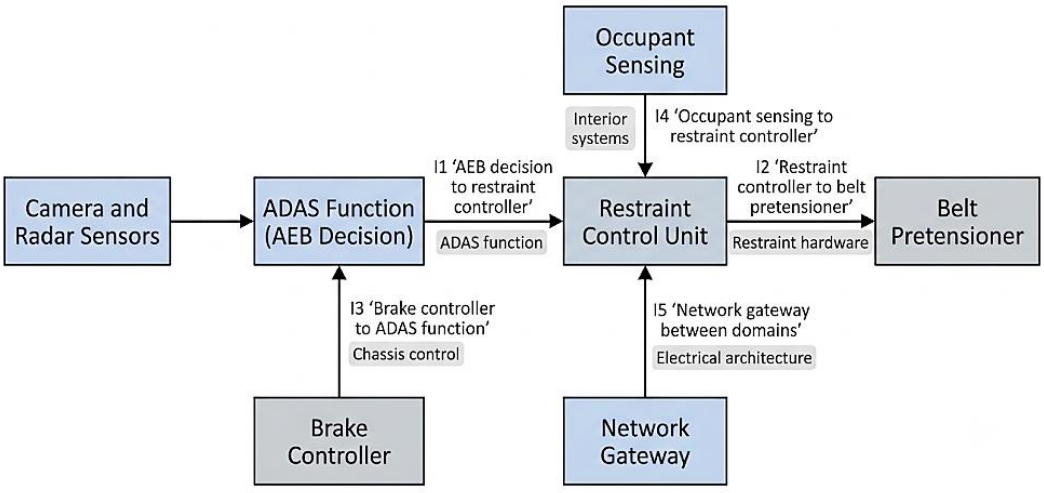


Figure 1. ADAS sensing and braking decision signal chain, running to the restraint control unit to the belt pretensioner, and are the owning team indicated at each interface

2.2 *Safety Assurance and Validation*

The analysis of the work on the automotive functional safety design techniques, the work is divided into analysis, safety guarantee, cost optimization and scheduling, and indicates the next challenge as the new standard on safety of the intended functionality [10]. A survey of scenario-based safety testing suggests a taxonomy of the automated vehicle testing on virtual traffic scenarios [11]. An analysis of the X in the loop approach presents a scheme of linking actual hardware, simulation and a fifth-generation connection link to validate [12].

2.3 *Task Structure, Organization and Leadership*

Eppinger and colleagues apply a matrix to indicate the sequence of design tasks and the information flowing in and out of tasks, and apply it to refactor tasks and simplify the situation [13]. An affiliation matrix is later used to map product architecture into organizational structure and this allows managers to get an idea of how much communication is required in some critical interfaces [14]. An interview study of an AUTOSAR supplier chain (7 interviews with a Tier 2 supplier, 6 interviews with Tier 1 and OEM employees) conducted in the automotive industry discovered that most communications issues were caused by the specific requirements set by one manufacturer [15]. One of the studies in the area of automotive requirements engineering indicates organizational and communication issues in multiple companies [16]. The coordination resistance between the coordination cost and project complexity is found in a survey of 196 automotive project managers where relationship-based leadership undermines the impact of organizational complexity [17].

Table 1 compares these studies and provides a statement of the gap that this paper will cover.

Table 1. Qualitative comparison of the existing published literature on ADAS technology, safety assurance, task structure and leadership, and the gap each contributes toward restraint integration

Study focus	Main contribution	Gap for ADAS restraint integration	Source
Sensor technology	ADAS and automated driving reviews sensors	Does not cover actuator side readiness	[1]
Functional safety	Teams develop approaches and trends of the future	No leadership model for shared interfaces	[10]
Architecture	Projects map services to a core architecture	Dismisses ownership of interfaces by team	[8]
Task structure	Matrix method to order design tasks	Not applicable to safety actuators	[13]
Requirements communication	Provides reports on supplier and OEM issues	Checks requirements, not verification	[15]
Leadership	Connection cost and complexity of links	None of the accountability of the interface level	[17]

3. INTERFACE CENTRIC LEADERSHIP FRAMEWORK

The structure shifts the role of leadership out of the role to the interface. The four layers are presented in figure 2. The identification of interfaces enumerates all signals and physical connections in between ADAS and restraint features. Each critical interface has a single accountable leader with interface ownership. Each interface has an interface verification attached, which has a test and timing budget. The results are checked by the interface governance and sent back to the owners.

