ANALYSIS OF ADVANCED DRIVER ASSISTANCE SYSTEMS IN POLICE VEHICLES

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BACKGROUND

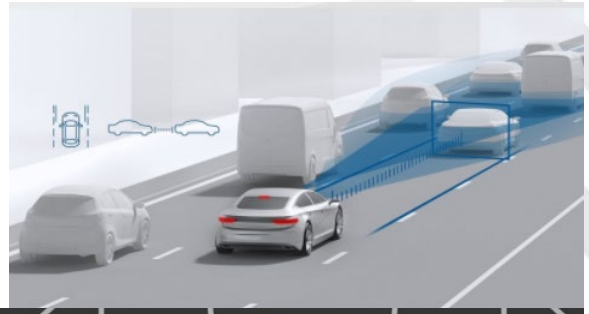
- Motor vehicle crashes are a leading cause of line-of-duty death for law enforcement
- Among all public safety workers, police officers are involved in a significantly higher number of fatal crashes as compared to firefighters and emergency medical services workers
- Main causes:
  - High speed driving and pursuit situations
  - Use of in-vehicle technology
  - Fatigue

ADVANCED DRIVER-ASSISTANCE SYSTEMS (ADAS)

- Vehicle control systems that improve driving comfort and traffic safety by using vehicle sensors (e.g., radar, laser) helping the driver identify and react to potentially hazardous traffic situations
- **Example:** Forward collision warning, Blind spot monitoring
- Prior studies have reviewed ADAS used by **civilian drivers** in **non-emergency vehicles** (e.g., Gietelink et al., 2006; Tigadi et al., 2016)
- Several differences in driver and vehicle state between the police and civilian drivers
- Benefits that ADAS provide for civilian vehicles may not be as effective for police officers

RESEARCH OBJECTIVES

1) Determine the existing ADAS features in police vehicles
2) Identify potential ADAS features that can be implemented in police vehicles to improve driver safety
3) Understand officers' opinion/perception on ADAS features
4) Investigate the effect of ADAS on officers' workload, performance, and trust

