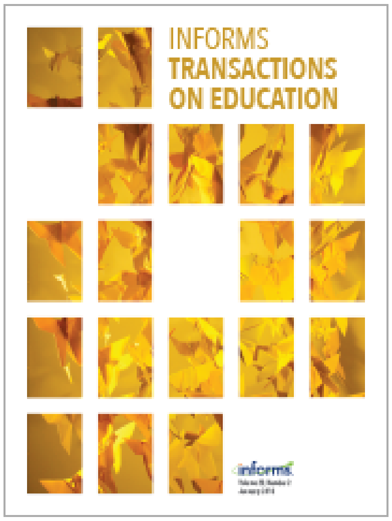

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Game

Logistics to the Rescue: An Elementary Introduction to Planning in Disaster Response Decision Environments

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Abstract. *Logistics to the Rescue* is a spreadsheet K–12 game designed as a platform to familiarize students with emergency logistics. In the game, students play the role of an emergency dispatcher, assigning locations to routes. The challenge presented is threefold. Students must serve as many locations as possible within a time-frame. Midroute, an additional set of locations whose requests may be inaccurate is revealed; these requests are termed *unverified demand locations*. Students must balance uncertainty and time while serving as many accurate locations as possible. Finally, they are interrupted to learn whether the unverified demand locations' requests are accurate. The game serves as a pedagogical tool for simulating a postdisaster environment and it exposes the real-time implications of social media and the data it produces. It emphasizes the importance of social and ethical awareness in the field of emergency logistics by showcasing the consequences induced by civilians' reliance on social media in times of crisis. In doing so, it highlights the expansive boundaries of engineering's disciplines and content. It is our hope that *Logistics to the Rescue* will encourage students, especially girls, to pursue careers in science, technology, engineering, and mathematics by providing a distinctive narrative where engineering is viewed as creative/collaborative rather than technical/a-social.

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Supplemental Material: The Teaching Note, spreadsheet, and presentation are available at https://www.informs.org/Publications/Subscribe/Access-Restricted-Materials.

Keywords: disaster response • humanitarian logistics • role-playing games

1. Introduction

On October 29th of 2012, after Hurricane Sandy's landfall, the United States experienced its first wave of mass civilian reliance on social media as a form of emergency communication (Council 2012). Since then, it has been globally observed that during catastrophic events, social media users turn to platforms such as Facebook and Twitter to exchange real-time information on developing disaster situations. For example, in 2014 after Typhoon Haiyan made landfall in the Philippines, digital volunteers at Micromappers were able to harness information on social platforms and compile a real-time map to display rescue requests and identify areas that were heavily impacted by the storm (Mackenzie 2013). In 2015 after the devastating earthquakes in Nepal, Google was able to procure information on social platforms to reunite families and inform loved ones of their safety through their website, Google Person Finder (Baker 2016). Most notably, in 2017 after Hurricane Harvey made landfall in Texas, grassroots organizations were able to provide relief to over 14,600 victims by displaying social data on an interactive map consisting of demand locations, with pending and fulfilled rescue requests, and mobilizing civilians with the necessary equipment to conduct rescues at these demand locations (MacMillan 2017, Sullivan and Holley 2017).

The aforementioned response efforts substantiate a claim that social media platforms have the potential to rapidly cultivate vital information about civilian safety during disasters. This information can be used by official response agencies in their rescue efforts. Traditionally, these agencies have relied on ground assessments, that can often take days to conduct, to collect this type of data (FEMA 2016). Emergency responders have been reluctant to incorporate social methods in their data collection efforts (Su et al. 2013). This reluctance can be partly attributed to the perceived credibility of the data retrieved from social platforms. To official responders, these data are initially considered unverified, as it is not being relayed by a trusted source. In fact, a survey of emergency response agency personnel found that over 75% of respondents would not consider social media data unless they could be verified by a credible source, a process that, as previously mentioned, could take days to conduct (Su et al. 2013). It is well known that the rapid administration of supplies to affected areas significantly reduces human suffering and loss of life; hence, logistics critically influence the effectiveness and efficiency of a response operation (International Federation of Red Cross and Red Crescent Societies 2000, Van Wassenhove 2006). The information concerning demand locations significantly affects the distribution of relief to affected populations, thus it is critical to ascertain the advantages and disadvantages of employing these social media data in response operations.

