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Analysis on vehicle and walking speeds of search and rescue ground crews in mountainous areas

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ABSTRACT

In recent times, the growing number of people enjoying nature-based tourism and recreation activities has led to an increase in search and rescue (SAR) missions in mountainous areas. During SAR responses time is of essence, and the speed of SAR ground responses is affected largely by the mode of transportation and the road and trail network. This study presents a detailed analysis of vehicle and walking speeds of SAR ground crews along a secondary transportation network and on off-trail areas, culminating in mode-specific regression models. Thereafter, these models are integrated into GIS to generate maps of the total accumulative travel time of a rescue area. This GIS model is then evaluated by calculating likely rescue times when using small All-Terrain Vehicles (ATV) as an alternative to 4WD cars.

The results show that vehicle speeds strongly depend on the quality of the secondary transportation network in terms of roughness and gradient. The spatial analysis in the GIS model reveals that the alternative use of small ATV can reduce the total cumulative travel time of SAR crews significantly, especially in areas where the quality of the secondary transportation network is poor.

MANAGEMENT IMPLICATIONS

With the ever increasing popularity of mountain-based outdoor activities, search and rescue (SAR) missions in challenging terrain are becoming increasingly important. Therefore, a rigorous analysis of the effectiveness of modes of transport as a function of terrain characteristics is an important contribution to SAR operations. The study finds that:

- A GIS based rescue concept is recommended as a precautionary measure in all mountainous areas; it should include trail characteristics to document the accessibility of the management area.
- An ATV is most likely the best means of ground transportation, especially when searching for missing recreationists and for providing first aid.
- In areas with frequent accidents it might worthwhile to consider improving trail conditions for ATV access.

1. Introduction

The multifunctional use of natural resources (Farrell et al., 2000; Tomè, 2005) is also an important factor in mountainous areas (Beedie & Hudson, 2003, Perlik, Messerli, & Bätzing, 2001), especially in Central Europe and in the Alps (Breman et al., 2010). In this region, nature-based tourism and recreation activities (Thiene & Scarpa, 2008) have led to a consistent increase in the number of visitors to mountainous terrain (Muhar, Schauppenlehner, Brandenburg, & Arnberger, 2007). In view of this, Lischke, Byhahn, Westphal and Kessler (2001) initiated a discussion about the possible relationship between the increase in the number of participants in mountain-based outdoor recreation activities and the rising number of search and rescue (SAR) missions. The same discussion has emerged in North America, where Heggie (2008) confirms that the growing popularity of outdoor recreation and wilderness activities is one of the main causes for the increasing number of SAR operations, especially in National Parks (Boore & Bock, 2013, Heggie & Heggie, 2009).

It is a common impression among rescuers that many injuries and fatalities in mountain areas are caused by the ignorance

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of many participants who engage in mountain-based outdoor activities without the appropriate training, equipment, or even maps, and in ignorance of local weather conditions and their own physical conditioning (Brandley, 2011, Heggie & Heggie, 2009). Consequently the number of SAR interventions increases, especially in areas where outdoor activities by casual mountain visitors is gaining popularity. Lischke, Berner, Kopp and Mann (2012) report the experiences of SAR crews in the Bavarian mountains, highlighting the fundamental role of coordination of the rescue crews and the importance of appropriate technologies for the specific mountain conditions.

SAR operations usually consist of two parts: the search for missing or distressed persons, usually followed by their rescue. The helicopter is one important tool during these operations (Doherty, Guo, & Alvarez, 2012). While the use of helicopters has many advantages over ground rescue, especially when fatalities are involved (Tomazin & Kovacs, 2003), helicopter operations are often hampered by local weather and terrain conditions. In fact helicopters may be asked to assist in wilderness SAR operations to quickly provide medical care and to transport injured persons. Otherwise the priority for any medical helicopter involved in an SAR operation is safety (Grissom, Thomas, & James, 2006), which is considered at each decision point according to the weather condition as well the landing terrain. Doherty et al. (2012) recommend that helicopter landings should meet specific safety standards. In fact, landing a rescue helicopter in a wilderness environment requires suitably flat areas without adjacent tree canopies, and free of other hazards. Therefore, it is worthwhile to evaluate the employment of SAR ground crews, especially when the criteria for utilizing a helicopter are not fully satisfied (Grissom et al., 2006).

Forest roads (Janowsky & Becker, 2003) and mountain trails (Thiene & Scarpa, 2008) constitute highly relevant infrastructure for rapid SAR responses by ground transportation such as 4WD vehicles or All-Terrain Vehicles (ATV) (Lischke et al., 2012).

