The 2024 Roxborough Park Wildfire Evacuation Drill - Lessons learned after planning, running, and studying a community evacuation exercise

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ABSTRACT

In June 2024, the community of Roxborough Park, Colorado conducted a wildfire evacuation exercise (or drill for short) that was observed by a team of researchers. This collaborative effort involved residents, community organizers, first responders, emergency managers, and researchers. The drill aimed to test and refine evacuation protocols, communication strategies, and coordination among various stakeholders and gave the opportunity to researchers to collect information related to human response in a wildfire evacuation. The present contribution describes the community as well as the roles and activities of the parties involved, the drill itself, followed by lessons learned. Drill participants practiced real-time decision-making, route navigation, and emergency response actions in response to a hypothetical wildfire threat. The exercise highlighted strengths in community readiness and identified areas for improvement, such as traffic management and information dissemination. Feedback from participants and observers was collected to inform future planning and training. The drill underscored the importance of community engagement and interagency cooperation in mitigating wildfire risks and ensuring the safety of residents. This proactive approach could serve as a model for other Wildland-Urban Interface (WUI) communities striving to enhance their wildfire resilience.

Keywords

WUI, wildfire, evacuation, community preparedness.

INTRODUCTION

As communities in the Wildland Urban Interface (WUI) are increasingly exposed to wildfires, timely, efficient and safe community evacuation has become an essential tool to mitigate wildfire related risks (Bénichou et al., 2021). Community evacuations are complex events that require a large number of individuals and organizations to collaborate, including emergency management, first responders, community organizations, and residents. Community evacuation exercises - or drills for short - are opportunities for the involved parties to practice evacuation procedures and to diagnose potential pain points in the evacuation process (Menzemer et al., 2024; Ronchi et al., 2023; Steen-Tveit et al., 2020). In addition to that, drills are of value to researchers as a source of data that can be used to gain insights into community evacuation dynamics as well as a source of data to calibrate computational evacuation modeling tools (Gwynne, et al., 2020).

In the context of crisis management, several frameworks regarding planning, executing, documenting and analyzing drills have been proposed (Gebbie et al., 2006; Grunnan & Fridheim, 2017; Steen-Tveit et al., 2020). Previous research included observations from table-top exercises and field observations (Lotter et al., 2016; Steen-Tveit et al., 2020). Drills have shown to increase perceived preparedness (Perry, 2004). In addition, some studies have explored how drills relate to performance; for example, one study documented more errors in medical procedures that were carried out during a disaster drill compared to routine operations (Claudius et al., 2008). Another study found that total evacuation times from buildings were significantly slower during unplanned evacuations compared to routine fire drills (Kinateder et al., 2021).

To the best of our knowledge, community wildfire evacuation drills including residents, emergency management officials, and researchers, have not been described in detail previously. Planning and executing a drill are challenging tasks that require collaboration among several parties. The present contribution therefore describes the roles of three different types of organizations - community, emergency management, and research - during a drill in Roxborough Park, Colorado that was held on June 29. This is the second drill of this kind in this community that was observed by researchers after a first drill performed in 2019 (Gwynne et al., 2023). The remainder of this contribution describes the community of Roxborough Park as well as the roles and activities of the parties involved, followed by a discussion of the lessons learned from the drill 2024 (For a detailed report, see Dugstad et al. 2024).

ROXBOROUGH PARK, COLORADO

Roxborough Park is a WUI community in the United States of America and located in Douglas County along the Front Range of Colorado in the foothills southwest of Denver. The community was developed in 1974 comprising approx. nine km^2 of heavily vegetated land bordered by the Dakota Ridge to the east, Roxborough State Park to the east, south and the extreme southwest and the Pike National Forest to the west and northwest and the 250 home/golf course subdivision of Ravenna. There are 1,057 homes with a current population estimated around 3,000 people. Many areas in Douglas County are at exposed to noticeable wildfire risks, and more than one third of the population live in wildfire risk areas (Douglas County Sheriff's Office, 2021). In addition, the community has experienced notable wildfires in the past (e.g., 1996 Buffalo Creek Fire and the 2002 Hayman Fire).

There is only one entrance and exit road to Roxborough Park through a gap in the Dakota Ridge. However, Roxborough Park does have three additional Emergency Egress Easements (EEE). One EEE to the south is a dirt road that takes evacuees through densely forested areas to the town of Sedalia. The two EEE to the north take evacuees through the Ravenna subdivision to Waterton Road. Figure 1 shows a map of the community.

