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The VISUS methodology for the multi-hazard safety assessment of learning facilities: ten years of applications under UNESCO coordination

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ABSTRACT Safety and resilience of learning facilities are critical issues in disaster-prone areas, in which natural hazards can pose significant risks to students, staff, and infrastructures. To address these issues, the SPRINT-Lab researchers at the University of Udine, under the UNESCO umbrella, conceived and developed the Visual Inspections for defining Safety Upgrading Strategies (VISUS) methodology. VISUS consists of visual inspections of school facilities, with the aim of providing decision-makers with evidence-based recommendations for upgrading safety and resilience in learning environments. This paper summarises the key features of the VISUS methodology and illustrates the progression of its application in the last decade, achieved through its implementation in pilot projects promoted by the UNESCO Unit on disaster risk reduction (DRR). In particular, the paper showcases the results achieved from the application of VISUS in various projects worldwide, and provides examples on how these results can be used to support decision-makers in formulating plans and strategies to improve school safety. Furthermore, the paper highlights the knowledge acquired and conclusions drawn from the various VISUS projects and provides insights into the practical implications of its implementation within the UN DRR policies, so as to improve the safety of learning facilities.

Key words: school safety, disaster risk reduction, resilience, multi-hazard, SDG4.

1. Introduction

Natural hazards, such as earthquakes, hurricanes, flooding and fires, can severely impact schools and educational infrastructures, thus leading to the interruption of children's education. The heavy toll that such disasters can take on children and the educational sector has prompted policy- and decision-makers to prioritise disaster risk reduction (DRR) efforts in the education sector. The mitigation of natural hazard impacts requires significant economic resources, which should be allocated on the basis of a thorough understanding of the actual risk faced by schools. Several resolutions have been developed to guide DRR in the education sector, with the specific purpose of enhancing the safety of school facilities, among which, the United Nations (UN) 2030 Agenda for Sustainable Development (United Nations General Assembly, 2015), the Sendai Framework for DRR 2015-2030 (UNDRR, 2015), and the Comprehensive School Safety Framework (CSSF) 2022-2030 (GADRRRES, 2022) hold particular importance. Goal no. 4 of the UN 2030 Agenda for Sustainable Development emphasises the need to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. The goal recognises the critical role of education in sustainable development, and the need to prioritise DRR efforts in the education sector, so as to build safer and more resilient schools. Similarly, the Sendai Framework for DRR (2015-2030) highlights the need to substantially reduce the damage that disasters may cause to critical infrastructures, including educational facilities. The Sendai Framework also acknowledges the importance of involving communities and stakeholders in DRR efforts, and promoting a culture of prevention and resilience. In addition to these commitments of the UN, the Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector (GADRRRES) has been developing the CSSF, which outlines strategic goals for DRR in the education sector, based on four key components (Fig. 1), represented by a cross-cutting foundation and three intersecting pillars. The foundation refers to the enabling systems and policies: Pillar 1 to safer learning facilities, Pillar 2 to school safety and educational continuity management, and Pillar 3 to risk reduction and resilience education. The framework emphasises the need for a multi-hazard and intersectoral approach to DRR, acknowledging that schools face a diverse range of hazards, including natural, technological, and human-induced.

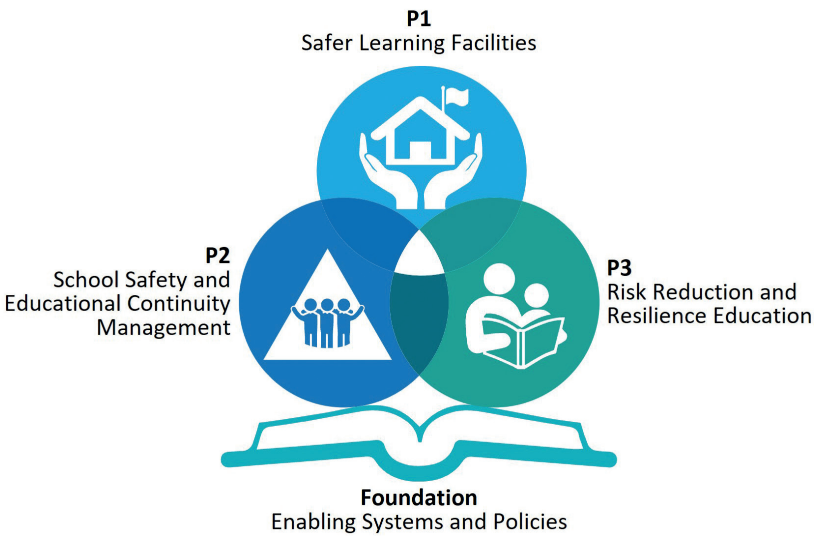


Fig. 1 - CSSF structure (modified by GADRRRES, 2022).

To meet the commitments outlined in these agendas and frameworks, decision-makers must take steps to define strategies for upgrading the safety of learning facilities, especially those that currently fall below acceptable safety levels. To achieve this objective, decision-makers require an evidence-based understanding of safety conditions, in order to define and implement plans and strategies for school safety upgrading.

To support decision-makers in the above-mentioned tasks, the SPRINT-Lab research team at the University of Udine, under the UNESCO umbrella, devised a methodology called Visual Inspections for defining Safety Upgrading Strategies [VISUS (Grimaz and Malisan, 2019a)]. This methodology encompasses visual inspections of learning facilities aimed at assessing safety conditions, and identifying safety upgrading needs, to support decision-makers in formulating safety upgrading and resilience enhancement strategies for a large number of existing learning facilities. Since 2013, the year in which the UNESCO HQ Disaster Risk Reduction Unit (hereinafter referred to as UNESCO DRR) began testing and promoting VISUS, the methodology has been adopted in various projects worldwide.

This paper initially outlines the essential characteristics of the VISUS methodology and illustrates the use of the Rapid Application Development (RAD) approach in enabling a progressive adaptation and improvement for various VISUS implementations in pilot projects, globally over the past ten years. It, then, provides examples that confirm the main results achieved in the pilot projects, as well as the role played by VISUS in supporting decision-makers when formulating school safety upgrading strategies and action plans. Lastly, the paper summarises the findings from a decade of VISUS implementations under UNESCO coordination.

2. The VISUS methodology

Through a multi-hazard perspective, the VISUS methodology (Grimaz and Malisan, 2016, 2019a) focuses on the safety assessment of a large number of existing learning facilities. This section provides a brief overview of the VISUS methodology, since the aim of the paper is to show the results of ten years of applications and summarise the findings. For a more detailed description of VISUS, reference should be made directly to Grimaz and Malisan (2019a, 2019b, 2019c).

The VISUS methodology is based on a technical triage approach, which aims to provide decision-makers with information required to comprehend the multi-hazard safety condition of schools, and, hence, to provide support in defining safety upgrading action plans for the learning environment. The methodology, designed to be applied to a large number of learning facilities, enables an overall evaluation of the multi-hazard safety condition of an entire set of schools, whilst, at the same time, outlines the situation of each school. Furthermore, the VISUS outcomes, supporting the multi-criterion identification of the schools requiring priority interventions, also furnish the reasons for intervening, and an estimate of the potential budget allocation required for the implementation of necessary safety upgrading interventions. The outcomes are also intended to support decision-makers in communicating the assessment results to the community, and developing an action plan that can be easily managed by policy-makers, and negotiated with the donor communities in the country.

As described in detail in Grimaz and Malisan (2016, 2019a), the VISUS technical triage approach aims at conducting a risk assessment and treatment plan, thus answering the need of decision-makers for essential information to plan rational and cost-effective safety upgrading strategies on a large scale. This approach helps narrow down the number of schools for which detailed safety upgrading actions are necessary, and, therefore, improves the efficiency of fund allocation. The VISUS technical triage was adopted based on the analogy with medical triage in disaster medicine, where there is a need to quickly assess the safety condition of a high number of patients in order to promptly administer the suitable treatment. For a pragmatic and effective assessment, in medical triage, medical personnel (usually nurses) are trained to promptly identify, mainly through a visual examination, the substantial critical issues in patients, in order to prioritise intervention and treatment for each patient. A similar rapid and pragmatic approach was adopted by the VISUS methodology to assess the safety of the learning facilities (i.e. the ‘patients’ of the technical triage). Similarly to nursing tasks, VISUS surveyors are trained to identify and characterise the school safety condition, through a specific procedure based on visual inspection (i.e. a survey). The VISUS survey aims to pragmatically identify and collect information that experts have pre-classified as essential, in order to conduct a comprehensive multi-hazard safety assessment of the learning facilities. Consequently, experts from various fields were called to identify the essential information needed for the safety assessment (applying the 'as much as enough' criterion) and to formulate the algorithms utilising this information to evaluate the safety of each school.