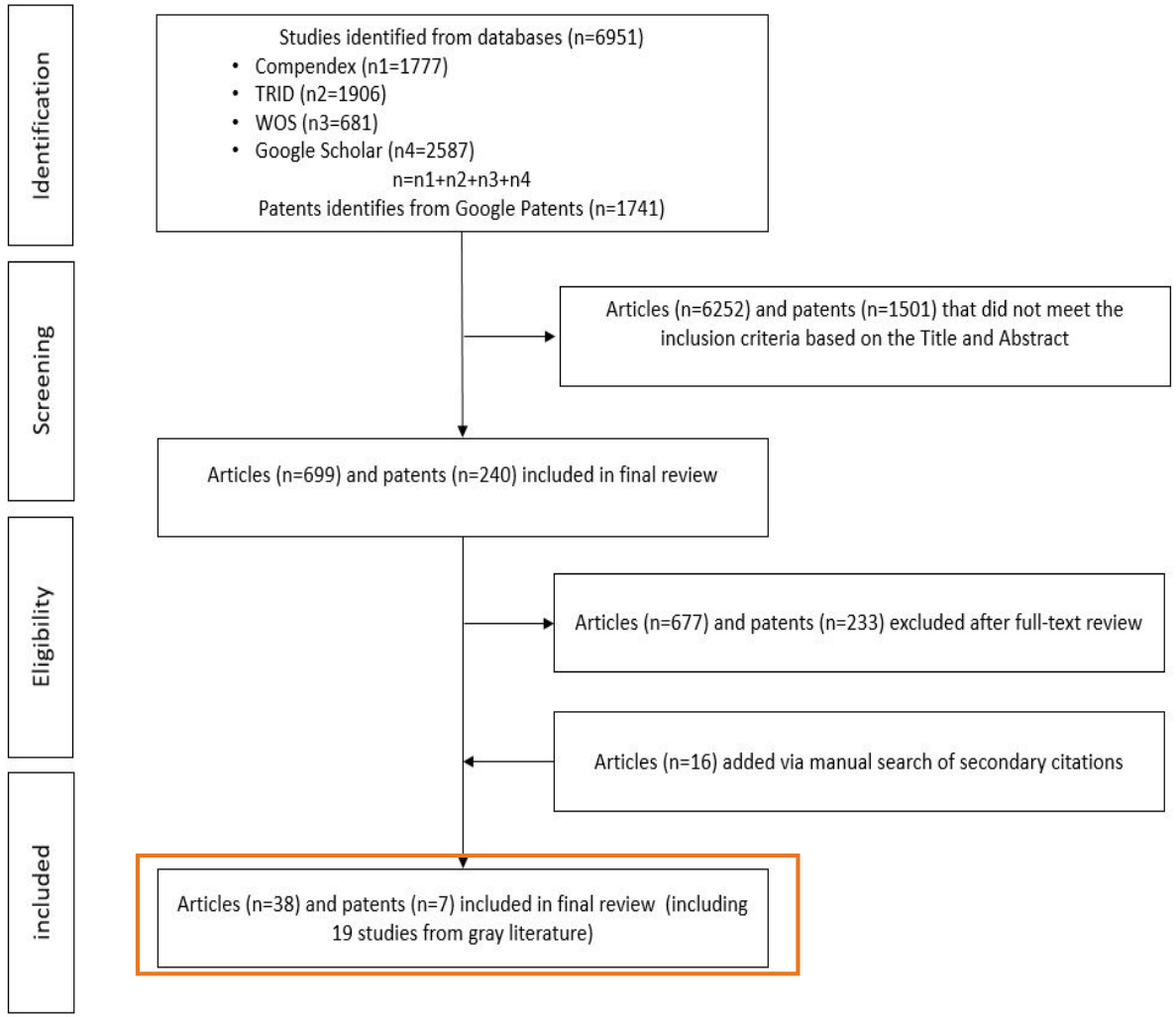


METHOD: PHASE 1

- **Systematic literature review**
  - Databases:
    - Google Scholar, Compendex, Web of Science (WOS), Transport Research International Documentation (TRID), and Google Patents
  - Keywords:
    - Group 1: *assistance features, automation, advanced driver-assistance systems,* and *safety*
    - Group 2: *police* and *officer*
    - Group 3: *car, driving,* and *vehicle*
  - Top three police car models: Ford Police Interceptor Utility, Chevy Tahoe Police Pursuit Vehicle, Dodge Charger Pursuit

METHOD: PHASE 1

- **Systematic literature review**
  - Inclusion criteria:
    - Studies that focused on the effects of ADAS on driver safety and performance
    - Active and application granted patents
    - Gray literature:
      - Government reports, newsletters and bulletins, fact sheets, theses, and dissertations.



METHOD: PHASE 1

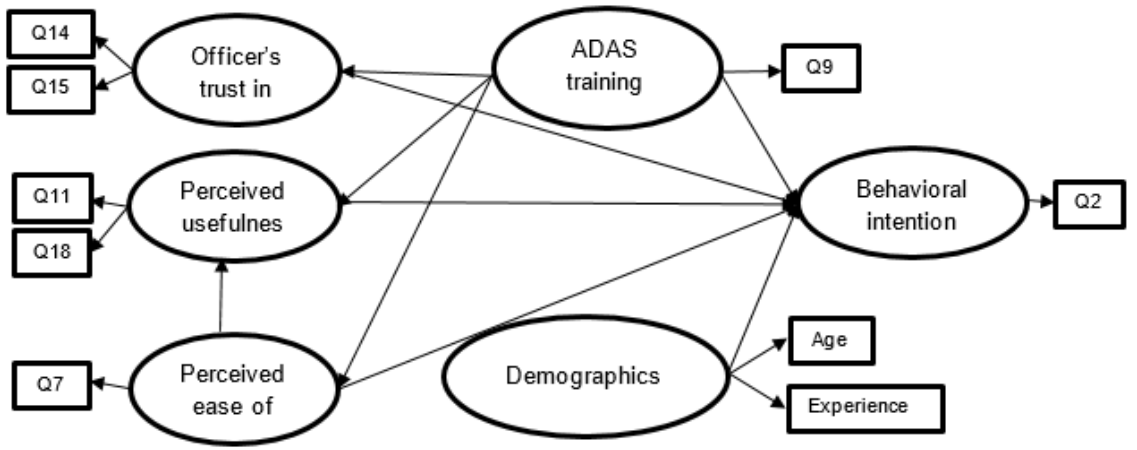
- **Online Survey with 19 questions**
- **Participants**
  - 73 police officers (68 males, 5 females)
- Questions were focused on perceived usefulness, perceived ease of use, trust, training, and behavioral intension in compliance with the Technology Acceptance Model (TAM)
- Example of survey questions:

