MODELING OF RISK ASSESSMENT SUPPORT SYSTEM FOR OUTDOOR RECREATION IN CROATIA

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Abstract
Due to increasing number of incidents occurring during outdoor recreation in Croatia, idea and motivation for research and development of the model for risk assessment support system for outdoor activities arises. In order to reduce human and financial losses, more effort has to be made to understand the opportunities and the importance of using spatial analysis for risk management with an emphasis on the quality of input spatial data as the basis for risk analysis, assessment and risk mapping. Using combination of environmental, spatial and social data we conducted simulation on real world data from Croatian National Protection and Rescue Directorate. This paper seeks to improve the existing approaches to risk assessment, and to develop and define a model for risk assessment and public service for introduction to incident likelihood and spatial allocation of resources where incidents are likely going to occur resulting with risk reduction.

Keywords: risk assessment modeling, outdoor recreation, incident likelihood, geospatial analysis, Croatia

1. INTRODUCTION

Relatively neglected area both of real-world significance and of academic study, outdoor recreation issues related with risk assessment and raising public awareness of threats included are important for overall health and financial safety of society related with that kind of generally accepted active leisure. This paper strives to define main components necessary for establishment of risk assessment support system for outdoor recreation due to which we hope to reduce number of incidents resulting with injury or death by providing information about potentially dangerous locations for whole of Croatia.

1.1. Key definitions

Outdoor recreation is simply recreation that is typically carried on outdoors requiring space and resources for its enjoyment with no sharp line between recreation and all other activities – the same activity may be work at some times and recreation at others (Clawson et al 2013). Outdoor recreation overlaps with tourism in the distinctive characteristics and behavior associated with each; they both involve travel and interaction with other people, and with the environment in its widest meaning (Jenkins et al. 2005). The places associated with outdoor recreation have always included forests, the coast, lakes and rivers, mountains and other spectacular scenery that is nowadays frequently designated as national park or similarly protected (Bell et al. 2007), although Seeley (1973) points out possibility of few activities like swimming, that can take place either outdoors or indoors. Outdoor recreation often implies activities such as hiking (trekking), bicycling, swimming in lakes, streams or ocean, downhill skiing, cross-country skiing, photography, nature study, orienteering, trail running, rock climbing, fishing, canyoning, geocaching, picnic and many other practiced by wide population. Participation in all outdoor activities has been increasing when measured by number of participating people according to Cordell et al. (1999) and Cordell (2004) thus becoming important factor for potential risk which may be posed to health of certain part of population – in specific, the participants of outdoor recreation.

According to ISO 31000 (2009), risk is the “effect of uncertainty on objectives” and an effect is a positive or negative deviation from what is expected. In other words, this definition implies the chance of unplanned events despite our plan.
Our each action contains uncertainty, thus containing element of risk that requires management. Our actions for accomplishing objective will not always get the results we expected – sometimes resulting with positive results, and sometimes negative, with possibility of both occurring in the result. That being said, we should reduce uncertainty (or lack of certainty) to lowest level possible.

Uncertainty, in the context of risk management, represents a state involving lack of information that leads to inadequate understanding or incomplete knowledge of a likelihood, consequence or event. According to the ISO 31000, the term risk management refers to the architecture that is used to manage risk, including risk management principles, a risk management framework, and a risk management process.

Risk assessment, as part of risk management, is a process made up of 3 processes: risk identification, risk analysis, and risk evaluation. Risk identification is used for finding, recognizing and describing the risks that may affect the objective. Data for it may be obtained from experts, historical data, theoretical analysis and stakeholder input. Risk analysis implies process used for understanding the identified risks and estimating level of risk. Risk evaluation defines a process used for comparison of risk analysis results based on which it will be decided if level of risk is within acceptable limits.

An injury (damage to body) is often considered as general term which is usually a result of hits, accidents, falls, weapons and other events that range from non-significant to life-threatening. There is an acknowledged risk of both severe and frequent injuries associated with sport, active recreation or leisure (e.g. Gabbe et al. 2005; Finch et al. 2007; Flores et al. 2008).

