Reliability Analysis of a Glacier Lake Warning System Using a Bayesian Net

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Introduction

Warning and alarm systems have become important measures for dealing with Alpine natural hazards. Comparing their effectiveness with structural measures requires quantification of the reliability of these systems. However, little is known about how reliability of warning systems can be quantified.

We conducted a reliability analysis of a warning system located in Grindelwald, Switzerland. The warning system was built for warning and protecting residents and tourists from glacier outburst floods as consequence of a rapid drain of the glacier lake [1].

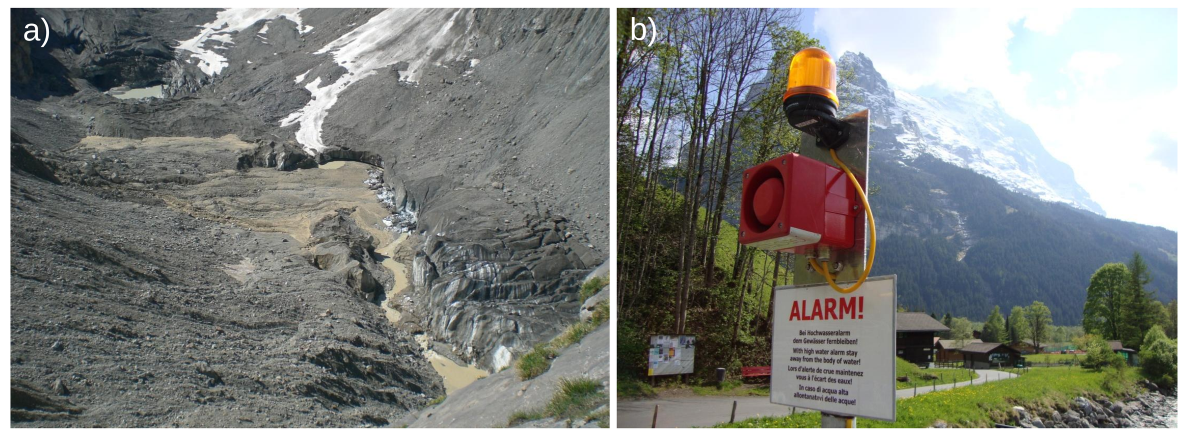


Fig. 1. (a) Almost empty glacier lake Grindelwald, Switzerland; (b) visual-acoustic alarm unit at a bridge in the valley.

Bayesian Net

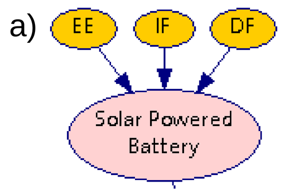
We have set up a Bayesian Net (BN, BPN) [4] that allowed for a qualitative and quantitative reliability analysis. The following steps have been effected:

1. Defining the nodes, i.e. the events
2. Linking the nodes according to their relations
3. Defining the states of the nodes
4. Assigning the probability values for each node in the Conditional Probability Tables (CPT)

The CPT of the BN were derived from manufacturer's reliability data and recorded previous events for each component of the system as well as by assigning weights for specific BN nodes accounting for information flows and decision-making processes of the local safety service.

Each node has two states: *working* and *faulty*. Basically, the nodes can fail for two reasons. Either an internal error occurs or an external event takes place. Where existing, diagnostic system failure is included, too.

a)



b)

EE	yes				no			
IF	yes		no		yes		no	
DF	yes	no	yes	no	yes	no	yes	no
working	0	0	0	0	0	0	0	1
faulty	1	1	1	1	1	1	1	0

c)

yes	0.0215
no	0.9785

Fig. 3. (a) Sample node with the three failure causing parent nodes 'external event' (EE), 'internal failure' (IF) and 'diagnostic system failure' (DF); (b) corresponding CPT for the sample node in (a); (c) CPT for 'EE' in (a) – derived from recorded events in the past of the warning system.