The VISUS safety assessment mainly focuses on Pillar 1 of the CSSF, i.e. on the physical school environment, including school buildings and facilities, schoolyards, and school locations. The learning facilities are assessed through a multi-hazard perspective, namely considering earthquakes, air- and water-related hazards, as well as fires and day-by-day threats that could occur in schools (named: ordinary use). The safety condition of the schools is assessed by taking into consideration the 'reference events', i.e. the values which describe and quantify the hazard adopted for assessing the safety condition. These values are established by local experts and authorities involved in the VISUS local committee and collaborating in the implementation of VISUS in the project. Generally, the reference events are derived from local hazard maps used for the design of new buildings, or identified and assigned based on other local-level decisions (e.g. the largest credible earthquake, or the maximum flood level sustained during past events).

In this context, the safety assessment process in VISUS considers multiple dimensions that could affect the learning facilities, such as:

- global structural behaviour of the buildings (e.g. potential collapse or damage to structural elements);
- local structural behaviour (e.g. potential collapse or damage of a portion of a structural element);
- presence of non-structural problems (e.g. potential fall of false ceilings);
- functional aspects (e.g. escape routes blocked during or after a hazardous event);
- school locations (e.g. schools in landslide-prone areas).

The top part of Fig. 2 gives an overview of the VISUS implementation process. This process starts from the need to understand the situation of existing schools, in terms of safety conditions and safety upgrading needs, and ends with the definition of safety upgrading action plans. The bottom part of Fig. 2 illustrates the four main implementation steps of the VISUS methodology, namely training, survey, elaboration, and outcomes.

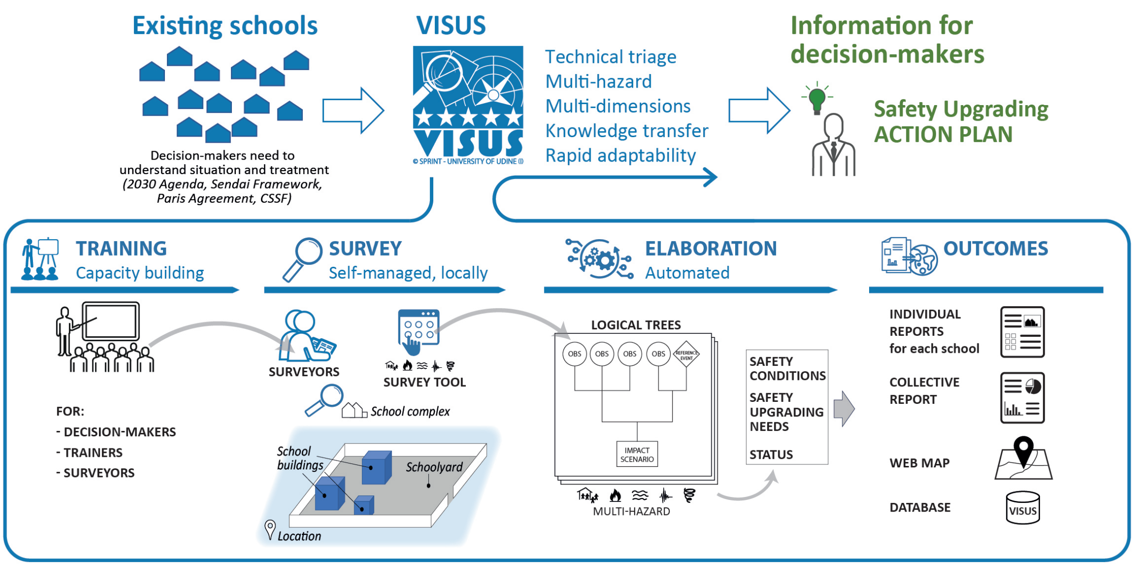


Fig. 2 - Overview of the VISUS methodology and its main implementation steps.

Training aims at locally transferring VISUS knowledge, in order to develop local capacities and enable the self-management of future implementations.

Capacity building is achieved through three types of training:

- for decision-makers, based on the meaning of the VISUS outcomes and their potential use to draft school safety upgrading action plans;
- for trainers (usually professors from local universities, or local civil engineering experts), based on the scientific basis of the VISUS methodology and on its implementation aspects;
- for VISUS surveyors (usually students from local engineering or architecture faculties or local technicians), based on the main principles concerning the VISUS survey execution, and inspection of the learning facilities to identify the substantial information collected by the methodology.

Surveyors are tasked with identifying visual evidence of unsafe situations in a school complex, as well as various characteristics of school facilities necessary for implementing the VISUS algorithms. The summary of the aspects investigated through the VISUS methodology is presented in Table 1. For each of these aspects, one or more observables (referred to as OBS in VISUS) are provided and summarise the information to be observed and collected. This information is conveyed using graphical representations and concise textual descriptions. These include, for example, specifications such as the construction period or the structural system typology (e.g. confined masonry, unreinforced masonry, etc.). The training modules for VISUS surveyors contain detailed descriptions with real-case examples and photographs for each OBS.

The data collected during the surveys are automatically elaborated implementing the VISUS pre-codified algorithms, which were defined taking into account expert knowledge and instances of real-case damage in schools (see Grimaz and Malisan, 2019c). The elaboration is carried out for each hazard, and, subsequently, the multi-hazard assessment is evaluated considering the worst cases. The elaboration results are, then, used to create the VISUS outcomes.

Thanks to VISUS training, surveyors can almost autonomously manage the survey activities with the support of local trainers and of the VISUS local committee. The survey activities are facilitated by the development and use of an Information Technology (IT) application, created to support both desk-work activities, through a web-browser, which can be accessed via computer, and on-field activities, through an Android device, which can also work offline (Grimaz *et al*., 2023). The survey information (comprising photographs of the schools) is elaborated by means of an automated elaboration process, which applies the rules and criteria pre-codified through the elicitation of expert knowledge. With this elaboration, the following VISUS outcomes are obtained:

- VISUS graphical indicators, summarising the situation of each school (see Fig. 3);
- individual reports for each school, including a technical description and survey photographs;
- a collective report summarising all results;
- a web-map;
- a database with VISUS survey and outcome data.

The VISUS methodology outcomes enable decision-makers to develop various safety upgrading strategies based on their own criteria. For example, schools could be prioritised based on the classification of the safety condition, exposure to specific hazards, or physical vulnerability. This approach enables identifying multiple action plans that could be compared, considering factors such as required resources.

The need to rapidly transfer knowledge, and promptly adapt the methodology, underscores the advantage of employing a graphical language to enhance user accessibility. The graphical language, a distinctive feature of VISUS, is used for representing both the substantial information

Table 1 - Summary of the aspects investigated through the VISUS methodology. The aspects are grouped considering the related hazards and the surveyed components (i.e.: location, schoolyard, and building).

Hazard	**Investigated aspects**		
	Location	**Schoolyard**	**Building**
General (for all hazards)	Topography Context Natural and human-induced hazards	-	Building characteristics: utilization, geometry, design information Structural system: reinforced concrete, masonry, earth, steel, wood, other Organization of lateral resistance elements Material resistance Construction quality and building condition Floor and roof behaviour and connection Roof covering and architectural features Egress
Ordinary use	Access to school Healthiness	Dangers Healthiness	Falls of elements or objects Falls of people Dangerous contacts Healthiness Comfort
Fire hazard	Wildfire Lightning	Ignition sources Combustible material Protection	Interdependence with context Combustible material and disposal Ignition sources Protection systems Egress
Water-related hazard	Wave action Water velocity Debris generation Local characteristics	Protection Ground scouring Releases Safe areas	Protection from floodwater Water flow into the building Foundations Resistance to water loads Dangers Content losses
Earthquake hazard	Soil stiffness Geomorphology Local characteristics	Falls of elements Safe areas	Irregular vertical mass distribution Stress focus and local weaknesses Falls of elements or objects Anti-seismic devices Egress
Air-related hazards	Land roughness Debris generation	Protection Falls of elements Shelter	Air permeability Connection to ground Roof shape and slope Local stress Connections of structural elements Falls of elements or objects Egress

that the surveyors must collect (i.e. in VISUS forms during the inspection of learning facilities), and the outcomes for decision-makers (used in the final reports).

