III.2 VULNERABILITY TO MOUNTAIN HAZARDS – FUNDAMENTALS AND APPLICATIONS WITH RESPECT TO AN OPTIMAL SAFETY OF STRUCTURES ♥

III.2.1 Introduction

The historical shift of a traditionally agricultural society to a service industry- and leisure-oriented society led to socioeconomic development in mountain environments and foreland regions. This shift is reflected by an increasing use of those areas for settlement, industry, and recreation. On the other hand, areas suitable for land development are relatively scarce in mountain regions, e.g., in Austria, only about 20 percent of the whole area is appropriate for development activities [1]. Moreover, those areas are located line-shaped along valley bottoms. In other mountain regions of Europe, areas of economic activity interfere with areas periodically affected by natural hazards such as flood plains of rivers or torrential fans developed over centuries or even longer. Consequently, a conflict between human requirements on the one hand and naturally determined conditions on the other hand results. Due to an increasing concentration of tangible and intangible assets and to an increasing number of persons exposed to natural processes, which in the case of harm to human life or property are considered as natural hazards, there is an emerging need for the consideration of risk in land-use development.

Dealing with natural hazard processes has a long tradition in European alpine countries. Early attempts in dealing with natural hazards include the establishment of official authorities in the second half of the 19th century, e.g., in Switzerland in the late 1870s [2] and in Austria in 1884 [3]. For more than half a century, technical mitigation measures were developed and implemented. These active measures, which represent the human reaction to hazard processes, appeared to be the appropriate way to cope with this challenge. There was little impetus toward an integrative dealing with natural hazards before the 1950s and 1960s, when extreme events occurred over wide areas of the Alps. Extraordinary governmental expenditures involved with technical coping strategies resulting from those extreme events made traditional reactive measures increasingly obsolete. Consequently, ideas of complementary passive protection measures emerged, such as hazard mapping and land-use restrictions.

Only recently, the responsible authorities in most of the European mountain countries developed theoretical models of integrated risk management, which follow mainly the engineering approach to express risk ($R_{i,j}$) as a function of hazard and values at risk [4-7, see Equation 1]. Consequently, information on the hazard potential and the related probability of occurrence (p_{Si}), the values at risk exposed (A_{Oj}) and the vulnerability of objects at risk ($v_{Oj,Si}$) is needed for the evaluation of risk. The development of these models is strongly connected to the considerable amount of damage in European mountain regions and related forelands due to natural hazards in recent years [8].

$$R_{i,j} = f\left(p_{Si}, A_{Oj}, v_{Oj,Si}\right) \tag{1}$$

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The aim of this chapter is to present the current practice of hazard management strategies for landslides in Austria and future needs with respect to the holistic framework of risk management. Thereby, the focus is not only on methods of vulnerability assessment, but also on permanent and temporary mitigation measures implemented by public authorities nation-wide, and on measures suitable to reduce vulnerability on a regional scale, such as local structural protection of buildings. Furthermore, the problem of risk evolution is addressed by a concept of multi-temporal risk management.

III.2.2 <u>Current practice of hazard management in Austria</u>

The legal foundations of dealing with natural hazards in mountain regions of Austria are regulated at federal level by the Forest Act [4] in the respective current version. According to this law, hazard maps have to be provided to protect settlements and infrastructure against natural hazards; the responsibility for the compilation and implementation of these maps is assigned to the Austrian Service for Torrent and Avalanche Control (WLV), a subsidiary authority of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management [4, § 11 Abs. 1]. Further regulations concerning the content, the form and the specific design of hazard maps are defined in the Decree on Hazard Zoning [5]. According to this decree, hazard maps provide the basis (1) for any planning and implementation of mitigation measures by the WLV as well as for the prioritisation of these measures, and (2) for any planning activities concerning regional development, land-use and construction engineering. Thus, the overall aim of hazard mapping is (1) to delineate areas endangered by avalanches, torrent processes, landslides, and rock fall (2) to assess the level of exposure of such areas, and (3) to depict areas used for mitigation measures against these hazards.

Hazard maps are based on a design event with a return period of 150 years, and an event occurring more frequently with a return period of 10 years [5]. In § 6 of the Decree on Hazard Zoning, the criteria for delimitation of hazard zones is prescribed. According to these prescriptions, red hazard zones indicate areas where the permanent utilisation for settlement and traffic purposes due to avalanches and torrent processes is not possible or only possible with extraordinary efforts for mitigation measures. Yellow hazard zones indicate those areas where a permanent utilisation for settlement and traffic purposes is impaired by such processes. Furthermore, specific other areas have to be displayed in the hazard maps: (1) Blue colours mark areas to be provided for future mitigation measures, (2) brown colours indicate areas affected by landslides and rock fall and (3) purple colours indicate areas that can be used as protection due to their natural properties, such as protection forests or natural retention basins.

