Transportation Safety Advancement Group (TSAG) Annual Public Safety Research Assessment and Knowledge Transfer Report—2018-2019

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Transportation Safety Advancement Group (TSAG) Literature Review

This document provides a summary of literature that represents current and recent work conducted by a host of public agencies, private sector entities, and associations related to improving the safety of responders and the public at traffic incidents. This work contains elements which are either directly or indirectly relevant to the emergency response community and TSAG stakeholder group. While many of the resources cited herein pertain to research and product development undertaken in the last decade, some older publications are included to provide historical context on current safety issues faced by the emergency responder community.

The references cited demonstrate that over the last ten years, much of the advancement within the transportation safety and emergency responder community has been through the enhanced instrumentation of emergency vehicles and transportation infrastructure. This includes the development of enhanced algorithms and applications meant to identify emergency vehicles and responders in the travel space and share this information with surrounding drivers. It includes enhanced data gathering capabilities for the roadway environment, in areas such as traffic and weather conditions, to provide emergency responders with enhanced decision-making capabilities to reach the site of a disaster or medical emergency more efficiently. It also touches on emerging research looking at the application of big data analytics, collaborative information sharing among vehicles deploying automated driving systems, and the use of data available through Smart Cities, Cloud computing, and the Internet of Things. In the past five or so years, greater attention has been given to increasing the safety and situational awareness of emergency responders once they have left a vehicle, to enhance safety in the more complex environments in which these individuals operate.

Connected Vehicles

Connected vehicle (CV) technology includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-everything (V2X). CV technology allows vehicles to talk to each other and to the infrastructure through in-vehicle or aftermarket devices, sharing important safety and mobility information. Anticipated V2V applications can enhance responder safety through blind spot warning, lane change warning, intersection movement assist, do not pass warning, and other proposed applications. Proposed V2I applications include curve speed warning, red light violation warning, restricted lane warning, and spot weather impact warning. An overview of CV technology and the business case for advancing CV technology in public safety was developed by TSAG in 2016. (TSAG, 2016)

The US DOT Dynamic Mobility Applications program was designed to identify, develop, and deploy applications to leverage the full potential of CV. One of the applications included in this effort is the Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) bundle. The concept of operations for this bundle was documented in 2012. (USDOT, 2012) Prototype development and demonstrations were completed and published in 2015. (USDOT, 2015)

The Federal Highway Administration (FHWA) developed the Cooperative Automation Research Mobility Applications (CARMA) platform to encourage collaboration in support of transportation efficiency and safety. CARMA is intended to support automated driving systems by facilitating cooperative tactical maneuvers with other vehicles, roadway infrastructure, and roadway users. It uses open source software and is currently developing use cases for the CARMA platform. One of these involves scenarios for traffic incident management to support strategies for first responders interacting with automated driving systems. (USDOT, 2019)

A Transportation Research Board project is currently under development to investigate how traffic incidents might change in a more connected transportation system and how public safety responders should be included in CV research going forward. This study will look at CV research to determine if public safety responder needs are being considered, survey vehicle manufacturers to gain insight into how responders can safely interact with CVs, investigate how traffic incident management will change in a CV environment, and develop a plan to include public safety responders in ongoing CV research. (Transportation Research Board, 2018)

Intersection Collision Avoidance

Intersection collision avoidance technologies are meant to facilitate the safe navigation of intersections for emergency responders, particularly when those responders may be operating in conflict with the prevailing movement of traffic; for example, when a fire truck must pass through an intersection against a red light. Many of the same technologies which can facilitate safe passage for emergency responders are also those which have been identified and piloted for intersection safety through collision avoidance for the general traveling public.

In 2016, the National Highway Traffic Safety Administration (NHTSA) released a comprehensive report which investigated a wide range of technologies for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. This report built off of earlier work from NHTSA on evaluating different scenarios for intersection collision avoidance and notification, including model which would override driver control of conflicting vehicles, and models which would rely on a positive input from drivers to avoid a collision, once a notification was issued. (Pierowicz, Jacoy, Lloyd, Bittner, & Pirson, 2002) The principal goal of the 2016 report was to develop standards for testing, but in doing so, evaluations of the current state of the various V2V and V2I technologies were also undertaken.

