TITLE PAGE

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Chapter Title
Rural First Responders and Communication Technology: A Mixed Methods Approach to Assessing Their Challenges and Needs

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Abstract

Although new technology may benefit rural first responders to help them serve their communities, to date little is known about what communication technology problems rural first responders most need addressed and what future technology they desire. This chapter explores communication technology problems and needs of rural first responders in the United States (US) based on data from semi-structured interviews with 63 rural first responders and survey responses from 2,698 rural first responders. Data from both the interviews and the survey come from rural first responders representing four disciplines: Communications Center & 9-1-1 Services, Emergency Medical Services, Fire Service, and Law Enforcement. Analysis of both qualitative and quantitative data are used to identify the problems rural first responders experience with communication technology and the technology needs they identify as most important moving forward. Their greatest problems were with reliable coverage/connectivity, interoperability, information technology (IT) implementation and cost of technology, and physical ergonomics. Rural first responders' greatest need was to address the problems they experience with current communication technology, but they were interested in new technology that leverages real-time access to information and location tracking. Implications for researchers and developers of public safety communication technology are discussed.

Keywords

Communication technology, first responders, public safety, rural communities, usability.

1. INTRODUCTION

1.1 Rural Environments and Incident Response

First responders in public safety disciplines, namely Communications Center & 9-1-1 Services (COMMS), Emergency Medical Services (EMS), Fire Service (FF), and Law Enforcement (LE) personnel, respond to emergency incidents to serve and protect their communities. These professions face many dangers and difficulties. First responders in rural communities encounter unique challenges by nature of the rural areas they serve. To better understand these challenges and how to mitigate them, rural areas have been a topic of research in the US (Ricci et al., 2003; Tiesman et al., 2007) and in countries around the world (Aftyka et al., 2014; Birdsey et al., 2016; Hang et al., 2004; Jennings et al., 2006). Many studies focus exclusively on rural emergency response (Gamache et al., 2007; O'Meara et al., 2002; Oliver and Meier, 2004; Ramsell et al., 2019; Reddy et al., 2009; Roberts et al., 2014).

A commonality across studies above is that rural first responders are tasked to serve small communities that span wide landmasses. This can lead to longer ambulance response times in rural areas as supported by studies (Aftyka et al., 2014; Jennings et al., 2006).According to the US Census Bureau's definition, rural areas comprise 97% of the US's landmass, but only 19.3% of the population (Ratcliffe et al., 2016; US Census Bureau).

Rural first responders also respond to incidents resulting from the unique terrain of the area. Some rural areas are impacted by seasonal weather, experiencing high rates of sporting injuries during certain seasons, such as skiing in winter(Birdsey et al., 2016). There are also high rates of injuries during times of the year with more severe weather, such as monsoons (Hang et al., 2004). Injury-hospitalization and death percentages are often higher in rural than urban areas (Coben et al., 2009; Tiesman et al., 2007). Unfortunately, rural areas are often served by rural first responders with small staffs that rely on volunteers or community workers who often have less experience and training (Gamache et al., 2007; Roberts et al., 2014).

1.2 Rural Barriers to Technology

Environmental features make incident response different for rural first responders relative to their urban and suburban counterparts. Rural first responders also face challenges in utilizing the proper equipment to respond to incidents. Communication technology, such as radios, cell phones/smartphones, and mobile data terminals (MDTs), are some of the most important tools first responders use in incident response, allowing them to obtain information about incidents and coordinate the appropriate response (Choong et al., 2018). Unfortunately, rural first responders face two primary barriers that prevent them from accessing and using communication technology.

First, rural areas tend to lack the infrastructure needed to implement the latest communication technology (Federal Communications Commission (FCC), 2020). This lack of infrastructure results in a lack of broadband access in many rural areas (FCC, 2020) and slow broadband speeds in some areas (Meinrath et al., 2019; Perrin, 2019) that may ultimately prevent rural first responders from accessing and using technology for incident response. Moreover, the costs for buying, installing, and maintaining broadband infrastructure are high in rural areas (Strover, 2001; Yankelevich et al., 2017), sometimes due to the impact of natural geographic barriers (e.g., mountains) and harsh weather conditions on equipment (Pötsch et al., 2016; Surana et al., 2008).

Second, some studies suggests that people in rural areas are reticent to adopt new technology. Despite many rural areas gaining more access to broadband infrastructure, the urban-rural broadband adoption gap continues to persist (Dickes et al., 2010; Department of Commerce (DOC), 2010; Whitacre, 2008). Some studies suggest demographic disparities between rural and urban areas are related to these lower adoption rates (Whitacre, 2008). Another study finds that broadband adoption in rural areas is predicated on individuals' prior experience, expected outcomes, and self-efficacy when using the internet (LaRose et al., 2007). Relatedly, studies examining non-internet users found that their primary reason against adopting broadband in their homes was that they did not have any interest or need for broadband (DOC, 2010). This was the top reason for both rural and urban households. However, a larger share of rural households than urban had this belief. These studies suggest that people in rural areas may not adopt technology because the benefits of new technology are not made clear to them (Dickes et al., 2010; LaRose et al., 2007), possibly preventing rural first responders from utilizing tools that would help them during incident response.

1.3 Opportunities to Address Barriers

New legislation has created opportunities for mitigating these challenges by developing new technology specifically for first responders. The US Middle Class Tax Relief and Job Creation Act of 2012 (Public Law 112-96, 2012) provided funding and dedicated broadband to establish the Nationwide Public Safety Broadband Network (NPSBN). While NPSBN development is in progress, this network will improve broadband access for first responders by supplementing land mobile radio (LMR) with Long-Term Evolution (LTE) solutions. In addition, the Public Safety Communications Research (PSCR) program at the National Institute of Standards and Technology (NIST) is leading a coordinated, multidisciplinary research effort to facilitate the LMR to LTE transition (see NIST Public Safety Communications Research Division in Reference list).

The public safety research and development community has focused on developing new communication technology for first responders to operate with the new network. By improving broadband access and developing new communication

technology, rural first responders can better share critical information during emergencies and disasters (Comfort et al., 2004) as well as use new capabilities such as those that improve location information (Weichelt et al., 2019) and assist with providing care to people in remote locations ahead of ambulance arrival (e.g., telehealth; Ricci et al., 2003).

The NPSBN is poised to help address rural first responders' need for broadband infrastructure. However, solutions are needed to ensure that rural first responders will adopt new communication technology. Recent studies have emphasized adoption as a critical consideration when developing new technology for rural first responders and communities (Gasco-Hernandez et al., 2019; Weichelt et al., 2019). These studies including those from the NIST PSCR program (Choong et al., 2018) emphasize that technology showing great promise to help first responders must be developed with the context and needs in mind for first responders to adopt its use. The concept of including users of technology in technology development is central to human factors research and user-centered design (International Organization for Standardization (ISO), 2019). By understanding the user, a developer can design technology with the users' needs in mind (Hackos and Redish, 1998). Ultimately, this improves the usability of a product, increasing its efficiency, effectiveness, and satisfaction to the user (ISO, 2019). Therefore, rural first responders must be directly included in research so that technology meets their needs within their context of use.

1.4 Relevant Research on Rural First Responders

To date, most studies that focused on rural first responders examined their unique context of use. Studies examining the context for rural emergency and health care workers have found that rural emergency responders rely on community workers and volunteers (Greene et al., 2019; Roberts et al., 2014), feel overburdened (Iversen et al., 2002; Oliver and Meier, 2004), have fewer resources and equipment (Greene et al., 2019; Oliver and Meier, 2004; Pilemalm, 2018), and serve wide, remote, and geographically diverse areas (Greene et al., 2019; Iversen et al., 2002; Oliver and Meier, 2004). However, fewer studies have investigated how rural first responders perceive, interact with, and use communication technology.

The studies that have assessed rural first responders' perceptions and use of communication technology has focused broadly on emergency and health care professionals, including nurses, emergency department workers, and EMS personnel (O'Meara et al., 2002; Reddy et al., 2009) as well as community citizens, volunteers, and organizations (Pilemalm et al., 2013; Ramsell et al., 2019). These studies find that emergency, health care, and volunteer personnel are hindered by their communication devices due to the lack of interoperability between the numerous devices they use (O'Meara et al., 2002; Reddy et al., 2009) and connectivity problems (Reddy et al., 2009) from a lack of infrastructure (O'Meara et al., 2002; Pilemalm et al., 2013). Recently Ramsell et al. (2019) found that

usability and interoperability are important for semi-professional emergency responders and community volunteers when using a smartphone application supporting communication during incident response.