As far as pure sliding processes and slumps are addressed, the spatial extent of the mass movement has to be described in the hazard map. Currently, there are no regulations for a further classification of such processes. With respect to hillslope debris flows and shallow landslides, the lateral extent has to be included and marked by red colour in the hazard map. Torrent debris flows have to be classified according to their accumulation height of < 0.7 m and ≥ 0.7 m; the respective areas have to be indicated in red and yellow colour in the hazard maps.

The procedure of hazard assessment is methodologically reliable in determining the hazard potential and the related probability of occurrence (p_{Si}) by studying, modelling, and assessing individual processes and defined design events [9, 10]. So far, little attention has been given to elements at risk (A_{Oj}) affected by hazard processes, particularly concerning spatial patterns and temporal shifts. Furthermore, studies related to the vulnerability of the object ($v_{Oj, Si}$) to a defined scenario have predominantly been carried out so far as proposals to determine the risk of property and human life with the focus on a specific location and a specific point of time [7, 10, 11-14].

Socioeconomic developments in the human-made environment led to an asset concentration and to a shift in urban and suburban population in European mountain regions. Thus, the temporal variability of damage potential is an important key variable in the consideration of risk. Recently, conceptual studies related to the temporal variability of damage potential exposed to hazards have been carried out, focusing both, on the long-term and the short-term temporal evolution of indicators [15-17]. Furthermore, owing to the requirement of economic efficiency of public expenditures on mitigation measures, there is a need for a precautionary, sustainable dealing with natural hazard phenomena, taking into account particularly the values at risk [18-21].

Table III.2-1: Average reconstruction values for buildings in Austria applied in the GIS-based assessment of values at risk [23:122].

Type of building	Floor height [m]	Number of floors	Value/m³ [€]
Detached house	2.8	3.5	350
Apartment building	2.8	4.0	385
Hotel	3.0	5.0	528
B&B	3.0	3.5	435
Restaurant	3.0	3.0	399
Public building	3.5	3.5	406
Office	3.5	1.0	342
Shop	4.0	1.0	330
Garage	4.0	1.0	212
Barn	2.8	1.0	200
Haystack	6.8	1.0	94
Indoor swimming pool	6.0	1.0	601
Gym	6.0	1.0	160
Carpark	2.8	1.0	235

III.2.3 Assessment of elements at risk

Currently, only few conceptual suggestions and operational methods are available for the comprehensive assessment of elements at risk endangered by natural hazards [10, 22]. Accordingly, the evaluation of damage potential is often based on subjective estimations rather than on widely-accepted standardised approaches. Hence, results of such assessments are rarely comparable, and do not necessarily mirror the actual situation satisfyingly. With respect to integral risk management, the assessment of elements at risk has to be based on a spatially explicit valuation using GIS techniques.

Thus, the following procedures outlined in [7] and further developed by [23] are recommended for an area-wide application in European mountain regions with respect to persons, infrastructure lines and buildings at risk.

The basis for this procedure is a digitised layer of the elements at risk, e.g. a building shapefile originating from orthophotos and information extracted from the land register plan. The surface area of buildings provides the source for any further economic valuation. This valuation is carried out by means of average reconstruction values for different building categories, multiplied by further characteristics of these buildings such as building height and technical equipment, see Table III.2-1. The number of persons at risk is derived from the number of households per building and multiplied by the average number of persons per household, e.g. by using information from the respective national statistical offices. If a considerable amount of elements at risk is comprised by tourist infrastructure, the number of tourists being present in endangered buildings could be derived from the number of beds in the hotel and restaurant industry, multiplied by the respective rate of occupation.

As a result, a relational database is developed within the GIS environment, containing spatially precise information on the economic value of buildings at risk, and the number of inhabitants and tourists. If necessary, people at risk can be further evaluated using economic techniques such as the human capital approach [24], a well established method derived from the insurance industry [e.g. 25, 26]. A similar approach is recommended for infrastructure lines in [27, 28] based on earlier works [23]. Hence, the damage potential is monetised and can be further processed with respect to the risk equation (Equation 1). Therefore, information on the vulnerability of values at risk is necessary.