The VISUS graphical indicators (Fig. 3) have been designed to reflect the multi-hazard and multi-dimensional aspects of the methodology while providing a rapid overview of the situation. They provide quick information for the three main aspects assessed by the VISUS methodology, i.e.:

- the safety condition, including the warning levels assigned to the various facilities and location; the rose diagram of intervention needs, indicating the judgments associated with each dimension; and the overall judgment for each hazard, and multi-hazard condition;

- the safety upgrading needs, including the suggested safety upgrading actions, defined on the basis of the outcomes of the rose diagram of intervention needs, that can be classified as ‘relocation’, ‘reconstruction’, ‘retrofitting’, ‘refurbishment’ and ‘restoration self-made’; the upgrading requirement class; and the budget allocation estimated for the implementation of the suggested upgrading actions;
- the status (i.e. the quality conditions), with a short characterisation of accessibility, water and sanitation, maintenance, comfort, content and equipment, security and COVID-19 manageability.

Through a multi-hazard perspective, the overall picture of the VISUS outcomes, for each assessed school, aims to summarise:

a) where and what safety problems have been identified;
b) how the identified problems can be solved in terms of actions to be taken, and their cost in comparison to a new construction;
c) the status of the school, in terms of quality of fundamental aspects and services.

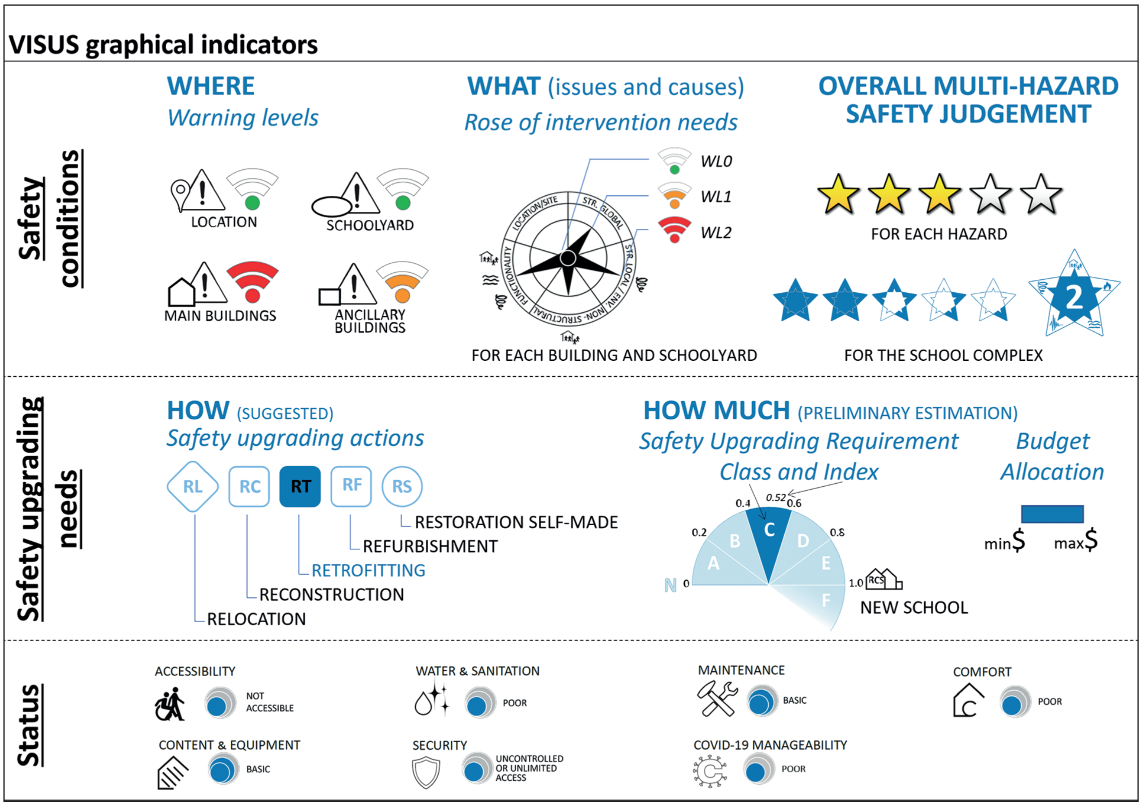


Fig. 3 - VISUS graphical indicators for outcomes.

The VISUS safety judgments are provided with a three-level classification of the so-called warning level (WL):

- WL0: absence of concerns for personal safety;
- WL1: potentially difficult situations for personal safety;
- WL2: potentially severe consequences for personal safety.

The VISUS safety stars provide an overall judgement of the safety condition. The concept behind the safety stars is similar to the one adopted in other situations where a comprehensive judgement on the quality of services is required (e.g. hotel rating). Once the assessment has been completed, stars are assigned upon compliance with specific requirements. The stars are progressively assigned, in accordance with the following performance criteria:

- no star: unsuitable site;
- one star: suitable site; there are no severe natural or human-induced threats affecting the school site;
- two stars: stability of the building (no WL2 for the global structural safety issues); a global collapse of the building is very unlikely considering the adverse action defined in the reference events;
- three stars: life safeguard (no WL2 for all safety issues); there are no critical situations with potentially severe consequences for personal safety (no collapse or critical fall of non-structural elements);
- four stars: rapid resumption of operations (no WL1 for the global and local structural safety issues); the only criticalities are those that could lead to difficulties for personal safety (no widespread damage);
- five stars: immediately operational (no WL1 for all safety issues); after an event, it is possible to immediately use the school without interventions.

It is worth noting that the multi-hazard safety stars reflect the worst case of safety condition across all school buildings and schoolyard, considering the various hazards. This means that even if a single small building faces significant safety issues from one hazard, the overall safety assessment of the entire school complex is impacted by it.

The VISUS safety upgrading requirements are expressed by an index that takes into account the safety upgrading intervention needs and their extent, indicating the needs in proportion to the construction requirements of a new school of the same size. The index is, then, used to classify the safety upgrading requirements into six classes (A, B, C, D, E, and F), which are associated with the estimated costs required to improve the safety of the school assessed, in comparison with the construction of a new school with the same dimensional characteristics and educational services. For instance, a school with a class F requirement indicates that the estimated intervention cost is higher than the construction cost borne to build a new school according to the current reference construction standards of the country. This suggests to decision-makers that it may be better to build a new school instead of retrofitting the existing one. Conversely, schools in class A require interventions that cost less than 20% of the cost borne to build a new school, and, therefore, this suggests that intervening on the school is more convenient. The budget allocation estimates the funds necessary for school safety upgrades. This is primarily based on the safety upgrading requirement index, the school area, and the cost range for constructing a reference school (in dollars per square metre).

As required by the UNESCO DRR, the VISUS methodology has been designed to be quickly and easily customisable and adaptable to local situations and specificities, thus making it applicable in various countries. Local experts facilitate the customisation and adaptation process by providing the necessary information through a pre-codified procedure. The adaptation goal is also to enhance VISUS methodology training through examples obtained from local contexts and specificities. The rapid customisability and adaptability of VISUS is a result of the iterative and incremental development process described in the next section.

3. The iterative and incremental development of the VISUS methodology

In order to enable the necessary upgrades and adaptation, the VISUS methodology was iteratively developed and improved over the years by adopting the RAD approach (Fig. 4), usually adopted for software development. VISUS development follows the RAD approach as it emphasises rapid prototyping and iterative design (see Martin, 1991; Yan and Davis, 2020; and references therein), and it is based on the principles of user-centred design.

In detail, the RAD process can be divided into four main steps (Fig. 4):

1. analysis and quick design, which involves gathering requirements from stakeholders and end-users, and, then, creating a preliminary design for the application;
2. prototype cycles, which create a working prototype of the application and, then, refine it through a series of iterations;
3. testing, which aims at ensuring that the application meets user requirements, and is free of defects;
4. deployment, which makes the application available to end-users.