Question	Response Type	Category
1. What are the most beneficial ADAS features in your police vehicle? Please select all that apply and provide a short explanation for your selection.	Checkbox	Perceived usefulness
2. How often do you use available ADAS features in the police vehicle?	Likert scale	Behavioral intention
3. Are there any helpful ADAS features that your personal vehicle has that you would like to have in your police vehicle as well? Which ones?	Free Response	Perceived usefulness
4. Are there any ADAS features in your police vehicle that you do not use at all? If so, please explain.	Yes/No	Perceived usefulness
5. What are your recommendations to improve the current ADAS features in police vehicles?	Free Response	Perceived ease of use
6. If you were the manufacturer of police vehicles, what ADAS features would you add to the vehicle? Why?	Free Response	Perceived usefulness
7. Do you know how to easily turn on and off your ADAS features?	Yes/No	Perceived ease of use
8. Is there any situation in which you would prefer to have your ADAS features turned off? If so, please explain.	Yes/No	Perceived usefulness

METHOD: PHASE 1

- **Technology acceptance model (TAM)**
- List of hypotheses

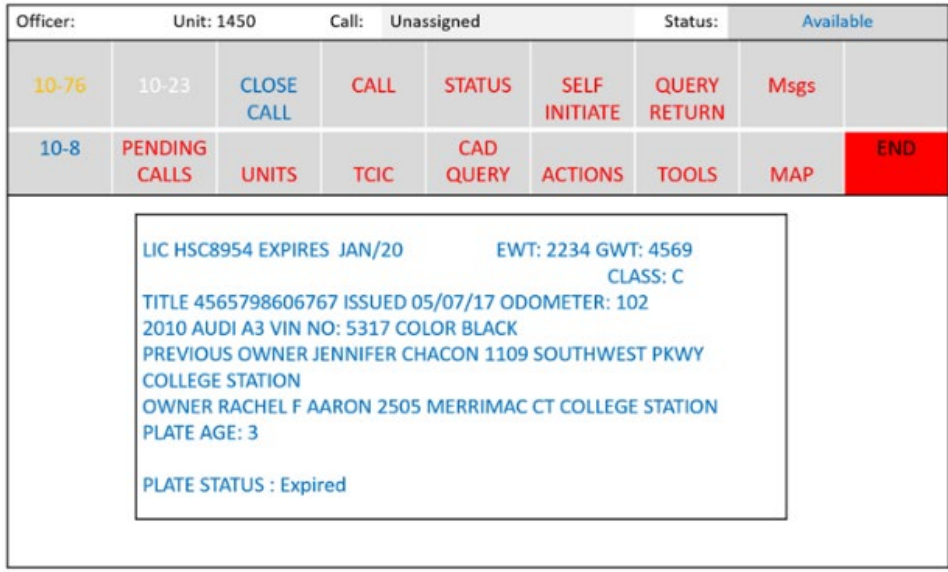
H1	Trust in ADAS significantly and positively affects officers' behavioral intention to use ADAS (Gefen et al., 2003; Kidd et al., 2017).
H2	Perceived usefulness (PU) has a significant positive impact on behavioral intention (Davis, 1989).
H3	Perceived ease of use (PEU) will have a significant positive impact on behavioral intention (Davis, 1989).
H4	PU mediates the effect of PEU on behavioral intention; however, the mediation is not a complete mediation. In other words, PEU significantly affects behavioral intention, above and beyond PU (Davis, 1989).
H5	Demographic information significantly affects officers' intention to use ADAS. It is expected that younger officers would be more intended to use ADAS as compared to more senior police officers (Lee et al., 2019).
H6	Training the officers on ADAS functionalities and advantages will have a significant positive impact on behavioral intention towards ADAS use (Biassoni et al., 2016).
H7	Training the officers on ADAS functionalities and advantages will have a significant positive impact on PEU (Biassoni et al., 2016).
H8	Training the officers on ADAS functionalities and advantages will have a significant positive impact on PU (Biassoni et al., 2016).
H9	Training the officers on ADAS functionalities and advantages will have a significant positive impact on their trust in ADAS technologies (Lee and See, 2004).