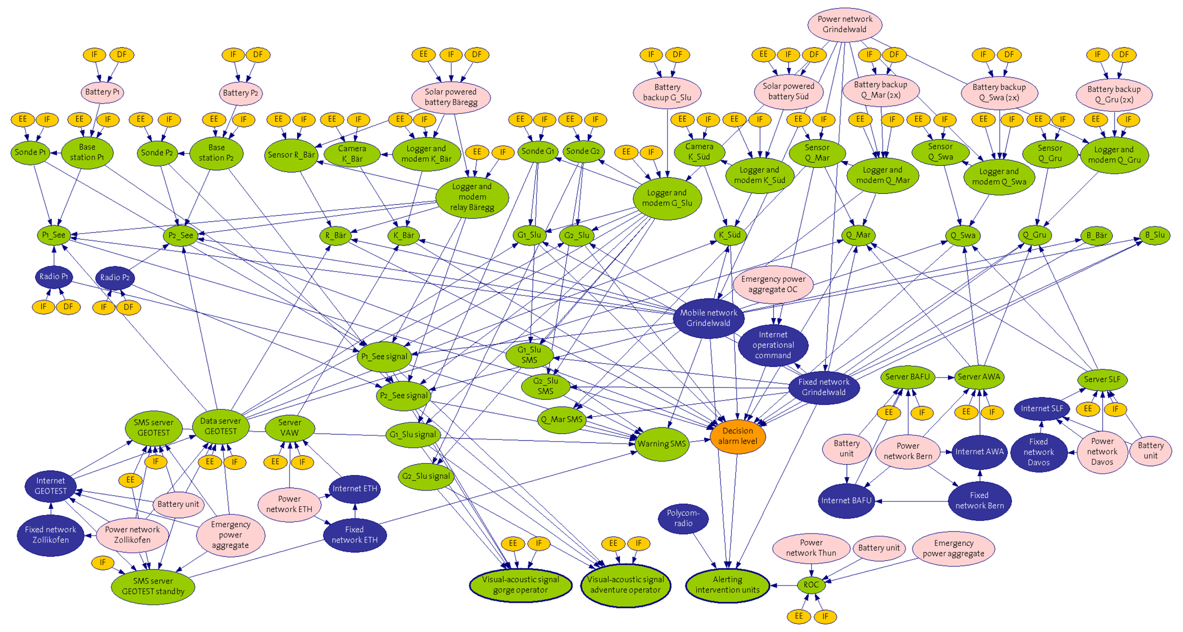


Fig. 4. Bayesian Net for the warning system based on the overview in Fig. 3; processed with GeNIe [5].

Risk Values

For possibly endangered people, the following question is of vital importance: How likely is the failure of components leading to a highly reduced reliability of the alerting units?

$$CR * RS = RVS$$

$$CR * RA = RVA$$

The acronyms are explained in Tab. 1.

Tab. 1. Reliability values for the most serious failures including the corresponding measures for risk. Green: approximately 100 % reliability; red: lowest values for the two alerting units.

Failed Components	Components' reliability (CR)	Reliability for visual-acoustic signal (RS)	Reliability for intervention units' alerting (RA)	Risk-value signal (RVS)	Risk-value alerting (RVA)
none	variable	93.6 %	83.0 %	-	-
Sondes P1,2 & G1,2	100.0 %	0.0 %	36.7 %	0.0 %	36.7 %
Mobile and fixed network GW	100.0 %	82.4 %	0.0 %	82.4 %	0.0 %
Internet operational command	100.0 %	93.4 %	0.0 %	93.4 %	0.0 %
ROC	100.0 %	93.6 %	0.0 %	93.4 %	0.0 %
SMS & data server GEOTEST	96.1 %	93.6 %	22.6 %	89.9 %	21.7 %
Fixed network GW	100.0 %	93.6 %	30.1 %	93.6 %	30.1 %
Data server GEOTEST	80.2 %	93.6 %	38.1 %	75.1 %	30.6 %
P1,2_See & G1,2_Slu	80.1 %	93.2 %	38.1 %	74.7 %	30.5 %
G1,2_Slu	78.6 %	93.2 %	41.7 %	73.3 %	32.8 %
P1,2_See	75.3 %	91.4 %	44.2 %	68.8 %	33.3 %