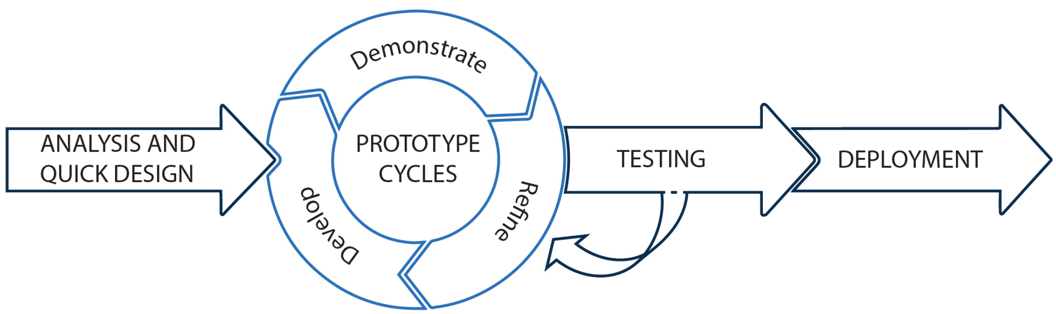


Fig. 4 - The RAD applied to the VISUS methodology over the years.

The application of RAD to the VISUS projects aimed at improving the methodology and its tools, by demonstrating its outcomes to stakeholders and users, and refining everything according to feedback provided by users. Initially, the main requirements of decision-makers were identified, on the basis of the international context on school safety commitments. Next, the prototype cycle phase was applied for the development of *ad hoc* pilot projects, for the safety assessment of learning facilities, firstly considering the seismic hazard, and subsequently considering a multi-hazard perspective. During these prototype cycles, the methodology has been improved and adapted several times according to user and stakeholder feedback, and also considering expert suggestions on assessment algorithms. Subsequently, the testing phase was applied in pilot projects in various countries all over the world, in order to check if the methodology met the requirements and permits necessary to achieve the goals. Ultimately, the deployment phase started after many applications in pilot projects, and once the scientific content of the methodology had been checked by worldwide experts. As a result of this RAD process, VISUS has been integrated into the latest UNESCO commitments for DRR (UNESCO, 2022).

The next section details the development process of the VISUS methodology, showcasing its implementation through UNESCO coordination, and highlighting some of the results achieved, during the last decade, with its application in various projects around the world.

4. Ten years of VISUS implementations under UNESCO coordination

The evolution of the VISUS methodology has gone through three main phases over the last ten years (Fig. 5): the first was the set-up of the methodology based on the seismic hazard; the second, the evolution towards a multi-hazard assessment and scientific revision; and the third, the implementation in worldwide pilot projects.

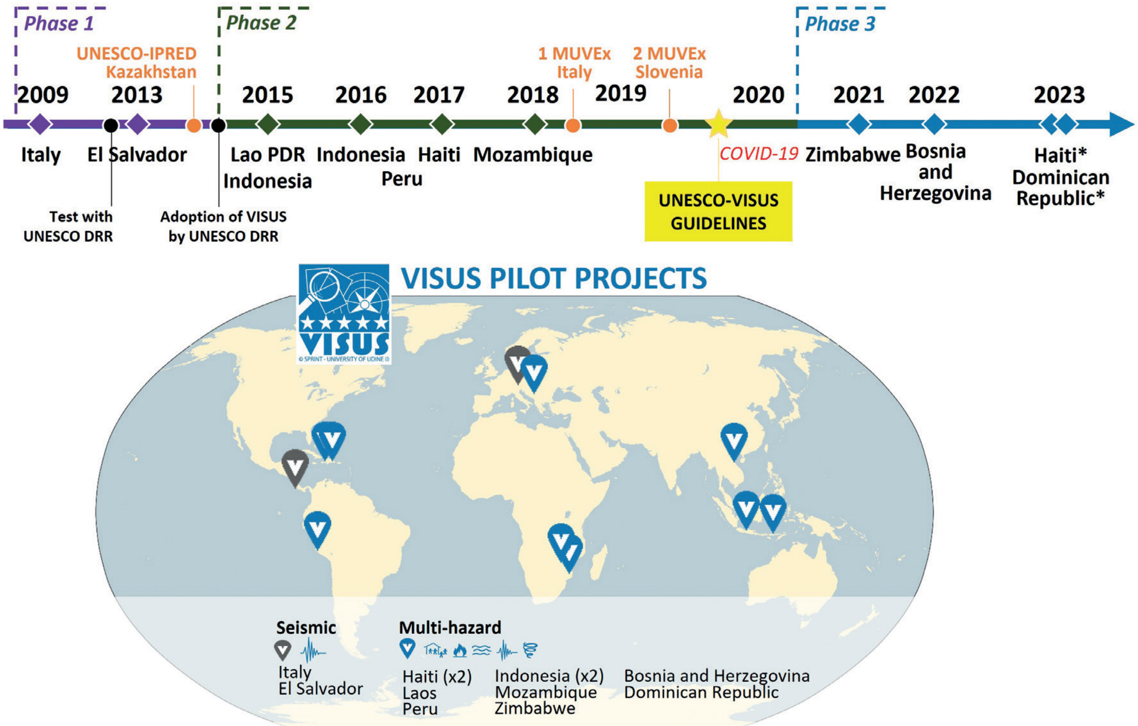


Fig. 5 - VISUS pilot projects implemented over the years. The colours of the timeline distinguish the three main VISUS implementation phases.

During phases one and two, the methodology and its tools were developed through the continuous interaction and feedback from users, as described with the RAD approach, while in phase three the methodology was available for deployment.

In 2009, VISUS was created within the framework of the Italian project "Analysis of seismic scenarios of school buildings for a definition of intervention priorities for the seismic risk reduction – ASSESS" (Grimaz and Malisan, 2016; Grimaz *et al.*, 2016). During the first phase, the VISUS methodology was set up considering the seismic safety assessment, and the main requirements of decision-makers were defined considering the Italian context. Nevertheless, the need for a multidimensional safety assessment arose, with the need to distinguish structural, non-structural, functionality, and site safety-related aspects. At this stage, capacity building and the rapid adaptation feature were not substantial for the development of the project, and, therefore, they assumed minor importance in the activities. In 2012, VISUS was identified by UNESCO DRR as a candidate for the UNESCO evaluation of school safety, and, in 2013, it was tested for the assessment of seismic safety of school facilities during a pilot project in El Salvador (Peña

Figueroa *et al*., 2020). The purpose of the El Salvador pilot project was both to assess the seismic safety of schools, and to test the possibility of using VISUS as a methodology for knowledge transfer, capacity development and VISUS trainee and surveyor training. The project yielded positive results and provided valuable feedback for improving the methodology. One key finding was the identification of the need for a survey support tool that could be quickly customised to meet local requirements. Additionally, another improvement of the VISUS concept consisted in the suggestion to broaden school safety assessments with the inclusion of multiple hazards. As a result, UNESCO DRR (UNESCO, 2015) promoted and endorsed the use of VISUS applications in various pilot projects. The goal was to further develop the VISUS methodology so as to assess learning facility safety on the basis of different hazards, and to enable a rapid compliance with the local requirements of the various countries where it would have been applied. This required a step backwards to a new cycle of prototype development within the RAD process.

The new prototype cycle started with a thorough revision and innovation of VISUS aimed at extending multi-hazard assessments to include a pragmatic perspective. At this stage, experts of various fields were involved in order to identify the substantial information to acquire for the assessment of the safety conditions of learning facilities with a multi-hazard perspective. Additionally, greater importance was assigned to the use of a graphical language, not only for the representation and summary of the outcomes (Fig. 3), but also for the representation of the substantial information that the VISUS surveyors were to check during the inspections (VISUS survey forms). Surveyor feedback confirmed that the adoption of a graphical language enables a better and faster synthesis of the information compared to text descriptions, and hence it improves the transfer of the methodology knowledge. In 2015, the new VISUS multi-hazard methodology was first tested on pilot projects in Laos and Indonesia (Bandung and Pangandaran) areas. These tests confirmed the efficacy in the use of a graphic language to overcome communication difficulties. The tests, however, highlighted some aspects related to the survey organisation, which was adapted on the basis of the suggestions received. The applications that followed in Indonesia, in 2016, aimed to improve both the methodology and training, also thanks to surveyor feedback on the main difficulties they encountered, and to the possibility of improving training with the use of photographs acquired during the previous VISUS projects. From 2017, SPRINT-Lab researchers, with the support of UNESCO DRR, started to elaborate the VISUS guidelines, which were revised in 2018 during the first meeting of UNESCO-VISUS experts (1st MUVEx). In the meantime, further applications were developed in Peru, Haiti, and Mozambique. Moreover, new prototype IT tools were developed to support the survey procedures, which also enabled establishing a finalised RAD process for the development of a specific application for data acquisition, named SPRINT-Engine (Grimaz *et al*., 2023). SPRINT-Engine is a data collection tool that can be quickly and simply adapted to better respond to specific and conditional needs, which allows for an automated elaboration of situation results, and enhances a prompt exchange of information with decision-makers. The SPRINT-Engine application was finalised, and, at the end of 2020, it was ready to be applied to projects. In 2019, the three volumes of the “UNESCO Guidelines for Assessing Learning Facilities in the Context of Disaster Risk Reduction and Climate Change Adaptation” were published (Grimaz and Malisan, 2019b, 2019c; Torres *et al*., 2019):

- volume 1 (Introduction to learning facilities assessment and to the VISUS methodology) provides decision-makers with an understanding of the outcomes of the implementation of the VISUS methodology;
- volume 2 (VISUS methodology) explains the theoretical aspects of the VISUS methodology, and, in its annexes, presents the rules and criteria that are the basis for assessment and evaluation;

- volume 3 (VISUS implementation) explains the phases of VISUS implementation, and, in its annexes, presents the tools developed for it.

