Landslide Research and Technology in International Standards

Matjaž Mikoš

Abstract

Science, Technology, and Innovation play a pivotal role in the Sendai Framework for Disaster Risk Reduction 2015–2030 (SF DRR). The International Consortium on Landslides (ICL) initiated the Sendai Landslide Partnerships 2015–2025 as a voluntary commitment to SF DRR. In 2020, the ICL launched the Kyoto 2020 Commitment for Global Promotion of Understanding and Reducing Landslide Disaster Risk (KLC2020) as a follow-up of the Sendai Landslide Partnerships 2015–2025.

Landslide-related scientific articles discussing methodologies were extracted from the Web of Science and SCOPUS, using different search terms in the article titles, abstracts, and keywords. SCOPUS yielded a somewhat higher number of extracted articles, especially when using article abstracts. The extracted articles were mainly related to assessment, hazard, and risk, and less to vulnerability or damage.

A list of 22 international standards containing landslide-related terms (landslide, debris flow, rock fall) was prepared using the Online Browsing Platform by the International Organization for Standardization (ISO). This is a rather small fraction of over 22,000 ISO standards published so far. Next, two ISO standards are discussed in a more detailed way. Additionally, a set of Austrian standards in the field of torrent control are mentioned.

The International Consortium on Landslides with its global membership may contribute more to the field of standardization for landslide disaster risk reduction.

M. Mikoš (✉)
University of Ljubljana, UNESCO Chair on Water-Related Disaster Risk Reduction & Faculty of Civil and Geodetic Engineering, Ljubljana, Slovenia
e-mail: matjaz.mikos@fgg.uni-lj.si

Keywords

Disaster risk reduction · Early warning systems · International standards · Landslides · Sustainable development goals

1 Introduction

Landslide risk assessment, landslide mitigation strategies and technologies should to some extent be harmonized and based on some standardized procedures or standardized engineering mitigation works, if we want to estimate a global situation and make comparisons between regions and/or countries; or even transfer good practices from one part of the world into another one.

For example, recognition of landslides through the visual analysis of stereoscopic aerial photography is an empirical and uncertain technique, and standards for it do not exist (Guzzetti et al. 2012). The authors stated that there is a need for standardized landslide maps. Furthermore, the United States Geological Survey report from 2000 about the national landslide hazards mitigation strategy (USGS 2000) stated that in general, there are no standards for landslide hazard mapping and assessments in the USA. But spatial data used for risk assessment (i. e. spatial data infrastructure), also in the field of landslide disaster risk assessment, need to be harmonized to make it possible interoperability for any international collaboration or comparison/exchange (Núñez-Andrés et al. 2022). Any inventory data for modelling of natural hazards should be kept in harmonized databases based on internationally recognized standards so that such data can be shared (Wirtz et al. 2014). The European directive INSPIRE (Infrastructure for Spatial Information in the European Community) (Directive 2007) is based on the International Organization for Standardization (ISO) standards (ISO 2006) required harmonization of EU databases to obtain interoperable services to access to the databases. For natural risk zones, there are technical

I. Alcántara-Ayala et al. (eds.), *Progress in Landslide Research and Technology, Volume 2 Issue 1, 2023*,
Progress in Landslide Research and Technology, https://doi.org/10.1007/978-3-031-39012-8_7

guidelines for data specification on natural risk zones (INSPIRE 2013). European geological surveys are nowadays using the INSPIRE directive to harmonize their landslide databases (Herrera et al. 2018). The INSPIRE directive is also useful for development of multi-risk databases, which is the way to go to support multi-hazard risk assessment.

A landslide zoning methodology for Tasmania was developed by Mazengarb and Stevenson (2010) following the Guideline for landslide susceptibility, hazard and risk zoning for land use planning, produced by the Australian Geomechanics Society (AGS 2007a, b).

Choi and Cheung (2013), when discussing man-made slopes in Hong Kong susceptible to landsliding during periods of high seasonal rainfall, reported that prior to 1977, this situation was exacerbated by the lack of proper engineering standards in their design and construction.

Ortigao and Sayao (2004) in the Handbook on Slope Stabilization is mentioning standards, looking into the Subject Index, only in case of drilling and standard drilling diameter. Bobrowsky (2013) in Encyclopedia on Natural Hazards as the major reference work is mentioning standards, looking into the Subject Index, only when referring to building codes and standards. Bobrowsky and Marker (2018) in the Encyclopedia of Engineering Geology as the major reference work has only a few mentions of ISO standards, mainly in the context of diverse laboratory and field testing. In this encyclopedia, Van Westen (2018) wrote a contribution on Risk Mapping, stating that ISO 31000:2009 (revised as ISO 31000:2018) defines risk assessment as a process made up of three processes: risk identification, risk analysis, and risk evaluation.

The Indian National Landslide Risk Management strategy (NDMA 2019), based on wide spread property loss during recent landslides stated that most of the construction plans are ill-conceived and do not follow standard norms for landslide safety. Therefore, it recommends that the existing bylaws and regulations at local body or state level in India should be incorporated in the National Landslide Mitigation Policy and the National Landslide Mitigation Strategy.

Genevois et al. (2022) recognized the importance of standardization for the design of remediation works for mitigation and prevention against geological hazards: "*The choice of the most appropriate and cost-effective intervention must consider the type of hazard and environmental issues, and selects, wherever possible, naturalistic engineering operations that are consequently implemented according to the environmental regulations or the design and specification standards imposed by the competent public administrations*".

1.1 The Focus of This Study

A wide topic of landslide guidelines was recently covered e.g. by Flentje et al. (2007), Fell et al. (2008), and later Wang et al. (2013), who found in their review paper more than 30 such guidelines from around the globe. Landslide guidelines and best practices for professional engineers and geoscientists were also studied by Bobrowsky et al. (2014). Corominas et al. (2014) published recommendations for the quantitative analysis of landslide risk.

Some methodologies or guidelines are further developed and approved as international standards. The aim of this paper was focused on international standards. In this paper, the following research questions were the starting point for the study:

– Is standardization mentioned in important landslide-related international documents, such as the Sendai Framework for Disaster Risk Reduction, and the United Nations 2030 Agenda for Sustainable Development.
– Are there in the International Organization for Standardization (ISO) database with international standards documents related to landslide research, practice and technological applications for landslide disaster risk reduction.

2 Materials and Methods

2.1 Landslide Disaster Risk Reduction and the Sendai Framework for Disaster Risk Reduction 2015–2030

The Sendai Framework was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan in 2015. It outlines seven targets and four priorities for action to prevent new and reduce existing disaster risks (SF DRR 2015).