For the intersection movement assist (IMA) technology, it was found that the operation was largely reliable, but that the current state of operation was such that the notifications were sent too early in many cases, alerting vehicles in the intersection of approaching vehicles which may or may not present a conflict by the time they reach the intersection. For example, if the alert is issued early enough, the approaching vehicle may in fact have the green light by the time they reach the intersection. This limitation is more of an impediment for commercial vehicles, whose application of these V2V and V2I technologies were the original motivation of the report. For emergency vehicles, this limitation is less of an impediment to adoption, as earlier notifications will make all drivers in the vicinity aware of the presence of an emergency vehicle, regardless of whether said vehicle ultimately represents a potential intersection conflict to avoid. (Howe, Xu, Hoover, Elsasser, & Barickman, 2016)

One of the largest danger areas associated for emergency responders at intersection environments is the risk of side, or right-angle collisions. In addition to tending to be greater in severity, due to several factors – higher speeds, less protection for drivers in vehicles struck from the sides, etc. These types of crashes are increasingly becoming an area of concern with the rise of driver assistance technologies that are meant to detect obstructions in the longitudinal path of the driver; that is, in front of or behind the vehicle. This puts emergency responders at greater risk, due to a dearth of collision avoidance technologies which include detection zones lateral to the vehicle.

One potential technology which could address this risk is the PRE-SAFE system being developed by Mercedes Benz. This technology, using a series of radar and other proximity sensors, aims to identify objects with a high likelihood of immediate intrusion into the passenger space of the motor vehicle, particularly from the side (such as in the case of a right-angle collision). Once an object has been identified, the PRE-SAFE system physically moves the vehicle occupant towards the center of the vehicle, thereby increasing the buffer space between the rider and the colliding object, while continuing to rely on existing side impact safety technologies (e.g., side air bags) to absorb the energy of the collision. Such technologies could be outfitted to emergency vehicles as early adopters to better assess their effectiveness and efficacy. (Schoneburg, et al., 2017)

Emergency Vehicle Traffic Signal Preemption

Significant prior work has been undertaken by such organizations as the Federal Highway Administration (FHWA) and NHTSA to quantify the benefits associated with emergency vehicle preemption for responders and safety agencies. This includes a comprehensive report in 2006 which leveraged the use of case studies around the U.S. to assess the impacts of preemption with respect to responder safety (e.g., incidences of intersection crashes for emergency vehicles), response times, and the required density of deployed resources to meet minimum response times. The report also laid out recommendations and best practices associated with ensuring a proper line of command and responsibility with respect to the maintenance and operations of preemption systems. (Paniati & Amoni, 2006) Research has also been performed outside of FHWA to identify practice-ready methodologies for use in quantifying the safety benefits associated with preemption. (Louisell, Collura, Teodorovic, & Tignor, 2004)

In addition to quantifying the benefits associated with emergency vehicle traffic signal preemption, the FHWA has undertaken significant efforts to promote its effectiveness and raise awareness of its use with transportation and emergency response professionals, through its Intersection Safety Strategies Program. (USDOT Federal Highway Administration, n.d.) (USDOT Federal Highway Administration, 2008)

There are currently several predominant technology types utilized in emergency vehicle preemption at signalized intersection. These include:

- Acoustic detection: involves the use of directional listening devices that can detect the high-decibel sound of an approaching emergency vehicle. Some of these systems may combine audible warnings with some type of radio-frequency transmission (Bachelder & Foster, 2008)

- Optical detection: involves the use of directional sensors that detect specific flash patterns emitted from a device mounted on top of the emergency vehicle
- GPS-based detection: involves automated vehicle location (AVL) using a vehicle-based transmitter, and interpolating the future vehicle location based on measured speed and directional indicators to determine the proper time at which to preempt the signal
- Radio detection: involves the use of a radio transmitter installed in the emergency vehicle to broadcast a specially-coded radio signal to a receiver installed at the intersection.