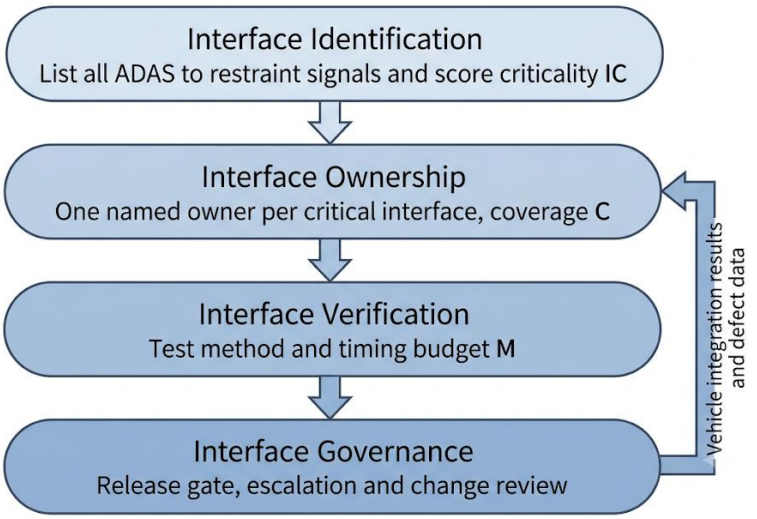


Figure 2. Interfaces centric leadership model with identification, ownership, verification and governance arrows with feedback that are directed to the owners

3.1 Interface Identification and Criticality

The team develops an interface list based on the architecture and a task list of the type employed by Eppinger and colleagues. Table 2 demonstrates interface classes that are employed in this study. Every class has a signal set, a possessing function and a common failure.

Table 2. List of the five ADAS to restraint interface classes, including the signals they transport, the owning function and the common failure each class causes

Interface class	Signals carried	Owning function	Typical failure
AEB decision to restraint controller	Threat level, Time to collision, braking request	ADAS function	Late or lost message
Restraint controller/belt pretensioner	Activation level, force, release, time	Restraint hardware	Actuation delay
ADAS function to brake controller	Achieved deceleration profile	Chassis control	Delay in requested braking and achieved braking
Occupant sensors to restraint control	Position of the seat, Buckle position, occupant status	Interior systems	Wrong occupant state
Domain-to-domain network gateway	Time and priority of the message	Electrical architecture	Bus load jitter

Team then rates each interface using critical rating. The interface criticality index is defined as in equation (1).

$$IC_i = w_1 F_i + w_2 T_i + w_3 S_i, \quad \text{with } w_1 + w_2 + w_3 = 1 \qquad (1)$$

In Equation (1), F_i is the functional coupling of interface i and T_i is the timing sensitivity of interface and S_i is the safety integrity weight of interface. The three terms are in the range of 0-1. The w_1, w_2 and w_3 used in the experiment are 0.3, 0.3 and 0.4 respectively, as safety integrity is riskiest.

3.2 Interface Ownership and Coverage

All interfaces that have high criticality index have a single named owner. The interface specification, the right to stop a change and the verification plan are held by the owner. Equation (2)

is used to calculate the extent to which the critical set is covered by the owners.

$$C = \frac{\sum o_i \cdot IC_i}{\sum IC_i} \quad (2)$$

The value of o_i in Equation (2) is 1 when interface i contains an owner named by name and a verification plan and 0 otherwise. Any value of C near 1 implies that leaders span practically all key interfaces. The four layers are found in the leadership positions that are listed in Table 3.