The methodologies and models for risk assessment is mentioned in the SF DRR text under Priority 1: Understanding disaster risk, namely at national and local levels: "*24 (j) To strengthen technical and scientific capacity to capitalize on and consolidate existing knowledge and to develop and apply methodologies and models to assess disaster risks, vulnerabilities and exposure to all hazards.*"

The development of standards is mentioned in the SF DRR under:

i) Priority 2: Strengthening disaster risk governance to manage disaster risk, namely at national and local levels: "*27 (j) To promote the development of quality standards, such as certifications and awards for disaster risk management, with the participation of the private sector, civil society, professional associations, scientific organizations and the United Nations.*", and
ii) Priority 3: Investing in disaster risk reduction for resilience, namely at national and local levels, it is important: "*30(h) To encourage the revision of existing or the development of new building codes and standards and rehabilitation and reconstruction practices at the national or local levels, as appropriate, with the aim of making them more applicable within the local context, particularly in informal and marginal human settlements, and reinforce the capacity to implement, survey and enforce such codes through an appropriate approach, with a view to fostering disaster-resistant structures."*
iii) Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction, namely at national and local levels, it is important: "*33(j) To promote the incorporation of disaster risk management into post-disaster recovery and rehabilitation processes, facilitate the link between relief, rehabilitation and development, use opportunities during the recovery phase to develop capacities that reduce disaster risk in the short, medium and long term, including through the development of measures such as land-use planning, structural standards improvement and the sharing of expertise, knowledge, post-disaster reviews and lessons learned and integrate post-disaster reconstruction into the economic and social sustainable development of affected areas. This should also apply to temporary settlements for persons displaced by disasters.*" and "*33(k) To develop guidance for preparedness for disaster reconstruction, such as on land-use planning and structural standards improvement, including by learning from the recovery and reconstruction programmes over the decade since the adoption of the Hyogo Framework for Action, and exchanging experiences, knowledge and lessons learned.*"
iv) Furthermore, technical standards are mentioned in the section V. Role of stakeholders in the manner that States should encourage actions such as: "*36(c) Business, professional associations and private sector financial institutions, including financial regulators and accounting bodies, as well as philanthropic foundations, … actively participate, as appropriate and under the guidance of the public sector, in the development of normative frameworks and technical standards that incorporate disaster risk management.*"
v) Also support from international organizations is covered by: "*48(c) The United Nations Office for Disaster Risk Reduction, in particular, to support the implementation, follow-up and review of the present Framework by: … reinforcing a culture of prevention among relevant stakeholders through supporting development of standards by experts and technical organizations, advocacy initiatives and dissemination of disaster risk information, policies and practices, as well as by providing education and training on disaster risk reduction through affiliated organizations ...*"

2.2 Landslide Disaster Risk Reduction and the United Nations 2030 Agenda for Sustainable Development

The General Assembly of the United Nations adopted in 2015 a resolution on the 2030 Agenda for Sustainable Development (UN 2015) and declared 17 Sustainable Development Goals (SDGs). Today, the Division for Sustainable Development Goals (DSDG) in the United Nations Department of Economic and Social Affairs (UNDESA) provides substantive support and capacity-building for the SDGs and their related thematic issues. The implementation of the 2030 Agenda for Sustainable Development and it 17 Sustainable Development Goals is supported by:

– A list of 169 targets of the 17 SDGs;
– A global indicator framework as contained in the UN resolution (UN 2017)—as of June 2022, it includes 231 unique indicators;
– The Global SDG Indicator Data Platform (https://unstats.un.org/sdgs/dataportal/)
– The annual SDG reports—as of June 2022, an advance unedited version of the SDG Progress Report 2022 is already available.

Strongly natural-hazard-related SDGs are:

• SDG9 Industry, Innovation and Infrastructure: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" with 8 targets, among them:
  – Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.
• SDG11 Sustainable Cities and Communities: "Make cities and human settlements inclusive, safe, resilient and sustainable" with 10 targets, among them:

- Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
- Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.
- Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels.

• SDG13 Climate Action: "Take urgent action to combat climate change and its impacts" with its 5 targets, among them:
  - Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.
  - Target 13.3: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

• SDG15 Life on Land: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" with its 12 targets, among them:
  - Target 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

Looking at the global indicator framework for SDGs, landslides are not mentioned in SDG indicators at all, they are covered by the more general term "disaster(s)".

In 2020, the Making Cities Resilient 2030 (UNDRR 2022) initiative was launched, supporting especially SDG11. ISO has supported these efforts by recently issuing three ISO standards on sustainable cities and communities in order for a city to recognize its level of resilience. The Intergovernmental Panel on Climate Change (IPCC 2012, p. 5) defines resilience as "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions".

2.3 The International Organization for Standardization (ISO) and the United Nations 2030 Agenda for Sustainable Development Goals

A practical guide how the practical experience of regulatory authorities, governments and local administrations, as well as regional groups of countries are using standards towards sustainable development and the implementation of the Agenda 2030 was prepared by the United Nations Economic Commission for Europe (UNECE 2018).

The implementation of the UN SDGs is supported also by the International Organization for Standardization (ISO) and their over 22,000 standards (ISO 2018). A special web platform (ISO 2022b) was developed for stakeholders to search for any ISO standards that correspond to each of the 17 SDGs. Using ISO Advanced Search for Standards web page, for each of the SDGs, relevant ISO standards can be searched for, using keywords or phrases.

2.4 Landslide Definitions in International Standards

Hungr et al. (2014) have defined the variety of landslide forms, and described their visible signs to be recognized in the field as well as their peculiarities. Such a system to distinguish between different landslide forms is mainly used to systemize various landslide processes. When looking at international standards, such a fine-tuned system on landslide classification is not used at all, and the definitions are much more rudimentary.

The International Organization for Standardization (ISO) has launched a new Online Browsing Platform (OBP). With this search engine it is possible to access the most up-to-date contents in ISO standards, graphical symbols, codes or terms and definitions.

Using Online Browsing Platform (ISO 2022a) for looking for terms in ISO standard database, the terms are defined:

i) the term »landslides« is defined as:

- »wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill or a combination of these« in two standards: ISO 22300:2021(en) and ISO 22327:2018(en)
- »phenomenon of rock mass, earth mass or debris moving down a slope under gravity" in one technical guidelines IWA 33-1:2019(en) 5.8;

ii) the term »debris flow« and "mudflow" is defined as:

– "sudden flood carrying a lot of solid matter like sediment and rocks, which takes place in a mountainous area, in most cases due to a rainstorm or intense melting of ice and snow" in one technical guidelines IWA 33-1:2019 (en) 5.12—the definition is given jointly for "debris flow" and "mudflow", no distinction is made;

iii) the term »rockfall« is defined as:

– "phenomenon of rock falling abruptly down a steep slope" in one technical guidelines IWA 33-1:2019(en) 5.9.