So far the literature lacks any systematic analysis of the travel times required for SAR operations by ground vehicles and crews on foot during missions. Such an evaluation of response times by SAR crews when using secondary road and trail networks would be highly useful, especially when considering the possible effect of different road and trail characteristics and types of vehicles.

This paper presents an analysis of vehicle and walking speeds of SAR ground crews along a secondary road network, a trail network, and in off-trail areas in order to verify, with a GIS-based model, the cumulative travel time when providing first aid to injured people in rugged mountainous terrain.

2. Materials and methods

The study consists of the following elements:

1. Analysis of the speed of SAR ground vehicles related to the road network characteristics;
2. Analysis of the walking speed of a SAR crew along the trail network and off-trail routes;
3. Creation of a GIS-based model for calculated travel time to evaluate the efficiency of specific ground vehicles as a function of road and trail network conditions; and
4. Comparison of scenarios based on the use of different vehicles.

2.1. Study area

The area of the Comunità Montana Agno-Chiampo in north-eastern Italy (N45°43′00–45°35′00, E11°08′00–11°18′00) was identified as a representative mountainous study area for the above stated research questions (Fig. 1). The study area covers 90 km^2 and ranges in elevation from 200 m to 2000 m a.s.l. The most widespread land cover is forest (64% of the area), followed by grassland and pastures (23%). The low elevation portion of the area contains a dense network of forest roads, most of them of poor standard, and hiking trails under forest cover. These roads are mainly used by small forest landowners, mushroom pickers, hunters, mountain bikers and hikers. The higher elevation mountain area contains narrow forest roads with steep gradients and alpine trails that people mainly use to pursue outdoor activities like mountaineering, hiking and mountain biking.

Data of SAR missions for the 20 year period from 1992 to 2011 provided by the local SAR Station (Recoaro-Valdagno, Vicenza province) document an increase in the numbers of SAR responses in recent years (CNSAS Recoaro-Valdagno). Between 2002 and 2011 the local SAR station was engaged in 205 operations, attending to a total of 230 injured people. The ground operations relied mostly on small 4WD vehicles because of the poor standards of the secondary road network. Almost one third (29.8%) of the missions occurred in snowy conditions, and helicopters were used in one quarter of the operations. These trends mirror SAR events in other mountainous regions (Heggie, 2008; Hung & Townes, 2007; Lischke et al., 2001). The characteristics of the area are considered suitable to study the use of small ATV as an alternative SAR mode of transport to support ground operations. The analysis below pertains to the snow-free period only.

2.2. Road and trail network characterization

A geo-database of the road network containing the width, gradient, type of pavement and maintenance condition of all roads in the study area was acquired from the local Forest Service (Regione del Veneto, 2011). Based on these variables, road sections were first categorized into functional classes according to their main use (public roads, multifunctional road and forest roads with restricted access), and then categorized into five operational classes according to the main types of possible transportation systems as a function of width and vehicle manoeuvrability.

The information about the road network was then adapted for this study to serve as an operational description for the use of SAR vehicles (Table 1), and the information about the road network was integrated with the information about the trail network extracted from aerial photos as well as technical and topographic maps.

During the summer of 2011, field surveys of the rural and forest roads as well as the trail network were conducted to verify and improve the information about all roads and trails in the geo-database. Forestry roads were classified into uniform sections according to gradient (%), width (m) and surface condition (good condition; degradation starting; complete degradation of road surface). Trail sections suitable for ATVs were also divided into uniform sections by gradient (%) and surface conditions (regular, partially irregular, and irregular). Trail sections only suitable for travel on foot were only classified in terms of gradient (%), while the classification of off-trail routes also included land cover (grassland and meadow or forest).

The travelled tracks (i.e., roads and trails) were surveyed using a differential D-GPS antenna (PROXH TRIMBLE®) and a mapping-grade GPS handler (NOMAD TRIMBLE®) with a specific GPS-software (TERRASYNC®). The survey of the uniform section of each track was based on the GPS coordinate acquired at the starting point of the section by averaging 120 measurements, ensuring an accuracy of the GPS coordinate of up to 20–25 cm. Hence the slope distance, the gradient and the azimuth of the section were measured by a laser rangefinder (Trupulse® 360B – Laser Technology®) at accuracies of ±0.3–1.0 m in distance, ±0.25° in inclination and ±1° in azimuth.