Roxborough Park has been a Firewise USA recognized community since 2007 and has had a volunteer Fire Mitigation Committee (RPFMC) since 2003 that coordinated with agencies and researchers for the 2024 evacuation drill (National Fire Protection Association, 2024). The RPFMC developed a Community Wildfire Protection Plan (CWPP) that aims to reduce wildfire risks in the WUI and protect the lives, properties, and natural resources of Roxborough Park (Roxborough Park Foundation Fire Mitigation Committee, 2020).

Douglas County Office of Emergency Management (DCOEM)

The Douglas County Office of Emergency Management (DCOEM) is the main hub for the coordination of disaster

management and training, homeland security, emergency preparedness and education, multi-agency cooperation, as well as emergency medical and trauma system coordination within Douglas County, Colorado.

The Director of Emergency Management coordinates and facilitates incident management and emergency preparedness in Douglas County and collaborates with private and public agencies, emergency response agencies, and elected officials to effectively respond to incidents.

DCOEM is responsible for emergency documents and board approved policies, including the county's disaster preparedness guide, aerial support for wildfires, fire restrictions, and coordinating animal shelters during an emergency. They oversee a wildland firefighting handcrew that specializes in remote wildland fires that engines cannot access. DCOEM also provides information on evacuation plans, conducts evacuation drills, planning and building an emergency kit and more.

The DCOEM is a division of the Douglas County Sheriff's Office (DCSO). DCOEM tries to conduct, on a rotating schedule, emergency evacuation drills at least every five years in WUI communities. Drills are intended to prepare residents for the eventuality of an evacuation. This also allows deputies and first responders to familiarize themselves with the intricacies of the communities, engage with residents, and train for evacuation procedures.

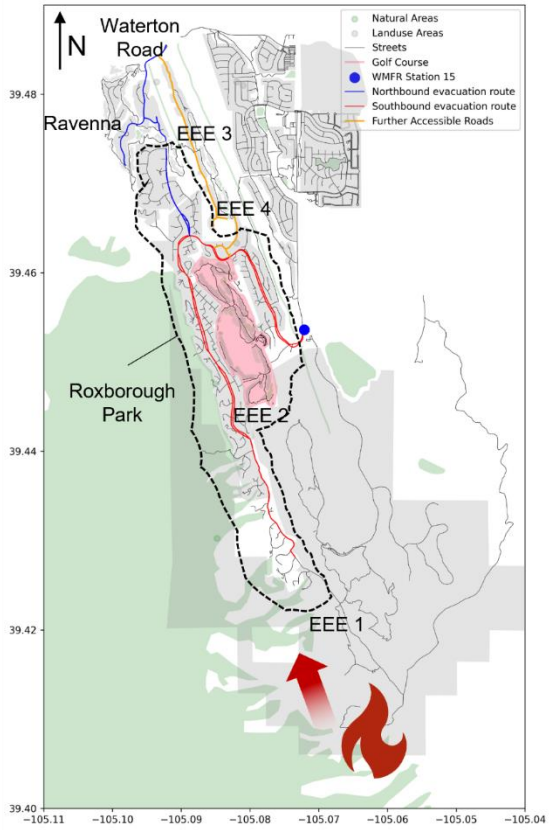

Figure 1. Overview of Roxborough Park, Colorado. Black dotted line: Roxborough Park; approximate area participating in the drill; Red arrow and flame: wildfire scenario illustration. Note that only EEE 3 and 4 were available during the drill. Source: Roxborough Park Foundation and Open Street Map.

DCOEM uses an emergency notification service for emergency communications with Douglas County residents. The system is an opt-in system, and residents must register with the DCSO, create a profile, and select how they wish to receive alerts: text, voice, or email. For the 2024 drill, only residents registered as participants in the drill would receive the alert (i.e., residents who registered for the emergency notification service but not for the drill did not receive an alert).

West Metro Fire and Rescue (WMFR), the district fire agency, collaborated with DCOEM on the evacuation drill. WMFR Station 15 was used as the command center for the drill and the rendezvous point for resident evacuees to report their completion of the drill.