III.2.4 <u>Assessment of vulnerability</u>

From a technical perspective, vulnerability is usually considered as a function of a given process intensity towards physical structures, and is therefore related to the susceptibility of elements at risk. Thus, vulnerability – often referred to as 'physical' vulnerability in this context – is defined as the expected degree of loss for an element at risk as a consequence of a probability of failure [14]. Accordingly, if elements at risk are monetised within the framework of risk assessment, the vulnerability value provides the proportion of expected loss and ranges from 0 (no damage) to 1 (complete destruction). Its assessment involves in general the modelling and evaluation of several different parameters and factors such as the structural behaviour of the element at risk resulting from the hazard impact. This includes information on building materials and techniques, state of maintenance, presence of protection structures and so on [29, 30]. On the impact side, process parameters such as the intensity are – due to a lack of data[1] – often empirically analysed based on theories of probability, which is usually undertaken by mapping the geomorphologic disposition

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[1] Up to now, the most popular approaches in practice are mainly empirically based, given the limited scientific background in the field of structural vulnerability evaluation resulting from the hazard impact [31]. Finite element modelling, however, is increasingly used to model the physical impact on structures. So far, this method is able to account for material properties that might provide information on structural resistance. Due to the amount of uncertainties included, however, such methods concerning the reliability of structures have not been verified with respect to incurring losses, and conventional empirical relationships are used instead for operational risk analyses [32].

and the extent of previous events, and by modelling (defined design) events. Thereby the magnitude-frequency concept plays a key role. When the activity of different hazard processes is compared on a given timescale some processes appear to operate continuously while others operate only when specific conditions occur. The term eposidicity was used [33] to refer to the tendency of processes to exhibit discontinuous behaviour and to occur sporadically as a series of individual events. Episodicity appears when discontinuity is inherent in the forcing process, however, with respect to mountain hazards, the relationship between the initiating forcing process (e.g., intense but discontinuous rainfall) and the geomorphic response (e.g., formation of debris flows as a result from erosion and mobilisation of solid particles in a channel bed) is not constant. Operationally, triggering thresholds are used instead to indirectly approach the probability of occurrence of a specific design event, and connectivity is assumed to deduce the behaviour of the hazard process from that of the triggering factor itself.

By applying the concept of risk, the definition of vulnerability plays an important role in natural hazards research and in practical application within mountain environments [12, 13]. Hence, from an engineering point of view, considerable areas in European mountain regions are vulnerable to hazard processes. Even if the theory of vulnerability had been subject to extensive research and numerous practical application for the last decades, considerable gaps still exist with respect to standardised functional relationships between impacting forces due to occurring hazard processes and the structural damage caused [12, 13, 34]. This has to be attributed to the overall lack of data, in particular concerning losses caused by mountain hazards, often as a result of missing empirical quantification. Recently, promising approaches for a quantification of vulnerability have been made by [7, 11, 22] with respect to avalanches and rock fall processes, respectively. These suggestions are based on (partially estimated) empirical relations between impact forces (e.g., pressure, accumulation height) and observed damage to exposed buildings located in the respective run-out areas. However, sound suggestions for landslides and torrent processes are still outstanding, even if these processes caused major losses in the Alps in recent years [12, 35, 36].

A review of existing approaches relating to landslide risk assessment is provided by [12] and [34], and summarised with respect to landslides and torrent processes in Table III.2-2. The approaches for the evaluation of vulnerability vary significantly in detail of analysis and resulting numerical values. Although vulnerability is part of consequence evaluation, many approaches do neither specify the type of process they are applicable to (e.g., landslides, debris flows, hyperconcentrated flows), nor the physical mechanisms (e.g., travel distance) or the structural resistance of an endangered object. In particular, information on the process intensity is often missing and is therefore only described semi-quantitatively. Moreover, in none of the studies the universal set and the sample taken for empirical calculations were clearly specified.

Suggestions for a quantitative vulnerability-intensity relationship for the application in torrent risk assessment have been made by [12] based on case studies in Austrian torrent catchments, these have been extended by additional Swiss data [37], see Figure III.2-1. The applied method followed a spatial approach, and was based on accumulation heights as a proxy for process intensities, spatial data from elements at risk and average reconstruction values in dependence on the surface area on an object basis. The relationship between process intensity *x* and vulnerability *y* was found to fit best to the data by a second order polynomial function for all intensities $0.33 \leq x \leq 3.06$ m, see Equation (2). The coefficient of determination R^2 is 0.97, which seems to be comparatively sound with respect to the amount of data available.

$$f_{(x)} = \begin{cases} 0 \ \ if \ \ x < 0.\overline{3} \\ 0.12x^2 - 0.04x \ \ if \ \ 0.\overline{3} \leq x \leq 3.06 \\ 1 \ \ if \ \ x > 3.06 \end{cases} \tag{2}$$