Warning System

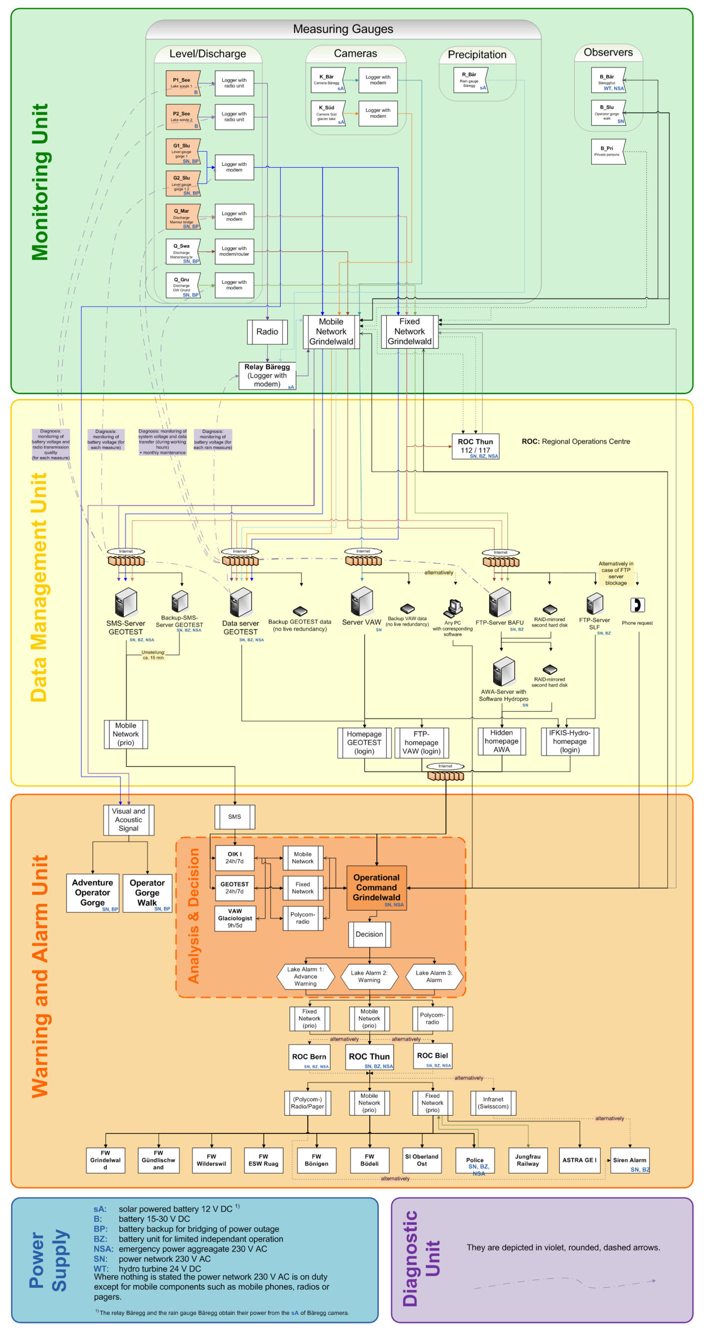


Fig. 2. Overview on the warning system with all components and corresponding data flow paths. Based on [2, 3].