DESCRIPTION OF THE DRILL

Figure 2 provides an overview of the various activities of the community, DCOEM, and the research team before, during and after the drill. Several weeks prior to the drill, residents were invited to participate. The invitation contained a description of the drill itself, the research component, as well as information on how to sign up. Critically, residents could sign up for the drill and the research separately to ensure that participation in the drill was possible without being part of the research. Residents who had signed up for the drill were added to an emergency notification service database and received additional information about the drill. Note that residents were informed about the date but not about the specific time the evacuation would be triggered (this results in a so-called semi-announced drill). Residents who also signed up for the research were sent additional relevant material (e.g., information about the research, consent forms, surveys). All in all, 128 households (ca. 12% of all households in the community) with 177 vehicles registered for the drill.

On June 29, 2024 at 9:00, residents who had signed up were alerted by DCOEM via the emergency notification service (voice messages, text messages, or e-mail). The notification informed residents of a wildfire encroaching from the south and further instructed them to evacuate the community via the northbound evacuation routes through the neighboring community and to assemble at WMFR Station 15. The evacuation scenario chosen included that not all EEE gates would be open for the drill. As in the event of a real evacuation where EEEs could be blocked, only the north EEE 3 & 4 were open (see Figure 1).

As residents arrived at the rendezvous point, they had the opportunity to ask questions and to hand in self-report data with the research team (e.g., surveys, postcards; for details regarding the surveys and other data collection methods, see Dugstad et al., 2024). Once residents had completed the drill, they were invited to explore the signed evacuation routes including the EEEs.