While all these technologies have been effectively used at signalized intersections, each has its own set of shortcomings. For instance, the optical detection system is very sensitive to the alignment of the optical receiver, typically required to be installed on each mast arm at a signalized intersection. If the receiver is knocked out of alignment or otherwise has its line of sight impaired (e.g., due to snow), it can reduce or completely inhibit the ability of the preemption system to function. Despite the drawbacks of these systems, they have proven track records with many public agencies and incremental improvements continue to be made, particularly in the GPS arena. This includes a combination preemption/intersection collision warning capability, and the ability to preempt additional intersections based on an emergency vehicle's indicated movement. (Gross, 2017)

Besides the current set of preemption strategies, research and development continues on strategies along several different paths: advanced signal controller algorithms, (Quin & Khan, 2012) which rely on adaptive traffic control and coordination strategies to minimize delay associated with preemption, and earlier notification systems, based on distributed sensing and reporting technology which doesn't require line-of-sight communications.

For the latter, a significant amount of work has been undertaken in recent years within the space of V2V and V2I which builds off of the early success of GPS-based vehicle detection and could conceivably be applied to emergency vehicles preemption scenarios. Much of this work falls under the umbrella of technologies intended to broadcast signal phase and timing (SPaT) information. In particular, the SPaT Challenge, an initiative by the American Association of State Highway and Transportation Officials (AASHTO) to equip twenty signalized intersections in each state with SPaT broadcasting capabilities by 2020, has spurred DOTs around the country to expedite consideration for the deployment of ITS technologies within their systems, particularly at signalized intersections. (National Operations Center of Excellence, n.d.) (Saleem, Swart, & Head, 2014)

The SPaT Challenge has also motivated consideration for potential applications of SPaT-based systems, including the eventuality of allowing two-way communications between vehicles and intersections (the current SPaT Challenge only specifies an infrastructure-to-vehicle, or I2V, implementation, so as to reduce security and safety risks as agencies refine the deployment and development of their systems), once such application is in emergency vehicle preemption. As an emergency vehicle approaches a signalized intersection, it would utilize dedicated short-range communications (DSRC) over the 5.9 GHz wireless band, to communicate its proximity to the intersection. This information would be passed along to the signal controller, which would attempt to serve the emergency vehicle a protected green movement, based on its path of travel. (Vehicle to Infrastructure Deployment Coalition, 2018)

Incident Scene and Traffic Safety Alerts

Besides intersections, one of the most dangerous locations for emergency responders and other safety professionals is any situation which violates an established flow of travel in the roadway environment. These situations can largely be reduced to two categories: temporary work zones and an incident scene itself. In the former scenario, it is common for lane markings and roadway signage to be temporarily altered to provide a path for motor vehicles around a site of construction. A lack of driver familiarity in this scenario can create confusion and lead to danger for other vehicles, including emergency responders, on the roadway. Road closures and detours can also cause confusion for emergency responders directly and can frequently lead to increased response times. On incident scenes, emergency responders may be required to quickly alter the travel environment for vehicle staging and response, while ensuring the continued flow of traffic. Again, the unfamiliarity of drivers with the new conditions can lead to dangerous interactions with other road users. (Yu, Bill, Chitturi, & Noyce, 2013)

In 2010, the International Association of Fire Fighters (IAFF), in partnership with the U.S. Department of Homeland Security (DHS) and the United States Fire Administration (USFA), released a comprehensive report of best practices associated with incident scene management, in which proper and effective traffic control was described as one of the most important factors in ensuring responder safety at the scene of an incident. (Church, Shynk, Brachman, & Baez, 2014)

In addition to incident scene safety for first responders, wireless sensor and V2V technologies, alongside expanded simulation exercises and novel concepts such as virtual operations centers, have been proposed to increase the safety of first responders in environments such as incident scenes and work zones. (International Association of Firefighters, US Fire Aministration and Department of Homeland Security, 2010) Additionally, a 2004 report from the U.S. Fire Administration (USFA) and the International Fire Service Training Administration (IFSTA) provided a comprehensive look at best practices to ensure safety for law enforcement and first responders. Many of these strategies were technology based, and focused on applications on the road (e.g., vehicle preemption and roadside monitoring equipment). However, some of the other strategies were more centrally based (e.g., advanced integration between emergency responder activities and traffic management centers) and even touched on human factors approaches which could leverage technology to improve responder safety (e.g., driving simulator training). (U.S. Fire Administration and the International Fire Service Training Association, 2004)