METHOD: PHASE 2

- **Participants**
  - 18 male police officers (Age: *M*=37.82 yrs., *SD*=5.41 yrs.)
- **Experiment setup**
  - High-fidelity driving simulator
  - Mobile computer terminal
- **Independent variables**
  - **Hazard type** (a braking lead vehicle, a vehicle in blind spot while the officer is changing lane, Combo)
  - **ADAS technology status (ON/OFF)**
  - Driving condition (normal vs. pursuit)
  - NDRT status (ON/OFF)

METHOD: PHASE 2



- **Driving Scenarios**
  - Normal (40 mph, following traffic rules)
  - Pursuit (could drive up to 60 mph)
- **Non-driving Related Task**
  - A plate number check task
- **Dependent variables**
  - Driving performance (e.g., minimum time to collision)
  - Workload (e.g., Driver activity load index)
  - Trust
- **Hypotheses**
  - **H1**: Using ADAS would improve driving performance
  - **H2**: Officers would report a lower level of workload when driving with ADAS as compared to the manual driving
  - **H3**: ADAS would increase officers' trust in the vehicle in safety-critical situations

DATA ANALYSIS

- **Correlation analysis**
  - To understand relationships between responses
- **Partial least square structural equation modeling (PLS-SEM)**
  - To study the complex interrelationships among variables
  - SmartPLS 3.2.9 software
  - Examined the validity and reliability of the model followed by testing the hypothesized relationship
- **Analysis of variance**
  - To test the effect of IVs on DVs in the driving simulation study

PHASE 1 RESULTS: LITERATURE REVIEW

- **ADAS features in police vehicles**
  - Many ADAS features common with civilian vehicles
  - Police vehicles are generally equipped with temporary disable switches so that officers can deactivate some features, such as AEB, in situations such as pursuit driving where ADAS would be more of a hindrance than an aid
  - List of ADAS features **currently available** in police vehicles

- Blind spot information systems
- Rear view camera
- Pre-collision assist
- Pedestrian detection
- Emergency braking
- Lane keep assist
- Lane departure warning
- Safety alert seat
- Adaptive cruise control
- Driver drowsiness detection system
- Curve control
- Hill start assist
- Hill descent control
- Reverse brake assist
- Front split view camera
- Automatic braking system
- Traction control system
- Electronic stability control
- Night vision
- Collision mitigation
- Multisensor platform

PHASE 1 RESULTS

- Recommended ADAS features
- The features were classified based on the **impact-oriented approach** using the authors' expert judgment and literature evidence
  - Using three criteria including **avoidance of inappropriate speed**, **keeping appropriate longitudinal and lateral distances**, and **support of driver awareness**.
  - Each recommended ADAS feature was assigned a high (H) or low (L) rating based on their direct impact on the corresponding road safety criteria
  - To ensure inter-rater reliability, two researchers first individually rated the features and then discussed the ratings together to come to a consensus. A third researcher rated the featured independently and those results agreed.

Recommended ADAS Feature	Avoidance of inappropriate speed	Keeping appropriate longitudinal and lateral distance	Support driver awareness
Traffic Sign Detection System	H	L	H
Front Vehicle Detection System	H	H	H
Autonomous Highway Driving	H	H	L
Traffic Jam Assist	H	H	L
Intersection Collision Avoidance	H	L	H
Left Turn Assist	H	L	H
Evasive Steering System	L	H	H
Two Lane Detection	L	L	H
Wrong-Way Alert	L	L	H
Lane-Ending Detection	L	L	H

PHASE 1 RESULTS

- Recommended ADAS features
  - Officers also ranked the features based on how useful they thought they would be in police operations (1 being the most useful and 10 being the least useful)
- Officers' ranking of ADAS features were generally similar (with the maximum of two rank differences) to authors' initial ranking except for the Wrong-Way Alert feature.