Nowadays, computer technologies play important role within risk assessment process, enabling people to collect and store data from different sources, perform fast analysis on large databases and help in risk evaluation. Decision support systems (DSS) are defined broadly as interactive computer-based systems that help people use computer communications, data, documents, knowledge and models to solve problems and make decisions (Power et al. 2009). DSS can also be applied for risk assessment. According to El-Baroudy et al. (2006) the main objective of risk assessment support system (RASS) is to identify potential hazards, estimate the impacts of each hazard and propose possible improvements and management actions which will significantly reduce the risk, usually consisting of two main components: qualitative risk assessment component (QLRA), and quantitative risk assessment component (QNRA). Although interaction between QLRA and QNRA is possible, often only one approach is used within RASS model.

Figure 1. The risk management process from ISO 31000 (2009)

Figure 2. Interaction between the two main components of the risk assessment support system (El-Baroudy et al. 2006).
2. RISK ASSESSMENT FOR OUTDOOR RECREATION

As mentioned before, risk assessment is a process of three separate parts; identification, analysis and risk evaluation. Each process should be defined separately on one hand and enable mutual interaction on the other hand.

2.1. Existing approaches to risk assessment for outdoor recreation

Historical approaches to risk management in organized outdoor activities have centered on the adoption of guidelines or on aspects such as (Hogan, 2002);

- minimum experience or qualifications of leaders,
- minimum and/or maximum number of persons in a group,
- maximum number of participants per leader,
- prior experience required of participants,
- minimum equipment standards, and
- intra-organizational approval processes.

In some cases, an assessment of risk may have already been carried out at an organizational policy level to meet certain aspects of their operation complied with industry standards, government policy or insurance requirements (Parkin et al. 1998). For example, in Queensland, Education Queensland has assessed rock-climbing at level 3 or “high risk” and canoeing on grade II water at level 4 (very high risk) in their Workplace, Health and Safety Guidelines document (QDOEM, 1996). Regardless of approach, all named authors strive to the same goal – find and recognize potential risk of outdoor recreation while trying to understand its nature and estimate risk level to determine is risk within acceptable limit not entering devastation and disaster state. Modern RASS should have exactly the same goal with possibility of dynamic adaptation based on stakeholders input data enabling constant improvement.

2.2. Risk identification

Understanding the role of the exposure to natural factors in the occurrence of incidents combined with the presence of dynamic effects is a complex problem. The occurrence of incidents in outdoor recreation is known to be related with a number of different factors, including exposure to objective (natural process and events in nature which itself, or in combination with other factors may pose a threat for people) or subjective threats, caused by human behavior and mistakes due to lack of knowledge, experience, skill or bad miscalculation (Petković et al. 2013). According to New Zealand Mountain Safety Council Risk Analysis and Management System (RAMS), dangers in outdoor activities can arise from three sources; environmental, human and equipment factors (Haddock, 1993). For purposes of Croatian RASS for outdoor activities equipment malfunctions will not be taken into account due to premise that it is high quality equipment (clothing, footwear, climbing ropes, helmets, harnesses etc.) with low or no possibility of failure and only objective (environmental) and subjective (human) threats will be used for risk identification. Stochastic nature of incident occurrence, both exposure to objective threats and participant’s background related, is contributing to the complexity of outdoor recreation risk understanding so this should be taken into consideration as a factor which might alter the results given by RASS.

2.2.1. Objective threats

When thinking about risks for outdoor recreation it is necessary to conduct an identification process to determine all potential risks associated with specific activity or area in which incident occurred. Possible sources of such information can be retrieved from relevant articles or reports, visitors in specific area, nearby employers, local inhabitants, or participants of incidents. Hogan (2002) mentions that objective threats originate from the surroundings; weather, terrain, availability of shelter and remoteness while Smerke (1989) continues by listing threats for outdoor recreation from dark, ultraviolet rays (sunburns, snow blindness etc.) and animal attacks among others.