Results

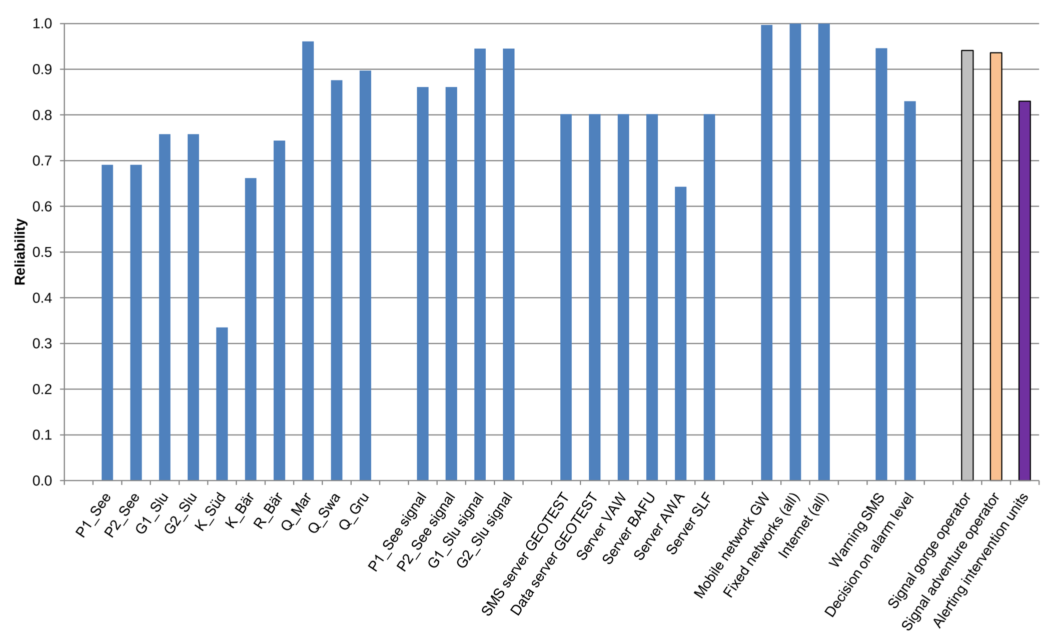


Fig. 5. Graphical presentation of the warning system components' reliability values.

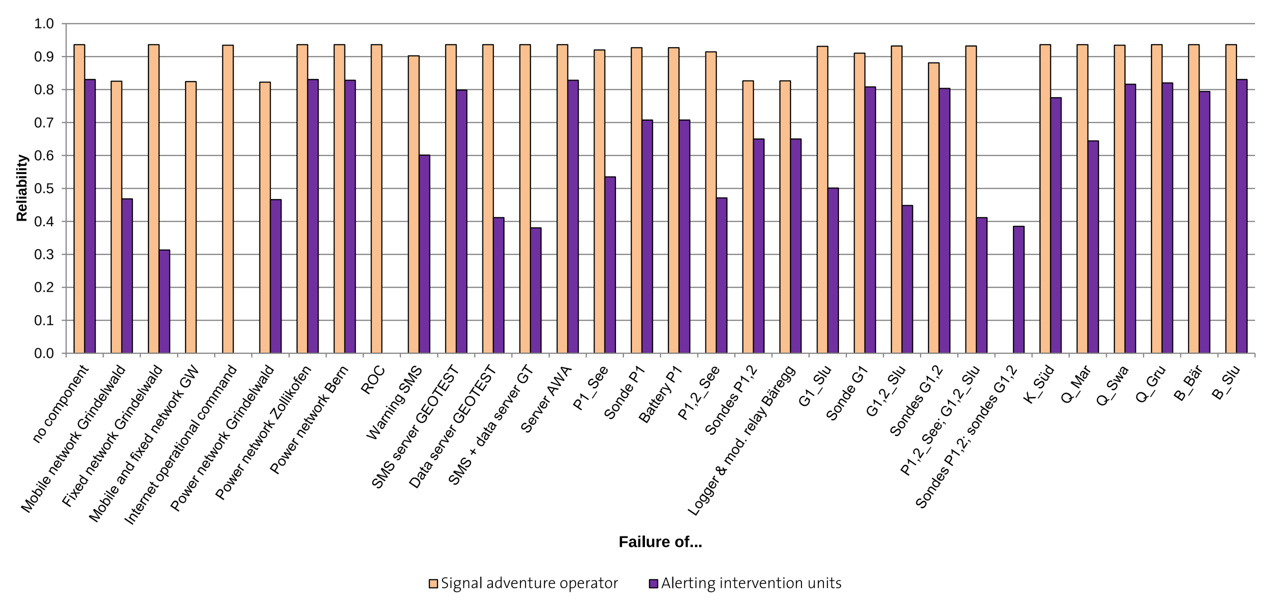


Fig. 6. Graphical presentation of the reliability values resulting from the investigated scenarios. Each scenario is created by assuming the failure of one or more components – depicted on the x-axis.

In order to obtain the probability of a system failure it is necessary to include the probability of the occurrence of an event. By assuming independence between the latter and the successful operation of the system components we are allowed to multiply the two values. This leads to the following two equations:

*P(event without alerting) = P(event)*P(failure of **intervention units' alerting**) = 0.0055*(1-0.83) = 0.00094*

*P(event without alerting) = P(event)*P(failure of **visual-acoustic signal**) = 0.0055*(1-0.94) = 0.00033*

Hence, the reliability of the warning system including event occurrence is 99.906 % and 99.967 %, respectively.

Conclusions

- We assess the BN method to be well suited for reliability analyses.
- All components leading to a certain failure of the system have a reliability of close to 100 %.
- The highest risk arises from the simultaneous failure of two servers situated close to each other.
- Due to numerous redundancies, the warning system is remarkably reliable and its influence on risk reduction is very high.

References

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