After the publication of the guidelines, and the development of the SPRINT-Engine survey app, the third phase has begun (Fig. 5). This phase corresponds to the fourth step of the RAD approach: deployment. The SPRINT-Engine tool is used to implement the finalised VISUS methodology in the pilot projects. Applications have been concluded in Zimbabwe and in Bosnia and Herzegovina (hereinafter also referred to as BiH). Despite the entire methodology being deployed, the tools and algorithms allow for further adaptation, in order to accommodate potential needs arising from local requirements. In Zimbabwe, the offline use of the SPRINT-Engine application [for more information see Grimaz *et al.* (2023) and the section on the VISUS projects] was improved. Moreover, for the application in Zimbabwe, VISUS was also developed to take into account an evaluation of how the learning environment adapts to the management of the physical restrictions required by COVID-19 pandemics (e.g. student distancing, the creation of isolation areas, availability of water and sanitation). In both projects, training was improved by preparing online training courses and improving the learning-by-doing training sessions. Two VISUS projects are currently being developed: the first in Haiti, which envisages VISUS inspections in 700 schools to identify those where safety improvement measures will be implemented; the second, in the Dominican Republic, in the framework of the UNESCO project “Capacity Building for DRR in the Built Environment in Latin America and the Caribbean” (BERLAC5). One of the components of this project requires the multi-hazard safety assessment of 100 schools in various contexts in the territory of the Dominican Republic. For this project, training is developed by providing specific face-to-face training on the VISUS methodology (VISUS Academy) to local reference trainers, who will subsequently train local experts and surveyors.

An innovative aspect of these two last projects is the online modality chosen for the training sessions. It consisted in the sharing of slides and a handbook, and in the provision of remote online training to trainers and surveyors thanks to the development and testing of a VISUS Academy platform.

Furthermore, the SPRINT-Engine facilitates the collection and categorisation of photographs, allowing them to be linked to specific safety issues identified in the VISUS assessment. With this feature, photographs can be used to draw up individual reports for each school and create an online VISUS photo album (VISUS album, 2023). The photo album serves multiple purposes, including enhancing the capacity building of VISUS surveyors.

Table 2 gives a comprehensive overview of the projects implemented over the years with the application of the VISUS methodology under the coordination of UNESCO. The next section describes and provides more detailed comments on the specificities, and results of such applications.

5. Overview of VISUS data from worldwide projects

The implementation of the VISUS methodology in the aforementioned projects resulted in the collection of two types of data. The first type comprises information obtained from surveys (data and photographs), while the second consists in data obtained from the analysis of project outcomes. Together, these data provide insights and knowledge that can inform the decision-making process and support the development of effective strategies for improving school safety.

The next sections summarise the results derived from ten years of applications of the VISUS methodology worldwide, and, more precisely, present:

Table 2 - Summary of schools assessed using the VISUS methodology, under UNESCO coordination.

Country (geographic area)	**Year**	**Schools**	**Buildings**	**Persons**
El Salvador	2013	100	300	47078
Laos	2015	10	43	2730
Indonesia (Bandung, Pangandaran)	2015	58	303	40377
Indonesia (Ambon)	2016	87	512	31695
Peru (Lima)	2016	53	142	13872
Haiti (north, north-east)	2017	101	504	48830
Mozambique (Maputo)	2018	100	869	215305
Zimbabwe (Chimanimani, Chipinge)	2021	15	257	9781
Bosnia and Herzegovina	2022	40	56	18136
Haiti*	2023	700	3500*	300000*
Dominican Republic*	2023	100	500*	45000*

* ongoing projects (May 2023). The indicated values are those expected for the area.

1. an overview on the different characteristics of the assessed learning facilities in the various countries where VISUS was applied;
2. an overview on VISUS outcomes in various countries, in terms of safety and upgrading needs with a multi-hazard perspective;
3. examples on the use of VISUS outcomes, by decision-makers, in order to outline safety upgrading action plans for schools on a large scale.

5.1. Overview of school facility characteristics

The graphs in Fig. 6 illustrate the dimensional characteristics of the schools assessed in the different countries where VISUS was implemented. Before delving into a discussion of the graphs, it is important to note two significant factors. Firstly, data for Laos are not included due to a low number of assessed buildings. Secondly, the information obtained from the Zimbabwe project may not be representative of the entire country, as only 15 schools in two districts were assessed.

Fig. 6a shows the number of buildings in each school, divided by the various countries. With the exception of BiH, the majority of schools has more than two buildings, with the Zimbabwe project having an average of 17 buildings for each school.

Graphs in Fig. 6b show the area distribution of each school building. It is possible to observe that (on average) Zimbabwe has the smallest buildings, while the buildings in BiH have an average area that is almost 20 times larger than the average areas of the other countries. On average, in BiH there is a larger number of built areas and a lower number of students in each school, resulting in a high number of square metres per built environment per each student (around 18 m^2/person), as illustrated in Fig. 6f.

Overall, the graphs illustrate significant variations in the dimensional characteristics of schools across different countries worldwide. These differences provide a rationale for UNESCO's call for a flexible and adaptable assessment methodology. Moreover, the diverse school characteristics in different countries justify the need of local decision-makers to adopt distinct criteria when identifying strategies for safety improvement. This highlights the importance of allowing decision-makers to independently shape an action plan, the bases of which can be provided by the results of VISUS assessments. Sub-section 5.3 presents several examples to demonstrate how decision-makers can formulate different strategies while using the outcomes from VISUS assessments.