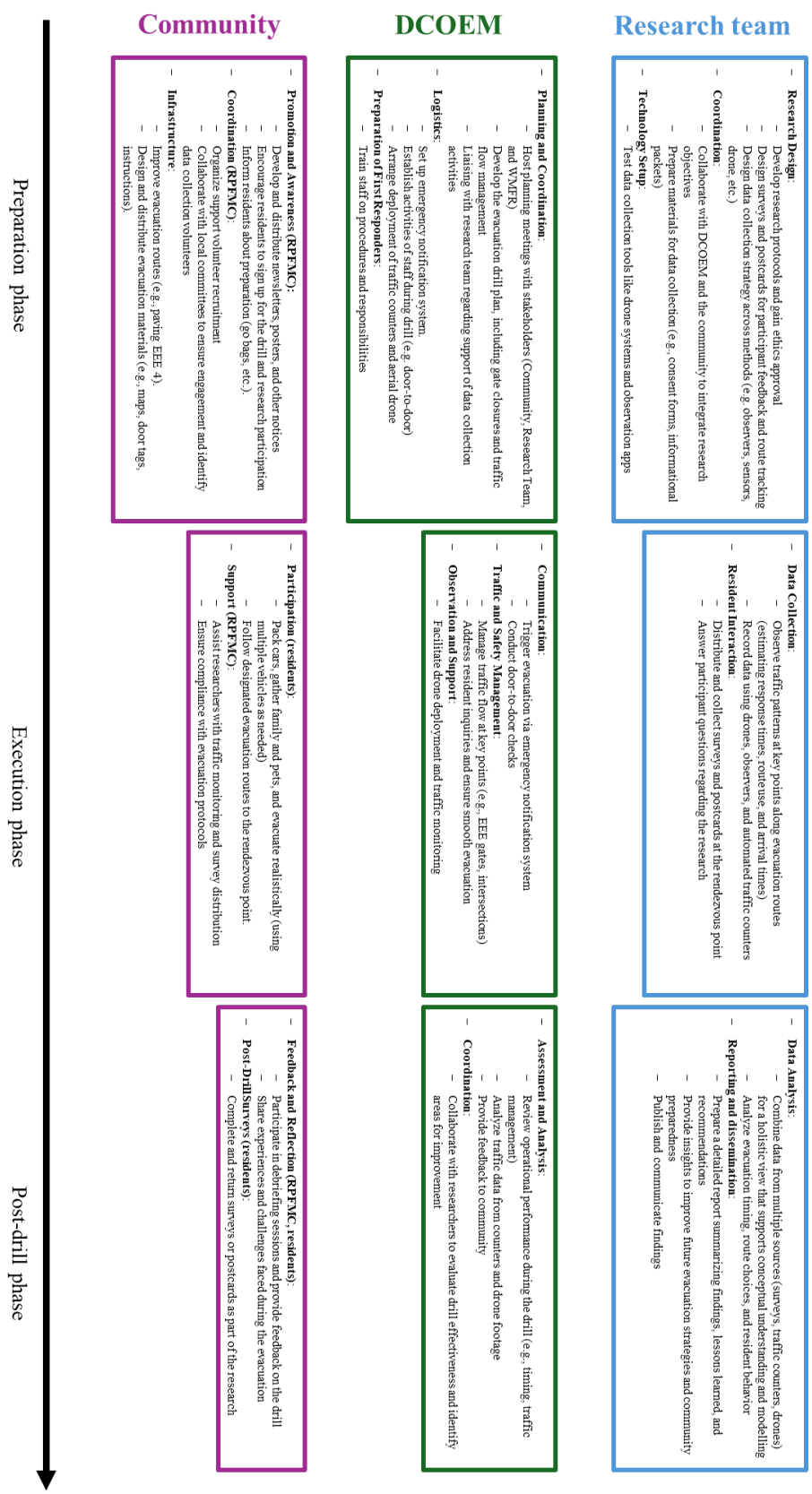

Figure 2. Flow chart of activities in the preparation, execution, and post-drill phases.

Roles and activities of the community

The RPFMC prepared a promotion plan for the evacuation drill in January 2024. The plan included the community communications alternatives and frequency in which they were to occur. The community communication alternatives include monthly community newsletter, email blasts, bulletin boards at mail pods, other public events. The principal messaging method was with the newsletter with monthly articles on the evacuation drill, information regarding signup, preparing go bags (a bag packed with essential supplies and documents kept ready for use in case of an emergency that requires rapid evacuation), and what to expect. An October 2024 community survey showed that 85% of residents read the newsletter. Posters were placed in the mail pod bulletin boards in June 2024, and online scheduling system was used for sign up and data collection.

Several lessons were learned during a previous drill in 2019. For example, the exact start time (9:00 AM) of the drill had been announced in advance. This led to residents lining up in their vehicles at the EEE at 9:00AM waiting for DCSO deputies to unlock the gates. That is, they had begun evacuating before the evacuation notice had been issued. In order to avoid a repeat of that experience in 2024, the residents were told the drill would occur between 8:00AM and 10:00AM.

Residents were encouraged to prepare go bags in advance of the drill and when alerted by emergency notification system, to pack their cars, gather their family and pets, and depart for the EEE. The rendezvous point for the drill was at WMFR Station 15 located just outside the entrance to the Roxborough Park community.

Residents were also encouraged to participate as realistically as possible and encouraged to evacuate as many vehicles as they would in a real emergency. As a result, of the 128 households that signed up for the drill, 177 vehicles were registered for evacuation (averaging 1.38 vehicles / household). To maximize participation and to accommodate distribution of evacuation materials needed for the research team registration was closed two weeks before the drill. Ninety-seven research participants returned completed surveys; they were on average 66.33 years old (SD = 9.74 years; Figure 3) and reported that they had lived in the community for approximately 11 years (SD = 9.04 years).

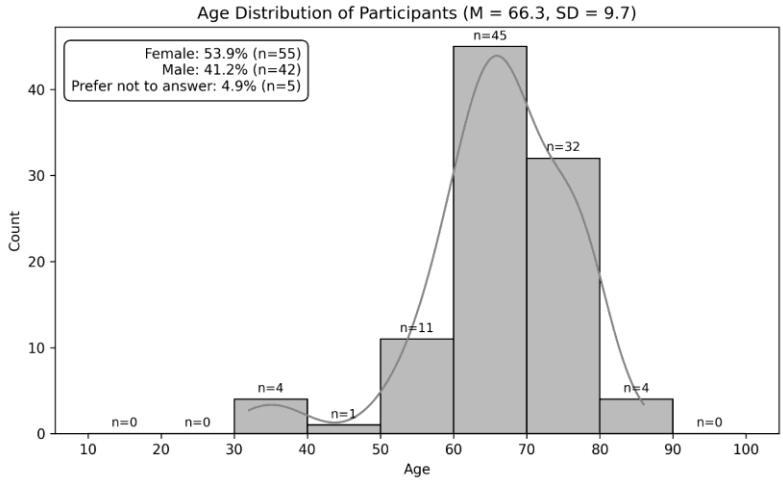

Figure 3. Age and gender distribution of drill participants.