Road Weather Alerts and Warnings

Besides the dangers associated with operating at the incident scene itself, as well as risks associated with responding to an incident from other drivers, emergency responders often face considerable danger from road conditions themselves and frequently find themselves having to operate in environments in which the travelling public is advised to avoid (e.g., snowstorms, flash floods). Elling (1989) estimated that approximately 25% of ambulance crashes occurred during wet-weather conditions, and a further 5% occurred during snow or ice conditions. (Chapman & Drobot, 2011) Consequently, technologies which can provide early notification of these treacherous weather-related road conditions, as well as tools and data which can provide a more accurate and comprehensive assessment of the environment, can result in safer decision making for emergency responders, including the possibility of advance staging operations or coordination across agencies if certain routes become impassable.

Several recent publications aim to address the state of practice and longer-term vision for road weather alert and warning technologies. A 2011 report from the USDOT lays out the proposed standards and applications associated with the adoption of a vehicle data translator (VDT), which can gather data from vehicle operations, such as speed and tire slippage from antilock brake systems and feed this information into a decision support system (DSS) for use by emergency responders. The use of VDT and an associated decision support system could have a multi-layered advantage for the safety community. Tactically, it could help responders chart the most efficient route to and from an incident, cutting down on response time and ensuring safety along the route. Strategically, it could drive decision making around the placement of resources in advance or during significant weather events, and longer term could inform the decision making around where to construct new emergency response facilities. (Elling, 1989)

Internet of Things (IoT)

The Internet of Things (IoT) is a network of devices with internet connectivity. It includes commercial applications such as security devices and electronics; public sector devices such as weather, roadway, and utility network sensors; and any other device that has sensors and software embedded to exchange information. Data from IoT can be exchanged directly between devices, machine-to-machine, or uploaded to cloud servers for analysis and distribution. The ever-increasing data available through IoT provides opportunities for enhancing responder and public safety through real-time data sharing and warnings that enhance situational awareness.

The National Public Safety Telecommunications Council (NPSTC) convened a Public Safety IoT Working Group to look at sensors and devices to support public safety. In 2018, the Working Group developed eight use cases looking at IoT solutions to a range of common scenarios or response types. These include transportation-related use cases that illustrate how IoT can support responder safety and situational awareness. (National Public Safety Telecommunications Council, n.d.)

I2R

Infrastructure to responder (I2R) technologies are an emerging area of IoT that can provide actionable information to responders in real and near-real time. TSAG developed two documents describing the opportunities presented by connecting responders to information from the digital infrastructure. Real-time warnings, GIS-based data, and situational information such as weather, infrastructure conditions, and proximity of hazards are just a few examples of the information that can be made available to responders on-scene through handheld, worn, or vehicle mounted devises. (TSAG, 2019)

Smart Cities

Smart Cities technology is being applied to public safety to provide interconnectivity and improved alerts, warnings, and notifications to enhance situational awareness. At the Federal level, the Smart City IoT Innovation (SCITI) Labs are working with the Center for Innovative Technology, TechNexus, and Smart City Works to apply new and existing technologies to public safety needs. One of the initiatives under development is a SmartHub, a body-worn device that provides responders with an interoperable platform that integrates personal area network communications with third-party sensor packages. (US Department of Homeland Security, 2018)

The Global City Teams Challenge, sponsored by the National Institute of Standards and Technology (NIST) is comprised of six SuperClusters of city technology teams. The Public Safety SuperCluster developed a Blueprint for Smart Public Safety in Connected Communities as a guide for cities to evaluate and apply technology to public safety challenges in smart communities. It looks at public safety and response, emergency management and preparedness, disaster recovery, and resilience to address specific requirements to support technology applications. (Bannan, Burbridge, Dunaway, & Skidmore, 2018)