1.4 Gaps in Past Studies

Past studies have provided important insights. However, they have two important gaps. First, the studies that have assessed rural first responders' perceptions and use of communication technology are largely specific to healthcare professionals and EMS personnel. It is unclear if these same problems transfer to other types of rural first responder disciplines, or if other disciplines have different problems with communication technology. Second, many of these studies examined limited types of technology, focusing largely on network coverage and mobile devices (e.g., smartphones) rather than on other communication technology more broadly such as radios, MDTs, and body cameras. More studies are required to identify useful functionalities beyond networks and smartphones and instead assess needs broadly across communication technology for rural first responders.

1.6 The "Voices of First Responders" Research

Our research is part of the User Interface/User Experience portfolio which is one of several major portfolios of NIST's PSCR program (see NIST PSCR portfolio for User Interface/User Experience in Reference List). Our research focuses on conducting research in human factors and user interfaces to understand important components for successful deployment and adoption of new communication technology. With this research goal, we conducted an exploratory, sequential, mixed methods study, *Voices of First Responders*, to understand the experiences of first responders. In this book chapter, we specifically discuss our findings regarding the communication technology problems and needs of rural first responders across four disciplines (i.e., COMMS, EMS, FF, and LE). In this way, our study addresses gaps in prior research and builds off prior studies (Greene et al., 2019; Iversen et al., 2002; Oliver and Meier, 2004) to understand rural first responders' context of use. Focusing on hearing the voices of rural first responders is important as historically their perspectives have been left out of research about rural environments (Chambers, 1994). Insights from this study can help developers to identify what shortcomings in current technology need to be addressed as well as where to invest future resources in developing technology for rural first responders. By ensuring solutions that are tailored to work within the unique environments in which rural first responders operate, rural first responders may be more eager to adopt and use new communication technology.

2. METHOD

We conducted an exploratory, sequential, mixed methods study with two phases. This type of design is often used when: a measure or instrument is not currently available; when the variables are not known (for example the technology needs and

problems of first responders); and/or when exploring a particular phenomenon such as public safety communication. In Phase 1 of the study, we conducted 193 qualitative interviews with first responders across the US to comprehensively explore their experiences with communication technology. Findings from Phase 1 were then used to design the Phase 2 quantitative survey instrument. The use of a large-scale, nationwide survey provided for greater representation from first responders across the country. There were 7,182 total survey responses. This allowed for the ability to confirm, clarify, and expand on the findings from Phase 1 of the study.

This chapter focuses specifically on data and analysis of rural first responders in the study. Of the 193 interviews in Phase 1 of the study, 63 of them were with rural first responders (32.64%). In Phase 2 of the study, 2,698 of the 7,182 responses were from rural first responders (37.68%).

Both phases of the study were approved by NIST Research Protections Office. All data were collected anonymously. Full methodological details related to study design, data collection, and data analysis can be found in relevant reports for the in-depth interviews (Choong et al., 2018) and for the survey (Greene et al., 2020).

2.1 Phase 1: Interviews

A semi-structured interview instrument was developed that focused on two high-level areas: 1) understanding first responders' contexts of work; and 2) identifying first responders' perceptions of and experiences with technology. To understand context of work, the instrument included questions and follow-up probes related to job tasks and routines, relationships with people they work with or for, and characteristics of the environment they work in. Questions about technology focused on what technology they use, what problems they have encountered, and what technology they wish they had for their jobs. The interview instrument was developed iteratively through a process with a literature review, pilot interviews with first responders, and feedback from first responders and human factors subject matter experts.

A demographic questionnaire was also developed to identify participant characteristics (i.e., discipline, years of service, area, location, gender, and age) to ensure interview data reflected the diversity of first responders. Additionally, we asked two questions related to technology experience and adoption to better understand first responders' familiarity with technology. For these two questions, participants could select as many options as were applicable to their own experiences.

Purposeful, convenience, and snowball sampling were used to recruit first responders for the Phase 1 interviews. Five of the ten Federal Emergency

Management Agency (FEMA) (2020) regions in the US were represented in the sample.

Prior to the interviews, participants were informed they could withdraw at any time, skip any question as needed, and decline to be audio recorded. They also completed a demographic questionnaire. Interviews lasted approximately 45 minutes. Recorded interviews were transcribed, de-identified, and assigned an interview number.

2.1.1. Phase 1: Participant Characteristics

Sixty-three rural first responders participated in Phase 1 consisting of 18 COMMS participants, 6 EMS participants, 19 FF participants, and 20 LE participants. Table 1 displays the number of participants across rural first responder disciplines by gender, age, and total years of service. The sample was less representative of female first responders than male first responders, with female first responders comprising only 13 participants, though this was consistent with low proportions of female responders in FF and LE disciplines nationally (Crooke, 2013; Evarts and Stein, 2020). Relatedly, the larger number of females in our COMMS sample was consistent with gender demographics for the discipline nationally (US Bureau of Labor Statistics, 2019). A majority of the sample was between 36 and 55 years old and had a wide range of total years of service.

Table 1. Rural interviewee demographics by disciplines.

		COMMS	EMS	FF	LE	Total
Gender	Female	10	1	0	2	13
	Male	8	5	19	18	50
Age (Years)	18-25	1	1	3	2	7
	26-35	2	1	3	5	11
	36-45	5	2	6	4	17
	46-55	8	1	5	8	22
	56-65	2	1	1	0	4
	over 65	0	0	1	1	2
Total Years of Service	1-5	2	3	3	3	11
	6-10	3	0	4	3	10
	11-15	4	1	2	2	9
	16-20	1	1	2	3	7
	21-25	1	0	5	7	13
	26-30	3	0	2	2	7
	Over 30	3	1	1	0	5
	No response	1	0	0	0	1

Table 2 displays rural first responders' experiences with using and adopting technology compared to responses from the overall dataset. Although nearly 83% indicated they could do most or all things with technology with some assistance,

19.04% indicated they had limited knowledge or needed help with technology. In looking at experience adopting new technology, nearly 40% mentioned they let others work out the kinks. Although 28.57% said they follow technology trends, nearly 20.64% either adopt new technology when theirs has died or it becomes required. Thus, rural participants self-report having slightly less experience with and knowledge about technology, and they adopt technology slightly later than participants in the overall dataset.

Table 2. Interviewees' experience with technology and technology adoption.

Technology Experience	**Rural %***	**Overall Dataset %***
I can do all things that I want to do with technology without help from others.	17.46 %	18.85 %
I can do most things that I want to do with technology and only need help occasionally.	65.08 %	71.20 %
I have some knowledge about how technology works, but often need to ask for help to perform more advanced activities – such as to configure the privacy settings on my cell phone.	15.87 %	10.99 %
I have limited experience using technology and I don't know much about how technology works.	3.17 %	1.05 %
Technology Adoption	**Rural %***	**Overall Dataset %***
I try the latest technologies as soon as they come out.	17.46 %	19.90 %
I follow technology trends.	28.57 %	38.22 %
I let others work out the kinks first.	39.68 %	39.27 %
I wait until my old technology dies.	12.70 %	8.38 %
I only adopt new technologies when it's required.	7.94 %	5.24 %

* The percentages do not sum to 100 % since participants could select more than one option.

2.1.2. Phase 1: Qualitative Analysis

As part of the qualitative analysis process, transcripts were coded. Coding refers to assigning categories to participants' responses as a way to reduce the data set so that it can be analyzed to find patterns and themes. The multidisciplinary research team first created an *a priori* coding list to be used for the initial coding of five randomly chosen transcripts from the entire Phase 1 dataset (see Choong et al., 2018). These five transcripts were independently coded by all team members, then the research team met to review their coding to ensure the codes were applied in consistent ways and to discuss and resolve any disagreements in coding. This provided the opportunity to revise codes and operationalize how each should be applied, ultimately resulting in a finalized code list. The researchers coded all remaining transcripts using the final code list. The data associated with each code were extracted into separate files so that the relationships within and amongst the codes could be explored and themes identified.

This chapter specifically focuses on codes related to communication technology problems and needs and the context of use rural first responders operate within. First, to identify communication technology problems and needs, we reanalyzed responses initially coded into the "problem: technology" or "wish list" codes by further classifying responses into more specific categories and subcategories (see Dawkins et al., 2019). This resulted in 18 technology problems and 15 "wish list" categories. These categories and their corresponding subcategories were created for the larger research study to identify the needs and requested functionalities that were most important to first responders (Dawkins et al., 2019). Two researchers independently identified the categories and subcategories for each response, with one researcher categorizing the problems and the other categorizing the needs. The research team then met to discuss, operationalize, and finalize the classifications. Here coding categories were examined only for the subset of the data with rural first responders. Second, to identify the rural context of use for problems and needs, we identified themes about the rural context from the extracted data (see Greene et al., 2019).