The RPFMC members and resident volunteers assembled envelopes with printed copies of instructions about the drill, informed consent forms for the research, survey, evacuation route maps, and a green evacuation door tag (Figure 4) to assist DCSO deputies in the door-to-door checks of evacuees. The tags were designed by the RPFMC and printed by a local electrical utility company. The envelopes were hand delivered to participating residents the week before the drill. In addition, the RPFMC recruited volunteers (e.g., high school students and scouts) from the area to assist the researchers with data collection, traffic monitoring, and debriefing evacuees.

In the weeks leading up to the drill, Roxborough Park Foundation paved EEE 4 which was considered unusable due to erosion. EEE 3 & 4 lead Roxborough Park evacuees through the Ravenna subdivision to the north on two major streets and merge just before the exit of Ravenna onto Waterton Road, which connects the communities to the greater Denver area.

The day before the drill, emails were sent out to inform the community of the drill to explain the presence of over 20 DCOEM, Sheriffs, and WMFR vehicles.

Roles and activities of emergency management

DCOEM facilitated the planning and execution of the drill. Prior to the drill, DCOEM organized several meetings with all involved parties (RPFMC, WMFR, research team) to plan and coordinate the drill. Residents who signed up for the drill were added to a database so that they would receive the evacuation notification. This database was explicitly established for the drill.

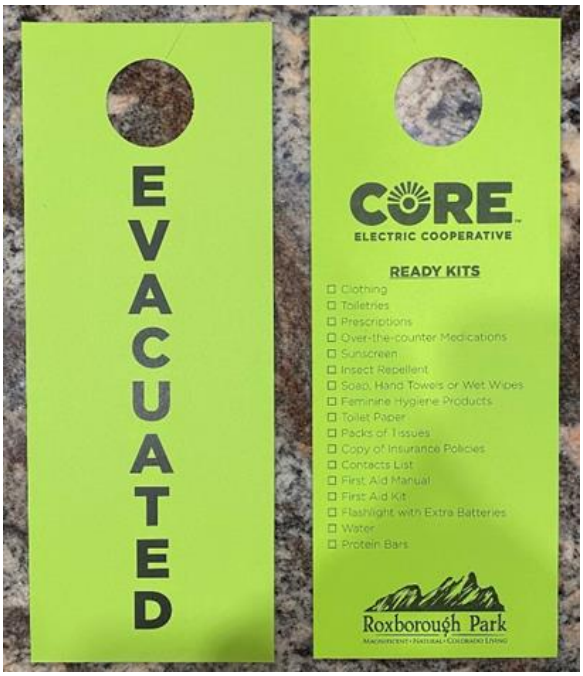

Figure 4. Evacuation door tag with checklist; Source: RPFMC.

DCOEM also supported the data collection by providing and installing automated traffic counters as well as piloting an aerial drone at a location critical for the research team.

On the day of the drill, DCOEM triggered the evacuation order, managed traffic in the community, and responded to questions from residents. Further, DCSO deputies practiced evacuation procedures for the chosen scenario. All in all, 38 DCSO/DCOEM/WMFR staff contributed to the drill.

Roles and activities of the research team

The research team observed traffic at several key points along the evacuation routes and surveyed participants after the drill. The research project aimed to understand evacuation timing, route choice, as well as the subjective experience of residents during the drill. The data collected provides insights that support the CWPP's goals by highlighting specific actions that could be taken to enhance community preparedness and resilience against wildfire threats.

Prior to the drill, the research team submitted a research ethics application as the data collection involved human participants and addressed several ethical considerations, such as privacy, confidentiality, data management and free and informed consent. For example, drone footage that was recorded during the drill had the potential to collect identifying information. To mitigate this, the drone flew at a height and recorded at an angle that allowed the tracking of vehicles at one intersection but not the identification of individual residents, license plates or home locations. In addition, residents could choose to participate in the drill without participating in the research. The research team asked residents who signed up for the research to sign an informed consent form and hand it in upon their arrival at the fire station. In addition, residents were asked to indicated their consent in participating in the research also by placing colored paper tags on their vehicle. The consent form described the purpose of the research, the methods of data collection used, the risks and benefits of participating in the research, and privacy

and confidentiality.