Recent studies by [12, 13] suggested that the vulnerability for buildings located on a torrent fan will be overestimated if such values are applied during the assessment of risk. As a consequence, the results mirror the average expected systems behaviour (expected destruction due to impacting forces) for a certain amount of values at risk, e.g., the entire area of a torrent fan or an avalanche run-out area presumably affected by a defined 1 in 150 year event. However, this design event does not cover the entire possible run-out area, but only a certain part of it. This assumption is based on the repeatedly observation that the individual design event accumulates in a lobe-shaped pattern, in particular if the accumulation area is convex. Hence, the spatial probability of occurrence of individual scenarios may be neglected during the application of vulnerability-intensity relationships, and is continuously taken into account by applying overall spatial reduction factors during operational risk analyses. Furthermore, since resistance against impact forces is dependent on the construction type of buildings which is typically to be identified by field studies, determining structural vulnerability is very time-consuming and thus costly. Furthermore, the effects of processes in the run-out area is not yet completely known[2], consequently, modelled impact pressures can only be a rough estimate of the real system behaviour. With respect to mountain hazards, there were examples where an avalanche destroyed a building situated perpendicular to the avalanche axis (e.g., in the hamlet of Valzur, Paznaun, Austria, in February 1999), but there were cases where such a building was able to stop such an avalanche completely (e.g., in the village of Airolo, Ticino, Switzerland, February 1951). To conclude, the component of structural vulnerability within risk analysis for mountain hazards is still roughly specified, mainly due to a lack of intensive experimental or observational data. Nevertheless, within the present study, structural vulnerability is understood to be the source for any other vulnerability concept, since if there was no impact due to a hazardous event on elements at risk, no loss would result, and the society as a whole would not suffer harm.

[2] Future research concerning the behaviour of processes in the run-out areas is needed, in particular related to the structure of buildings. Buildings can have similar effects on hazard impacts as retarding mounds used for technical mitigation. Thus, due to a shift in the building pattern within the accumulation area [15, 38], buildings oriented towards the valley bottom tend to result in smaller risk than buildings that are located closer towards the transit area. Independent from the related political implications and the associated impacts on land-use planning, further studies on this effect should be carried out due to the probable reduction of the run-out areas and, as a consequence, the resulting risk.

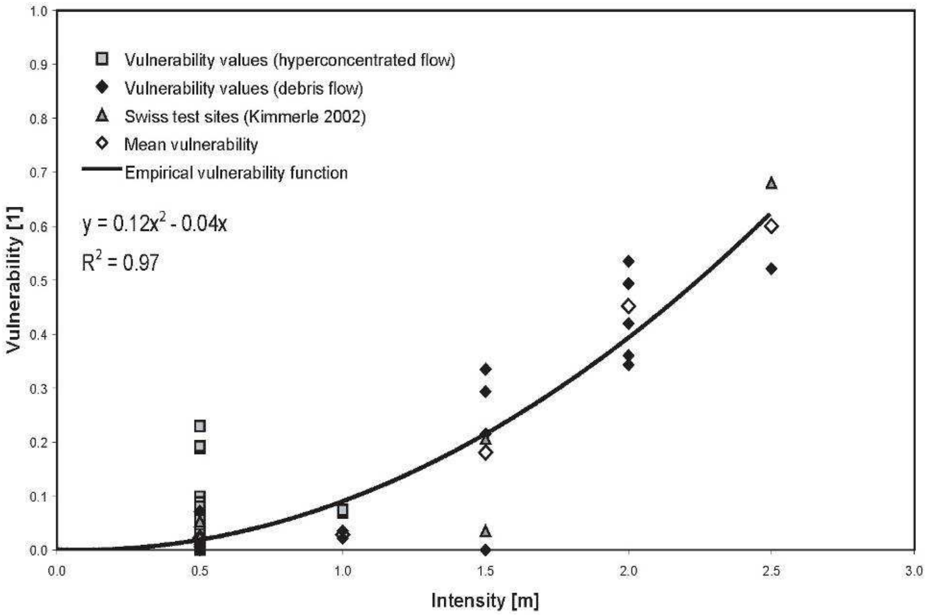

Figure III.2-1. Empirical vulnerability function for torrent processes in Austria. Data related to debris flows is shown by solid black rhombi (mean by framed white rhombi). Data from Swiss test sites is presented by grey triangles. Data originating from hyperconcentrated flows is shown by grey squares [14].

Without doubt, vulnerability is considerably decreased if local structural protection measures are implemented. However, further studies are needed in order to enhance the database on losses resulting from landslides, and to enable the development of a vulnerability function applicable on different spatial scales [14]. Until now, standardised values for average loss are used instead by public authorities for the operational application within cost-benefit analyses for protective measures [39]. Following these guidelines, the uniform damage of average buildings resulting from landslides is estimated to be € 28,800. However, there is some evidence from recently analysed data that these average values do not mirror the vulnerability of buildings towards landslides precisely with high accuracy [12].