Through RASS input option users should be able to report not only location of injuries but also risk associated with it; for ex. head injury due to fallen rock from cliff. In that way we could gather and store information about risk sources and consequences caused by objective threats. From scenario in example we could conclude that there is potential risk of injury close to cliffs due to falling rocks. If this occurs on several occasions in different locations with cliffs we could conclude that there is risk of injury close to cliffs and with analysis of terrain RASS needs to detect such areas using DEM and provide information about risk. With time, as we get more information about injury locations related with cliffs, fine modeling should be possible. Off course, for this example, DEM quality is directly influencing on results so that is something we should bear on mind.
2.2.2. **Subjective threats**

Many authors describe predictable patterns in participants' motives within outdoor activity (Donnelly et al. 1986), how people believe they have control over the outcome of events (Knopf, 1983) and social group structure (Heywood, 1987) with the goal of achieving a better understanding of subjective threats in outdoor recreation. Hogan (2002) mentions that subjective threats originate from people's attributes, such as skills, knowledge, experience, health and fitness, age, fears, etc. When looking at just running, Blair et al. (1987) discuss stretching habits, age, time and place of running, weight relative to squared height (BMI), average speed of running and average distance run per week as factors which might possibly be related to sustaining running injuries but only BMI and average distance run were found to be related to an elevated risk of being injured. We need to bear in mind that defining a strong relation between participant's profile and risks is not an easy task. Profile of outdoor recreation participants inevitably influences on the risk leading to the conclusion that person's attributes should be recorded so we could define and monitor pattern of subjective threats within RASS leading not only to a better understanding of threats but also as a tool used for prediction of participants' motives.

2.3. **Risk analysis**

After identifying potential threats, the next step is to approach to risk analysis. As said before, risk analysis by ISO 31000 is developing an understanding for each risk – namely likelihood of the consequences and consequences itself. Analysis can be qualitative, semi quantitative, quantitative, or a combination of these, depending on the circumstances (Purdy, 2010). ISO 31000 does not prefer qualitative over quantitative risk analysis and vice-versa, as both represent a significant role in better risk understanding. For outdoor recreation qualitative risk analysis is most commonly used, especially in the UK and Australia (e.g. Camp Coolamatong 2007; Girl guides 2012; Barton Camp 2018) mainly describing likelihood of an accident happening with likelihood rating ranging from rare to almost certain. Quantitative risk analysis on the other hand, is rarely applied for outdoor activities. Reason for that might be lack of research in this field due to high costs and lack of reliable data, complexity of the issue, as well as the fact that most of involved stakeholders are oriented towards personal interests (of company or person), without involvement of a National administrative body or insurance company which could require numerical likelihood of events.

2.3.1. **Quantitative risk analysis (QNRA)**

QNRA produces numerical outputs presenting likelihood of events presented with probability level. QNRA can be used on situations involving quantifiable measures. QNRA models should be made by experienced stakeholder of RASS with deep understanding and knowledge of risks and factors involved with it so we could retain reliable and realistic results.

Uitenbroek (1995) in his paper discussed about the mathematical relationship between the number of events in which people are injured and the number of injured people using Poisson distribution to express the relation. The number of injury causing events in a population will be larger than the number of injured people as same person can be injured on more than one occasion. The expected average number of events per head of the population (μ) is related to the chance of not sustaining an injury (p₀) according to the following formula (1).

\[ μ = -\ln(p₀) \quad \text{and} \quad p₀ = \exp(-μ) \hspace{1cm} (1) \]

In this paper, mathematical relationship between the number of people injured and the number of times people sustained injuries was not subject of research.