To better understand participants' subjective experience and route during the drill, they completed two self-report measures: (1) a survey and (2) a postcard. The survey contained demographic questions (e.g., age, gender, household size) and questions on decision-making (e.g., reason for following a particular route), actions (e.g., actions performed before leaving their property), and perceived preparedness (e.g., how prepared they felt to evacuate from a wildfire). The survey comprised mainly single-choice and multiple-choice questions to minimize cognitive load as well as some open-ended questions to allow participants to describe their experience in their own words. The postcard asked participants to report the timing of evacuation-related actions while enroute (e.g., receiving the evacuation notification, leaving their property, arriving at the fire station) and to draw the route that they followed during the drill. The postcard provided structured and close to real-time subjective recall of departure and arrival times and route use.

After the drill, the range of different data sources needed to be combined to describe the drill holistically; this required, for example, assessing the reliability of different observation methods (e.g., by comparing data from human observers to automated traffic counters) and to tie the observed data to the experiences shared by residents. For details on the data analysis, see the scientific report (Dugstad et al., 2024).

RESULTS, DISCUSSION AND LESSONS LEARNED

Overall, the drill achieved its goal in improving the community preparedness and produced several key insights. Through participation it encourages community familiarity with the plans in place (although the extent of this was not assessed in this work). Most notably it provided estimates for the evacuation times generated by the community response, including pre-evacuation times (i.e., the time between the emergency notification was triggered and residents were on the road), route use, and travel times (i.e., the time residents needed to reach the rendezvous point). Figure 5 shows the cumulative pre-evacuation and total evacuation times. It took 55 minutes until 90% of participants began evacuation travel, and 37 minutes for 90% for participants to complete the evacuation. This somewhat counterintuitive observation reveals that variability in total evacuation times was primarily driven by pre-evacuation behavior and not the time needed for travel and highlights that even in a semi—announced drill pre-evacuation times can vary significantly.

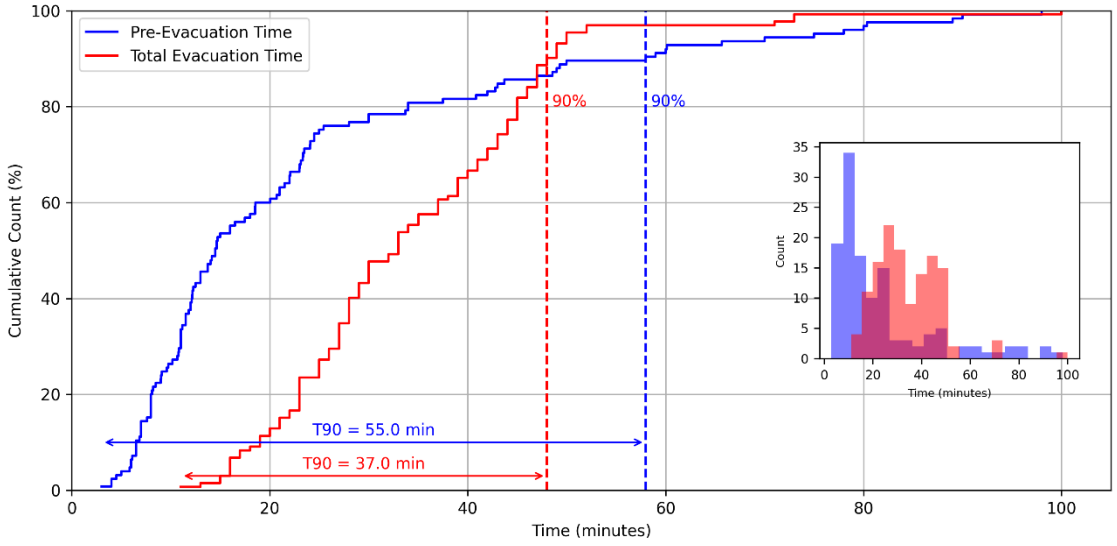

Figure 5. Cumulative count and histogram (inset) pre-evacuation and total evacuation times.

The drill also improved perceived preparedness, with average self-reported preparedness increased from 2.81 to 3.65 (on a scale from one to five). This was exemplified by statements from residents such as, "I'm better prepared and have a timeline knowledge I didn't before". This finding is in line with previous work, e.g. in the health care domain, that found that preparedness exercises improved perceived preparedness (Skryabina et al., 2017).

Further, the drill identified challenges in the deployment of the emergency plan, such as that not all residents received the alert - potentially due to poor cell service coverage and that not all residents followed the suggested

evacuation routes. When asked for the reasons of the chosen evacuation route, the majority (78%) stated that they followed instructions, but some also indicated that they took the shortest (22%) or most familiar (12%; see Dugstad et al., 2024). These findings indicate that the drill successfully served as a diagnostic tool to identify potential pain points (Gwynne et al., 2020; Menzemer et al., 2024).