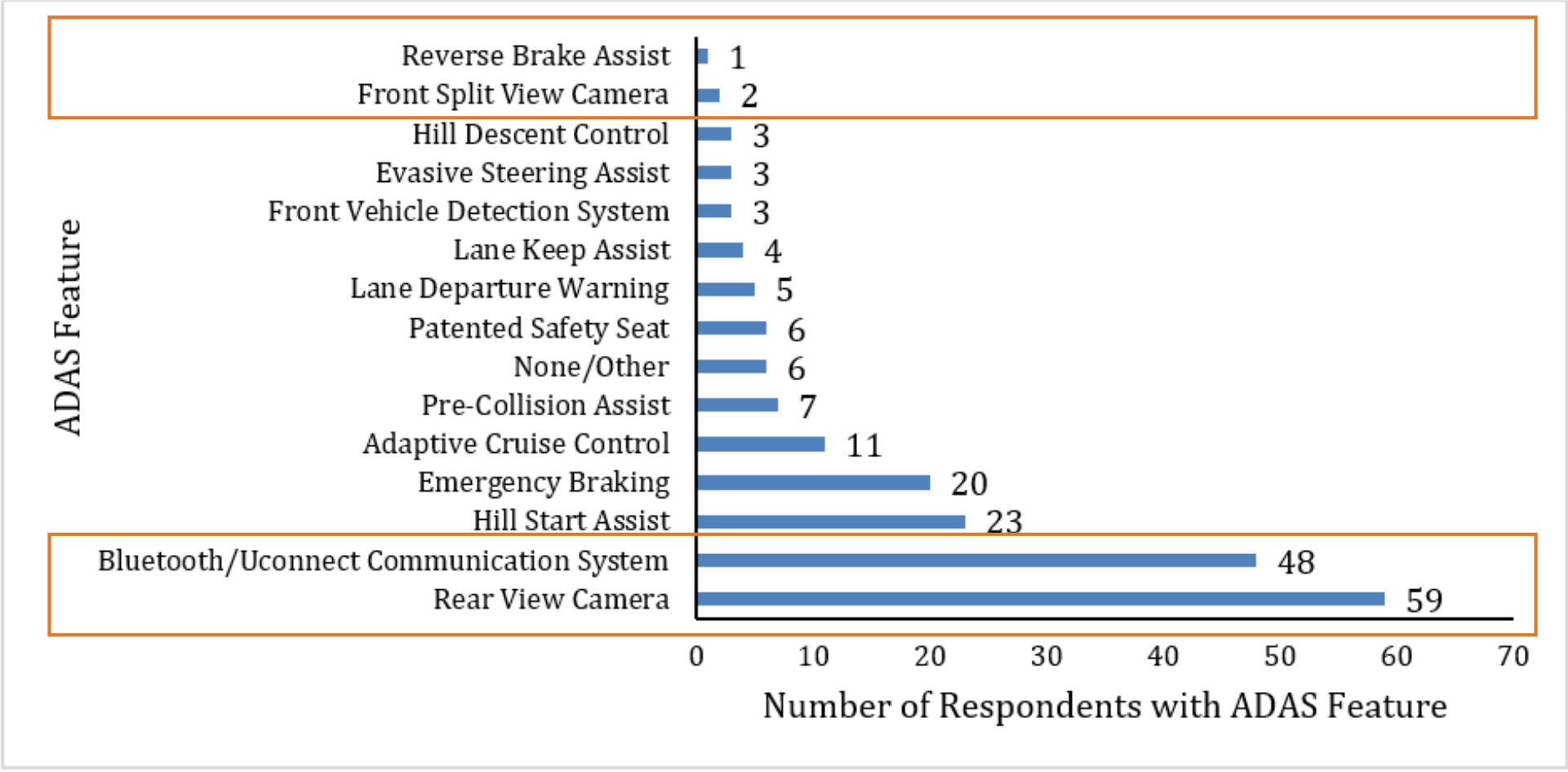
Feature	Total number of high safety impacts (H)	Authors' ranking	ADAS rating based on the online survey (Lower ratings indicate more useful ADAS features)	Ranking based on the mean of police officers' ratings
Front Vehicle Detection System	3	1	Mean: 7.02 SD: 4.81	3
Intersection Collision Avoidance	2	2	Mean: 6.69 SD: 4.79	1
Evasive Steering System	2	3	Mean: 7.69 SD: 4.38	4
Left Turn Assist	2	4	Mean: 8.15 SD: 4.30	6
Traffic Sign Detection System	2	5	Mean: 8.87 SD: 4.49	7
Traffic Jam Assist	2	6	Mean: 8.16 SD: 3.96	8
Two Lane Detection	1	7	Mean: 7.91 SD: 3.56	5
Lane-Ending Detection	1	8	Mean: 8.94 SD: 3.81	9
Wrong-Way Alert	1	9	Mean: 6.95 SD: 4.65	2
Autonomous Highway Driving	2	10	Mean: 8.98 SD: 4.73	10

LESSONS LEARNED FROM LITERATURE

- No studies on the impact of ADAS features on police officers' safety
- Potential impact of the recommended ADAS features
  - **Front vehicle detection system** (useful in pursuit situations)
  - **Intersection collision avoidance** (useful when visibility is obstructed)
  - **Evasive steering system** (useful when engaged in secondary tasks)
  - **Left turn assist** (useful in high workload situations)
  - **Traffic sign detection system** (useful for promoting safe driving habits)
  - **Traffic jam assist** (useful in congested areas and when the officer needs to use secondary tasks)
  - **Two lane detection** (useful in pursuit situations)
  - **Lane ending detection** (useful in distracted driving situations)
  - **Wrong-way alert** (can reduce the severity of crashes, useful in standard patrol situations)
  - **Autonomous highway driving** (useful when performing secondary tasks)