Wearable Technology

Many of the technologies currently under development or in use that could benefit the emergency response community, particularly those in the V2V domain, hold little benefit once a responder has exited their vehicle. In these cases, the responder becomes operationally similar to a pedestrian, and thus vehicle-to-pedestrian (V2P/P2V) and infrastructure-to-pedestrian (I2P/P2I) applications, or even peer-to-peer communications that bypass fixed infrastructure (which may not be functional after an incident) should be considered. (Beauregard, 2009) (Dilmaghani, 2006) (Panitzek, Schweizer, Bonning, Seipel, & Mullhauser, 2012)

Research development into these applications is much more limited. There is growing interest and conceptual discussion around the use of connected responder technologies, (Kunnath, Pradeep, & Ramesh, 2012) and many of these focus around the idea of constantly connecting responders to a wide-area broadband system, such as FirstNet, (Otto, n.d.) (Peha, 2013) or through the use of LTE or ad-hoc networks to provide situational proximity and real-time status updates to first responders (Honeywell, 2015) (RapidSOS, n.d.), although detailed demonstrations of these applications and their benefit to the safety and transportation communities remain to be seen. (Chan, Wan, Seyed, & Maurer, 2016)

There is also some limited research into the use of robust indoor position systems, both for emergency responders and individuals who report emergencies. (Moon, Chun, Hur, & Jee, 2013) (Turetzky, 2012) The continued development of these technologies holds promise to reduce response times, by ensuring that responders arrive at the correct location for an emergency. There is also the possibility of adapting these strategies and technologies for emergency responders in constrained outdoor operating environments, such as urban canyons and areas where fixed infrastructure elements have been rendered inoperable due to a natural or manmade disaster.

AACN

Advanced Automatic Collision Notification (AACN) captures data from vehicle crashes and sends the information to emergency responders. AACN information includes the location of the crash and vehicle telemetry that support quick response, transport, and treatment of injured parties. It can also predict injury severity and provide information on the nature of the crash to support response by specialized equipment as needed. AACN can save lives and improve patient outcomes. (Plevin, Robert Kaufman, Laura Fraade-Blanar, & Eileen M. Bulger, 2017) The 2019 TSAG White Paper on AACN discusses the benefits and opportunities of AACN, as well as the challenges to implementation and research needs and recommendations for addressing the challenges. As connected vehicle technology matures and becomes more ubiquitous, AACN will become integrated into vehicle technology and response protocols. (TSAG, 2019)

Big Data

A recent NCHRP study looked at the opportunities to use big data to improve traffic incident management. The study looked at 32 sources of data to determine the maturity and usability of the data for big data analytics. Data collected from statewide crash records and from emergency medical system, traffic management center, and connected vehicle data was studied to identify opportunities to use the information in big data analytics. Big data analytics uses data differently from traditional data analysis, it collects and stores data in its original form and runs analytics designed specifically for big data to explore the data for trends and relationships. The analytics can be repeated as new data becomes available and is designed to produce actionable information. The report explored the opportunities to use big data to enhance traffic incident management (TIM) practices and the challenges facing the use of big data in TIM. Some of the challenges identified include data silos, interoperability, privacy, public records laws, data retention, proprietary data, issues associated with emerging forms of data, security, technical expertise, and concerns with cloud usage. The final report developed guidelines on the use of big data for TIM to overcome challenges and improve TIM. (Pecheux, Pecheux, & Carrick, 2019)

Communication

An essential component of public safety response is interoperable, reliable communication. Communications from the public to responders in an emergency generally come in by phone to the public safety answering point (PSAP) on the 911 system. Communications between the PSAP and responders, and between responders, is generally facilitated through radio systems. Next Generation 911 (NG911) and FirstNet are changing how those communications are handled and providing new opportunities for enhanced communications through Internet Protocol (IP) and wireless broadband systems. (TSAG, 2019)

NG911 is an IP-based system adapted to how people communicate today through mobile and digital devices. It will allow digital data, texts, photos, and videos to be sent from the public to the PSAP. It will also support data transmitted from vehicles, such as AACN information, and wearable medical devices. NG911 will change the way information comes into a PSAP and how callers interface with the public safety system.