In *Logistics to the Rescue*, a single vehicle response to a disaster is considered. Initially, all known demand locations and their associated rescue requests are traditionally sourced and considered *verified*, signifying that the rescues requested at these demand locations are known to be accurate. Players are then interrupted midgame, twice. The first time, a set of socially sourced demand locations and their associated rescue requests, considered *unverified*, are revealed and students must decide whether to incorporate these demand locations in the remainder of their route. The accuracies of the rescues requested at these unverified demand locations are unknown, meaning that the rescue request of an unverified demand location may or may not exist and servicing the point may or may not result in a life saved. The second time the players are interrupted, the accuracy of the rescue requests at the unverified demand locations is revealed and students are able to complete their route knowing the full picture of the decision environment. The game consists of two rounds. The first round mimics a three-stage decision process. Each stage corresponds to the revelation of new data and captures a subset of the route created in the previous step. This gently introduces students to the permanence related to their routing decisions. The second round mimics an online decision environment where data evolve over time and where each decision made is locked in, no longer allowing for any route flexibility and exposing the high-stakes nature of disaster response.

Much effort throughout the development of *Logistics to the Rescue* was focused on encouraging girls to pursue careers in science, technology, engineering, and mathematics (STEM). The intentional focus on girls was motivated by the disproportionate percentage of bachelor's degrees awarded to women versus the percentage of engineering-specific bachelor's degrees awarded to women. A report published by the National Science Foundation indicates that, in 2014, 57% of bachelor degree recipients were women, whereas only 20% of engineering-specific bachelor degrees were awarded to women (National Center for Science and Engineering Statistics 2017). The National Academy of Engineering has stated that the use of empathetic and philanthropic language in job descriptions is effective in attracting more girls to engineering (National Academy of Engineering 2008). Research has shown that fields like industrial engineering allow women to "find an authentic way of combining the prestigious social credentials of being an engineer with practices they value, without losing their sense of self" (Brawner 2012, p. 312). It has even been documented that different fields in engineering value different principles, which affects women's participation (Godfrey 2007). Godfrey's (2007, p. 11) study found that

> Engineering Science [. . .] attracted high numbers of female students for whom mathematics held no fear. Mathematics was seen by these students as the tool that opened the doors to problem solving and modelling that required innovative and quite creative thinking. The modelling of real life, identifiable problems, [...] was accessed through very specialized computational mathematics techniques. These were applications seen by students as useful to people and challenging intellectually. Therein, it is suggested, lay the attraction Engineering Science held for female students and others who sought a connection with the material they were studying.

Logistics to the Rescue simulates a disaster response operation that employs the use of industrial engineering (IE) methods for routing. By eliciting an understanding of the situation that postdisaster victims may find themselves in and by seeking to promote the welfare of these victims, the game is able to embody philanthropic and empathetic concepts. Concurrently, the game is also demonstrating how STEM disciplines can help others and how mathematics can be used to solve problems that may directly or indirectly affect participants.

Section 2 provides a review of the relevant routing literature and examines how the fundamental routing problem presented by *Logistics to the Rescue* relates to the existing literature on disaster relief routing. In Section 3, we discuss the development of the game and how the game supports a disaster decision-making process. In Section 4, the materials required to support the game are listed. Section 5 outlines how the game should be played. Our experience with the game and our final remarks are, respectively, presented in Sections 6 and 7.