3 Results and Discussion

3.1 Methodologies for Landslide Disaster Risk Reduction

The two databases: Web of Science Core Collection (WoS) by Clarivate Analytics, and SCOPUS by Elsevier were used to look at the total number of landslide-related articles published in these two databases that discuss methodologies. For the WoS we used the following search term: "landslide* AND methodology*" in Title, Author keywords, Abstract, and Topic (title, abstract, author keywords, and Keywords Plus). For the SCOPUS we used the same search term: "landslide* AND methodology*" in Article Title (TITLE), Keywords (KEY), Abstract (ABS), and in Article title & Abstract & Keywords (TITLE-ABS-KEY).

The same approach was applied also for the terms "debris flow*", "mud flow*", "rockfall*" and "rock fall*", respectively. The total number of landslide-related articles in these two databases is shown in Table 1. Generally, as expected, more articles were found in SCOPUS than in Web of Science Core Collection (Clarivate 2022); especially when looking at article abstracts. Each of the collected groups of articles were further sub-categorized with respect whether they also contain one of the six landslide-related terms: susceptibility, hazard, vulnerability, damage, risk, and assessment. The most abundant were landslide-related articles containing also the terms hazard, risk, and assessment. Much less abundant were articles containing the terms susceptibility, vulnerability and damage (see Table 1 for details). The landslide-related articles about methodologies are rather general, covering hazard, risk, and hazard and risk assessment, and much less about methodologies for susceptibility, vulnerability and damage. From process point of view, the largest number of collected articles were related to landslide(s), followed by debris-flow(s)-related and rockfall-related articles; the least articles were found to be related to mud flow(s). We should remember that all collected articles were about methodologies.

A step in the direction of standardization in the field of landslide disaster risk reduction is also to develop (joint) methodologies for assessing different parameters relevant for landslide DRR. Klose et al. (2014, 2015) proposed a methodological approach to landslide cost modeling for transportation infrastructures.

3.2 Graphical Symbols for Landslides

There are only two registered landslide-related graphical symbols defined in ISO standard for graphical symbols ISO 7010:2019(en), namely sign W076 for warning of a "debris flow zone", and W078 for warning of a "Landslide zone", respectively:

– the former is used to warn of a zone where large debris flow or flash flooding can occur with the intention to understand the warning by: "*taking care in the vicinity of zones susceptible to flash flooding or debris flow following torrential or persistent heavy rainfall*", and
– the latter is used to warn of landslide or unstable slopes with the intention to understand the warning by: "*taking care in the vicinity of zones susceptible to landslides or unstable slopes following earthquake, heavy rain or stormy weather*".

A reference to these warning signs is given in ISO 22578:2022(en).

A good overview of natural disaster safety way guidance system ISO/DIS 22578 is given on the web (Sanwa Sanko 2022).

3.3 Landslide-Related International Standards (ISO)

In Table 2 shown international standards are mentioning landslide-related terms to a different extent—it is more clearly related to landslides if the used term is mentioned in the section "1 Scope" of the standard.

There are though a few more specific international standards related to landslides. We will show two case studies in this regard on the basis of ISO standards. The third case study will be dedicated to the Austrian standards in the field of torrent control that cover broad field of landslide phenomena in mountain areas, including debris flows and rock falls.

Table 1 The total number of landslide-related articles discussing methodologies from Web of Science Core Collection and SCOPUS databases (as of the end of July 2022)

Web of Science Core Collection						
Total number	. . . article further related to:					
	Susceptibility	Hazard	Vulnerability	Damage	Risk	Assessment
*Landslide**						
Title: 84	18	12	3	2	13	15
Author keywords: 17	4	6	2	0	2	4
Abstract: 1443	353	523	137	243	476	460
Topic: 1900	596	953	219	316	732	786
*Debris flow**						
Title: 9	0	3	1	0	1	1
Author keywords: 4	1	1	1	0	1	0
Abstract: 349	39	119	29	66	99	99
Topic: 554	93	229	51	96	166	210
*Mud flow**						
Title: 0	0	0	0	0	0	0
Author keywords: 0	0	0	0	0	0	0
Abstract: 92	2	7	1	12	6	8
Topic: 115	5	9	2	13	11	15
Rockfall OR Rock fall**						
Title: 19	0	9	1	0	4	9
Author keywords: 3	1	2	1	0	1	0
Abstract: 293	29	113	21	44	91	87
Topic: 361	61	175	29	58	138	136
SCOPUS						
*Landslide**						
Article title: 115	20	17	3	2	22	20
Keywords: 247	49	86	23	16	70	101
Abstract: 2088	437	783	219	332	711	635
Article title, Abstract, Keywords: 2389	493	1,017	278	378	891	1,091
*Debris flow**						
Article title: 15	0	5	1	0	3	3
Keywords: 59	2	15	3	6	12	19
Abstract: 544	47	199	47	97	167	150
Article title, Abstract, Keywords: 824	58	247	56	124	210	274
*Mud flow**						
Article title: 1	0	0	0	1	0	0
Keywords: 7	0	0	0	0	0	0
Abstract: 271	4	14	2	37	25	20
Article title, Abstract, Keywords: 324	4	23	2	47	40	36
Rockfall OR Rock fall**						
Article title: 6	0	4	0	0	2	3
Keywords: 6	0	3	0	0	2	2
Abstract: 290	15	71	16	31	81	60
Article title, Abstract, Keywords: 365	16	101	18	39	104	117

Note: An article can be related to several categories

Table 2 An overview of international standards containing landslide-related terms (debris flow, landslide, rock fall) as found in the Online Browsing Platform (ISO 2022a). The standards are given in a numerical order