PHASE 1 RESULTS: SURVEY

- Frequency of existing ADAS features in police vehicles



PHASE 1 RESULTS: SURVEY

- Interesting correlations between responses

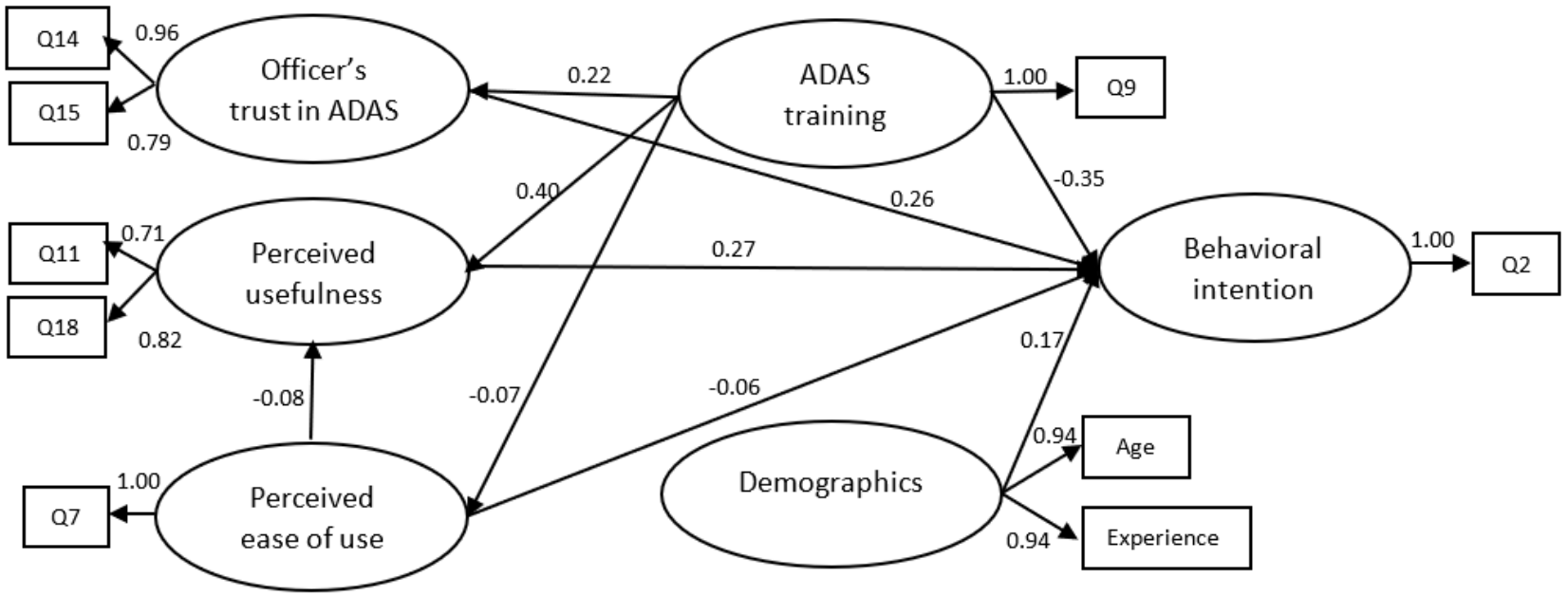
ADAS have the potential to reduce officer workload in pursuit situations

Officers who trust ADAS to improve their driving safety also use ADAS while they are performing secondary tasks and believe that ADAS can improve their attention to roadway

Comparison Pair	Correlation Results
Q9 and Q18	$\phi = .28$ ($p = .024$)
Q13 and Q18	$\phi = .36$ ($p = .003$)
Q14 and Q16	$\tau = .41$ ($p < .001$)
Q11 and Q16	$\tau = .35$ ($p < .001$)
Q16 and Q15	$\tau = .34$ ($p = .0013$)
Q14 and Q15	$\tau = .46$ ($p < .001$)
Q12 and Q14	$\tau = .32$ ($p = .0017$)
Q11 and Q14	$\tau = .35$ ($p < .001$)
Q11 and Q12	$\tau = .33$ ($p = .0011$)
Q9 and Q11	$X^2(1, N = 66) = 9.11$ ($p = .0025$)
Q14 and Q13	$X^2(1, N = 66) = 19.03$ ($p < .001$)
Q14 and Q18	$X^2(1, N = 66) = 9.86$ ($p = .0017$)