2.3.2. **Qualitative risk analysis (QLRA)**

Though numerical data are preferred in risk management, QLRA often provides support used for detailed investigation of QNRA and can also provide information needed for risk management providing satisfying results. QLRA is usually performed due to ease of implementation, simple structure and is easily recognizable by policy makers and stakeholders. Often it is also impossible to define likelihood of events due to complex factors and influences of risks in which QLRA is the only possible way to present risk exposure.

Within QLRA, impact/probability matrix is usually used to represent the severity of a risk based on a presumption that combination of consequence and likelihood defines magnitude of risk severity:

\[ \text{Risk Exposure} = \text{Probability} \times \text{Impact} \hspace{1cm} (2) \]
2.3.3. Semi-quantitative risk analysis (SQRA)

SQRA extends quantitative concept of risk analysis to apply numerical thresholds to the matrix cell edges resulting with finer delineation between risk exposures. In other words, position of risk within each matrix cell can be adjusted and moved either higher or lower in the cell, while qualitative matrix places risk in the mid-point of each cell.

2.4. Risk evaluation

Risk evaluation is responsible task since based on it risk treatment will be decided (if necessary) with intention of risk reduction. On the other hand, some risk will be declared as acceptable and no action will be taken on the terrain. It is obvious that this should be done by educated and professional personality of RASS stakeholders. Several Croatian authors (e.g. Martinić et al., 2008; Bulat, 2015; Martinić et al., 2015) have already been publishing scientific papers related with that subject with focus on risk evaluation within protected area. Protected areas today account for 8,54% or 7.528,03 km² of the total area of the Republic of Croatia, i.e. 12,22% of the land territory and 1,94% of the territorial sea (Hrvatska agencija za okoliš i prirodu, 2018) and are often well attended, especially in summer tourist season. During last years, number of visitors in protected areas in Croatia has been growing, as well as the offer of outdoor recreation within them making it logical choice for making emphasis on them as one of main stakeholders which should be involved into risk evaluation as part of RASS.

19% of search and rescue incidents reported to Croatian National Protection and Rescue Directorate from 2010-2017 took place in protected area (National or Nature Park).

3. RISK ASSESSMENT SUPPORT SYSTEM FOR OUTDOOR RECREATION IN CROATIA

Establishing RASS for outdoor recreation in Croatia among other requires active participation of national stakeholders as well as active citizens which should not only be educated about it through public interface but to also participate in it as one of main stakeholders.

3.1. Possible stakeholders for data sourcing

Input data should cover as much as possible known threats for users of outdoor activities – among other;

- Croatian Mountain Rescue Service and National Protection and Rescue Directorate should have the most significant role since they as recognized legal entities have both knowledge and infrastructure to carry out RASS on national level. Both stakeholders should be involved into all parts of risk assessment.
- Croatian Meteorological and Hydrological Service could provide weather information as one of most dynamic factor (both historical, current and forecast). This data could ensure that risk factor changes dynamically based on weather conditions thus providing more reliable information for participants.
- State Geodetic Administration could provide relief data and maps for terrain analysis. Using this data it is possible to detect dangerous areas such as sheer cliff edges, rivers, dangerous drops, very steep climbs etc.
- Croatian Mine Action Centre needs to be included by providing locations of mine fields.
- Citizens should be informed about RASS and they should strive to be engaged through incident report and help in collecting data related with it.

3.2. Specification of structure and content of RASS for outdoor recreation

Suggestion for gathering information needed for risk identification is to collect as much as possible data about surroundings that might be relevant for further use in risk analysis. Quality of spatial data is of great significance hence special care should be taken for its analysis. Preferably official National data should be used for risk identification ensuring control and supervision over input data which will directly have influence on risk analysis.

It is also necessary to get feedback about incidents from public (validation of data quality needs to be monitored by national RASS stakeholders to avoid misleading conclusions). Locations of incidents should be recorded in ideal case by reliable measuring instrument – use of GNSS devices will most probably do the job due to its wide recognition and ease of use. In any case, description of incident and location should be included into data for further analysis of risk likelihood and impact on outdoor activity users. Here it is crucial to educate users how to recognize potential threats which should be specified in the description.
Risk analysis is a complex procedure and it should be made by integrated approach of expert personality from different scientific fields. Modeling of RASS is done by altering variables used for risk analysis. Population behavior analysis, incident scenario and finding correlation with surroundings are just some of the parts which national RASS stakeholders should implement for successful risk analysis.