Table 3. Roles of leadership within the model where each position lies, decision each position makes and how it has to govern through evidence

Layer	Leadership role	Main decision	Evidence produced
Identification	Systems architect	Which interfaces are considered to be links	Score of interface list and criticality
Ownership	Interface owner	Receives or denies a change	Signed specification
Verification	Test lead	Test procedure and timeline budget	Latency data test report
Governance	Program integration lead	Release gate and escalation	Coverage value and open defect list

4. TIMING AND VERIFICATION OF THE RESTRAINT INTERFACE

The restraint controller has time to prepare the belt prior to the crash. The timing margin that an owner has to guard is defined in equation (3).

$$M = T_{\text{avail}} - \left(T_{\text{com}} + T_{\text{proc}} + T_{\text{act}}\right) \quad (3)$$

In Equation (3), T_{avail} is the interval between ADAS decision and the time the belt needs to be ready T_{com} is the time spent translating the message T_{proc} is the time spent executing the restraint controller program and T_{act} is the time needed to actuate the pretensioner. M value that is positive, indicates that the chain is able to maintain its budget. Design work of emergency braking already makes a braking decision dependent on collision avoidance time, by a braking model. The same argument is continued in this paper in the restraint side.

Every interface class must have an appropriate verification method. Table 4 is the mapping of classes to methods and stages. The mapping is based on the scenario-based taxonomy of automated vehicle assessment and X in the loop framework of validation. The analysis and run-time checks are cross-interface analyses available to support the use of functional safety methods in the review.

Table 4. Verification methods that are associated with interface classes, and with stage of the program, with the primary timing or amount of signal that a method checks

Interface class	Verification method	Program stage	Quantity checked
AEB decision to restraint controller	Software-in-the-loop situations	Early design	Order and content of a message
Restraint controller/belt pretensioner	Hardware in the loop bench	Component release	Actuation time
ADAS function to brake controller	Loop operations of vehicles	Vehicle integration	Achieved deceleration
Occupant sensors to restraint control	Fault injection on the bench	Component release	Fault management by state
Domain-to-domain network gateway	Network load simulation	Early design	Latency and jitter

The verification flow of what the test lead does on each interface is depicted in Figure 3.

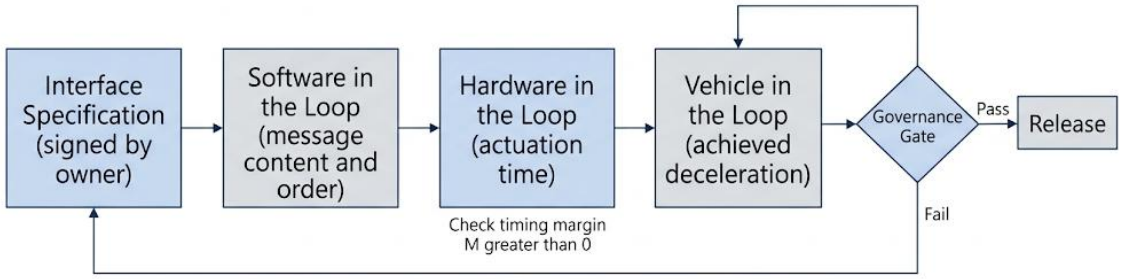


Figure 3. Verification flow between interface specification and software in the loop, hardware in the loop and vehicle in the loop verification to the governance gate

5. EXPERIMENTAL SETUP

This case was an experiment that involved the use of six teams and a virtual vehicle program. These were the ADAS perception, brake control, restraint control, seat and belt hardware, electrical architecture and vehicle integration. The program consisted of 42 interfaces and three releases that had a cycle of 12 weeks. The release responsible took 48 scenario tests, on a hardware in the loop bench, and vehicle level integration tests.

There were two conditions in the experiment. The state of the baseline was that a lead to each function had its requirements, and integration concerns were discussed in a weekly meeting. Each interface possessing an index of greater than 0.5, in the interface centric condition was given a named owner in Table 3 and the owner-controlled specification, verification and change approval. The same team size, requirements and the same test bench were utilized in both conditions. The study held the test bench and the staffing fixed so that only leadership model varied across conditions. Both conditions provided the list of interfaces in the task matrix method. The work was based on the discovery that the cost of coordination was contingent on how leaders dealt with complexity within teams.