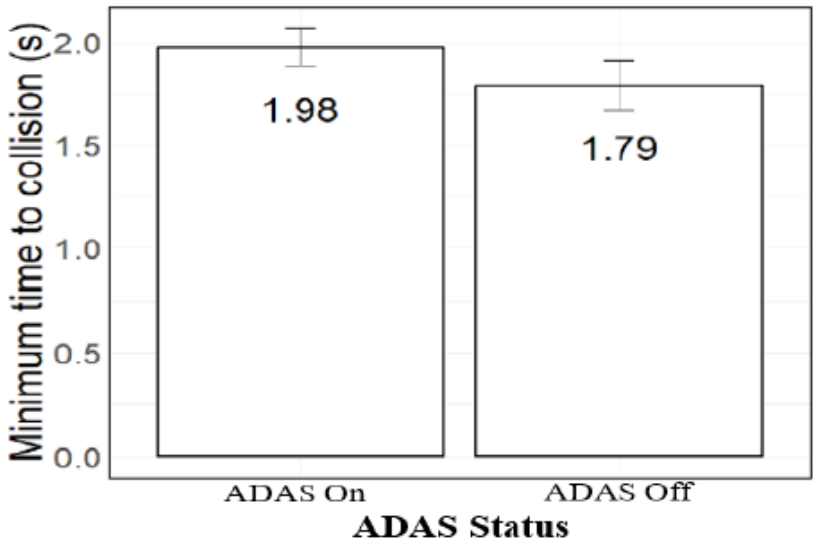
PHASE 1 RESULTS

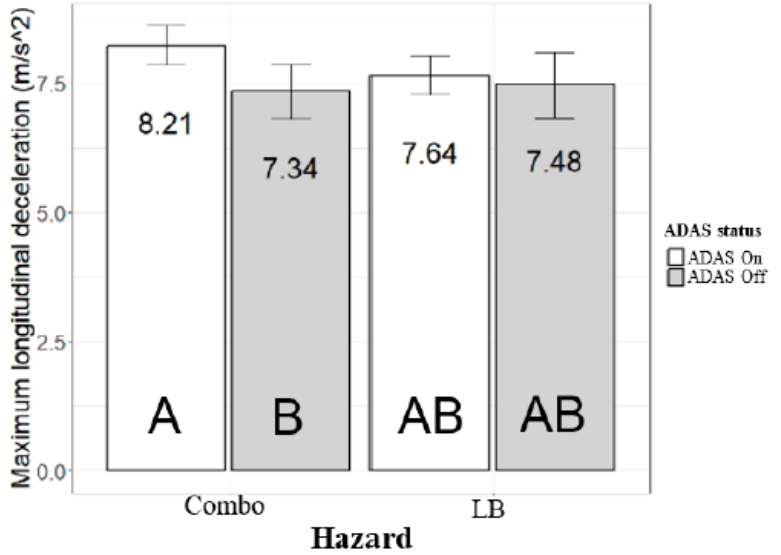
- Officer's trust in technology (β = 0.26, t = 2.27, p = 0.01, f^2 = 0.07) and ADAS training (β = -0.35, t = 3.54, p< 0.01, f^2 = 0.14) affected officer's behavioral intention to use ADAS
- ADAS training was a significant predictor of driver's perceived usefulness of ADAS features (β = 0.4, t = 2.69, p< 0.01, f^2 =0.2)



PHASE 2 RESULTS

- A significant effect of ADAS on drivers' minimum TTC ($F(1,172.35) = 7.03$, $p = 0.009$)
- In hazardous situations, officers demonstrated a larger maximum longitudinal deceleration when utilizing ADAS as compared to manual driving ($F(1,174.32) = 4.66$, $p = 0.03$)
- Significant effect of ADAS on officers' trust in the vehicle ($F(1,323.16) = 17.56$, $p < 0.001$)
- Officers reported a significantly lower workload when BSM and FCW/AEB system were on (M=2.64) as compared to driving without ADAS (M=3.09) in normal driving





DISCUSSION ON SIGNIFICANT FINDINGS

- **Phase 1**
- **Hypothesis 1: Supported**
  - Trust in ADAS positively impacts officers' intension to use ADAS
  - Since trust is based on drivers being able to effectively use and rely on ADAS features, it is important to find an effective way to train police officers on ADAS functionalities and effectiveness.
    - By having officers use ADAS in situations similar to real world patrols, they will be more likely to implement and use them as they become more experienced with the technology.
  - Research and manufacturing should concentrate on lining up the capabilities of what ADAS features can do with what police officers expect to build trust and best encourage ADAS use.