![Figure 3. Structure of RASS for outdoor recreation](image)

Based on risk analysis results, risk evaluation will be done and actions (if necessary) will be taken to reduce risk. Among others, risk can be avoided, mitigated, transferred or accepted. Also, national RASS stakeholders should monitor the risk on regular basic providing information about risk towards public via public interface. Simulation of described procedure is described below.

### 3.3. Simulation on real-world data

For testing purposes we have selected Croatian National Park Paklenica. 95 km² was proclaimed as National Park in 1949 due to extraordinary geomorphologic structures and unique natural features. Park is well attended by outdoor activity enthusiasts – especially climbers and hikers due to high mountain peaks (up to 1752 m) and dense network of provided hiking trails so it seems like interesting area for testing RASS for outdoor recreation.

First step implies risk identification. For this purpose we have retrieved data from Državna uprava za zaštitu i spašavanje (Croatian National Protection and Rescue Directorate) – DUZS, in total 1270 reported incidents in Croatia from 2010-2017 with stress that data for 2017 contains incidents reported till November 2017. When analyzing spatial data of incidents we can detect 10 most common types of risks in Croatia – Figure 4.

![Figure 4. Most common reported risks to Croatian National Protection and Rescue Directorate](image)

After identification of risk in test area from incident reports, bearing on mind that objective threats originate from surroundings, we have combined several sources such as hiking trail register, land cover and digital surface model to closely provide insight into ambient which might pose a threat for outdoor activity users and result with an injury.

Modeling of risk was made containing information about incidents that happened till given moment. For instance, first model was made with incident data from 2010 and its quality was checked with incident data for next year and all previous years. Results were then analyzed, and if necessary improvements of RASS were made. Steps would repeat for next year’s data. In this iteration process idea is that each year model improves by gaining more data and information about incidents that should (at least in theory) provide better results. For our simulation, first year included risk mainly of falling from cliff. All cliffs in test area were extracted from national topographic map and hypothesis that cliffs and their surrounding represent risk were given. Described 2010 model was than tested with incident data from 2010-2011. Shortcomings of model were obvious as more different outdoor activities were included (namely hiking and cycling).
We have than improved 2010 model with new hypothesizes based on new information gathered from incident reports. New RASS model – 2011 which was further tested and developed with new data was developed annually till 2013. We have noticed that since we had relatively small number of incidents, new input data was changing model fast. We decided to make 2 year gap to gain more data for modeling. For 2015 we had 58 incidents which originate from different outdoor activities and have different surrounding. From this data we have concluded that visitors are more likely to become injured or sick in steeper terrain, tend to spend more time in close vicinity to trails and especially close to entry into National Park (up to 4 km into park) influencing on likelihood of incident. Also correlation of incidents with landcover was noticed. All of this lead to improvements of RASS model resulting with solution presented on following figure (only southern part where most of incidents occurred is presented).

With this approach, we have managed to predict locations of incidents with more than 92% incident likelihood in defined area as well as to improve detection of high risk areas. Lowest prediction was from 2010 model when we managed to correctly predict 87% of incidents in 2011 what is logical due to lowest number of incidents.

We would like to mention that risk from dark, snake attack and fall into holes/caves was not considered due to lack of data for modeling and complexity of risk. It is important to stress again that this part should be done by experienced
person and that results in this paper are only made for purpose of testing possibility of RASS use for outdoor recreation in Croatia and that by no means we take any responsibility for use of presented results.