2. Disaster Routing Literature

Previous publications have explored topics related to the dispatch of emergency vehicles in disaster response. For example, Hsueh et al. (2008), Mguis et al. (2012), Wex et al. (2014), Kirac et al. (2013, 2015), and Kirac and Milburn (2018) allocate the position of demand locations on the schedules/routes of emergency vehicles by minimizing the total tour cost. Although there is ample literature related to the optimization of disaster routing, few works consider models whose objectives allow for unserved demand locations to remain at the response stage. Examples of such models are proposed by Qin et al. (2017), Najafi et al. (2014), and Kirac and Milburn (2018). There are even fewer works that consider the uncertainty of data in a disaster response. Intuitively, the future demand locations of disaster victims are not known with certainty at the time of planning a disaster response. Most publications regarding disaster routing assume that all data are available in the planning stages of a disaster response (Najafi et al. 2014). Two strategies have been used to model uncertainty in regard to the manifestation of future demand locations within postdisaster communities: a dynamic planning strategy where data evolve over the response period and plans can be changed accordingly, utilized by Najafi et al. (2014), Özdamar et al. (2004), Hsueh et al. (2008), and Kirac and Milburn (2018), and a stochastic strategy where uncertain data are used to plan a response, utilized by Qin et al. (2017) and Shen et al. (2009). Although the incorporation of uncertainty related to the future revelation of previously unknown demand locations may, intuitively, seem to be the most appropriate characterization of uncertainty in the field of disaster response, the uncertainty related to the accuracy of the requests being made at demand locations proves to be just as critical when developing emergency routes (Shen et al. 2009). Kirac et al. (2013, 2015), Kirac and Milburn (2018), and Houston et al. (2015), model disaster response problems under uncertainty and analyze the implications of incorporating uncertain social media data in disaster response. Ntalla and Ponis (2015), Plotnick et al. (2016), and Tapia and Moore et al. (2014) examine and summarize the current and future roles of social media in disaster response by reviewing relevant literature and conducting expansive studies as well as interviews. All of the abovementioned academics have indicated that social media has much potential to become a useful tool in disaster response and that, although the uncertain nature of these data does pose significant challenges, the development of generalized models to quantify the improvements accomplished by incorporating these data might facilitate a shift in the perception of social media's role in disaster response. Moreover, the papers allude to the notion that the critical shift in emergency management (EM) agencies' perspectives is not likely to come from justifying that the qualities of social media data are comparable to those of 911 data. Instead, they propose that academics aid EM agencies in redefining their data performance metrics to measure helpfulness rather than accuracy.

Logistics to the Rescue is intended to mimic the role of a dispatcher, working within the first 72 hours of a large-scale disaster response operation. A dispatcher's job is to relay uncertain information and organize the appointment of people/vehicles in emergency services. Because of its simplicity, this paper's formulation of this problem most closely resembles that presented by Kirac and Milburn (2018), as players are asked to solve variants of the orienteering problem (OP), a special case of the team orienteering problem (TOP). For more information concerning the OP, we direct readers to Tsiligirides et al. (1984) and Golden et al. (1987). In disaster routing, the scheduling of service to demand locations within supply routes can drastically change depending on the objective of the model (Luis et al. 2012). This implies that any misinterpretation of the game, on the players behalf, will lead to insignificant results. Thus, given that stochastic modeling is considered to be an advanced topic in engineering and that the target audience of the game is composed of K–12 children, *Logistics to the Rescue* considers a variation of the dynamic programming strategy in order to account for the uncertainty related to the future revelation of previously unknown demand locations. Specifically, it considers a three-step dynamic planning strategy where the player is allowed to reroute only after two specified time intervals. Information concerning additional demand locations and their requests are only revealed at these specified times. One of *Logistics to the Rescue's* objectives is to help expose K–12 students to the potential advantages of incorporating social data in disaster response. More specifically, the game is intended to reveal a scenario where disaster routes that consider both 911 and social data perform at least as good as, if not better than, disaster routes that only consider 911 data, even when accounting for highly inaccurate social media data. To accomplish this objective, experimental design choices that incorporate the uncertainty pertaining to the accuracy of the requests, made at demand locations, were derived from Kirac et al. (2013, 2015), and Kirac and Milburn (2018), and integrated into a user-friendly format, which could be easily distributed and accessible to K–12 children. At the conclusion of the game, the routes created by players in each step are measured in terms of total lives saved and compared with one another using a benchmark from a case study.