III.2.5 Protective measures

In Austria, strategies to prevent or to reduce the effects of natural hazards in areas of settlements and economic activities trace back in the mediaeval times; official authorities were only founded in 1884 [40] based on a first legal regulation [41]. In the second half of the 19th and in the early 20th century, protection against natural hazards was mainly organised by implementing permanent measures in the upper parts of the catchments to retain solids from erosion and in the release areas of avalanches. These measures were supplemented by silvicultural efforts to afforest high altitudes. Since the 1950s such conventional mitigation concepts – which aimed at decreasing both, the intensity and the frequency of events – were increasingly complemented by more sophisticated technical mitigation measures. Until the 1970s, mitigation concepts mainly aimed at the deflection of hazard processes into areas not used for settlements.

Table III.2-2: Compilation of different suggestions related to an assessment of vulnerability of structural elements with respect to landslides and torrent processes [12:500].

			Intensity							
			qualitative				**(semi-)quantitative**			
			low	medium	high	very high	low	medium	high	very high
			not specified	not specified	not specified	not specified	not specified	h < 1 m or v < 1 m/s	h > 1 m and v > 1 m/s	not specified
Vulnerability	**qualitative**	[42-44]	not linked to process intensity							
		[45]	superficial	functional	structural	structural				
	quantitative	[30]	0.1	0.4	0.7	1.0				
		[46]	0.1 (distal)		1.0 (proximal)					
		[47]	0.1	0.2	0.5	not specified				
		[35]	not specified	0.1 - 0.2	0.5	not specified				
		[7, channel debris flows]					not specified	0.1	0.5	not specified

III.2.5.1 Conventional mitigation within the framework of risk management

In the Republic of Austria, conventional mitigation of natural hazards institutionally originates from the 1890s when the French system of forest-technical torrent and avalanche control was adopted. Watershed management measures, forest-biological and soil bio-engineering measures as well as technical measures (construction material: timber and stone masonry) had been implemented. Thus, conventional mitigation concepts only consider technical structures within the catchment, along the channel system or track and in the deposition area. According to the approach of disposition management (reducing the probability of occurrence of natural hazards) and event management (interfering the transport process of the hazard itself), a wide range of technical measures is applicable [48].

Conventional technical measures against land slides, such as deflection and retention walls and dams as well as torrential barriers against torrent related mass movements, are not only very cost-intensive in construction, moreover, they interfere with the ecology of the adjacent landscape [e.g., 49-51]. Additionally, because of a limited lifetime and therefore an increasing complexity of maintenance in high-mountain regions, future feasibility of technical structures is restricted due to a scarceness of financial resources provided by responsible authorities [52]. If maintenance is neglected, mitigation measures will become ineffective and can even increase the catastrophic potential of natural hazards. Since conventional technical measures do neither guarantee reliability nor complete safety [53], a residual risk of damage to buildings, infrastructure and harm to people remains.

Experiences from last years suggested that values at risk and spatial planning should be increasingly considered within the framework of natural hazard reduction [54]. To meet this goal, integral risk management strategies seem to be a valuable instrument to reduce the susceptibility of buildings and infrastructure to natural hazards and to develop strategies for a strengthened resistance, above all by means of local protection measures.

III.2.5.2 Local protection measures

Besides conventional technical mitigation measures, structural precaution is achieved by an adapted construction design and the appropriate use of an object. Structural precaution is the main application domain for local structural measures, since the individual vulnerability of buildings can be fundamentally decreased by strengthening e.g. brick walls with reinforced concrete components, and/or the adopted interior design of the different rooms according to occupancy time and hazard potential. A well organised utilisation of the rooms can influence the vulnerability and as a result the risk considerably [54].

The principles of planning and implementation of local structural measures to reduce vulnerability against natural hazards are neither highly sophisticated nor very innovative. However, the performance of local structural measures often is neglected or even ignored following the proverb that cheap solutions cannot be effective. Generally, local structural measures are “the afterthought of a tragedy rather than a forethought of prevention” and are “developed based on individual experiences more than scientific knowledge” [55]. Besides, in relation to the potential damage caused by natural hazards, the construction of local structural measures seems to be reasonable, in particular if renewal or reconstruction is planned [56].

Some basic principles should be considered for the implementation of local structural measures:

1. Knowledge of the interactions between all the possible hazard processes within the area concerned is required.
2. Spatial measures should be preferred to structural measures. The most effective way to avert the impact of natural hazards to damage potential is to keep the affected areas clear of values at risk.
3. Permanent measures should be preferred to mobile equipment. Due to high transport velocities of mountain mass movements and a short lead time for reaction, mobile mitigation measures cannot provide the same safety level than fix installed protective systems since they need a certain amount of time for installation.
4. Damage to third parties is not acceptable; hence, local structural protection must not cause negative impacts to adjacent or downstream riparian owners’ values at risk.
5. Combination of miscellaneous local structural measures decreases considerably the vulnerability.