2.2 Phase 2: Survey

In Phase 2, we developed a survey instrument that was distributed to first responders across the US The survey instrument was developed iteratively using findings from Phase 1 interview data, reviews from subject matter experts (first responders from all four disciplines) and survey experts, and survey pilots with first responders. Two major categories of questions were used in the final survey instrument: the first section focused on experiences with technologies for day-to-day incident response and the second section focused on large scale events (major disasters or large planned events such as football games or concerts). The overall survey structure and flow were largely similar across the four disciplines: all began with a section on demographics, followed by a section on use of technology[1] for day-to-day incident response (including questions on apps/software), problems with technology, and perceived usefulness of futuristic technology. The survey concluded with a section on use of technology in major disasters or large events (Figure 1).

Figure 1. Major survey components and flow.

[1] For those respondents who chose the response option that they did not have a particular device, those devices were piped forward to the futuristic technology section of the survey. In that section, a list of futuristic technology that might be useful for their job was presented. The list included both a preset list of emerging technologies plus those devices they selected "do not have" earlier.

The surveys for EMS, FF, and LE were similar, although the types of devices and apps/software asked about were somewhat different for each discipline, along with the technology problems experienced. The survey for COMMS varied slightly more, due to the different nature of their working environment. For example, COMMS respondents were asked questions about call centers and Next Generation 9-1-1 (NG 9-1-1), a digitally-based 9-1-1 system (see National Highway Traffic Safety Administration's Office of Emergency Medical Services National 911 Program in Reference list). Since they were asked these additional questions, they were not asked questions about specific problems with technology but were instead asked about information problems they experience. This was done in order to respect the time it took to take the survey. More detailed descriptions of survey logic, branching, and all questions can be found in the relevant report (Greene et al., 2020).

The target population for this survey was first responders in the U.S., including COMMS, EMS, FF, and LE. Three different types of outreach occurred during survey dissemination: 1) emails sent to a general sample from an online database purchased from a national public safety directory and data firm (database includes first responder departments/agencies in all 50 states and the District of Columbia); 2) via previous points of contact within the public safety community; and 3) through a variety of different public safety organizations. Individuals contacted were asked to forward the request to as many of their personnel as possible, as well as to colleagues from other departments/agencies. To have broad representation, the goal was to reach as many departments and agencies as possible, and through them to reach first responders.

2.2.1 Phase 2: Participant Characteristics

Overall, there was a total of 7,182 completed survey responses. Of these, 2,698 responses were from rural first responders (37.68%). Of these 2,698 responses, 23.68% were from COMMS, 18.12% from EMS, 33.06% from FF, and 25.13% from LE. This was the only question that required a response on the survey; participants could choose not to answer any of the other questions. In general, demographic variables of interest showed good variability and were similar to the demographics of the overall study. Male respondents represented 78.34% of the rural responses and females represented 21.66% of those who responded (n=2,668). As shown in Figure 2, all age groups were represented in the responses, with the majority of participants between 46 and 55 years of age (33.65%). Less than six percent of participants were 25 or younger or 66 or older. Almost half of the participants who responded had between 16 and 30 years of experience working in public safety (45.57%).

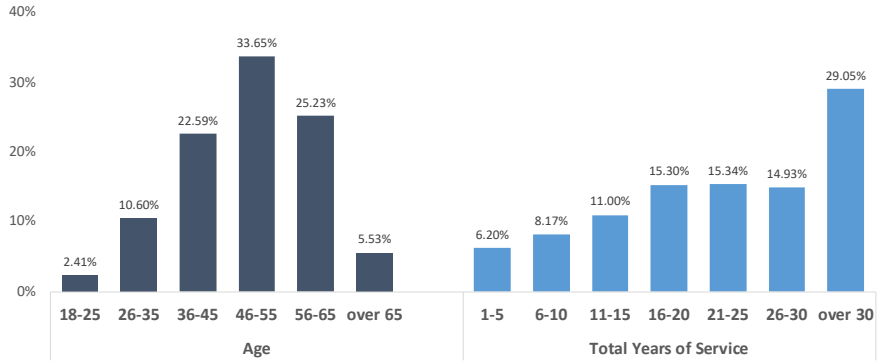

Figure 2. Rural survey respondents' age and total years of service.

2.2.2. Phase 2: Data Analysis

While the survey covered a broad range of questions and first responder demographics, the analysis in this chapter presents descriptive statistics focused on rural first responders, specifically their problems with technology, and futuristic technology they would like to have or think would be useful. Additionally, most survey sections included questions with open-ended fields. Open-ended survey responses were analyzed by sorting, counting, and/or coding responses to identify similarities, differences, and/or patterns in the data. Thus, the survey data provides quantitative evidence to support themes identified from Phase 1 interview data.

3. RESULTS

Results present both qualitative and quantitative data. The qualitative results present themes using direct quotes given by rural first responders. The quantitative results present percentages of first responders who provided each survey response.[2] Throughout this RESULTS section qualitative data from both the interviews and open-ended survey questions are illustrated with exemplar quotes that are representative of the data set as a whole. Each quote is in blue, indented text and followed by a reference to the participant in parentheses, including their discipline (i.e., COMMS, EMS, FF, or LE), area (R = Rural), and participant number (e.g., 001). Interview quotes are identified by the prefix "INT" and the use of dashes to separate participant information (e.g., INT-LE-R-048). Quotes from the open-ended survey responses do not have a prefix and separate participant information by colons (e.g., LE:R:8193). Because participants were anonymous, identifiers are not tied back to a specific participant.

[2] Full data and sample sizes are available at https://publicsafety.nist.gov/analyzer.html.

3.1 Technology Problems

Technology problems are presented below in two sections. First, we discuss the qualitative findings for the five important problem areas: connectivity/coverage, interoperability, IT implementation and cost of technology, physical ergonomics, and reliability. Where applicable, survey results are presented to support each of these main themes. Predominately, results from the surveys for EMS, FF, and LE are used to support the themes, as each survey for these disciplines included specific questions about device problems. Second, we present qualitative findings for problems specific to each of the four disciplines with supporting survey results.

3.1.1. Technology Problems Across Disciplines

Coverage. Many rural first responders discussed the problems with dead zones and lack of bandwidth or coverage for both radios and smartphones, as evidenced by the following interview quote:

> … we're in some kind of a remote location and sometimes you know we don't get cell service either. I mean we do have a co-op up here, a telephone co-op and that's been so much better now but it's not perfect either and so we've got some areas too where it's a little more difficult even with a cell signal. (INT-LE-R-046)

Some discussed dead zones in buildings or other structures, but many mentioned dead zones specific to rural terrain (e.g., mountains) that limit communication technology.

> We have that technology in the field when we don't have a cell signal which in the mountains here is soon as you get north of town 5 miles you start losing signal. You don't get it back until you're like two spots on [town/city redacted] and then not until you're down on the valley floor. (INT-FF-R-046)

> In a rural area, radio coverage is severely hampered by distance and cell phones experience regular, known dead zones. Our CAD system for text message dispatching through our county regularly fails - messages aren't transmitted fully or at all for periods of time. (EMS:R:504)

This finding is supported by the survey results, as a majority of rural first responders from EMS, FF, and LE had radio and smartphone coverage problems at least "sometimes" (i.e., selecting survey response "always," "most of the time", or "sometimes"). Evidence suggests coverage problems are pervasive: 30.00% of EMS, 34.33% FF, and 25.69% of LE participants experienced radio coverage problems "always" or "most of the time." Although the percent of rural first responders who experienced smartphone coverage problems were comparable to those who experienced radio coverage problems for EMS, fewer FF and LE survey

participants reported smartphone coverage problems compared to radio coverage problems. Figure 3 shows the percentages of radio and smartphone coverage problems for EMS, FF, and LE.

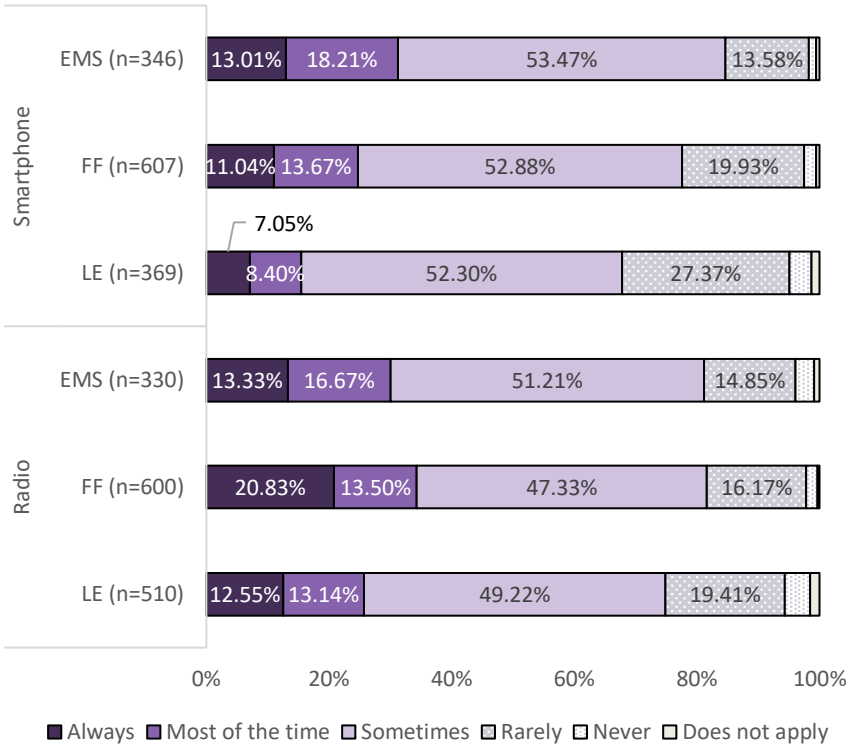

Figure 3. Radio coverage problems for EMS, FF, and LE.