3. Background

In 2018, a short disaster response activity was developed for, and administered to, an engineering summer camp comprised of middle school girls at the University of Arkansas. The purpose of the activity was to deepen the girls' understanding of and appreciation for the use of social data to improve

Table 1. 2018 Pedagogical Goals

Concepts	Description	Link to *Logistics to the Rescue*
Logistics	Field dedicated to the optimization of the purchase, transport, storage, and distribution of goods/services	The objective is to optimize the distribution of services in a postdisaster environment such that accurate demand served is maximized within a given time.
Search and rescue dispatching	High-impact branch of logistics concerned with the organization of transport between rescuers and victims	Each step in the game simulates the planning of a rescue team's dispatch route.
Deterministic static ("multistage") routing	The a priori coordination of effective and efficient routes when all parameters and variables associated with demand are known with certainty at the time of planning	In Step 1, all demand is verified and the accuracy of each demand location is known with certainty at the time of planning.
Uncertain static ("multistage") routing	The a priori coordination of effective and efficient routes when all demand variables are known but the demand parameters can only partially be determined at the time of planning	In Step 2, both verified and unverified demand are considered. The accuracy of unverified demand locations is not known with certainty at the time of planning. In Step 3, uncertainty is resolved and the accuracy of demand locations is known with certainty.
Uncertain dynamic ("online") routing	The real-time coordination of effective and efficient routes when the parameters and variables associated with demand are only partially known at the time of planning and further information is revealed during the execution of the routes	In Step 4, players are initially presented with verified demand. They are interrupted twice during route execution. The first time additional unverified locations are revealed and the second time the accuracy of these locations is disclosed.

disaster response; a more exhaustive list of goals for the activity can be found in Table 1. The activity consisted of a brief preliminary seminar overviewing the role of social data in disaster response logistics and was followed by a hands-on game to more formally introduce the intricacies of disaster response planning. The focus of the activity was on search and rescue (S.A.R.). The lecture highlighted the upward trend of population size and emphasized the proportional relationship between population, cost of infrastructure, and destruction caused by disasters. By escalating the risk of catastrophic damages while simultaneously increasing the value of the demand at stake, the lecture emphasized the significance of dispatch decisions. The game employed two modeling approaches, a multistage approach and an online approach. In the multistage approach, information was incrementally revealed over three separate stages. In every successive stage, a portion of the route created in the previous stage was made permanent and the remainder of the route could be modified to either incorporate new data or disregard data revealed to be insignificant. In the online approach, data were also incrementally revealed over time; however, every decision was made permanent upon its inclusion in the route. In a real postdisaster environment, decisions cannot be reversed and demand data are continuously evolving; thus, the inclusion of demand permanence and dynamic demand not only increased the complexity of the game but also increased the accuracy of the simulation.

4. Preparation

To play *Logistics to the Rescue* with students in a classroom setting, a spreadsheet was developed using Excel 2016 for Mac OS. However, it is also compatible and has been tested with Excel 2016 for Windows OS. *Logistics to the Rescue* is not compatible with some versions of Excel, for example, Excel version 16.22 for Mac OS. *Logistics to the Rescue* is a single-player game, and every participating student will require access to a computer running Excel 2016. The key operational procedures, regardless of the operating system being used, are Excel macros, which must be enabled upon the initiation of the spreadsheet game.

The game's pedagogical value hinges on a strict adherence to a layered curriculum approach. In this approach, steps are revealed one at a time such that each new concept builds upon the last. Consequently, it is recommended that all participants be unfamiliar with the entirety of the activity and that each individual instruction be withheld until the step corresponding to its predecessor has been finalized. The following paragraph outlines the content of the preliminary lecture as well as facility recommendations.