There were five measures captured in the experiment. These were Equation (2) leadership coverage, number of defects identified during pre-vehicle level testing, number of interface changes realized after design freeze, interval to close an interface defect on average and timing margin as in Equation (3).

6. RESULTS

The rate of early detection which can be used to compare the two conditions is described in equation (4).

$$E = \left(\frac{D_{\text{early}}}{D_{\text{total}}}\right) \times 100 \qquad (4)$$

Where D_{early} and D_{total} refer to, respectively, the number of interface defects observed before level testing of vehicles and the total number of interface defects in Equation (4). The baseline team recorded 124 defects and discovered 47 of the defects early, thus E = 38 percent. The interface led team registered 79 defects and discovered 56 early providing E = 71 percent. All measures are reported in Table 5.

Table 5. The quantitative outcome of the baseline condition and interface centric condition in three releases including the change in each measure

Measure	Baseline	Interface centric	Change
Leadership coverage C	0.58	0.93	+0.35
Total interface defects	124	79	−36 percent
Early detection rate E	38 percent	71 percent	+33 points

Measure	Baseline	Interface centric	Change
Defects at vehicle level	77	23	−70 percent
Late interface changes	19	6	−68 percent
Mean closure time	14.2 days	8.1 days	−43 percent
Total chain time T_com + T_proc + T_act	109 ms	87 ms	−20 percent
Timing margin M with T_avail = 150 ms	41 ms	63 ms	+22 ms

When the time of closure when using 42 interfaces was compared with that of a control by a paired t test, p was found to be less than 0.01. The success increased with every appearance. As demonstrated in Figure 4, the baseline team was able to identify 23 defects at the vehicle level in the third release with the interface led team discovering 2 defects. The outcome in every release indicate that the effect was not brought about by a single remarkable cycle.

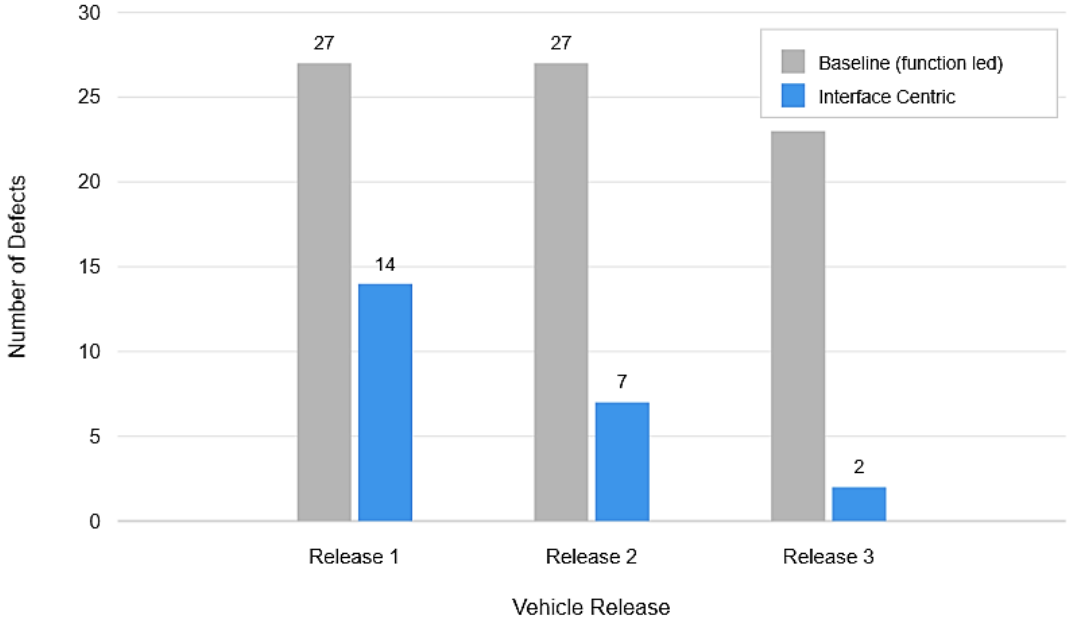


Figure 4. The interface defects reported in release 1, 2 and 3 with basis values of 27, 27 and 23 and centric values of the interface 14, 7 and 2