Standard	Mention in the standard text
ISO 2394:2015(en)	1 Scope This International Standard constitutes a risk- and reliability-informed foundation for decision making concerning design and assessment of structures both for the purpose of code making and in the context of specific projects. The principles presented in this International Standard cover the majority of buildings, infrastructure, and civil engineering works, whatever the nature of their application and use or combination of the materials used 6.2.2.2 Classification . . . Geotechnical actions from soil or rock, including earth pressures, earth slides and earthquakes, sub-soil vibrations, settlements . . .
ISO 6421:2012(en)	1 Scope This International Standard describes methods for the measurement of temporal and spatial changes in reservoir capacities due to sediment deposition. 4.1 Origin of the sediment deposited in the reservoir . . . to the rock type and slope of the drainage basin. In addition, ***landslides*** produce ***debris flows***. Sediment is delivered to the reservoir both as suspended sediment load and as bed ...
ISO 7010:2019(en)	1 Scope This International Standard prescribes safety signs for the purposes of accident prevention, fire protection, health hazard information and emergency evacuation. Amendment 117: Safety sign W076: Warning; ***Debris flow*** zone. Amendment 119: Safety sign W078: Warning; ***Landslide*** zone.
ISO 10252:2020(en)	1 Scope This International Standards provides requirements and guidelines for the design and assessment of structures in relation to the possible occurrence of accidental actions induced by human activities. Fire and man-made earthquake, however, are not included. 5.1 Types of accidental actions Accidental actions due to human activities shall be considered in the design and assessment of buildings and other civil engineering structures. These actions include but are not limited to: – Impact from vehicles, trains and tramways, ships, aircrafts, helicopters, forklift trucks, falling materials (***rockfall***, ***debris flow***, dropped objects from cranes), machine related impacts like toppling cranes, wind turbines, parts detached from a rotary machine, blades detached from turbines, etc.; . . .
ISO 13628-15:2011 (en)	1 Scope This part of ISO 13628 addresses recommendations for subsea structures and manifolds, within the frameworks set forth by recognized and accepted industry specifications and standards. It covers subsea manifolds and templates utilized for pressure control in both subsea production of oil and gas, and subsea injection services. 5.5.1 General . . . subsurface obstacles such as boulders, as well as drilling aspects such as mud pressure, ***mudflow***, washout, etc., as part of the selection criteria. In order to design ...
ISO 14055-1:2017 (en)	5.3.1.1 Soil erosion by water ... of deep incisions, down into the subsoil, due to concentrated runoff; —***landslides***, ***mudflows*** or mass movements of soil that occur locally and often cause widespread serious damage; ... A.5.2 Volcanic eruptions . . . Hazards associated with volcanic eruptions include lava flows, falling ash and projectiles, ***mudflows***, and toxic gases. Volcanic activity may also trigger other natural hazardous events . . .
ISO 16063-42:2014 (en)	1 Scope This part of ISO 16063 specifies the instrumentation and procedure to be used for the accurate calibration of seismometer sensitivity using local gravitational acceleration (local Earth's gravitation; local value for the acceleration due to the Earth's gravity) as a reference value. The intended end-usage of the seismometer to be applied is as follows: a) measurement and observation for the earth science including geophysics usage; b) measurement and observation for disaster prevention, such as detecting the precursor of a ***land slide***; . . .
ISO 17745:2016(en)	1 Scope This International Standard specifies the characteristics of steel wire ring net panel for retaining of unstable slopes controlling and preventing ***rockfalls*** and loose ***debris flow*** along roads, highways and railway, urban areas, mines and quarries, and for snow avalanche protection produced from metallic-coated steel wire or advanced metallic coating. It is not applicable to anchors or soil nails for fixing of steel mesh to an unstable slope.
ISO 17746:2016(en)	1 Scope This International Standard specifies the characteristics of steel wire rope net panels and rolls for retaining of unstable slopes controlling and preventing ***rockfalls*** and loose ***debris flow*** along roads, highways and railway, urban areas, mines and quarries, and for snow avalanche protection.
ISO 19901-2:2017 (en)	1 Scope This International Standard contains requirements for defining the seismic design procedures and criteria for offshore

(continued)

Table 2 (continued)

Standard	Mention in the standard text
	structures; guidance on the requirements is included in Annex A. The requirements focus on fixed steel offshore structures and fixed concrete offshore structures. The effects of seismic events on floating structures and partially buoyant structures are briefly discussed. 5 Earthquake hazards . . . the design and, when warranted, should be addressed by special studies (e. g. ***mudflow*** loading, seabed deformation) . . .
ISO 19901-8:2014 (en)	1 Scope This part of ISO 19901 specifies requirements, and provides recommendations and guidelines for marine soil investigations. A.1 Scope of work . . . description and dating of turbidites, of soil in a deposition area of previous ***debris flows***. In some cases, specialized combinations of shallow geophysical investigation and marine soil ...
ISO 19901-10:2021 (en)	1 Scope This part of 19901 provides requirements and guidelines for marine geophysical investigations. A.10.6 Investigation of geohazards . . . the resulting mass-transport deposits (stacked or rafted blocks, slides, slumps, ***debris flows***, ***mudflows***, creep features, turbidites, meta-stable slopes, loose sands, etc.) . . .
ISO 20074:2019(en)	1 Scope This International Standard specifies requirements and gives recommendations on the management of geohazards risks during the pipeline design, construction and operational periods. This standard is applicable to all reasonable and credible natural hazards induced by natural forces and hazards induced by human activity that manifest similarly to natural hazards collectively referred to as "geological hazards" or "geohazards", or through industry as attributed to "natural forces". Geohazards covered by this standard include, but are not limited to: – Mass wasting processes, including ***landslides***, lateral spreads, ***rockfalls***, ***debris flows***, avalanches, and similar processes whether naturally occurring or anthropogenic; . . .
ISO 22327:2018(en)	1 Scope This International Standard gives guidelines for a ***landslide*** early warning system. It provides a definition, aims to improve understanding, describes methods and procedures to be implemented, and gives examples of types of activities. It is applicable to communities vulnerable to ***landslides***, without taking secondary effects into consideration. It recognizes population behaviour response planning as a key part of the preparedness. It takes into account the approach of ISO 22315:2014(en) and provides additional specifications for ***landslides***.
ISO 22328-1:2020 (en)	Introduction Disasters such as earthquakes, tsunamis, volcanic eruptions, high river flows (e. g. floods, low river flows, sudden flash floods), ***landslides***, storm surges and hurricanes as well as slow-onset events such as drought, extreme temperatures, heat waves or soil erosion can have devastating impacts. 1 Scope This International Standard gives guidelines for the implementation of a community-based disaster early warning system (EWS). It describes the methods and procedures to be implemented and provides examples. This document is applicable to communities vulnerable to disasters, without taking secondary/indirect effects into consideration.
ISO 31000:2018(en)	1 Scope This International Standard provides guidelines on managing risk faced by organizations. The application of these guidelines can be customized to any organization and its context. This document provides a common approach to managing any type of risk and is not industry or sector specific.
ISO 37120:2018(en)	1 Scope This International Standard specifies and establishes definitions and methodologies for a set of indicators for smart cities. As accelerating improvements in city services and quality of life is fundamental to the definition of a smart city, this standard, in conjunction with ISO 37120, is intended to provide a complete set of indicators to measure progress towards a smart city. 3 Terms and definitions 3.7 Natural hazard Geological or meteorological phenomena that can cause damage to physical infrastructure or loss of life in cities
ISO 37122:2019(en)	1 Scope This International Standard specifies and establishes definitions and methodologies for a set of indicators for smart cities. As accelerating improvements in city services and quality of life is fundamental to the definition of a smart city, this standard, in conjunction with ISO 37120, is intended to provide a complete set of indicators to measure progress towards a smart city.
ISO 37123:2019(en)	1 Scope This International Standard defines and establishes definitions and methodologies for a set of indicators on resilience in cities. This standard is applicable to any city, municipality or local government that undertakes to measure its performance in a comparable and verifiable manner, irrespective of size or location. Maintaining, enhancing and accelerating progress towards improved city services and quality of life is fundamental to the definition of a resilient city,