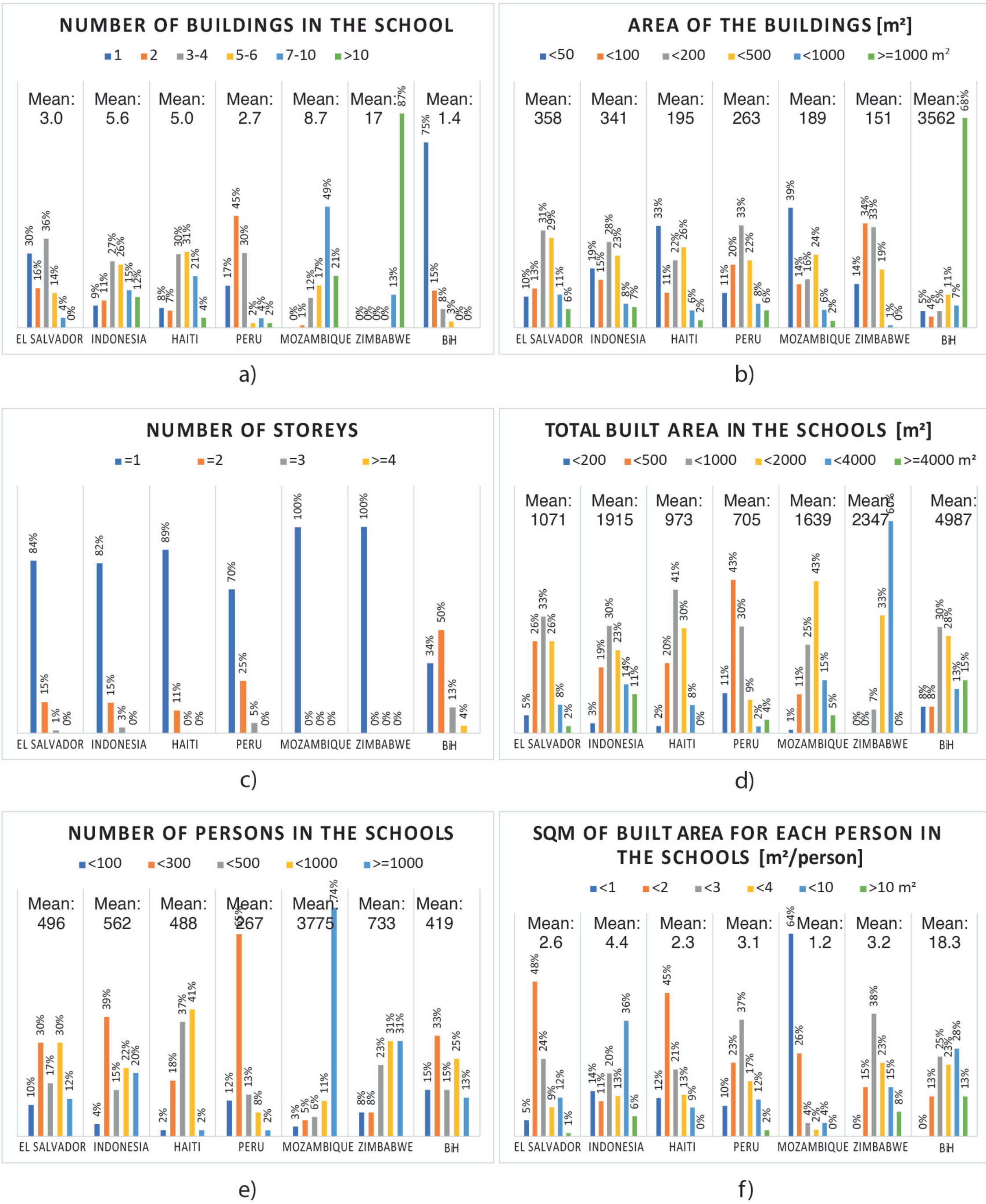


Fig. 6 - Comparison of some typological school characteristics acquired during VISUS pilot projects in El Salvador, Indonesia, Haiti, Peru, Mozambique, Zimbabwe, and BiH. The graphs illustrate the distribution of the values for the various VISUS projects considering: a) the number of buildings in the school; b) the area of the school buildings; c) the number of storeys of the school buildings; d) the total built area in the schools; e) the number of persons in the schools; and f) the square metres of built area for each person in the school.

5.2. Overview of VISUS outcomes

Considering the safety outcomes of the pilot projects, Figs. 7, 8, and 9 summarise the distribution of the VISUS safety stars for the different hazards, and the distribution of the safety upgrading requirement classes. Graphs provide an overview that considers all the projects as well as the country-specific outcomes in Indonesia, Haiti, Peru, Mozambique, Zimbabwe, and BiH.

In particular, Fig. 7 illustrates the distribution of schools considering the VISUS multi-hazard stars, and the hazards assessed by VISUS (i.e. multi-hazard, ordinary use, and fire, water, earthquake, and air related hazards). Fig. 7a shows the outcomes grouped by all projects, while Fig. 7b divides the outcomes on the basis of the various countries. In Fig. 7a, the multi-hazard distribution of the VISUS safety stars shows that a small number of schools have a performance reaching or exceeding the three stars, i.e. the life-safety performance. However, worthy of consideration is the fact that the multi-hazard safety star is assigned reflecting the worst-case situation for the school, thus considering all the buildings (and schoolyard) in the school, as well as all the hazards. In the same figure, the distribution of VISUS safety stars is also illustrated with respect to the distinct hazards evaluated using the methodology (ordinary use, and fire, water, earthquake, and air related hazards). Fig. 7a illustrates how, for multi-hazard assessments, the majority of schools have zero, one, or two stars, with schools with zero stars (indicating an unsuitable location in the event of a hazard) being just over 10% of the total. For such schools, decision-makers may consider intervening to reduce the hazard in the site or relocating the school to a more suitable site.

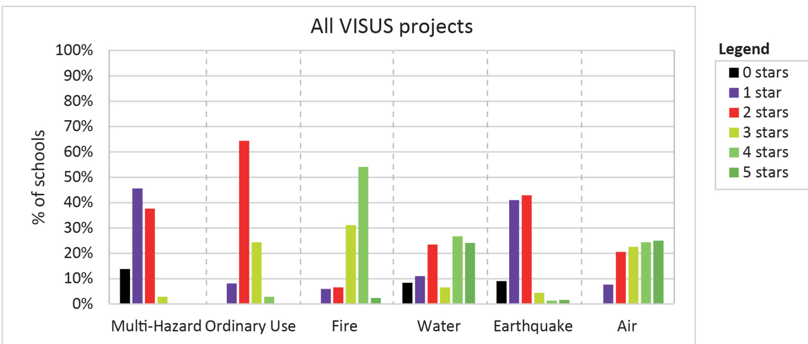
The results, grouped according to the different hazards, highlight the following:

- ordinary use of schools: almost 65% of schools were assigned only two stars, thus indicating that at least one facility within the school (e.g. a building or schoolyard) presented a situation in which students could potentially encounter a WL1 situation (which could be, for example, caused by falls or bumps); these situations can often be solved with simple interventions, which could improve the safety condition at a relatively low cost. Nevertheless, approximately 30% of the schools obtained three or more stars for ordinary use, indicating an acceptable performance;
- fire hazard: most schools were assigned more than three stars, indicating generally good performance, which in most cases is related to the absence of ignition sources, and to the presence of a low quantity of combustible materials in the visited schools;
- water hazard: the data are fairly evenly distributed among the various star classes; this distribution is generally related to the hazard values considered for the assessments. In fact, many schools, have low or zero water level values as they are located in areas not affected by floods;
- earthquake hazard: it is observed that most schools have less than three stars. In particular, just over 40% of the schools have one star, indicating a potential collapse of at least one building in the school due to the earthquake considered as a reference event. It is important to underline that VISUS considers all buildings in the school, included those (known as ancillary buildings) used only temporarily by persons (e.g. buildings only with toilet services). Often, the structural characteristics of these buildings are very poor, thus affecting the entire outcome. However, in the methodology, the results are calculated for each building, and, therefore, it is also possible to take into consideration which buildings have specific problems. About 40% of the schools are assigned two stars for earthquake hazard, indicating that at least one building could suffer severe damage, but, unlikely,

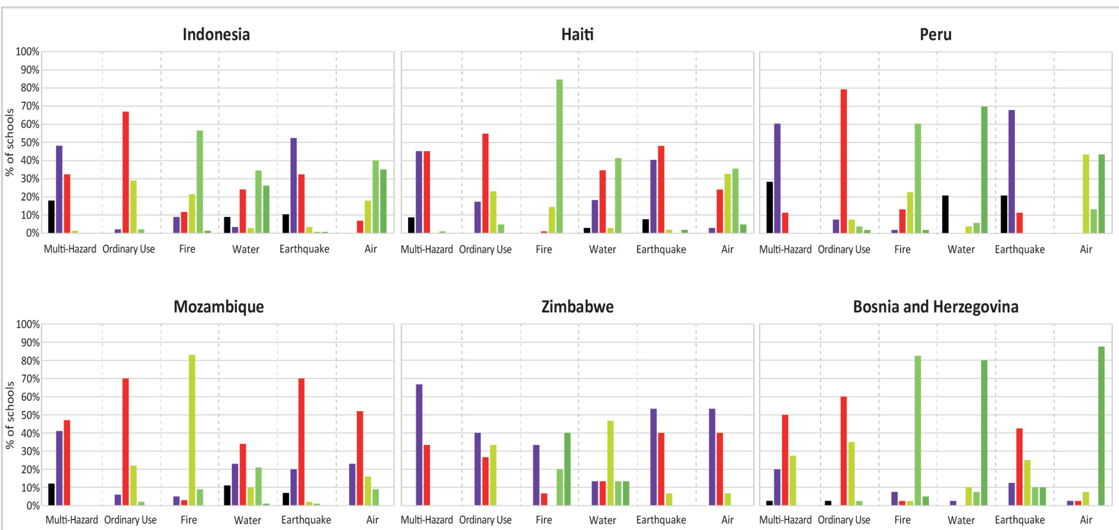
overall collapse. In addition, almost 10% of the schools have zero stars, meaning that, in the event of an earthquake, the school site is not suitable (e.g. due to landslides);

- air hazard: a fairly even distribution in the assignment of the safety stars to the assessed schools is observed among the various classes; as expected, there are no cases with zero stars in relation to wind, due to the absence of unsuitable site conditions; on average, schools with one star for air hazard are less than 10%, but such values are observed to be significantly higher when the data are divided considering the various countries.