Taken together, results suggest that coverage problems occur frequently for rural first responders. The dead zones and lack of coverage unfortunately often result in rural first responders being unable to rely on their communication technology during incident response.

Interoperability. Communication across disciplines, areas, and jurisdictions is vital to first responders' incident response and coordination efforts, and this communication is especially important for rural first responders who often cover a wide area. Rural first responders described difficulties with communicating among disciplines across rural areas and also during situations where they must work with other jurisdictions.

> … I mean, I can't call [county name redacted], call on the cell phone. I can't call [another county name redacted]; we don't have their frequencies available, so it would all have to be relayed from us to here to County, to their dispatch to their officer and then back to the state again…
> . (INT-LE-R-060)

> Biggest problem is interoperability. In 17 years I've heard a lot of plans and big talk; NO ACTION. (EMS:R:936)

Rural first responders also discussed that the numerous devices they use are not well integrated. As described in the following interview quote, lack of device interoperability can result in first responders carrying too many devices that each perform specific functions.

> I think my biggest gripes are that e-ticketing machine and just the fact that it's not well thought-out for the application. I don't think there's any reason why it couldn't be done on the phone that I already carry or the computer that's already in the car. (INT-LE-R-018)

These findings are supported by the survey data: rural EMS, FF, and LE first responders experienced problems with device interoperability for radios, MDTs, laptops, tablets, and computers (Figure 4). The highest percentage of EMS, FF, and LE survey participants had interoperability problems with their radios, MDTs, and laptops at least "sometimes", though many also reported issues with tablets and computers.

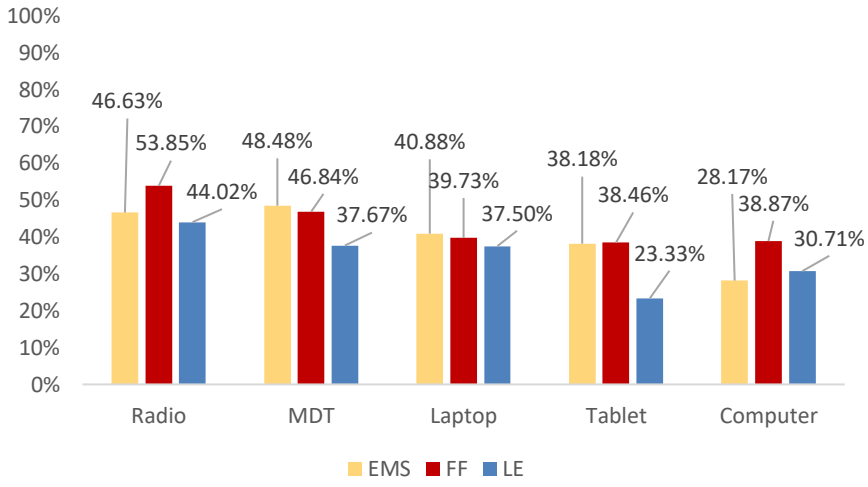

Figure 4. Interoperability problems occurring at least sometimes for EMS, FF, and LE.

Our findings suggest that devices' interoperability problems often result in unreliable communication during incident response. Lack of device interoperability may also have the unintended consequence for rural first responders, such as physical and cognitive burdens from carrying multiple devices that all perform different but related functions.

IT Implementation and Cost of Technology. Rural first responders described problems implementing and installing communication technology. One reason mentioned in the interviews was that some updates require access to the latest technology or use of broadband speeds to which many rural first responders do not yet have access.

Rural first responders often discussed these issues with implementation as being related to a broader issue of funding.

> We try to stay updated but with tight budgets and changing technology and software and govt requirements with no funding for requirements it's not easy for volunteer depts. radios are something we just can't keep updates on not to mention purchasing new ones. (EMS:R:3437)

> Technology is great, but, the cost is out of hand a lot of times and small centers like mine cannot buy the latest and greatest. Needs to be more affordable. (COMMS:R:231)

Results show that cost is often a prohibitor for rural first responders in accessing, training for, updating, and replacing communication technology. Problems with the price of devices was also pervasive across devices for EMS, FF, and LE survey participants (Figure 5). Over 50% of survey respondents in each of these disciplines had price problems at least "sometimes" with radios, smartphones, MDTs, laptops, and computers. The device with the highest reported price problems was radio, with over 75% of rural first responders in each discipline reporting they had price problems with radios at least "sometimes." Rates of having price problems were generally consistent across EMS, FF, and LE, except for pagers in which rural EMS and FF first responders had comparatively higher rates of having these problems than LE. However, this is likely due to LE having low rates of using pagers in the survey data (597 LE participants out of 648 who answered the pager frequency of use question (92.13%) did not have a pager).

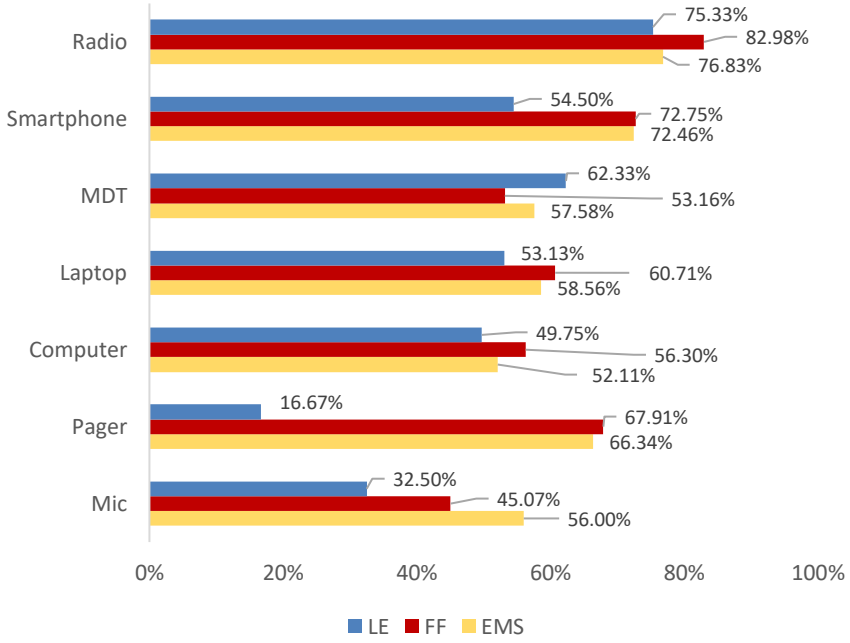

Figure 5. Device price problems occurring at least sometimes for EMS, FF, and LE.

This suggests that rural first responders do not just have issues purchasing devices specific to the first responder discipline such as MDTs and radios; rather, they have problems purchasing all kinds of communication technology, even more common communication technology such as laptops and computers. They also are unable to quickly replace broken or old technology. When rural departments cannot purchase the communication technology they need, rural first responders may have to rely on unreliable, outdated, and poorly functioning technology during incident response.

Physical ergonomics. Physical ergonomics problems encompass a wide range of topics, with some related to the number, size, and weight of devices, and others related to physical aspects of devices such as robustness, battery life, comfort, and safety concerns. Rural first responders discussed problems with devices' robustness in rural environments. Rural first responders must have durable equipment to meet the challenges of the incidents they respond to and the environments they work within, as they often encounter difficult terrain such as mountains or rivers.

> One of the issues that we see is that the equipment that's being issued is not rugged enough…police officers were out there in the sun, we're out there in the freezing cold, in the rain, they're getting in and out of their

> police units so they equipment needs to be more rugged…Or you're in the middle of a rainstorm, and a tree falls on the people's house and you're trying to get them out, you're trying to rescue them, and your radio doesn't work because it got wet. It needs to be able to function in any type of environments. (INT-LE-R-053)

Survey results support that durability is a frequently experienced problem for rural EMS, FF, and LE first responders across many devices. For all three disciplines, the largest number of first responders reported having problems with durability at least "sometimes" for smartphones (EMS: 50.00%; FF: 46.12%; and LE: 38.15%) and laptops (EMS: 48.07%; FF: 46.43%; and LE: 31.88%). Durability problems differed between the disciplines for the other devices: more EMS and FF survey participants reported problems at least "sometimes" with the durability of their tablets (EMS: 41.82%; FF: 42.31%; and LE: 23.33%), MDTs (EMS: 45.45%; FF: 35.44%; and LE: 24.65%), and pagers (EMS: 27.32%; FF:34.22 %; and LE: 16.67%).