Local structural measures can be distinguished and classified in various ways, i.e., according to the applicability for protection against the hazard process, the location with respect to the protected object, as well as the type of construction and material used; a further differentiation is possible whether the local structure is of permanent or temporary use [54].

Table III.2-3: Local structural measures for new buildings as well as for an upgrade of existing objects with respect to possible impacts of landslides [57].

Relevant impact	**Objective**	**Local structural measure**	**New building**	**Upgrade building**
Endangering the stability of the exposed object	Prevention of general damages	Stabilising sliding masses (supporting elements, vegetation)	+	+
		Drainage of sliding masses	+	+
	Prevention of damage to outwalls	Strengthening of exposed walls (reinforced concrete)	+	–
		Reinforced facing formwork	+	+
	Prevention of damage on intermediate ceilings	Strengthening of intermediate ceilings	+	–
	Subsidence, tilting, translational displacement	Static separation of structural levels	+	~
		Static separation of outbuilding	+	–
		Strengthened bedplate with cellar by reinforced concrete	+	–
		Deflection of load to stagnant ground	+	–
		Non-stop reinforcement from bedplate to wall	+	–
		Lightweight constructions by timber	+	–
Intrusion of sliding solids	Prevention of damage due to mechanical demolition and contamination	No openings in exposed walls	+	~
		Small windows (located far above ground level)	+	~
		Impact protection for windows (massive shutter)	+	–
		Concept of internal and external use of the object	+	+
		Combination of protection measures	+	+
		Constructive easily feasible		+
		Constructive hardly feasible		~
		Constructive not feasible		–

Impacts originating from the dynamic or static load of sliding material endanger the stability of a building (Figure III.2-2), in particular with respect to translational slumps. Several local structural measures can be implemented, the most popular are described in Table III.2-3 [57]. Two strategies mitigating losses due to land slides can be pursued, (1) stabilising unstable soil layers to prevent the initiation of mass movements, and (2) deflecting and/or retaining of already triggered masses.

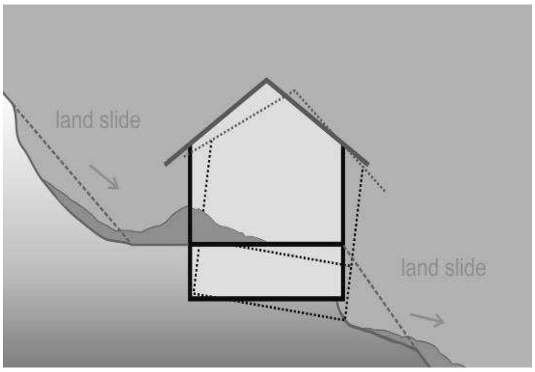

Figure III.2-2. Damage patterns to buildings due to landslides.

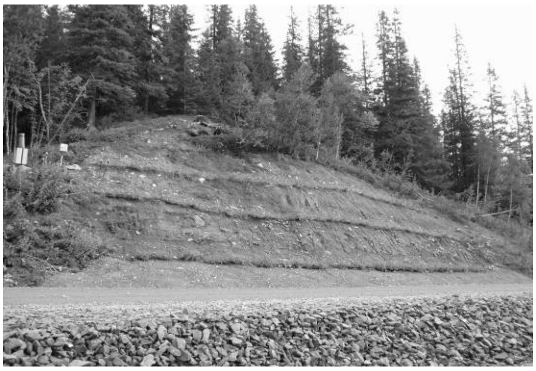

Figure III.2-3. New building and upgrade: Soil bio-engineering measures to stabilise unsteady slopes (courtesy of Rankka, 2005).

Figure III.2-4. New building and upgrade: Soil nailing measures to stabilise unsteady slopes (courtesy of Rankka, 2005).

Figure III.2-5. Enclosing structures: Drainage system to stabilise the sliding layers of the slope.

Figure III.2-6. New building and upgrade: Splitting wedge for splitting and deflecting mass movements.

Figure III.2-7. New building and upgrade: Deflection wall.

Considering the catalogue of local structural measures to protect buildings against landslides, selected examples of protection measures such as soil bio-engineering and soil-nailing are presented in Figures III.2-3 and 4. Moreover, the stabilisation of sliding masses is strongly supported by an efficient drainage system installed in the subsurface layers (Figure III.2-5). Instable and mobile masses can be deflected by suitable facilities (Figures III.2-6 and 7) constructed from appropriate materials, such as earth-filling, timber, gabions, stone masonry and reinforced concrete.