The objective of this contribution was to provide practical information to those who are interested in conducting and studying community evacuation drills. Throughout the planning, execution, and analysis of the drill, several lessons were learned:

1. **Planning.** Organizing and facilitating a community evacuation exercise requires planning and time. The planning effort for this drill started several months prior to the drill. Consideration in the planning included timing and availability of the required resources (e.g., staff, volunteers, etc.). The goal was to have the drill during good weather conditions but before the beginning of the fire season. The research goals and methods need to be adjusted to the available time and resources. It should also be noted that the data collection activities (and associated objectives) provided additional input into the drill planning – placing additional emphasis on the observations made and the detailed planning required (e.g., in the logistics of distributing surveys).
2. **Communication.** Depending on the scale of the evacuation drill and associated research work, more or less communication among parties is required. However, clear communication and documenting roles and responsibilities are essential. For example, in the Roxborough Drill, DCOEM supported the research by placing automated traffic counters along evacuation routes. This required both an understanding of the layout of the community as well as agreements on when and where the devices were to be installed. Similarly, it was critical that the observers from the research team who were placed within the community did not obstruct the drill and conducted their tasks safely.
3. **Buy-in from stakeholders**. Community organizations, emergency management and most importantly residents need to be engaged early to ensure the necessary buy-in from residents. For researchers this means transparent communication of study goals, methods, and data management. It further requires to select minimally invasive observation methods (see point on privacy below).
4. **Research ethics.** This requires rigorous research ethics protocols. For instance, the research team communicated with the relevant Research Ethics Board to ensure that ethical requirements were being followed. The main challenge, from an ethics and privacy perspective, is that informed consent had to be ensured. For example, residents needed to be able to participate in the drill without being obliged to also participate in the research.
5. **Privacy.** Given the relatively small size of the community, more care was required to protect the privacy of residents. For instance, after discussion with the community, the research team decided against using GPS recording devices as this would have allowed identifying the home addresses of residents. Further, additional considerations should be taken into account when it comes to collecting potentially identifying information that is unique to the local context. For example, to avoid collecting data from residents who did not want to participate in the research, those participating were asked to place colored tags on their vehicle.
6. **Reliability and redundancies.** Field observations can be messy and data collection is less controlled than in a laboratory (Haghani, 2020; Kinateder et al., 2014). This requires selecting robust research methods that are not prone to fail in the local conditions. For example, the research team used both manual (i.e., pen and paper) and cell phone based counting methods.
7. **Documentation**. Evacuation drills generate a significant amount of data, including the timing of evacuations, the effectiveness of communication methods, the behavior of residents, and the identification of any obstacles or issues encountered during the drill. To transform this raw data into meaningful information and actionable insights, a structured documentation strategy is crucial. This includes creating detailed reports that summarize the findings from the data analysis. These reports should highlight critical insights, such as which areas of the evacuation were most efficient and which encountered the most problems. From these, actionable recommendations can be extracted, for example to improve community preparedness or planning of future drills. For researchers this also means communicating key insights clearly and without scientific jargon to stakeholders.

Overall, the lessons learned are complementary with the existing literature. For example, one paper providing recommendations for crisis management discussion-based and operations-based exercises which highlighted the importance relevant scenarios (the drill used a scenario that was deemed to be most likely; see above), clear communication with all participants and detailed pre-planning (Grunnan & Fridheim, 2017).

The 2024 Roxborough Park Wildfire Evacuation Drill provided a crucial platform for testing and refining community evacuation protocols, communication strategies, and stakeholder coordination. The exercise

highlighted both strengths and areas for improvement, such as traffic management and information dissemination. Key lessons learned included the importance of thorough planning, clear communication, early stakeholder engagement, rigorous research ethics, and robust documentation practices. These insights are vital for enhancing community preparedness and resilience against wildfire threats. It is hoped that they can also serve as a practical guide for other WUI communities, authorities and researchers who aim to better understand and improve evacuation procedures through evacuation exercises. The detailed documentation and analysis of the Roxborough Park drill offer valuable methodologies and strategies that can be adapted and applied by other communities to conduct their own evacuation drills.

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