Many also discussed having battery issues with their devices, and this was supported in the survey data. The majority of the participants from each discipline had battery problems at least "sometimes" with their smartphone (EMS: 67.91%; FF: 66.21%; and LE: 59.00%) and radios (EMS: 59.24%; FF: 65.47%; and LE: 56.55%). Problems at least "sometimes" were also common for laptops (EMS: 60.77%; FF: 54.46%; and LE: 46.25%). Between 40% and 50% of EMS and FF survey participants also reported having battery problems at least "sometimes" for their pagers (EMS: 51.22%; FF: 52.67%; LE: 16.67%) and tablets (EMS: 45.45%; FF: 43.59%; LE: 16.67%).

These results suggest that communication technology can cause ergonomics challenges when technology is not developed with rural conditions in mind. Communication technology may work well in optimal conditions, but rural first responders often encounter temperatures, altitudes, and distances their communication technology was not designed to withstand.

Reliability. A major theme across interview and survey data was that communication technology is often unreliable. In fact, this came up often in the interviews when many rural first responders described past experiences in which their communication technology did not work in the way it was intended to.

> We have the [inaudible] MDTs [mobile data terminals], but I think we would call it a failed technology... We spend more time wasting time trying to keep that thing working than we do doing our job. So we've given up on it… (INT-FF-R-019)

Although the survey did not explicitly ask about devices' reliability, survey participants reported reliability issues in the open-ended survey questions. Often

rural first responders commented on the unreliability of their radios, but many also wrote about experiences with unreliable laptops, pagers, body cameras, and desktops.

> Due to our rural and remote location we are forced to use mobile repeaters, and they are less than reliable. Also, due to the restrictions of narrow-band radios and the low power output of the ones our agency can afford, actually reaching our dispatch center (which is several miles away) is hit-and-miss at best. There are higher-powered radios available, we just cannot afford them, and it seems that when the Federal government mandated the switch to narrow-band transceivers, it exacerbated an already bad situation for small and rural agencies like ours. (LE:R:8193)

> Interoperability with radios and software would be great, but is still not widely adopted. Being forced to use a person cell/tablet sucks when the network coverage is basically non-existent ([vendor redacted]). Cell coverage maps are absolutely unreliable and not a true indication of coverage (ALL carriers)... (EMS:R:2428)

As described in the open-ended survey response quotes, often problems with reliability were the result of other problems with connectivity, interoperability, implementation, and/or physical ergonomics. Thus, when one of these problems occurs, it often results in poor reliability, with rural first responders being unable to trust on their devices to keep them safe and perform their duties.

3.1.2. Technology Problems Specific to Each Discipline

Although many problems were common across all disciplines, each rural first responder discipline experienced unique problems specific to their job requirements and context of use. The discipline-specific data presented here were emphasized within a discipline but were not unique to that discipline.

Communications Center & 9-1-1 Services. Rural COMMS personnel experience unique problems by nature of the environment they work within. COMMS personnel do not respond on-scene; they instead take emergency calls and dispatch first responders to the scene. A major problem for rural COMMS personnel was technology's inability to track callers' locations. In the interviews, rural COMMS personnel discussed the difficulty in locating callers during 9-1-1 calls, as some rural areas did not have addresses. Some also discussed that this problem can be exacerbated when there is an increase in seasonal tourists who are unfamiliar with the area and cannot easily identify their location when calling 9-1-1.

> …Location information sometimes is difficult to get from a cell phone. And again, we have a lot of visitors here. And they never know where they're at. Had no clue. (INT-COMMS-R-002)

> Many phone providers CAN NOT provide good location information for their callers, if at all. We have one company that transfers calls to use from the other end of our state - which would be about an 8-hour response time. (COMMS:R:421)

This is supported in the survey data with the information problems rural COMMS personnel experienced (Figure 6). Over a fourth of COMMS survey participants (28.15%) had problems "always" or "most of the time" with tracking a caller's location from a cell phone, and an additional 61.01% experienced this problem "sometimes." Another common problem was the inability to receive accurate and complete information when dispatching first responders to the scene. Over 90% of rural COMMS personnel had problems with callers providing inaccurate or missing information at least "sometimes." Problem with maps and databases providing accurate information at least "sometimes" was also common for nearly two-thirds of COMMS personnel.

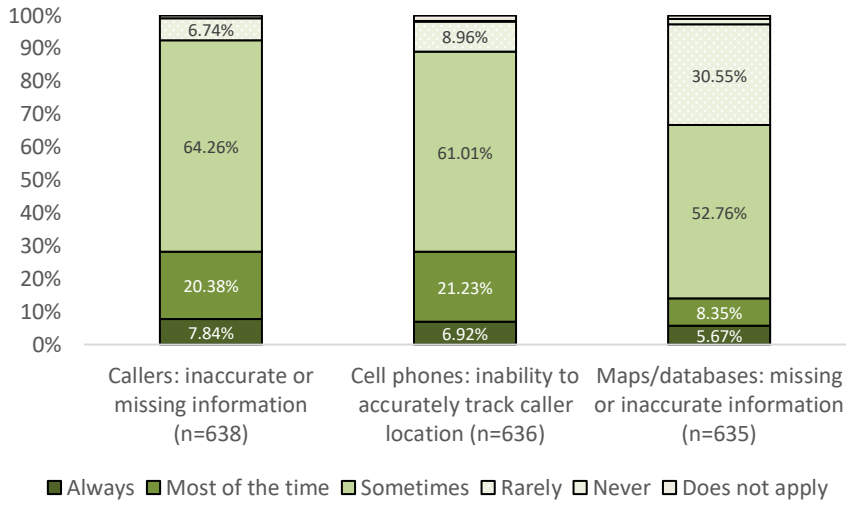

Figure 6. Caller, cell phone, and map/database information problems for COMMS,

Although they saw benefits to technology, rural COMMS personnel were often wary of both new technology and significant changes to existing systems. Many responses expressed trepidation for receiving text messages, pictures, and videos as well as using NG 9-1-1. COMMS personnel expressed concerns over seeing graphic or inappropriate images in texts as well as needing to slow down their response time to communicate via text with callers.

> …I have speculation, but I really don't know how's that going to impact and if that's going to take too much time. I don't know if it's going to slow things down or quicken it, I don't know. I know it's a technology that the millennials love and it's easy for them, but it may not be necessarily easy for us. I don't understand how a video would be better than a text or a call. (INT-COMMS-R-020)

> Texting takes considerably more time to communicate than voice communications, delaying the processing and response to emergencies. (COMMS:R:1668)

Survey results indicated that more COMMS personnel received texts at their call centers (46.38%) than pictures and videos (8.52%). The majority of COMMS personnel believed there were benefits to receiving texts (74.60%) and pictures/videos (51.81%). However, 17.14% were unsure that texts would be beneficial and 28.98% were not sure that pictures and videos would be helpful. Similarly, survey results showed that nearly 3 out of 4 COMMS personnel thought NG 9-1-1 would be helpful, and only 5.5% believed it would not be helpful. However, 20.13% were unsure about NG 9-1-1's helpfulness, suggesting some COMMS personnel are also wary about this new technology.

Taken together, these results suggest COMMS responders are open to changes in technology for receiving information and dispatching first responders, but some are concerned about potential negative impacts and new challenges that may come with new technology.

Emergency Medical Services. Rural EMS personnel mentioned a variety of problems, especially with writing patient reports and sending them to hospitals. They were often frustrated by how difficult their systems were to use. In fact, EMS personnel sometimes spent more time writing a report than they needed to, and in some cases had to rewrite their reports. This is supported by survey results, as 45.45% of rural EMS survey participants had problems with report writing on tablets at least "sometimes." Nearly a fifth experienced this problem "always" or "most of the time." This unreliability was often due to problems with devices connecting to the internet or with device software crashing.

> …It took 2 to 3 times as long to do your report which when you have a day where you only have 2 calls it's not that big of a deal because you have plenty of down time to get that report done but when you're running back to back calls and you're on a second call and you haven't even gotten to finish your first report it's very frustrating and they shut down a lot especially when these things depend on internet and we are so you get out here somewhere and then the information the things that you need won't load... (INT-EMS-R-019)

Internet connectivity and software crashes were frequently reported by rural EMS survey participants. A majority of EMS participants had internet connectivity problems at least "sometimes" with their laptops (81.48%) and tablets (79.55%), and of those, nearly a third of these problems were experienced "always" or "most of the time" (laptops: 32.72%; tablets: 29.55%). Fewer rural EMS survey participants reported internet connection problems with their computers, with 49.49% having problems connecting their computer to the internet at least "sometimes" and only 9.18% having these issues "always" or "most of the time." A majority of rural EMS survey participants reported having problems at least "sometimes" with their laptops (53.42%) and computers (47.42%) crashing, with fewer rural EMS participants indicating this problem occurred "always" or "most of the time" for computers (7.22%) than laptops (14.29%).