Logistics to the Rescue is ideally played during a lesson lasting anywhere between 1.5 and 2 hours, and it is best to have each student seated at her own computer. The primary instructor of the activity guides students through the presentation while additional instructors keep students on track and help with questions. Thus, it is recommended that at least two instructors be present, regardless of class size. If class size exceeds 20, we recommend that a 1:10 instructor to student ratio be followed. Students should be configured such that a projection of introductory materials and instructions is visible to everyone. Prior to initializing the game, students are engaged in a presentation concerning the implications of increasing population and propensity of vulnerable infrastructure on S.A.R. logistics. This subject is narrowed to highlight the rising threat posed by disasters and steered to focus on the value of information in the context of S.A.R. logistics. Methods of collecting this type of actionable information are discussed, beginning with traditional methods, such as 911, and transitioning to technologically advanced methods, such as social media platforms. The potential impact of choosing whether to incorporate information derived from state-of-the-art technologies is examined, and both the positive and negative implications are discussed. Questions such as "How might using social media data negatively affect a response effort?"; "How might discarding information posted through social media negatively affect a response effort?"; and "Can you think of any challenges in choosing how to use social media?" are used to guide students through a discussion surrounding the implications brought about by the use of social media in post-disaster responses. Through an example routing scenario, students are able to observe how information evolves over time for two distinct logistic strategies. The first strategy considers information collected using both traditional and technologically advanced methods. The second strategy only considers information collected utilizing traditional methods.

5. Playing the Game

Logistics to the Rescue is a single-player game. It is played in two rounds. The first mimics a three-stage decision process. The second mimics an online decision environment. Although each round follows a different approach, routes created in any round of the game must begin at the depot, end at the depot, and cannot service any demand location more than once. Additionally, routes created in any round of the game must be no longer than a prescribed duration, measured in our game as units of distance but also conceptualized as time in our analysis. The validity of the preceding statement relating distance to time hinges on a critical assumption, which states that the rescue teams on the field, being dispatched in the game, maintain a constant speed while traveling from demand location to demand location. This assumption ensures that distance is proportional to time and aids in the conceptualization of distance as time in the remainder of the paper.

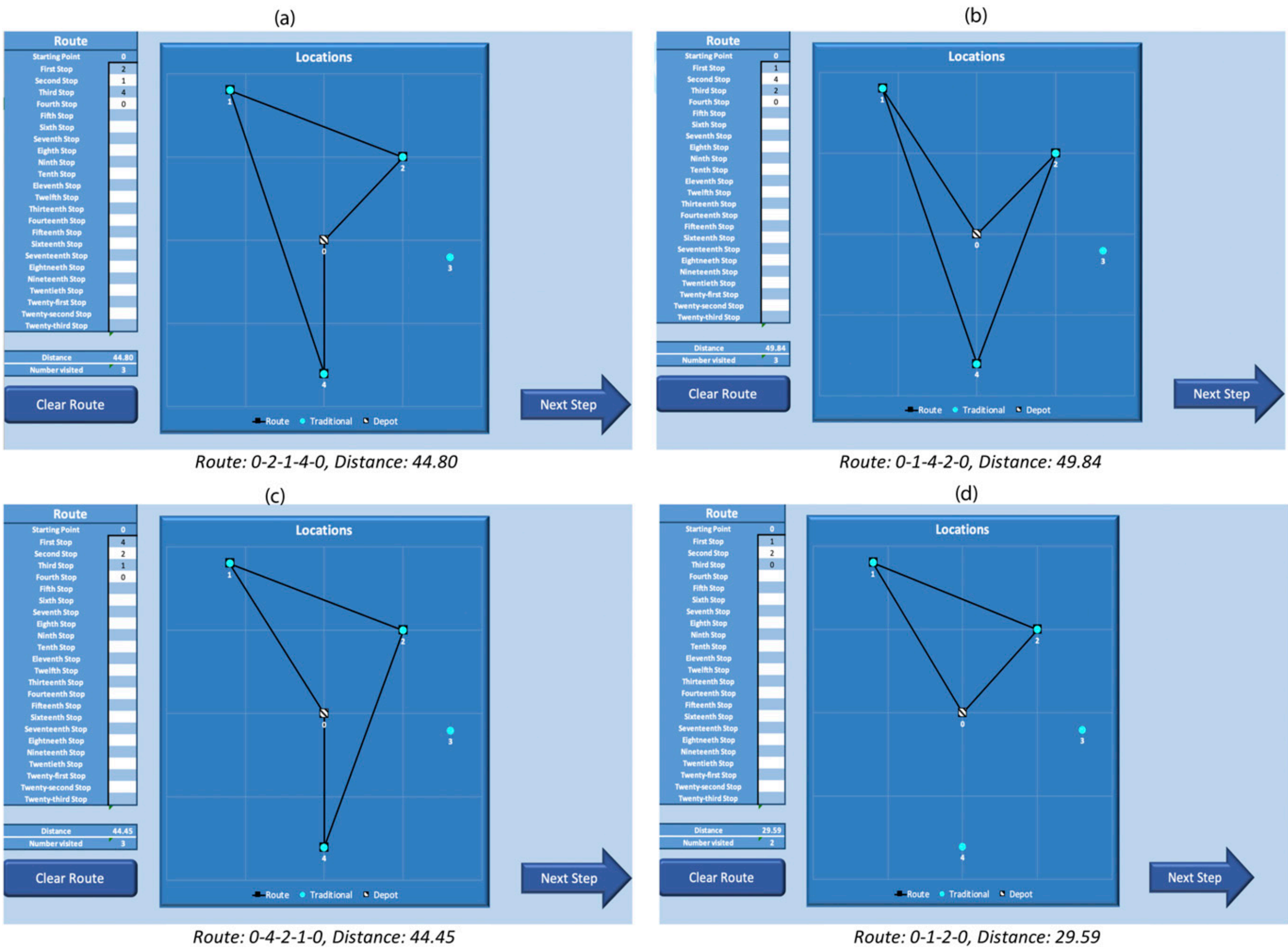
Because of the importance of maintaining a layered approach, the second round should not be discussed before the first round has been completed and the instructions and objectives concerning the stages within each round shall remain classified until the preceding stage has been finalized. Rounds one and two are briefly summarized below.