The 9/11 Commission Report that came out of the September 11, 2001, terrorist attacks identified gaps in emergency communication. The report recommended a nationwide communication network for law enforcement, fire-rescue, and emergency medical response personnel. This led to 2012 legislations to create the First Responder Network Authority to deploy FirstNet in all US states and territories. This independent authority's mission is to ensure the building, deployment, and operation of a nationwide broadband network for public safety responders.

References

Bachelder, A., & Foster, C. (2008). *US Patent*. Retrieved from Emergency Vehicle Traffic Signal Preemption System: https://doi.org/10.1016/j(73)

Bannan, B., Burbridge, J., Dunaway, M., & Skidmore, D. (2018). *Blueprint for Smart Public Safety in Connected Communities: An Initiative of the Global City Teams Challenge.* NIST.

Beauregard, S. (2009). Infrastructureless Pedestrian Positioning. *Arbeit*.

Chan, E., Wan, Y., Seyed, T., & Maurer, F. (2016). *ERWear: Wearables System Design through the Lens of First Responders.*

Chapman, M., & Drobot, S. (2011). *The Vision for Use of Connected Vehicle Data in Practical Road Weather Applications.*

Church, R., Shynk, J., Brachman, M., & Baez, C. (2014). *First Responder Support Systems Testbed (FiRST): Cross Cutting Cooperative Systems for Emergency Management.*

Dilmaghani, R. R. (2006). *On Designing Communication Networks for Emergency Situations.*

Elling, R. (1989). Dispelling Myths on Ambulance Accidents. *JEMS: A Journal of Emergency Medical Services, Vol. 14, No. 7*, 60-64.

Gross, D. (2017). *Recent Developments in Emergency Vehcile Traffic Signal Preemption and Collision Avoidance Technologies.*

Honeywell. (2015). *Honeywell and Intel Demonstrate Prototype of Wearable IoT Connected Safety Solutions for Industrial Workers and First Responders*. Retrieved from https://www.honeywell.com/newsroom/pressreleases/2015/11/honeywell-and-intel-demonstrate-prototype-of-wearable-iot-connectied-safety-solutions-for-industrial-workers-and-first-responders

Howe, G., Xu, G., Hoover, R., Elsasser, D., & Barickman, F. (2016). *Commercial Connected Vehicle Test Procedure Development and Test Results - Intersection Movement Assist.*

International Association of Firefighters, US Fire Aministration and Department of Homeland Security. (2010). *Best Practices for Emergency Vehicle and Roadway Operations Safety in the Emergency Services.*

Kunnath, A., Pradeep, P., & Ramesh, M. (2012). ER-Track: A Wireless Device for Tracking and Monitoring Emergency Responders. *Procedia Computer Science, No. 10*, 1080-1085.

Louisell, C., Collura, J., Teodorovic, D., & Tignor, S. (2004). Simple Worksheet Method to Evaluate Emergency Vehicle Preemtion and Its Impacts on Safety. In *Freeway Operations and Traffic Signal Systems* (pp. 151-162).

Moon, G., Chun, S., Hur, M., & Jee, G. (2013). *A Robust Indoor Positioning System Using Two-Stage EKF SLAM for First Responders in an Emergency Environment.*

National Operations Center of Excellence. (n.d.). Retrieved from SPaT Challenge Overview: https://transportationops.org/spatchallenge

National Public Safety Telecommunications Council. (n.d.). Retrieved from Public Safety Internet of Things (IoT) Working Group: http://www.npstc.org/IoT.jsp

Otto, G. (n.d.). *DHS Sees Wearables as the Future for First Responders*. Retrieved from https://www.fedscoop.com/dhs-wearables-first-responders/

Paniati, J., & Amoni, M. (2006). *Traffic Signal Preemption for Emergency Vehicle, A Cross-cutting Study.* Washington: US Federal Highway Administration.

Panitzek, K., Schweizer, I., Bonning, T., Seipel, G., & Mullhauser, M. (2012). First Responder Communication in Urban Environments. *International Journal of Mobile Network Design and Innovation*.