Fig. 7b shows the varying outcomes for diverse hazards, across different countries. Notably, in the natural hazard context, these outcomes are influenced by the magnitude of the specific hazard, within the assessed area. With regards to natural hazards (earthquakes, water- and air-related hazards), data highlight how earthquakes pose most of the risks (with exception to cases in BiH). It is relevant to note that many instances of two-star ratings are observed for ordinary use, emphasising the importance of assessing safety as a condition in which persons are not exposed to, or are protected from, danger, death, injury, and harm.



a)



b)

Fig. 7 - Distribution of the VISUS safety stars considering the multi-hazard assessments, ordinary use, and fire, water, earthquake, and air related hazards: a) distribution considering the outcomes of all projects; b) distributions per single country.

To outline safety upgrading action plans for schools on a large scale, decision-makers need both an overview of the situation in terms of safety conditions and safety upgrading requirements, which in VISUS are summarised through the safety upgrading requirement classes (hereinafter referred to as SURCs), with an indication of the relevant estimated budget allocation range. It is worth noticing that the SURCs are not directly related to the VISUS multi-hazard stars assigned to the school, since the SURC assignment takes into consideration the facility area that requires safety upgrading interventions, while the VISUS multi-hazard safety stars consider the worst case in the school. This aspect is clearly reflected in the graph in Fig. 8, which represents the distribution of the schools considering both the VISUS multi-hazard stars, and the SURCs. The graph shows that, in the SURC-A, there are many schools with two stars. In SURC-D, -E, and -F there are no schools with more than three stars, proving that schools with a sufficient performance do not require relevant upgrading interventions.

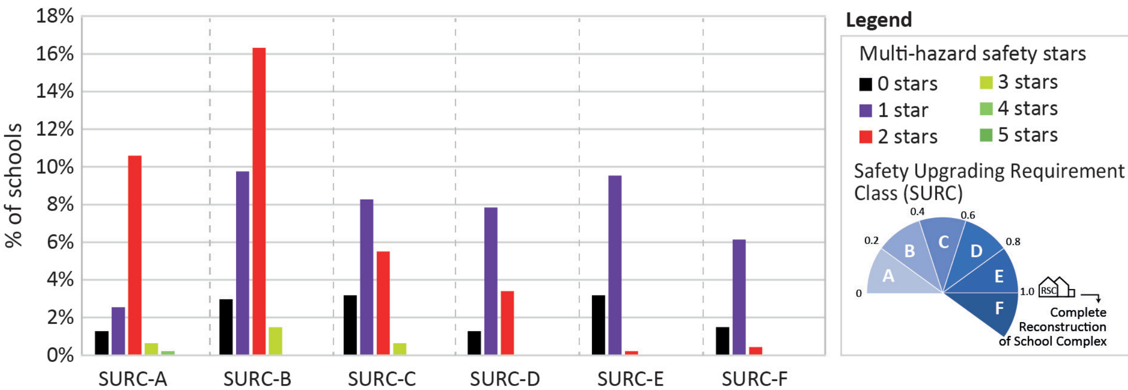


Fig. 8 - Distribution of schools (all VISUS projects) considering VISUS multi-hazard safety stars, and the SURCs.

Fig. 9 shows SURC distribution distinguishing between the country projects. The comparison of these outcomes does not show a common behaviour between the projects. For example, the percentage of schools in the SURC-A ranges from 5% in Peru, to 29% in Mozambique. In general, decision-makers prefer to proceed with retrofitting for SURC-A, -B, and -C (a dashed red line in Fig. 9 represents the usual threshold beyond which it is convenient to start considering the reconstruction alternative). It can be observed that in Peru, it is often more convenient to reconstruct schools, while in Haiti, Mozambique, Zimbabwe, and BiH, in most cases it would be more convenient to intervene and retrofit the existing schools.

Starting from the VISUS outcomes, the safety upgrading strategy could be different. The action plan can follow the specific criteria defined by the local decision-makers. The following sub-section presents some examples of safety upgrading strategies.

5.3. Examples of outcomes to support decision-making

The data and outcomes described above have been used in each project to create informative data-driven supports for decision-makers. These supports help identify potential action plans based on various strategies that are defined according to decision-making criteria. In the following, some examples of prioritisations, based on the indicators previously described, are illustrated. However, many other strategies and prioritisations are possible depending on requests

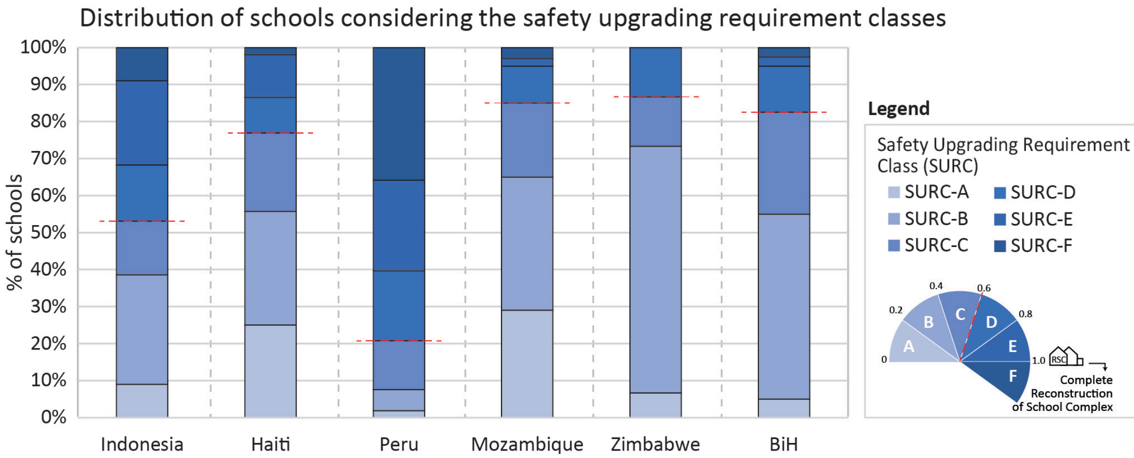


Fig. 9 - Distribution of the schools of the assigned SURCs, considering the various countries in which VISUS was applied.

made by decision-makers. Figs. 10 and 11 illustrate some examples that take into consideration the outcomes of a specific project (intentionally undisclosed for confidentiality reasons). The two figures represent two approaches on how to use the VISUS outcomes: one based on the identification of priority areas, and the other based on a data prioritisation list. Both approaches strongly depend on the criteria and decisions of decision-makers. In the figures, each star marker is associated with a specific school in the pilot project (this association is also undisclosed for confidentiality reasons), and the colour of the star is associated with the number of VISUS multi-hazard safety stars.

Figs. 10a and 10b show two examples of decision-making support based on the priority area approach. Fig. 10a represents each school through the number of persons, and the estimated average value of the budget allocation for each person. By using this graph, decision-makers can establish prioritisation criteria, and, consequently, identify which sets of schools to prioritise. As an example, decision-makers can choose to prioritise schools with more persons, and a lower value of budget allocation for each person, and subsequently to proceed with other sets.

A similar approach can be adopted considering Fig. 10b, in which the graph provides information on the number of stars, the people in the school, and the budget allocation for each school. This graph enables identifying various intervention sets, for which the total budget can be calculated by summing the individual budgets. The sets in the graph indicate examples that decision-makers can adopt to establish an action plan, ideally starting with schools hosting more people, and requiring less budget.

Worthy of note is the fact that the schools of set I in Fig. 10a and those of set A in Fig. 10b may not be the same.