5.1. Round 1: A Multistage Approach

The first stage of round one only considers demand locations whose requests have been sourced using traditional methods, such as 911. We term demand locations meeting these criteria as *verified demand locations*; visiting such locations guarantees lives saved. In this stage, players can visualize and evaluate any number of route sequences by reordering verified demand locations within their route as they please. Once players have selected their favorite route sequence, the first route is finalized. An example of rerouting in this stage is depicted in Figure 1. In this hypothetical example, a player completes an S.A.R route while highly prioritizing the minimization of the total distance traveled. The player formulates an initial route, (a), and experiments with an alternate sequence, (b). This new sequence is longer than (a), so the player reroutes to produce sequence (c). Route (c) is shorter than all previously explored routes; however, the player wishes to exclude verified demand location 4 as it is very far away from verified demand locations 1 and 2. This leads to the ordering of (d). Route (d) is significantly shorter than all routes previously explored by the player, so it is chosen as the favorite and is utilized to finalize stage one of round one.

Upon initiating the second stage, players are instructed to create a new route, termed the second route, which, in addition to the previously revealed verified demand locations, incorporates *unverified demand locations*, a term defining demand locations whose requests have been sourced from social media platforms and whose request accuracy cannot be ascertained with full certainty. Because of the uncertainty related to the accuracy of the rescue requests at unverified demand locations, visiting such locations may or may not save lives. The challenge presented to players is that all first route stops with arrival times under a prescribed limit are permanently inserted at the start of their second route and only the remaining stops can be reordered or altered to include unverified demand locations. In the third stage, the accuracy of the requests made by unverified demand locations is revealed and players can create a third route. Once the accuracy of unverified demand locations is revealed, the set of unverified demand locations can be partitioned into *accurate* and *inaccurate unverified demand locations*. Furthermore, all demand

Figure 1. Stage One of Round One, Routing and Rerouting



locations, verified and unverified, can be partitioned into accurate and inaccurate demand locations, where *accurate demand locations* include both accurate unverified and verified demand locations, whereas *inaccurate demand locations* only include inaccurate unverified demand locations. Although players know with full certainty which demand locations are accurate, there is a catch. All second route stops with arrival times under a second prescribed limit (higher than in stage two) are permanently inserted at the start of the third route. This leaves players with only a small amount of time to make adjustments and visit the remaining accurate demand locations.

5.2. Round 2: An Online Approach

In this round, every move dictated by the player is made permanent and cannot be changed. Upon the initialization of the route, each player is shown only verified demand locations. However, once their route has surpassed a prescribed duration limit, an additional set of unverified demand locations is displayed on the screen. Lastly, once their route's duration has surpassed a second prescribed duration limit, information concerning the accuracy of the unverified demand locations is revealed.