(continued)

Table 2 (continued)

Standard	Mention in the standard text
	so this standard is intended to be implemented in conjunction with ISO 37120. This standard follows the principles set out in ISO 37101, and can be used in conjunction with this and other strategic frameworks. 3 Terms and definitions 3.3 Hazard . . . Geological or geophysical hazards originate from internal earth processes (e.g. earthquakes, volcanic activity, ***landslides***, ***rockslides***, ***mud flows***). Hydro-meteorological hazards are of atmospheric, hydrological or oceanographic origin (e.g. cyclones, typhoons, hurricanes, floods, drought, heatwaves, cold spells, coastal storm surges). Hydro-meteorological conditions can also be a factor in other hazards such as ***landslides***, wildland fires and epidemics. . . . 3.4 Hazard map Map developed to illuminate areas that are affected or vulnerable to a particular hazard (e.g. earthquakes, ***landslides***, ***rockslides***).
ISO/DIS 22328-2	1 Scope This standard under development gives guidelines for a landslide early warning system. It provides a definition, aims to improve understanding, describes methods and procedures to be implemented, and gives examples of types of activities. It is applicable to communities vulnerable to landslides, without taking secondary effects into consideration. It recognizes population behaviour response planning as a key part of the preparedness. It takes into account the approach of ISO 22315 and provides additional specifications for landslides.
ISO/DIS 22328-3(en)	1 Scope This standard complements the generic guidelines in ISO 22328-1 by giving additional information related to tsunamis. It provides definitions, understanding, method, procedure, implementation, and activities specifically related to tsunamis.
ISO/TS 21219-19: 2016(en)	1 Scope This part of ISO/TS 21219 defines the TPEG Weather (WEA) application for reporting weather information for travellers. It provides general weather-related information to all travellers and is not limited to a specific mode of transportation. 9.27 wea110:HazardElements . . . Flooding 2 Localized flooding 3 Risk of flash floods 4 Storm surge 5 ***Landslides*** 6 ***Mudflows*** 7 Smoke 8 Smog 9 Ash cloud 10 Dust 11 Sand 12 Dust whirls . . .

3.4 Case Study 1: Standardization Efforts for Landslide Early Warning Systems (LEWS)

The implementation of a community-based disaster EWS is consistent with the Sendai Framework for Disaster Risk Reduction of 2015–2030 (SF DRR 2015), specifically target g) of the seven global targets: "*Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030*". Based on the fourth priority of the framework, the improvement of preparedness is the basis for the capability to respond effectively to a disaster. Improvement of preparedness can be achieved by implementing an EWS, in addition to improving the dissemination and communication of knowledge about the early warning of disasters at local, national, regional and international levels.

Also the Kyoto 2020 Commitment for Global Promotion of Understanding and Reducing Landslide Disaster Risk KLC2020 (Sassa 2021) recognizes the importance of EWS: the Priority action no. 1 "People centered early warning", and the Priority action no. 3 "Technologies for monitoring, testing & early warning".

An Early Warning System (EWS) was recognized by the Sendai Framework for Disaster Risk Reduction (SF DRR 2015) as an important contribution to the improvement of preparedness as a part of disaster risk reduction—also for landslide disaster risk. A community-based warning system is defined in ISO 22315:2014(en) as "*a method to communicate information to the public through established networks*".

A new proposal of a standard for community-based landslide early warning systems has been promoted to the International Organization for Standardization (ISO) by Universitas Gadjah Mada (Fathani et al. 2016, 2017, 2022; Fathani and Karnawati 2018), in corporation with the Indonesian Standardization Agency and the National Agency for Disaster Management (BNPB). The Indonesian proposal was accepted and published as ISO 22327:2018 Guidelines for implementation of a community-based landslide early warning system—a first international ISO standard coming from a developing country (Fathani et al. 2022). The work was led by the ISO Technical Committee 292 Security and resilience (ISO/TC 292), established in 2015 and currently with 47 participating members and 22 observing members (National Standards Bodies).

In 2020, LandAware as a new international network of landslide early warning systems was established. Among the network goals there is also a statement that its members are committed to: "producing common standards and terminology, guidelines, recommendations, opinion papers and white papers (Calvello et al. 2020).

3.5 Case Study 2: Standardization Efforts for Sustainable Cities and Communities

Since the world population in urban environments has overtaken the one in non-urban, rural areas, the importance of SDG11 on Sustainable Cities and Communities is obvious. The International Organization on Standardization (ISO) via its technical committee ISO/TC 268 has published three ISO standards on sustainable cities and communities defining indicators for: city services and quality of life (ISO 37120: 2018), smart cities (ISO 37122:2019), and resilient cities (ISO 37123:2019). The term natural hazard in the first standard on city services and quality of life covers geological and meteorological phenomena that can cause damage to physical infrastructure or loss of life in cities (see Table 2). As one of the ten safety indicators in this standard, "Number of natural-hazard-related death per 100,000 population" is a core indicator. The term hazard used in the standard on resilient cities covers flooding and also landslides, rockslides and mud flows (see Table 2); and a resilient city should be able to thrive regardless of the hazards, shocks and stresses it faces. Among city indicators, many are disaster-related or natural-hazard-related, among others the following ones:

- Historical disaster losses and average annual disaster loss as a percentage of city product.
- Percentage of population trained in emergency preparedness and disaster risk reduction.
- Frequency with which disaster-management plans are updated.
- Percentage of buildings structurally vulnerable to high-risk hazards.
- Percentage of damaged infrastructure that was "built back better" after a disaster.
- Percentage of population at high risk from natural hazards.
- Annual percentage of the city population directly affected by natural hazards.
- Percentage of city population covered by multi-hazard early warning system.
- Percentage of city area covered by publicly available hazard maps.