III.2.6 Integral risk management

The current method of dealing with natural hazards in Austria should be extended towards the holistic inclusion of damage potential exposed (cf. Equation 1), which is also prescribed by the European Directive on the Assessment and Management of Flood Risks adopted in July 2007 [58]. This extension directly brings about the concept of risk: The active and ex-ante management of natural hazards based on risk assessment, and including both, the assessment of elements in the natural environment and in society. With respect to natural hazards, the concept of integral risk management includes (1) risk analyses, mostly from a natural science point of view, (2) risk evaluation in collaboration with social scientists and politicians, and (3) interdisciplinary risk management strategies. Moreover, the comprehensive consideration of risk includes post-event concepts for recovery and an associated analysis of the damaging event in order to enhance and optimise the necessary risk management procedures [e.g., 9].

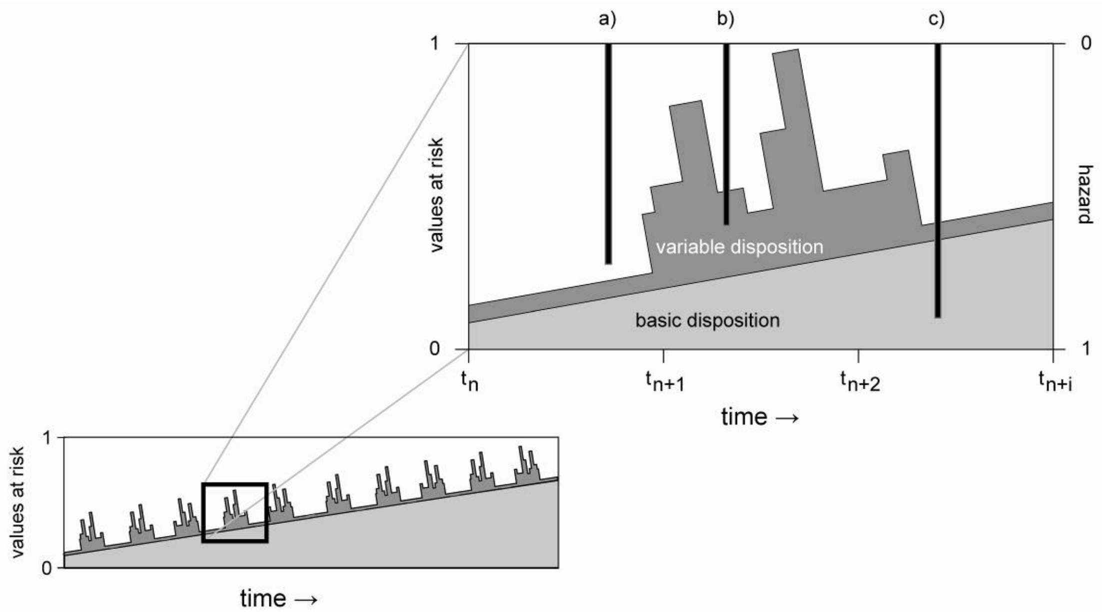

Figure III.2-8. Schematic description of the concept of basic (long-term) and variable (short-term) damage potential and the relation to triggering events [modified from 59:271].

However, risk changes over time since neither social systems not geosystems are static in space and time. Due to climate change processes and the associated impact on European mountain regions [60, 61], magnitude and frequency of natural processes will most probably slightly increase for those processes where water is the driving agent [62]. Furthermore, the change in risk – presumably indicated by remarkable damage in the 1990s – has to be attributed to changes in the damage potential affected [63]. The development of values at risk due to socioeconomic transformation in the European Alps varies remarkably on different temporal levels. These long-term and short-term variations in damage potential should be implemented into risk management approaches.

Long-term changes originate from the general increase in values at risk in mountain regions since the early 20th century. A considerable concentration of tangibles as well as intangibles had been proven [15-17] for different alpine regions, leading to a long-term increase in exposed values at risk. Superimposed short-term variations occur with respect to mobile damage potential and persons at risk. Information on the general development of damage potential and seasonal, weekly, or diurnal peaks should be implemented in the risk management procedure, because the range of the results is remarkably high, and the values at risk have a key influence on the risk equation.