6. Experiences with the Game

As previously mentioned, this game was used as an activity for an engineering summer camp, comprised of 6th and 7th grade girls, in 2018. In 2019, the game was administered to a new group of 6th and 7th grade girls participating in the same summer camp. A total of 35 campers, between 11 and 12 years old, participated in the activity and responded to the survey shown in Table 2. Of the 35 campers, 35 reported that the challenge was appropriate for their skill level and 34 reported that the challenge was appropriate for the skill levels of other students in their grade. Additionally, all 35 participants expressed that both their understanding of disaster response and their understanding of how social data can be used to support disaster response had improved in response to the activity.

The results of the 2018 and 2019 survey suggest that the game provided an appropriate level of difficulty for the 6th to 7th graders who participated in

Table 2. Postactivity Survey, Multiple Choice Section, 2018

On a scale from 1 (strongly disagree) to 5 (strongly agree), please rate your agreement with the following statements.
1. My understanding of disaster response improved as a result of this activity.
2. My interest in disaster response improved as a result of this activity.
3. My understanding of how social data can be used to support disaster response improved as a result of this activity.
4. My interest in the use of social data to support disaster response improved as a result of this activity.
5. The challenge presented by this activity was appropriate for my skill level.
6. The challenge presented by this activity was appropriate for the skill level of other students in my grade.
7. In order to effectively administer relief, emergency response agencies should monitor social media throughout the course of a disaster.
8. Social media is an effective way to communicate with officials when 911 is unreachable.

the activity. In fact, participants were asked to rate their agreement on a scale of 1–5 (strongly disagree to strongly agree) regarding whether the challenge presented by the activity was appropriate for their skill level. Of the 35 participants, 28 rated their level of agreement between 4 and 5, whereas only 7 participants rated their level of agreement as a 3. On both survey statements 5 and 6, the median of the responses reported between 2018 and 2019 is 4, indicating that students agree with the statements.

Our testing demographics are not exhaustive; however, the results support our opinion that the game is well suited for 6th to 7th graders between the ages of 11 and 12 years. Though appropriate for the aforementioned ages, the challenge presented by *Logistics to the Rescue* may not be appropriate for those of the upperclassmen grade level and above. Various factors limit the complexity of the activity. For example, the game only considers a small number of demand locations. Despite its superficial simplicity, *Logistics to the Rescue* is fundamentally a reproduction of two dynamic orienteering problem variants with uncertain demand. As a result, the game is able to retain a dimension of pedagogical value for higher-level audiences by providing instructors with a tool to illustrate very basic examples of both multistage and online planning problems. For advanced participants, the full pedagogical value of *Logistics to the Rescue* can be preserved by expanding its limitations. Recommended extensions are discussed in the teaching note.

7. Conclusions

Surveys conducted by The American Red Cross report that 80% of respondents expect emergency managers to monitor social sites; one-fifth of respondents would turn to an online channel if unable to reach emergency medical services (EMS); and over one-third expect responders to arrive within one hour of posting a rescue request to a social media platform (The American Red Cross 2011). These responses, in conjunction with the previously discussed emergency personnel survey disclosing that over 75% of respondents would not consider unverified social media data and coupled with the understanding that verification can take days to conduct, suggest the general public remains uniformed with respect to official S.A.R. procedures (Su et al. 2013). The general public's misunderstanding and lack of information motivated us to educate individuals on the current standard S.A.R. procedures and the avenues in which we believe they can be improved upon. This article presents a spreadsheet-based classroom game in which players assume the role of an emergency dispatcher, saving lives by ordering a subset of demand locations to create a route for a rescue team to follow. *Logistics to the Rescue* allows its participants to grapple with the trade-offs associated with the incorporation of unverified demand locations, sourced through social media platforms, in order to save the maximal number of lives while conserving limited resources. It is our opinion that *Logistics to the Rescue* can introduce the elementary concepts of S.A.R and help logistics/operations research instructors illustrate basic forms of multistage and online planning problems to K–12 students.

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