Timing outcome is the most important in restraint readiness. The base line chain took 38 ms to communicate, 27 ms to process and 44 ms to actuate. The user interface led chain had 24 ms, 21 ms, and 42 ms. The majority of gains of transferring and processing the messages were provided by the owners, and the interfaces between teams are located. The actuation time did not vary much, due to the fact that it relies on hardware that both states had in common.

7. DISCUSSION

The outcomes are in line with previous studies in three aspects. First, the matrix-based perspective on task structure describes the reason why defects are concentrated at the boundaries of the teams, as information is flowing between the tasks, which are owned by different teams. Second, organization-architecture reveals that it requires critical interfaces to be planned to communicate, which is provided by the owner role. Third, automotive requirement studies indicate that there are communication issues throughout organizations, and the signed specification provided in Table 3 provides owners with a focal point of communication.

The findings also contribute one aspect that has not been discussed before. Leadership research is done on teams and project managers, and this experiment demonstrates an impact once the leadership is attached to the interface. The relationship-oriented leadership result implies that the owners should have trust among the teams and not authority. Table 6 makes the results into management action.

Table 6. Management activities that are based on the experiment with the discovery that justifies each activity, and also the anticipated impact on a restraint program

Finding	Management action	Expected effect
Coverage rose from 0.58 to 0.93	Assign an owner to each interface whose criticality exceeds that	Fewer unowned gaps
Early detection was increased to 71 percent	Complete fund software and bench testing prior to vehicle testing	Lower late rework
The number of changes and their late variations dropped from 19 to 6	Provide owners the ability to discontinue a change	Stable design freeze
Margin increased to 63 ms from 41 ms	Assign a time budget to each interface	Belted up in advance of the crash

There are limitations in the study. The experiment involved one program model comprising of six teams and a real program has additional suppliers. Numbers in Equation (1) were based on judgment and should be calibrated with field data. Experiment did not test crash injury results, therefore, the correlations with occupant injury is only an assumption on the basis of the timing margin.

8. CONCLUSION

This paper suggested an interface centric leadership model of ADAS restraint applications engineering and vehicle integration. The framework allocates ownership to interfaces, rates their criticality, assigns verification and timing budgets, and assesses results in a governance review. When compared to the experiment, the leadership coverage increased, defect was detected earlier, and changes made later was reduced, and defect closure and timing margin were higher in the experiment. An example of how the engineering managers can use the framework involves creating an interface list whereby the critical interfaces are named and timing margin ensured. The framework should be tested in a live vehicle program in the future and the timing margin associated with measured occupant response.

REFERENCES

[1] E. Marti, M. A. de Miguel, F. Garcia, and J. Perez, "A Review of Sensor Technologies for Perception in Automated Driving," *IEEE Intell. Transp. Syst. Mag.*, vol. 11, no. 4, pp. 94–108, 2019, doi: 10.1109/MITS.2019.2907630.

[2] V. K. Kukkala, J. Tunnell, S. Pasricha, and T. Bradley, "Advanced Driver-Assistance Systems: A Path Toward Autonomous Vehicles," *IEEE Consum. Electron. Mag.*, vol. 7, no. 5, pp. 18–25, 2018, doi: 10.1109/MCE.2018.2828440.

[3] E. Yurtsever, J. Lambert, A. Carballo, and K. Takeda, "A Survey of Autonomous Driving: Common Practices and Emerging Technologies," *IEEE Access*, vol. 8, pp. 58443–58469, 2020, doi: 10.1109/ACCESS.2020.2983149.