DISCUSSION ON SIGNIFICANT FINDINGS

- **Phase 1**
- **Hypothesis 6: Supported**
  - Officers educated in ADAS are more likely to indicate high intention to use ADAS than officers that are not educated in ADAS use
  - Possible approaches for training: paper-based manuals, multi-media software tools, video-based training, and simulator-based training
- **Hypothesis 8: Supported**
  - Training can improve officers' opinion on the usefulness of ADAS features

DISCUSSION ON SIGNIFICANT FINDINGS

- **Phase 2**
- **Hypothesis 1 partially supported**
  - **Officers had a larger minimum TTC with ADAS**
    - i.e., more time to react in crash situations
  - **In combo scenarios where FCW and BSM were both active, officers demonstrated a higher level of maximum longitudinal deceleration as compared to driving without ADAS**
    - ADAS can be particularly effective in safety-critical driving situations, where there is a need for immediate and comprehensive information about surrounding vehicles
  - **The impact of BSM was limited, possibly due to its low salience**
    - The lack of an auditory signal unless the officers turned on their blinkers
    - Most participants did not use their blinkers
    - There is a need for improvement in the design of BSM warnings for officers to make them more noticeable.

DISCUSSION ON SIGNIFICANT FINDINGS

- **Phase 2**
- **Hypothesis 2 partially supported**
- Officers reported a lower level of workload in the combo scenario with ADAS on compared to the driving without ADAS in normal driving conditions.
  - In the combo scenario, the presence of both a lead vehicle and a vehicle in the blind spot creates a more complex driving situation that requires the driver to monitor multiple sources of information and make quick decisions.
- No significant difference in DALI scores between driving with and without ADAS during **pursuit driving situations**.
  - Wicken's multiple resource theory
- The effectiveness of ADAS may vary depending on the **driving condition** and the **cognitive demands imposed on officers.**

DISCUSSION ON SIGNIFICANT FINDINGS

- **Phase 2**
- **Hypothesis 3 supported**
- The use of ADAS can increase drivers' confidence in the safety of the vehicle and its ability to prevent or mitigate the impact of collisions.
- Increased trust in the vehicle can influence drivers' behavior and decision-making while driving.
  - When drivers have greater trust in the safety features of their vehicle, they may be more likely to rely on these features to prevent collisions, which can lead to safer driving behavior overall (Shahini et al., 2022)

GUIDELINES

1) *Emphasize clarity above everything else.*

- About **68%** of respondents affirmed that they would make greater use of ADAS if the functionality and advantages were more clearly explained.
- Since ADAS training significantly impacts perceived usefulness and officers' intention to use these features, improving officers' knowledge of ADAS can potentially increase ADAS acceptance among police officers.

2) *Improve ADAS accessibility and usability*

- About **38%** of police officers stated that there were situations where they preferred to have their ADAS features disabled. However, **over half** of the respondents identified that they were unable to easily turn on or off their ADAS features.

3) *Provide adaptive and personalized ADAS*

- Officers prefer to have their ADAS off in some situations such as pursuit driving
- ADAS should be compatible with existing police in-vehicle technology

GUIDELINES

4) *Focusing on perfecting a few features is better than having many less elaborate features*

- *As officers already have high mental workload associated with their jobs, a few features that help them perform their duties effectively would be much easier to understand and trust than a multitude of complex features.*

5) *Police vehicle ADAS features should focus on improving officer driving safety*

- *Very few officers believed that ADAS can reduce their mental workload*
- *More than half of the responders believed that ADAS can improve their driving safety*

LIMITATIONS

Phase 1

- Many of the surveyed participants drove police vehicles that had a limited number of available ADAS features.

Phase 2

- Participants were all males, while 19.7% of law enforcement officers across the U.S. are females
  - This might limit the generalizability of the findings to the overall office population.
- The experiment simulated daylight driving and cannot be generalized to night shifts.

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QUESTIONS?

For more information:

- Wozniak, D., Shahini, F., Nasr, V., & **Zahabi, M.** (2021). Analysis of advanced driver assistance systems in police vehicles: A survey study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *83*, 1-11.
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