EMS personnel discussed that reliable and usable technology was expensive, causing some departments to opt for outdated solutions. In some cases, EMS personnel discussed using pencil and paper for report writing rather than computers. Nearly half of the rural EMS survey participants indicated they experienced problems with their laptops and computers being old or outdated at least "sometimes" (Figure 7). Moreover, problems updating or upgrading laptops and computers occurred at least "sometimes" for over 60% of rural EMS survey participants. One in four had these problems "always" or "most of the time" with laptops.

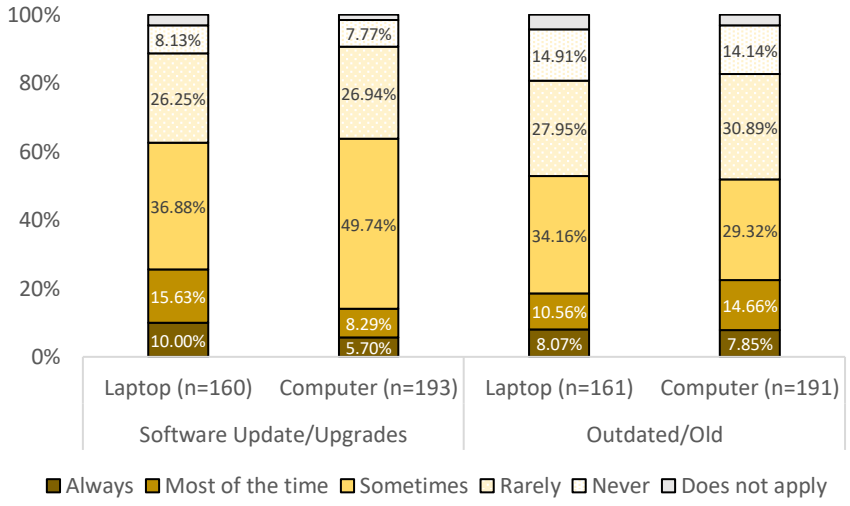

Figure 7. Problems with old and outdated devices and software updates/upgrades for EMS.

Not only did rural EMS first responders often have difficulties with their laptops, computes, and tablets reliably working, but when they did have these issues, finding a solution was difficult.

> What happens when it doesn't work? What happens when we have trouble with it? Who fixes it? Because I can't just call downstairs to IT, okay? I've got a contractor that does our IT because we don't have an IT department. They're budgeted two days a week, maybe. (INT-EMS-R-008)

As in the interview quote above, some mentioned that their departments do not have dedicated IT staff and experts to fix common problems. Ultimately the lack of support often results in rural EMS first responders spending considerable time and resources fixing their systems or finding alternate solutions.

Fire Service. Rural FF personnel had difficulty with mics and radios during incident response. They had problems hearing their radios when there was external sound caused by fire and alarms, and their mics picked up breathing and other sounds that made communications hard to hear.

> …we have handhelds, walkie talkies and they are hardest thing to hear when you are in a fire... (INT-FF-R-055)

Rural FF survey participants also frequently experienced problems with the audio quality of their radios and mics: 77.22% experienced problems with radios and 66.67% experienced problems with mics at least "sometimes." For some rural FF survey respondents, these problems were more frequent, with 22.95% experiencing audio quality problems "always" or "most of the time" for radios and 15.69% experiencing these problems with mics.

Many rural FF participants also expressed that their technology was outdated.

> …When a fire is paged out here they may page out the appropriate response it may or may not go out over the radio. We have somewhat of an outdated underfunded antiquated communications here in our county. (INT-FF-R-049)

Problems with old and outdated technology were a common experience across numerous devices for rural FF survey participants (Figure 8).

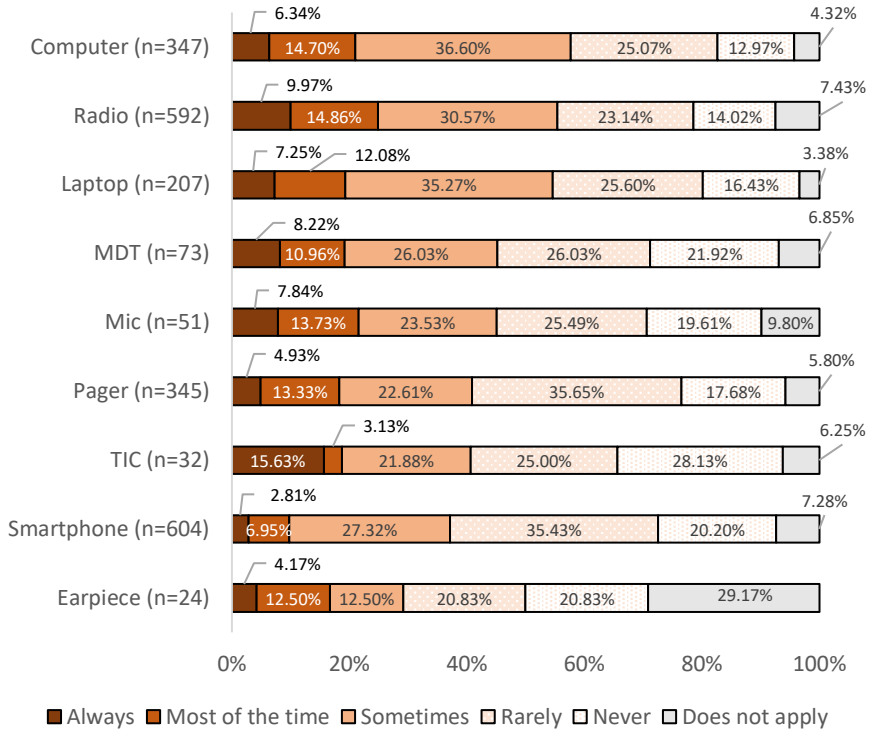

Figure 8. Problems with old or outdated devices for FF.

Note. TIC = Thermal Image Camera.

Nearly 1 in 5 rural FF first responders experienced these problems "always" or "most of the time" with their computers, laptops, MDTs, mics, pagers, and Thermal Image Cameras (TICs). This rate was even higher for radios, with nearly 1 in 4 having old and outdated radio problems "always" or "most of the time."

Law Enforcement. Use of body cameras is specific to LE personnel in their day-to-day work. Rural LE personnel expressed physical challenges securely attaching their body cameras to their uniforms, and many also mentioned that they spend significant time and effort storing and uploading the cameras' information.

> It can add quite a bit of time because for the most part the upload time is the real time…I think the longest recording I have was probably about 3 hours which it breaks it up into thirty minute intervals but it took almost 2 ½ or 3 hours for that one video to upload then I had 10 other ones that I had to upload so the upload speed is absolutely horrible. (INT-LE-R-045)

Survey results also revealed problems with body cameras (Figure 9). The most common problems with body cameras were with the price (at least "sometimes: 66.30%; "always" or "most of the time:" 48.32%) as well as with physical ergonomics challenges. Some problems were the same issues common across first responders and devices, as many rural LE respondents had problems at least "sometimes" with body camera battery (61.37%) and durability (45.45%). Other problems that occurred at least "sometimes" were more specific to the body camera, such as placement (58.13%), size (44.83%), and likelihood of falling off (39.09%). Problems at least "sometimes" with the using recorded data (37.07%), video transfer/storage (35.23%), turning the camera on and off (34.49%), and video quality (25.29%), occurred less frequently.