Pecheux, K., Pecheux, B., & Carrick, G. (2019). *NCHRP 17-75: Leveraging Big Data to Improve Traffic Incident Management.* Washington: TRB.

Peha, J. (2013). A Public-Private Approach to Public Safety Communications. *Issues in Science and Technology*.

Pierowicz, J., Jacoy, E., Lloyd, M., Bittner, A., & Pirson, B. (2002). *Intersection Collision Avoidance Using ITS Countermeasures, Final Report, Performance Guidelines.* Washington: National Highway Traffic Safety Administration.

Plevin, R. E., Robert Kaufman, B., Laura Fraade-Blanar, P., & Eileen M. Bulger, M. (2017, April). *Evaluating the Potential Benefits of Advanced Automatic Crash Notification.* Retrieved from www.cambridge.org/core: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/CD911B9D16847D697EFC3D3AA1740798/S1049023X16001473a.pdf/evaluating_the_potential_benefits_of_advanced_automatic_crash_notification.pdf

Quin, X., & Khan, A. (2012). Control Strategies of Traffic Signal Timing Transition for Emergency Vehicle Preemption. *Transportation Research Part C: Emerging Technologies, Vol. 25*, 1-17.

RapidSOS. (n.d.). Retrieved from RapidSOS Announces Parnerships to Link Wearables to First Responders in an Emergency: https://www.prnewswire.com/news-releases/rapidsos-announces-parnterships-to-link-wearables-to-first-responders-in-an-emergency-300499054.html

Saleem, F., Swart, N., & Head, K. (2014). *Maricopa County Department of Transportation SMARTDrive Program: Connected Vehicle Applications in Arterial Environment.*

Schoneburg, R., Fehring, M., Richert, J., Glashagel, M., Ruf, J., Walz, M., & Bogenrieder, R. (2017). *Effectiveness Potential of PRE-SAFE Impulse Using the Scenario of a Major Accident at an Intersection as an Example.*

TSAG. (2019). *Infrastructure to Responder (I2R) White Paper.* Washington: ITE.

Transportation Research Board. (2018). *Transportation Research Board*. Retrieved from NCHRP 20-102(16) [Anticipated]: https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4477

TSAG. (2016). *The Connected Responder - A Business Case for the Emergency Responder Agency and a Business Plan for Engaging the Responder Community.*

TSAG. (2019). *Advanced Automatic Collision Notification (AACN).* Washington: ITE.

TSAG. (2019). *FirstNet, Next Generation 911 and Connected Vehicles.* Washington: ITE.

Turetzky, G. (2012). *Indoor Positioning with SiRFusion for NextGeneration E-911.*

U.S. Fire Administration and the International Fire Service Training Association. (2004). *Emergency Vehicle Safety Initiative.*

US Department of Homeland Security. (2018, December 18). *Science and Technology.* Retrieved from Snapshot: S&T is Delivering Emerging Smart Cities Technologies to First Responders, Industry: https://www.dhs.gov/science-and-technology/news/2018/12/18/snapshot-st-delivering-emerging-smart-cities-technologies

USDOT. (2012). *Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.): Concept of Operations.* Washington: US DOT ITS JPO.

USDOT. (2015). *Prototype Development and Demonstration for Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.): Technical Report on Prototype Development and Field Testing of R.E.S.C.U.M.E. Applications.* Washington: USDOT ITS JPO.

USDOT. (2019, January 23). *USDOT Research - Operations*. Retrieved from Cooperative Automation Research Mobility Applications (CARMA) Overview: https://highways.dot.gov/research/research-programs/operations/CARMA

USDOT Federal Highway Administration. (2008). *Signalized Intersection Safety Strategies: Employ Emergency Vehicle Preemption.* Washington.

USDOT Federal Highway Administration. (n.d.). *Intersection Safety*. Retrieved from https://safety.fhwa.dot.gov/intersection/

Vehicle to Infrastructure Deployment Coalition. (2018). *SPaT Challenge Infrastructure System Model Concept of Operations.*

Yu, L., Bill, A., Chitturi, M., & Noyce, D. (2013). On-duty Struck-by Crashes. *Transportation Research Record*, 112-120.