3.6 Case Study 3: Standardization in the Field of Torrent Control in Austria

In Austria, there is a long tradition in the torrent control activities (Hübl and Nagl 2019). Therefore, different approaches for designing and numerous types of protection structures on different condition levels exist. A set on national standard rules as technical regulative acts were prepared by a national interdisciplinary working group in order to achieve a standardization of the load models, design, construction, and life cycle assessment of technical structures as protection works for torrent control founded on the Eurocode, encompassing: i) torrential processes, ii) snow avalanches, and iii) rock fall.

The new standardization for torrential processes in Austria encompasses the following rules:

- Protection works for torrent control—Definition and classification (ONR 24800:2009).
- Protection works for torrent control—Action on structures (ONR 24801:2013).
- Protection works for torrent control—Design of structures (ONR 24802:2011).
- Protection works for torrent control—Operation, monitoring and maintenance (ONR 24803:2008)

that would include among others also protection works against debris flows, especially debris-flow dams, their planning, design, and implementation.

The new standardization for rockfall processes in Austria encompasses the following rule:

- Technical protection against rockfall—Terms and definitions, effects of actions, design, monitoring and maintenance (ONR 24810:2021)

that applies to primary measures such as anchorage and nailing and also secondary measures (e. g. nets, dams). Static and dynamic load assumptions are described as well as proof of evidence for actions and materials. In addition, this ONR 24810:2021 specifies current surveillance of construction and acceptance of the measures implemented, maintenance and repair as well as durability of the measures taken.

These above mentioned national technical rules were published in German language, and are presented in details in professional literature (ASI 2014).

4 Conclusions and Further Work

This article is a companion paper to the original article on landslide research and technology in patent documents (Mikoš 2022). Taking both articles into consideration, further such studies are needed to enlighten the present state-of-the-art status of landslide research and technology around the world from this rarely used perspective (patents & standards).

It is true that landslide risk mitigation is in many respects location-impacted problem to be solved each in an original way, taking into account local conditions and triggering mechanisms as well as its own landslide dynamics, bringing in also "engineering judgement". But standardization in the field of landslide research and technology may nevertheless help to improve the overall success of landslide hazard and risk prevention and mitigation. The standardization is at the top of a pinnacle, composed of best available technologies (BAT), best practice case studies, Lessons Learned, white papers, opinion papers, methodologies, recommendations, guidelines etc. The existing landslide-related international standards are concentrated to landslide prevention on one side, and on the other side to field and laboratory methods for soil and rock investigations and technologies to design and execute mitigation measures, and on supporting building codes. Many more options are open to work on new standards to support landslide disaster risk reduction, locally and globally.

The International Consortium on Landslides with its global membership may take a more active role in this regard in future as a part of its voluntary contribution to the Sendai Framework for Disaster Risk Reduction 2015–2030 within the activities of the Kyoto 2020 Commitment for Global Promotion of Understanding and Reducing Landslide Disaster Risk.

Acknowledgments The author would like to acknowledge the financial support of Slovenian Research and Innovation Agency by core funding P2-0180, and of the University of Ljubljana from the Development Fund for the activities of the UNESCO Chair on Water-related Disaster Risk Reduction (WRDRR).

References

AGS (2007a) Guideline for landslide susceptibility, hazard and risk zoning for land use planning. Aust Geomech 42(1):13–36

AGS (2007b) Commentary on guideline for landslide susceptibility, hazard and risk zoning for land use planning. Aust Geomech 42(1):37–62

ASI (2014) Normensammlung Schutz vor Naturgefahren: Die Normenreihe ONR 24800 über Wildbach-, Lawinen- und Steinschlagschutzbauwerke. Austrian Standards Institute, Vienna, Austria. 512p. ISBN 978-3-85402-290-9. https://shop.austrian-standards.at/action/de/public/details/515135/Austrian_Standards_Institute__Hrsg____Normensammlung_Schutz_vor_Naturgefahren_-_Die_Normenreihe_ONR_24800_ueber_Wildbach-__Lawinen-_und_Steinschlagschutzbauwerke_____ISBN_978-3-85402-290-9

Bobrowsky PT (ed) (2013) Encyclopedia of natural hazards. Springer Dordrecht, 1133 p. https://doi.org/10.1007/978-1-4020-4399-4

Bobrowsky PT, Marker B (eds) (2018) Encyclopedia of engineering geology. Springer International Publishing, Cham, 978 p. https://doi.org/10.1007/978-3-319-73568-9

Bobrowsky P, VanDine D, Couture R (2014) Landslide guidelines and best practices for professional engineers and geoscientists. In: Lollino G, Arattano M, Giardino M, Oliveira R, Peppoloni S (eds) Engineering geology for society and territory, vol 7. Springer, Cham. https://doi.org/10.1007/978-3-319-09303-1_45

Calvello M, Devoli G, Freeborough K, Gariano SL, Guzzetti F, Kirschbaum D, Nakaya H, Robbins J, Staehli M (2020) LandAware: a new international network on Landslide Early Warning Systems. Landslides 17(10):2699–2702. https://doi.org/10.1007/s10346-020-01548-7

Choi KY, Cheung RWM (2013) Landslide disaster prevention and mitigation through works in Hong Kong. J Rock Mech Geotech Eng 5(5):354–365. https://doi.org/10.1016/j.jrmge.2013.07.007

Clarivate (2022) Web of Science Core Collection Cited References Search. Clarivate Analytics, Philadelphia, PA. https://www.webofscience.com/wos/woscc/cited-reference-search. Accessed 23 Apr 2022

Corominas J, van Westen C, Frattini P, Cascini L, Malet J-P, Fotopoulou S, Catani F, Van Den Eeckhaut M, Mavrouli O, Agliradi F, Pitilakis K, Winter MG, Pastor M, Ferlisi S, Tofani V, Hervas J, Smith JT (2014) Recommendations for the quantitative analysis of landslide risk. Bull Eng Geol Environ 73:209–263. https://doi.org/10.1007/s10064-013-0538-8

Directive (2007) Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Off J Eur Union, L 108/1–108/14. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007L0002. Accessed 16 Jul 2022

Fathani TF, Karnawati D, Wilopo W (2016) An integrated methodology to develop a standard for landslide early warning systems. Nat Hazards Earth Syst Sci 16:2123–2135. https://doi.org/10.5194/nhess-16-2123-2016

Fathani TF, Karnawati D, Wilopo W (2017) Promoting a global standard for community-based landslide early warning systems (WCoE 2014–2017, IPL-158, IPL-165). In: Sassa K, Mikoš M, Yin Y (Eds.): Advancing culture of living with landslides. 1 ISDR-ICL Partnerships 2015-2025. Springer, Cham 355–361.