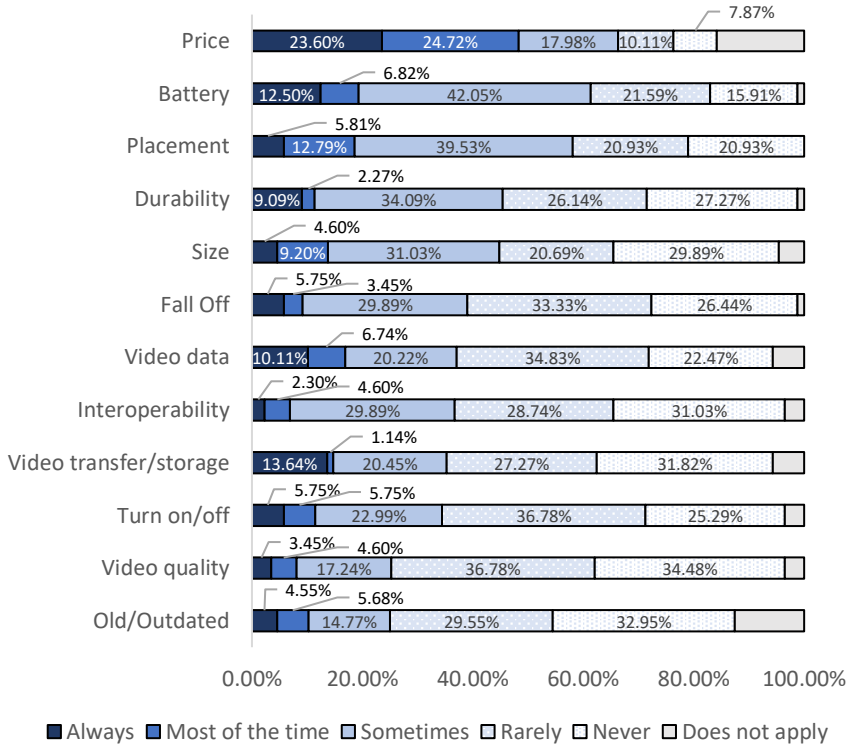

Figure 9. Problems with body cameras for LE.

Rural LE personnel mentioned challenges using devices that were bulky, too numerous, and/or not reliable. These ergonomics challenges were often specific to the equipment they use, such as e-ticketing devices. Survey results support that rural LE first responders often had issues with the size and weight of their devices. Nearly 40% had problems at least "sometimes" with the size of their MDTs (42.42%) and radios (39.41), and nearly 30% had problems at least "sometimes" with laptop

weight (29.25%). Tablet size and weight were the least common problem for rural LE participants, with less than 10% of rural LE survey participants having these problems at least “sometimes.”

3.2. Technology Needs

This section presents data from interviews and the survey related to the types of technology first responders need and want. This includes technology that first responders do not currently have and “futuristic” technology. Figure 10 below shows the list of futuristic technologies survey respondents were able to choose from and the percentages of respondents from each discipline who selected the various items.

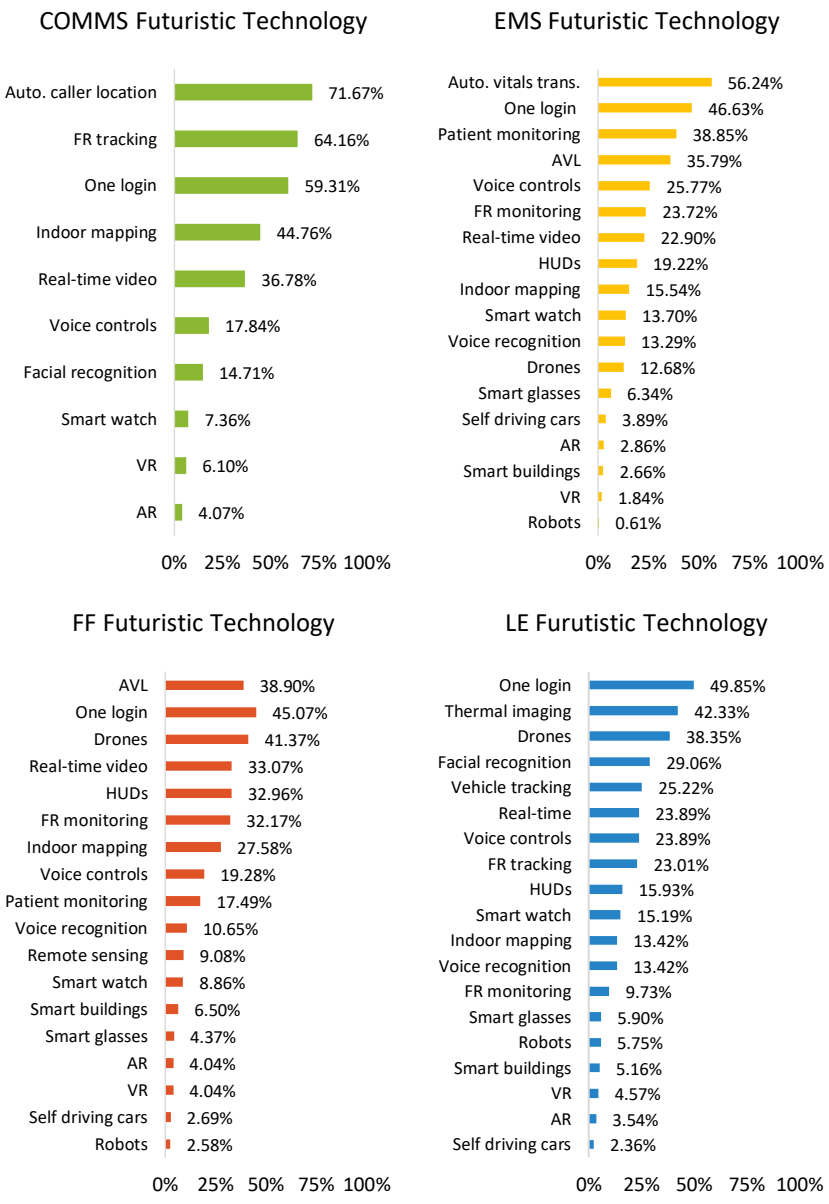

Figure 10. Futuristic technology needs.

Note. AR = augmented reality; Auto. = automatic; AVL = automatic vehicle location; FR = first responder; HUD = heads-up display; Vital trans. = transmission of vitals; VR = virtual reality.

3.2.1. Improving Current Technology

Overarchingly, rural first responders wanted greater reliability, functionality, and interoperability of their current devices. They emphasized that they need their current problems fixed and therefore wanted a strong focus on improving basic and current technology. Ultimately, rural first responders want to be able to trust the technology that they use, eliminating unnecessary burdens, disruptions, and stress they experience as a direct result of their current technology.

> Instead of new stuff it would be good to know that the tools we already use would work better rather than getting new stuff. We already can't afford things. (FF:R:5506)

Rural first responders most wanted to have radios and smartphones that work consistently and reliably, as data from both the interviews and the open-ended survey responses identify these devices as some of the most important tools for rural first responders. Because they use these devices often and need to rely on them, many expressed a need for improvement in these devices, especially in ensuring better coverage in rural areas.

> You want your radios to work and you want your cell phones to work all over the county. I mean that's pretty much it. (INT-LE-R-048)

> Cellular/internet coverage that reaches all areas of my fire district. Also cheap plans available to public safety. (FF:R:2118)

With access to wider coverage, rural first responders could improve the efficiency and effectiveness of communication with their team members, transmit information to other responders and hospitals, and maintain a lifeline in dangerous situations. Fixing problems and providing greater reliability for current communication devices could encourage usage and reduce frustration.

Data support that rural first responders had a stronger need for their current technology to be improved rather than for development of entirely new technology. Some rural first responders believed new technologies could disrupt their work or make it harder, making them less efficient and effective.

> None of these sound particularly useful and some could be disruptive to our normal work processes in dispatch. If one of the items listed was increased staffing then I would've happily checked that box. (COMMS:R:1545)

The survey results provide support that advanced technology is of less interest to rural first responders. Many of the futuristic technologies listed were selected by a low percentage of survey respondents as being important for their day-to-day work. In fact, many of the most futuristic technologies in the list were selected by 10% or less of survey respondents (Figure 10). For example, "AR (augmented reality)" and "VR (virtual reality)" were in the bottom four items selected by respondents from all four disciplines; neither was selected by more than 7% of respondents from any discipline. "Robots," "Self-driving vehicles," "Smart glasses," and "Smart buildings" were some of the other items selected by low percentages of respondents across disciplines.

Although rural first responders did not believe many advanced technologies would benefit them, there was one item from the futuristic list of technologies that rural survey respondents across disciplines chose. The item "one login (instead of many different usernames and passwords)" was in the top three items checked rural respondents from all four disciplines (COMMS: 59.31%; EMS: 46.63%; FF: 45.07%; and LE: 49.85%), demonstrating its importance to this population.

The open-ended survey responses also indicated that having only one login would be of tremendous benefit for rural first responders.

> One login would be at the top of everybody's list here. It is ridiculous the number of passwords and log-ins that have to be used and waste the time of first responders in their preparation and continuous log-in status. (LE:R:5075)

Rural first responders believed that having one login that works across platforms would improve the usability of many of their devices, increase interoperability, and ultimately save time and lead to less frustration.

Overall, these results suggest that advanced technology was not always perceived as the right answer to the problems rural first responders face. Instead, rural first responders overwhelmingly wanted improvement of current technology and believed that would be most helpful.

3.2.2. Location Information

Responses from rural first responders in interviews and on the survey show the importance of location information for their day-to-day work. While location information technologies were identified by all four disciplines as useful for day-to-day work, there were differences amongst the disciplines, due in large part to the fact that different disciplines saw different lists of futuristic technologies on the survey. For example, the top two futuristic items chosen by COMMS survey respondents were "Automatic caller location" (71.67%) and "First responder tracking" (64.16%). Qualitative data also show that accurate caller location was a

top priority for COMMS personnel, as was being able to track the first responders they dispatch to the field.