The VISUS outcomes also allow for a prioritisation list approach (as represented in Fig. 11, without clearly stating the specific school identification codes). Fig. 11 illustrates some examples of prioritisations defined considering only the budget requirements, and the number of persons affected by the safety upgrading action. The figures are created by sorting the (normalised) data according to different criteria based on budget allocation, number of persons, and multi-hazard safety stars. Then, cumulative values are calculated, and represented in the graphs, which, consequently, assume a characteristic exponential-like trend. A possible criterion for prioritisation is to maximise the impact of each dollar invested (all costs are calculated in US dollars, USD) by ensuring the safety of as many people as possible. To depict this criterion, the

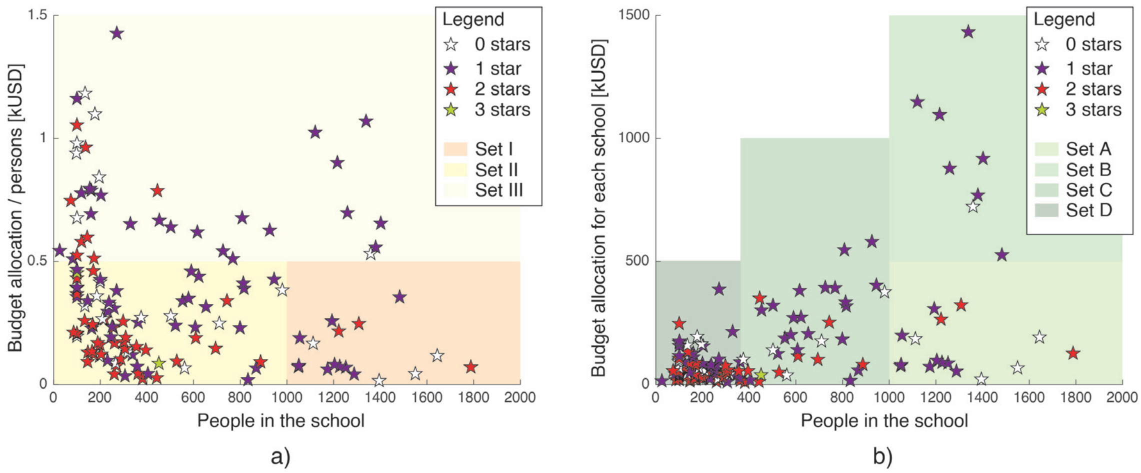


Fig. 10 - Distribution of the VISUS outcomes of the schools in a specific pilot project (intentionally undisclosed for confidentiality reasons). Each star represents a school. The coloured boxes represent examples of priority areas with the relative sets of schools to be considered in the definition of the safety upgrading action plans. Distribution considering the people in the school: a) the value of the estimated budget allocation per person, and the number of VISUS multi-hazard stars; b) the value of the estimated budget allocation for the school, and the number of VISUS multi-hazard stars.

budget allocation to person ratio has been calculated for each school, then, data have been sorted in an ascending way, and represented in Fig. 11a. It can be observed that by following this prioritisation criterion, with 20% of the budget, it is possible to improve the safety condition by almost 60% of persons (and upgrade approximately 55% of the schools). However, this criterion leads to actions such as intervening on schools with three stars, already in life safety conditions. Another potential criterion could be to prioritise schools with fewer stars, and, subsequently, those which enable improving the benefit of each dollar invested for each person (Fig. 11b). In this case, 20% of the budget allows about 43% of persons, and about 38% of the schools, to be involved. Another possible approach for prioritisation is to initially sort the data by the number of stars in ascending order, and, then, sort by the number of individuals in each school in

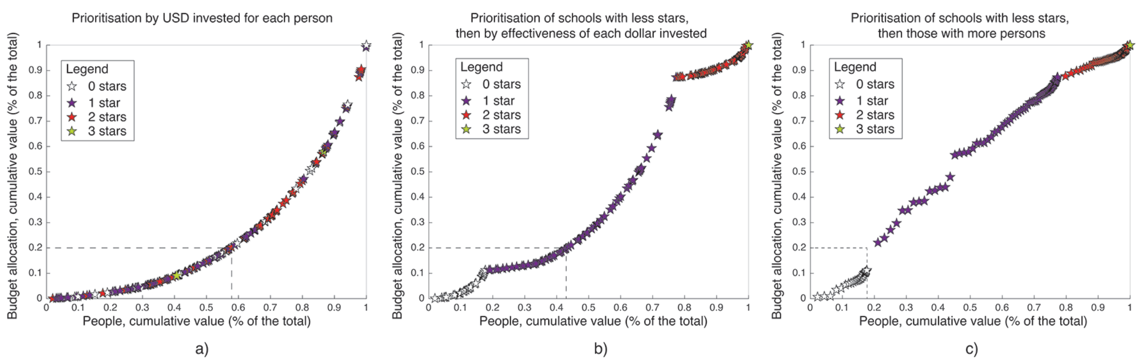


Fig. 11 - Examples of the prioritisation list approach adopting different prioritisation criteria; each star represents a school: a) prioritisation for improving the impact of each dollar invested in terms of number of persons placed in safe conditions; b) prioritisation of schools with firstly considering fewer stars, then the impact of each dollar invested in terms of number of persons placed in safe conditions; c) prioritisation of schools, firstly considering those with fewer stars, then, those with more persons.

descending order. This means that the focus would be to address schools with the poorest safety conditions, and the highest number of people first. It is worth noting that with this prioritisation criterion, allocating 20% of the budget would only be sufficient to address the funding needs of schools with zero stars; in fact, including the first school with one star would require an additional 2% of the budget.

It is worth noting that the examples illustrated represent only some cases of prioritisation and plans that could be developed with the VISUS outcomes; for instance, other prioritisations can be identified considering the number of buildings, the building area, or the number of classrooms. These possibilities prove how the VISUS methodology provides informative elements on the safety assessment of schools that allow the decision-makers to establish *ad hoc* criteria based on local policies or recommendations, and to identify the priorities and plans for upgrading the safety conditions.

It is important to emphasise that decision-makers also consider the location of the school when making their decisions. The VISUS assessment results are presented in web-maps, which enable decision-makers to determine the feasibility of relocating students to another school during the implementation of the interventions, or the need to carry out the interventions exclusively during school holidays. This consideration ensures that the implementation of the interventions aligns with the logistical aspects of each school location.

6. Knowledge acquired and conclusions

The VISUS methodology is a multi-hazard safety assessment methodology that aims to provide decision-makers with information to comprehend the multi-hazard safety condition of schools on a large scale, and to support the definition of safety upgrading action plans for the learning environment.

This paper briefly illustrated the VISUS methodology, and how it was developed and enhanced over the years, through the application of the RAD approach.

The paper analysed the outcomes of a decade-long implementation of VISUS under UNESCO coordination, revealing valuable insights into its application in school safety assessments. The results of pilot projects, and the feedback obtained over the last ten years of applications, lead to the following findings and considerations on the strength of the methodology:

- it is fundamental to approach school safety assessments from a multi-hazard, multi-dimensional, holistic, and intersectoral perspective. This entails considering not only the structural aspects but also the non-structural elements, functionality issues, and location suitability. By adopting such an approach, comprehensive evaluations can be conducted to ensure safety and continuity of education in schools. Implementation outcomes prove the importance of considering individual safety during the day-to-day use of schools, rather than only assessing safety in the event of natural hazards;
- successful project implementation should prioritise capacity building and knowledge transfer at the local level. By empowering the local community with the necessary skills and knowledge, it becomes better equipped to effectively address safety concerns, thus further enabling the self-management of future implementations;
- the adoption and promotion of VISUS by UNESCO DRR, requires the methodology to be globally implementable, and, consequently, highly customisable. VISUS is highly accessible and easy to comprehend, primarily due to its graphic language. In addition, it allows for continuous adaptation to accommodate local requirements, and specific project needs.

The flexible structure of VISUS allows for continuous improvements and enhancements through a peer-review process, and active contributions of a global network of VISUS experts and researchers;
- VISUS is a support tool for decision-makers, providing them with the necessary information to establish action plans for upgrading the safety of learning facilities through a multi-hazard approach. Data show that each country has its own unique characteristics and requirements, and that, therefore, decision-makers need to define and implement strategies that are tailored to the specific context of each country. While offering an adaptable methodology that can be globally applied, VISUS allows decision-makers to establish country-specific strategies for improving the safety of learning environments based on local needs. This is particularly relevant in countries prone to experiencing multiple hazards of significant magnitude. Action plans and strategies can be developed on-demand, with a multi-criterion perspective, so as to align with the requirements and priorities of decision-makers.

Moreover, the ongoing applications of VISUS aim to explore its potential further in evaluating the effectiveness of safety upgrading interventions. By conducting assessments before and after these interventions, the impact on school safety can be measured.

In summary, ten years of VISUS applications have proven the importance of providing a comprehensive and adaptable approach for school safety assessment that is life-safety centred, instead of sectorial-hazard focused, and that permit decision-makers to define their own safety upgrading strategies.

Lastly, considering the results and the progressive improvement of the methodology developed over the last decade, it is worth noting that, within the UNESCO commitment to DRR, VISUS has been acknowledged as a valuable tool to support member states in making schools safer, supporting the development of school-specific disaster management plans with a multi-hazard approach.

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