Fathani TF, Karnawati D (2018) TXT-tool 2.062-1.1: A landslide monitoring and early warning system. In: Sassa K et al (eds) Landslide dynamics: ISDR-ICL landslide interactive teaching tools, Fundamentals, mapping and monitoring, vol 1. Springer, Cham, pp 297–308. https://doi.org/10.1007/978-3-319-57774-6_21

Fathani TF, Karnawati D, Wilopo W, Setiawan H (2022) Strengthening the resilience by implementing a standard for landslide early warning system. In: Sassa K et al (eds) Progress in landslide research and technology, vol 1, No. 1. Springer, Cham. (in print)

Fell R, Corominas J, Bonnard C, Cascini L, Leroi E, Savage WZ (2008) Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Eng Geol 102:85–98. https://doi.org/10.1016/j.enggeo.2008.03.022

Flentje PN, Miner A, Whitt G, Fell R (2007) Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Aust Geomech 42(1):13–26. https://ro.uow.edu.au/engpapers/2823

Genevois R, Tecca PR, Genevois C (2022) Mitigation measures of debris flow and landslide risk carried out in two mountain areas of North-Eastern Italy. J Mt Sci 19(6):1808–1822. https://doi.org/10.1007/s11629-021-7212-6

Guzzetti F, Mondini AC, Cardinally M, Fiorucci F, Santangelo M, Chang K-T (2012) Landslide inventory maps: new tools for an old problem. Earth Sci Rev 112:42–66. https://doi.org/10.1016/j.earscirev.2012.02.001

Herrera G, Mateos RM, García-Davalillo JC et al (2018) Landslide databases in the geological surveys of Europe. Landslides 15:359–379. https://doi.org/10.1007/s10346-017-0902-z

Hungr O, Leroueil S, Picarelli L (2014) The Varnes classification of landslide types, an update. Landslides 11(2):167–194. https://doi.org/10.1007/s10346-013-0436-y

Hübl J, Nagl G (2019) From practical experience to national guidelines for debris-flow mitigation measures in Austria. In: Kean JW, Coe JA, Santi PM, Guillen BK (eds) debris flow hazards mitigation: mechanics, monitoring, modeling and assessment. Proceedings of the Seventh International Conference on Debris-Flow Hazards Mitigation, Golden, Colorado, USA, June 10–13, 2019. Association of Environmental and Engineering Geologists, Special Publication 28. pp 981–987. https://repository.mines.edu/bitstream/handle/11124/173051/Engineering_and_Mitigation.pdf. Accessed 10 Aug 2022

INSPIRE (2013) D2.8.III.12 INSPIRE Data Specification on Natural Risk Zones – Technical Guidelines Version 3.0. European Commission Joint Research Centre. 135 p. https://inspire.ec.europa.eu/id/document/tg/nz. Accessed 16 July 2022

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) Cambridge University Press, Cambridge, 582 pp. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf. Accessed 31 Jul 2022

ISO (2006) ISO/TC 211. Geographic information/geomatics. International Standard Organization, Geneva. http://www.isotc211.org. Accessed 16 Jul 2022

ISO (2018) Contributing to the UN Sustainable Development Goals with ISO standards. International Organization for Standardization, Geneva. 42 p. https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100429.pdf. Accessed 21 Jul 2022

ISO (2022a) Online Browsing Platform (OBP) Version 4.19.0. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#home. Accessed 5 Jun 2022

ISO (2022b) Standards – Sustainable Development Goals. International Organization for Standardization, Geneva. https://www.iso.org/sdgs.html. Accessed 21 Jul 2022

ISO 2394:2015(en) General principles on reliability for structures. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:2394:ed-4:v1:en. Accessed 8 Jun 2022

ISO 6421:2012(en) Hydrometry – Methods for assessment of reservoir sedimentation. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:6421:ed-1:v1:en. Accessed 5 Jun 2022

ISO 7010:2019(en) Graphical symbols – Safety colours and safety signs – Registered safety signs. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:7010:ed-3:v2:en. Accessed 5 Jun 2022

ISO 10252:2020(en) Bases for design of structures – Accidental actions. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:10252:ed-1:v1:en. Accessed 5 Jun 2022

ISO 16063-42:2014(en) Methods for the calibration of vibration and shock transducers — Part 42: Calibration of seismometers with high accuracy using acceleration of gravity. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:19901:-8:ed-1:v1:en. Accessed 8 Jun 2022

ISO 17745:2016(en) Steel wire ring net panels – Definitions and specifications. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:17745:ed-1:v1:en. Accessed 3 Aug 2022

ISO 17746:2016(en) Steel wire rope net panels and rolls – Definitions and specifications. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:17746:ed-1:v1:en. Accessed 3 Aug 2022

ISO 19901-8:2014(en) Petroleum and natural gas industries – Specific requirements for offshore structures – Part 8: Marine soil investigations. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:19901:-8:ed-1:v1:en. Accessed 6 Jun 2022

ISO 19901-10:2021(en) Petroleum and natural gas industries – Specific requirements for offshore structures – Part 10: Marine geophysical investigations. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:19901:-10:ed-1:v1:en. Accessed 6 Jun 2022

ISO 22300:2021(en) Security and resilience – Vocabulary. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:22300. Accessed 5 Jun 2022

ISO 22315:2014(en) Societal security – Mass evacuation – Guidelines for planning. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:22315:ed-1:v1:en. Accessed 8 Jun 2022

ISO 22327:2018(en) Security and resilience – Emergency management – Guidelines for implementation of a community-based landslide early warning system. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:22327:ed-1:v1:en. Accessed 8 Jun 2022

ISO 22328-1:2020(en) Security and resilience – Emergency management – Part 1: General guidelines for the implementation of a community-based disaster early warning system. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:22328:-1:ed-1:v1:en. Accessed 8 Jun 2022

ISO 22578:2022(en) Graphical symbols – Safety colours and safety signs – Natural disaster safety way guidance system. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:22578:ed-1:v1:en. Accessed 5 Jun 2022

ISO 31000:2018(en) Risk management – Guidelines. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:31000:ed-2:v1:en. Accessed 4 Sept 2022

ISO 37120:2018(en) Sustainable cities and communities — Indicators for city services and quality of life. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:37120:ed-2:v1:en. Accessed 12 Jun 2022

ISO 37122:2019(en) Sustainable cities and communities — Indicators for smart cities. International Organization for Standardization. Geneva, Switzerland. https://www.iso.org/obp/ui#iso:std:iso:37122:ed-1:v1:en. Accessed 12 Jun 2022