> Location is number one. We can dispatch. We can do anything else in the world with that call if we have the location. But getting that location is just paramount. We can't do anything if we don't get a location. (INT-COMMS-R-016)

"First responder tracking" was checked by 23.01% of LE survey respondents as well. Over 25% of respondents from EMS, FF, and LE identified "Automatic vehicle location" as something they think would be useful in their day-to-day work (EMS: 35.79%; FF: 38.90%; and LE: 25.22%).

3.2.3. Real-time Information

Rural first responders also indicated, in interviews and on the survey, they were interested in access to real-time information (Figure 11).

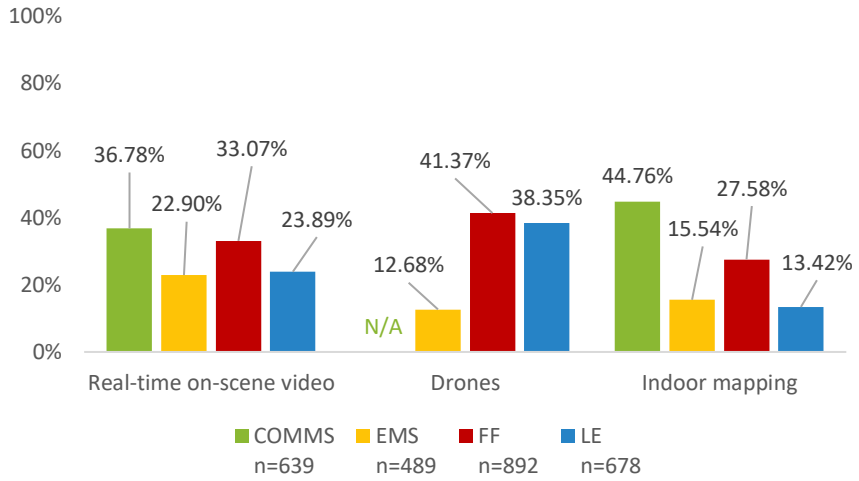

Figure 11. Real-time information

For example, high numbers of survey respondents across disciplines identified real-time on-scene video as a technology they would find useful in their day-to-day work (COMMS: 36.78%; EMS: 22.90%; FF: 33.07%; LE: 23.89%). This is supported by interview and open-ended survey data as well.

> Being able to be live at a scene would be a huge tool to have as a dispatcher. The same with receiving pictures that could help with cases. (COMMS:R:9199)

> Or that there's the ability that that camera would be tied to the MDC so that I could push a button, take a picture, and transmit that without sitting here and opening an email, figure out who's working today, who's going to get this email…(INT-FF-R-008)

Additional items that garnered relatively high percentages from first responders in all four disciplines are indoor mapping and voice controls. These items had relatively high percentages across the four disciplines, suggesting they are important technologies for public safety in rural communities.

Drones appeared as one of the items in the futuristic list of technology on the survey for three of disciplines (EMS, FF, and LE). Large percentages of FF (41.37%) and LE (38.35%) selected this item, which may indicate that FF and LE rural first responders can envision possibilities for the use of drones in their day-to-day work. A lower percentage of EMS respondents (12.68%) chose drones as beneficial. This may be because EMS first responders work more specifically with patients and medical issues, may not find drones beneficial due to the nature of their work.

Several discipline-specific items had high percentages of first responders who thought they would be useful in their day-to-day work. For EMS, more than half of respondents (56.24%) selected "Automatic transmission of patient vitals and information to the hospital" and nearly 40% also thought "Health/vitals monitoring of patients" would be useful (38.85%). Over 40% of LE respondents chose "Thermal imaging" (42.33%) and over 30% of FF respondents checked "Heads-up displays" as potentially helpful for their day-to-day work. These technologies provide specific functions and support for their particular area of public safety and are of tremendous importance to the disciplines that use them.

4. DISCUSSION

Rural first responders experienced problems with their communication technology, especially lack of connectivity, interoperability, reliability, and the cost of communication technology. Our results are consistent with studies that have examined both rural (Greene et al., 2019; O'Meara et al., 2002; Pilemalm et al., 2013; Reddy et al., 2009) and urban and suburban first responders (Dawkins et al., 2019), and further supports that the manifestation and impact of these problems is unique to the rural context of use. Rural first responders in the study often experienced situations in which their devices were not suited to rural contexts. Devices were often unreliable due to challenges connecting in rural dead zones, traversing long distances, and enduring through extreme weather and terrain. Often these challenges were exacerbated by funding limits. When these issues are compounded, rural first responders must do their jobs without proper equipment. This places a significant burden on rural first responders during incident response.

Technology has the potential to decrease these burdens by increasing the amount of information available to rural first responders and decreasing time spent on tasks. However, in many cases technology was an added burden, both mentally and physically to the day-to-day tasks of rural first responders. Thus, it is unsurprising that when rural first responders were asked what new technology would benefit them, they wanted their current problems fixed rather than entirely new communication technology. However, this does not mean that rural first responders were uninterested in new or futuristic technology. For example, rural first responders saw more utility for technology to improve access to location and real-time information. These findings are consistent with prior studies with urban and suburban first responders (Choong et al., 2018) and underscore the need for developers to address problems but also anticipate first responders' need for information.

The subsections below highlight four major areas that researchers and developers should consider as they improve and develop communication technology for rural first responders. Research and development in these areas are likely to benefit all first responders, but we specifically discuss how each area can be addressed in light of the rural context of use to improve the communication technology experiences of rural first responders.

4.1. Better coverage and connectivity

The lack of broadband infrastructure and geographic dead zones are largely unique to rural areas. Most rural first responders in this study relied on communication technology to communicate, and when these devices were unable to connect, rural first responders had no way to coordinate with other responders in the area or acquire new information. Although broadband coverage has been improving (FCC, 2020), some areas still have slow speeds (Meinrath et al., 2019; Perrin, 2019). Researchers and developers should carefully consider the communication technology they develop for use in rural areas; until broadband access and speed are improved, some devices may not work as intended or at all. Therefore, researchers and designers should continue to consider how to increase coverage and connectivity of communication technology in rural areas.

4.2. Durable and reliable devices

Rural first responders need devices that are durable and robust to conditions experienced by all first responders as well as to the extreme weather and terrains unique to the rural context of use. In addition to the environment, developers should also consider the additional distance and time rural first responders need for incident response in rural areas. Technology must be suited to long travel times and have long-lasting batteries for such journeys. Batteries should also be developed to be easily charged while rural first responders are traversing long distances.

4.3. Improved interoperability both for communicating across agencies, across devices, and across platforms

Rural first responders need devices that are both externally and internally interoperable. Because rural first responders often coordinate incident response across wide distances with many disciplines, areas, and jurisdictions, it is essential that the devices they are using can easily facilitate these connections. Devices must also be internally interoperable, working effectively and efficiently together to support first responders' needs during incident response. Improving internal interoperability may decrease the amount of time to transmit information and may also reduce the burden, frustration, and confusion of using multiple devices.

4.4. Affordable devices that are easy to fix and inexpensive to train on

Researchers and developers must consider existing barriers for rural first responders to implement communication technology. Rural first responders in this study had limited budgets that precluded them from replacing technology. Often, they had problems with the price of numerous devices and were also unable to update or upgrade their current devices. Additionally, our results suggest rural first responders often have few resources for technical support when they encounter problems their technology. Therefore, rural first responders would benefit from affordable technology that can endure for a long period of time, have low training burden, and be simple to update.

5. CONCLUSION

Research and development are needed to continue to improve and understand the communication technology of rural first responders. Efforts should be focused on reducing current problems and tailoring communication technology to be better suited to the rural context of use. We also encourage research in several areas. First, future studies are needed to move beyond self-report and begin to use scenario-based assessments (see Pilemalm, 2018) to elucidate problems experienced during incident response and highlight technology that works well in rural environments. Second, research is needed to understand the adoption of communication technology in rural areas, as our study suggests that rural first responders are hesitant to adopt new technology. Research is needed to understand both facilitators and barriers to adoption. Third, research using human factors and user-centered design is needed to ensure rural first responders are included in the research and development of communication technology made for them. This can ensure that technology will reflect the experiences, wants, and needs of rural first responders, as well as focus on alleviating the burdens currently caused by technology.

By continuing to study the communication technology experiences of rural first responders, technology can be developed and improved for this population. This could shift how rural first responders view, adopt, and use communication technology. Rural first responders may transition away from viewing

communication technology as a problem and burden, and instead view communication technology as a trusted tool for more effectively and efficiently protecting and serving their communities.

Acknowledgements

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