In Figure III.2-8, the significance for a consideration of basic as well as variable disposition with respect to values at risk is presented. The basic disposition is defined as the long-term increase in values at risk, e.g. regarding the creeping increase in buildings exposed to landslides, while variable disposition is defined as a short-term fluctuation in variable damage potential, e.g., persons exposed. The need for a comprehensive assessment of risk is obvious if different hazard situations are considered. As shown in example (a) a hazard will not hit any values at risk, and thus, the level of risk reduction is sufficient. In example (b), due to high amounts of variable values at risk, damage will occur. As a result, temporal mitigation strategies could reduce the variable damage potential until a critical level. In contrast to the immobile damage potential (buildings and infrastructure, etc.), persons and mobile values can be removed from hazard-prone areas in case of dangerous situations. For developing efficient and effective evacuation and emergency plans, information on the numbers of persons and mobile values as well as their location and movements in the area is needed. In example (c), basic and variable values at risk are affected by a process. Thus, temporal measures are no more sufficient enough for an effective risk reduction, either conventional mitigation measures or local structural protection, or a combination, will be needed for an effective risk reduction. These examples clearly indicate the strong need for an incorporation of dynamic assessments of damage potential in community risk management strategies. Such risk management strategies should include an objective risk assessment that is based on both, hazard analysis and an analysis of damage potential.

III.2.7 Conclusion

As presented in the previous sections, Austria experiences a long tradition in dealing with mountain hazards, i.e. torrent processes, avalanches, and landslides. The concepts of analysing and assessing the hazard are comparatively well-established. Based on the respective legal prescriptions in the Forest Act and the Decree on Hazard Zoning, technical mitigation is implemented, and hazard maps are compiled. Similar procedures can be found in other European countries. However, neither values at risk nor the corresponding vulnerability are operationally assessed in a spatial and temporal resolution. These shortcomings are – with respect to mountain hazards – a result of missing quantitative data related to impact forces on elements at risk affected. Consequently, it is still not possible to quantitatively link impact forces to the reliability of structures, and to a respective expected severity of loss. Therefore, the methodology of integral risk management and the underlying foundations are still not fully implemented. Furthermore, the risk-reducing impact of local structural protection has not been assessed quantitatively.

Risk assessment has to be followed by a risk evaluation procedure. In this evaluation process, the level of accepted risk and the level of (residual) risk to be accepted should be defined by a participative process. Using these results, the risk management strategy could be defined, aiming at both a risk minimisation and an economic efficient use of public expenditures. Thus, a combination of mitigation strategies, such as passive and active measures, could be chosen to meet these prerequisites. Thereby, temporal variations of the risk have to be considered seriously.

Information on the temporal variability of values at risk both from a long-term as well as from a short-term point of view provided in combination with process knowledge is the basis for dynamic risk visualisation. Such information may help to recognise high-risk situations more easily and enables a situation-oriented and risk-based decision making [28, 64]. Apart from the damage potential, risk analyses are based on the concept of recurrence intervals of hazard processes. If those defined design events would be exceeded, the remarkable increase of values at risk would result in a significant shift in monetary losses (and presumably fatalities). First results on risk associated with torrent hazards suggest an increase in the probabilities of the design events in the alpine region, however, these results still need some additional analyses to be verified, and are subject to ongoing research.

Furthermore, because socioeconomic development differs within Alpine regions, studies on the long-term behaviour of values at risk contribute to the ongoing discussion of passive and active developing regions and suburbanisation [63]. However, if a potentially dangerous natural event occurs, it depends on the actual amount of values at risk (basic and variable disposition) within the process area whether or not damage will be triggered.

To conclude, risk analyses concerning natural hazards should be carried out with respect to a dynamic change of input parameters. This is essential for efficient disaster risk reduction and contributes to the concept of resilience as part of proactive adaptation. Regarding landslides in European mountains, the most important input parameter is the temporal variability of damage potential, since the natural variability of process activity seems to increase due to global change processes.

Thus, future research is needed to quantify the impact of modifications in damage potential on (1) the result of risk analyses, (2) the assessment of risk in the cycle of integrated risk management, (3) the adjustment of coping strategies, and (4) the perception of risk by all parties involved, including policy makers. The latter is the most crucial issue in Europe, because until now, dealing with natural hazards is based on mono-disciplinary approaches. In Austria, the Forest Act of 1975 restricts all hazards planning to forestry engineers [4, 5], in France, experts responsible for these issues are predominantly geologists [65], while in Italy, the requirement for these specialists is a PhD in agriculture or a master’s degree in forestry or geology [66]. However, because risk resulting from natural hazards is a subject matter affecting life and economy within the whole society, multiple stakeholders’ interests have to be considered when mitigation measures and coping strategies are developed and decisions are made [1]. Thus, there is a particular need to involve (1) economists with respect to an efficient and effective use of public expenditures, (2) social scientists with respect to both society’s risk perception and an enhanced risk communication, (3) engineers and land-use planners as well as (4) all other disciplines representing any other party involved.

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