ISO 37123:2019(en) Sustainable cities and communities – Indicators for resilient cities. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:37123:ed-1:v1:en:sec:12.2.1. Accessed 12 Jun 2022

ISO/DIS 22328-2 Security and resilience – Emergency management – Part 2: Guidelines for the implementation of a community-based landslide early warning system. International Organization for Standardization, Geneva. https://www.iso.org/standard/83417.html. Accessed 21 Jul 2022

ISO/DIS 22328-3(en) Security and resilience – Emergency management – Part 3: Guidelines for the implementation of a community-based tsunami early warning system. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:22328:-3:dis:ed-1:v1:en. Accessed 5 Jun 2022

ISO/TC 292 International Organization for Standardization Technical Committee 292 Security and Resilience. Participation. International Organization for Standardization, Geneva. https://www.iso.org/committee/5259148.html?view=participation. Accessed 3 Aug 2022

ISO/TS 21219-19:2016(en) Intelligent transport systems – Traffic and travel information (TTI) via transport protocol experts group, generation 2 (TPEG2) – Part 19: Weather information (TPEG2-WEA). International Organization for Standardization, Geneva. https://www.iso.org/obp/ui#iso:std:iso:ts:21219:-19:ed-1:v1:en. Accessed 8 Jun 2022

IWA 33-1:2019(en) Technical guidelines for the development of small hydropower plants — Part 1: Vocabulary. International Organization for Standardization, Geneva. https://www.iso.org/obp/ui/#iso:std:iso:iwa:33:-1:ed-1:v1:en. Accessed 5 Jun 2022

Klose M, Highland L, Damm B, Terhorst B (2014) Estimation of direct landslide costs in industrialized countries: challenges, concepts, and case study. In: Sassa K, Canuti P, Yin Y (eds) Landslide science for a safer geoenvironment, Methods of landslide studies, vol 2. Springer, Berlin, pp 661–667

Klose M, Damm B, Terhorst B (2015) Landslide cost modeling for transportation infrastructures: a methodological approach.

Landslides 12(2):321–334. https://doi.org/10.1007/s10346-014-0481-1
Mazengarb C, Stevenson MD (2010) Tasmanian Landslide Map Series: User guide and technical methodology Record Geological Survey Tasmania 2010/01. https://www.mrt.tas.gov.au/mrtdoc/dominfo/download/UR2010_01/UR2010_01.pdf. Accessed 4 Sept 2022
Mikoš M (2022) Landslide research and technology in patent documents. In: Sassa K et al (eds) Progress in landslide research and technology, vol 1, no 2 (in print)
NDMA (2019) National Landslide Risk Management Strategy. National Disaster Management Authority, Ministry of Home Affairs, Government of India, New Delhi, India. https://nidm.gov.in/PDF/pubs/NDMA/26.pdf. Accessed 4 Sept 2022
Núñez-Andrés MA, Lantada Zarzosa N, Martínez-Llario J (2022) Spatial data infrastructure (SDI) for inventory rockfalls with fragmentation information. Nat Hazards 112(3):2649–2672. https://doi.org/10.1007/s11069-022-05282-2
ONR 24800:2009 Protection works for torrent control – Terms and their definitions as well as classification. Austrian Standard Rule. Austrian Institute for Standardisation, Vienna. 75p. (in German)
ONR 24801:2013 Protection works for torrent control – Static and dynamic actions on structures. Austrian Standard Rule. Austrian Institute for Standardisation, Vienna. 31p. (in German)
ONR 24802:2011 Protection works for torrent control – Design of structures. Austrian Standard Rule. Austrian Institute for Standardisation, Vienna. 95p. (in German)
ONR 24803:2008 Protection works for torrent control – Operation, monitoring, maintenance. Austrian Standard Rule. Austrian Institute for Standardisation, Vienna. 38p. (in German)
ONR 24810:2021 Technical protection against rockfall – Terms and definitions, effects of actions, design, monitoring and maintenance. Austrian Institute for Standardisation, Vienna. 107p. (in German)
Ortigao JAR, Sayao ASFJ (eds) (2004) Handbook of slope stabilisation. Springer, Berlin, 483 p. https://doi.org/10.1007/978-3-662-07680-4
Sanwa Sanko (2022) Natural disaster safety way guidance system ISO/DIS 22578. Sanwa Sanko Co., LTD. Tokyo. https://www.sanwa-sanko.co.jp/en/legal/jis-out/. Accessed 5 Jun 2022
Sassa K (2021) The Kyoto Landslide Commitment 2020: launched. Landslides 18(1):5–20. https://doi.org/10.1007/s10346-020-01575-4
SFDRR (2015) Sendai Framework for Disaster Risk Reduction 2015–2030. https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf. Accessed 12 Jun 2022
UN (2015) Resolution adopted by the General Assembly on 25 September 2015 – 70/1. Transforming our world: the 2030 Agenda for Sustainable Development. UN A/RES/70/1. 35 p. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed 12 Jun 2022
UN (2017) Resolution adopted by the General Assembly on 6 July 2017 – 71/313. Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development. UN A/RES/71/313. 25 p. https://digitallibrary.un.org/record/1291226/files/A_RES_71_313-EN.pdf. Accessed 12 Jun 2022
UNDRR (2022) My city is getting ready. Is yours? United Nations Office for Disaster Risk Reduction. Geneva. https://mcr2030.undrr.org/. Accessed 12 Jun 2022
UNECE (2018) Standards for the Sustainable Development Goals. United Nations Economic Commission for Europe, Geneva, Switzerland. 82 p. https://unece.org/sites/default/files/2021-03/ECE_TRADE_444.pdf. Accessed 21 Jul 2022
USGS (2000) National Landslide Hazards Mitigation Strategy – a framework for loss reduction. Open-File Report 00-450. U.-S. Geological Survey, Department of the Interior, Reston, VA. 49 p. https://pubs.usgs.gov/of/2000/ofr-00-0450/ofr-00-0450.pdf. Accessed 13 Jul 2022
van Westen C (2018) Risk mapping. In: Bobrowsky PB, Marker B (eds) Encyclopedia of engineering geology. Springer, Cham, pp 761–769
Wang B, Ruel M, Couture R, VanDine D, Bobrowsky P, Blais-Stevens A (2013) Current status of landslide guidelines around the world. In: Margottini C, Canuti P, Sassa K (eds) Landslide science and practice. Springer, Berlin. https://doi.org/10.1007/978-3-642-31313-4_35
Wirtz A, Kron W, Löw P, Steuer M (2014) The need for data: natural disasters and the challenges of database management. Nat Hazards 70(1):135–157. https://doi.org/10.1007/s11069-012-0312-4