Used variables and descriptions are presented in table below.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Hypothesis</th>
<th>Impact</th>
<th>Likelihood</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hiking trails</td>
<td>Euclidean distance (m) to hiking trails.</td>
<td>Visitors spend more time on or near hiking trails (150m buffer).</td>
<td>Minor (2)</td>
<td>Rare (2)</td>
<td>Low (4)</td>
</tr>
<tr>
<td>Cliffs inside trail buffer zone (150 m)</td>
<td>High risk of injuries from fall on cliffs located within distance of 150 m from trails.</td>
<td>Visitors are probably going to visit cliffs closer to trails.</td>
<td>Catastrophic (5)</td>
<td>Probable (5)</td>
<td>High (25)</td>
</tr>
<tr>
<td>Cliffs outside trail buffer zone</td>
<td>Medium risk of injuries from fall on cliffs located outside distance of 150 m from trails.</td>
<td>Visitors are probably going to visit cliffs closer to trails.</td>
<td>Catastrophic (5)</td>
<td>Rare (2)</td>
<td>Medium (10)</td>
</tr>
<tr>
<td>Zone around cliffs inside 150 m trail buffer zone</td>
<td>If zones around cliffs are inside 150m buffer from trail - higher likelihood of incident.</td>
<td>Zones around cliffs can be potentially dangerous – falling rocks.</td>
<td>Significant (4)</td>
<td>Rare (2)</td>
<td>Medium (8)</td>
</tr>
<tr>
<td>Zone around cliffs outside 150 m trail buffer zone</td>
<td>If zones around cliffs are outside 150m buffer from trail - lower likelihood of incident.</td>
<td>Zones around cliffs can be potentially dangerous – falling rocks.</td>
<td>Significant (4)</td>
<td>Negligible (1)</td>
<td>Low (4)</td>
</tr>
<tr>
<td>Slope</td>
<td>Slope angle (degrees) of terrain, derived from 25-m digital elevation model (DEM)</td>
<td>Visitors are more likely to become injured or sick in steeper terrain if &lt;20° than -1 if &gt;45° than +1</td>
<td>( \text{if } &gt;45° \text{ than } +1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remoteness from entry points</td>
<td>4km zones around entrances to National park</td>
<td>Visitors are probably going to visit area around entrance</td>
<td>Keep the same</td>
<td>if risk is within 4km from entry point add 1</td>
<td></td>
</tr>
<tr>
<td>Natural grasslands or transitional woodland-shrub</td>
<td>Incidents in tested area are occurring mainly on 2 types of landcover</td>
<td>Visitors are more likely to get injured on specific type of landcover</td>
<td>Keep the same</td>
<td></td>
<td>+1</td>
</tr>
</tbody>
</table>

4. DISCUSSION AND CONCLUSIONS

Essence of the modeling of risk assessment support system for outdoor recreation in Croatia presented in this paper lies on involvement of wide population, nature enthusiasts and outdoor recreation participants making it unique in whole World due to the fact that it also encourages all necessary and interested stakeholders on vertical and horizontal level of National services. Core idea behind it is in collectively built and publicly accessible Web service that is able to dynamically cope with new inputs and information about risks which may be encountered during outdoor activity, process this data and present to end-users information about possible risk level on one hand, and on the other hand to provide National stakeholders hazardous location for which risk treatment will be decided – hopefully resulting with
risk reduction. With years of collecting and analyzing data and results, RASS will constantly be improving, resulting with reliable tool for risk assessment with long term reduction of number of incidents, increasing public health, safety and decreasing costs of medical treatments, provided rescue services and insurance requirements.

Although we have decided to conduct test in small area, given results are promising and prove that with described approach of risk analysis we can produce reliable model of risk.

Probably the best first step for establishing RASS for Croatia is to involve National and Nature Parks where most of visitors engage into outdoor activities and where 1/5 of all reported incidents in Croatia occur. With raising awareness of risk we will reduce incident occurrence and establish foundations for safe development of outdoor activities what for a tourist destination like Croatia should definitely be of great importance.

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