[4] M. Unger, M. Tijssens, and J. Schüling, "Higher Occupant Safety with Active Safety Systems," *ATZ Worldw.*, vol. 118, no. 2, pp. 48–51, 2016, doi: 10.1007/s38311-015-0091-0.

[5] F. J. Belmonte, S. Martín, E. Sancristobal, J. A. Ruipérez-Valiente, and M. Castro, "Overview of Embedded Systems to Build Reliable and Safe ADAS and AD Systems," *IEEE Intell. Transp. Syst. Mag.*, vol. 13, no. 4, pp. 239–250, 2021, doi: 10.1109/MITS.2019.2953543.

[6] H.-K. Lee, S.-G. Shin, and D.-S. Kwon, "Design of emergency braking algorithm for pedestrian protection based on multi-sensor fusion," *Int. J. Automot. Technol.*, vol. 18, no. 6, pp. 1067–1076, 2017, doi: 10.1007/s12239-017-0104-7.

[7] T. S. Haque *et al.*, "A Review on Driving Control Issues for Smart Electric Vehicles," *IEEE Access*, vol. 9, pp. 135440–135472, 2021, doi: 10.1109/ACCESS.2021.3116353.

[8] S. Kugele, P. Obergfell, and E. Sax, "Model-based resource analysis and synthesis of service-oriented automotive software architectures," *Softw. Syst. Model.*, vol. 20, no. 6, pp. 1945–1975, 2021, doi: 10.1007/s10270-021-00896-9.

[9] M. Wagner, A. Meroth, and D. Zöbel, "Developing self-adaptive automotive systems," *Des. Autom. Embed. Syst.*, vol. 18, no. 3, pp. 199–221, 2014, doi: 10.1007/s10617-013-9124-3.

[10] G. Xie, Y. Li, Y. Han, Y. Xie, G. Zeng, and R. Li, "Recent Advances and Future Trends for Automotive Functional Safety Design Methodologies," *IEEE Trans. Ind. Informatics*, vol. 16, no. 9, pp. 5629–5642, 2020, doi: 10.1109/TII.2020.2978889.

[11] S. Riedmaier, T. Ponn, D. Ludwig, B. Schick, and F. Diermeyer, "Survey on Scenario-Based Safety Assessment of Automated Vehicles," *IEEE Access*, vol. 8, pp. 87456–87477, 2020, doi: 10.1109/ACCESS.2020.2993730.

[12] Z. Szalay, "Next Generation X-in-the-Loop Validation Methodology for Automated Vehicle Systems," *IEEE Access*, vol. 9, pp. 35616–35632, 2021, doi: 10.1109/ACCESS.2021.3061732.

[13] S. D. Eppinger, D. E. Whitney, R. P. Smith, and D. A. Gebala, "A model-based method for organizing tasks in product development," *Res. Eng. Des.*, vol. 6, no. 1, pp. 1–13, 1994, doi: 10.1007/BF01588087.

[14] M. E. Sosa, "A structured approach to predicting and managing technical interactions in software development," *Res. Eng. Des.*, vol. 19, no. 1, pp. 47–70, 2008, doi: 10.1007/s00163-007-0039-5.

[15] M. Soltani and E. Knauss, "Challenges of Requirements Engineering in AUTOSAR ecosystems," in *2015 IEEE 23rd International Requirements Engineering Conference (RE)*, 2015, pp. 294–295. doi: 10.1109/RE.2015.7320445.

[16] G. Liebel, M. Tichy, E. Knauss, O. Ljungkrantz, and G. Stieglbauer, "Organisation and communication problems in automotive requirements engineering," *Requir. Eng.*, vol. 23, no. 1, pp. 145–167, 2018, doi: 10.1007/s00766-016-0261-7.

[17] Y. Zheng, J. Jiang, W. W. Huang, X. Wu, and H. Ren, "Coordination Resistance in Cross-Functional NPD Projects: The Moderating Role of Temporal Leadership," *IEEE Trans. Eng. Manag.*, vol. 71, pp. 2138–2152, 2024, doi: 10.1109/TEM.2022.3153188.