Politecninco di Torino

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# *Developing a Risk Assessment Model for a School Building*

## *The Case Study of Acciarini Filippo 20*

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## Abstract

This paper checks the consistency of the risk analysis of the Torino school buildings with respect to structural, seismic, and functional vulnerability. Schools are also critical infrastructure for vulnerable populations, and their security is paramount to keeping education operational. The work takes a qualitative but quantitative character and is carried out through national legislation and international agreements such as the Sendai Framework on Disaster Risk Reduction.

The work applied these principles to a case study of specific buildings in the city of Torino in order to illustrate the most significant risk factors and to identify the deviations from codified standards. Meanwhile, the reports revealed severe insufficiencies in terms of earthquake strengthening of buildings, fire protection, and maintenance.

Based on the above observations, the thesis for local entities contributes to this via the adoption of the proposed structured scalable risk assessment model and the support of their decision-making activities from a data-driven perspective. The proposed model is intended to be technically and administratively rational and to provide consistency in assigning intervention priorities.

We argue that for the sake of public safety, and because educational resilience is a strategic safety interest, the construction of the schools' infrastructure as a matter of discretion is simply not right. It is a regulatory requirement and a social responsibility to proactively mitigate risk, particularly in older educational assets.

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# Chapter 1 – Introduction

## 1.1 Context and Importance of Risk Assessment in Schools

School buildings are essential public places where students, teachers, and staff conduct daily learning activities.

Before the reopening of schools, the soil, safety, and strength of school buildings must be investigated to ensure that they sustain no serious structural defects posed to their safety, function, and durability, not only as a precondition for education but also as a primary obligation of public authorities according to both national and European law.

The design of a school and its mechanical systems are integral parts of providing safety for the well-being – both physical and psychological – of its occupants from crime, natural, and anthropogenic disasters. Further, parents, teachers, and good-faith commissions of these schools rely on the notion that these schools are a safe place for learning.

Recent years have again shown the importance of systematic, science-based risk assessment in educational settings, as borne out by several catastrophic events: Those involving building collapse, fire, and seismic failure.

Bottom line: Schools are designed to house a vulnerable segment of the population – kids – who may not process emergencies as quickly as adults or with the same understanding. This exposure changes risk assessments, not as a regulatory calculus per se, but as an ethical obligation.

*Figure 1 – Key factors that make school safety risk assessment essential.*

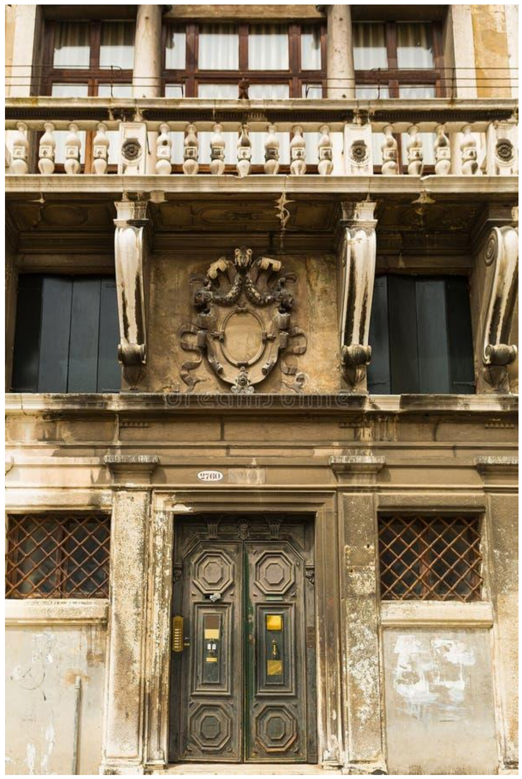
A graphic of the structural, regulatory, and social travails of many Italian schools.


*Figure 2 –*

Example of a mid-20th century Italian school building, illustrating the common architecture and materials used in constructions now over 50 years old.

*Figure 3 –*

Example of a mid-20th century Italian school façade, illustrating common masonry and degradation in buildings now over 50 years old.

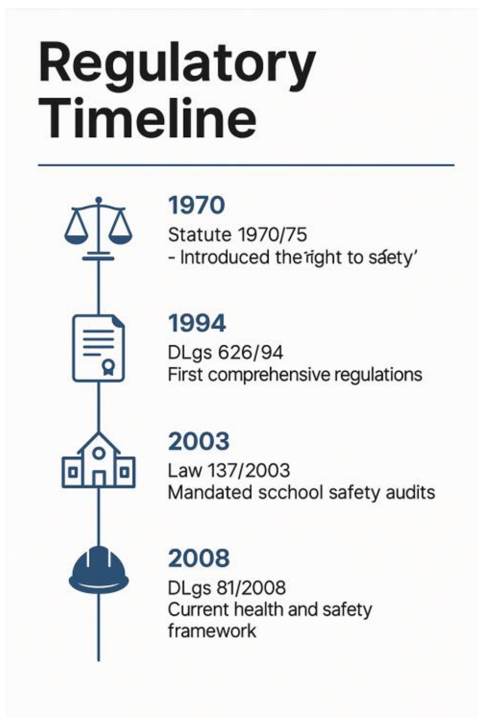


The Italian situation makes everything even more complicated. Many K-12 school buildings in Italy, especially in older cities like Torino, are located in old buildings erected before the advent of modern building codes and even stricter standards enacted after a series of significant earthquakes in the 1980s. Government and Civil Protection offices have issued reports that have revealed a high percentage of schools as still non-compliant when it comes to retrofitting for seismic activity, inadequate fire safety equipment, and unpracticed fire response training. National polls show that 40% of the nation's schools were built before 1970 when safety was less of a priority during construction.

In Torino, a city that has a mix of historic and modern architecture, there are many schools that have specific challenges because of their age. Many of Torino's city schools, constructed before contemporary seismic codes were established, are not retrofitted to survive natural disasters such as earthquakes. This is untenable and a genuine risk to the safety of children, particularly combined with antiquated fire safety systems and insufficient maintenance in many of the nation's schools.

*Figure 4 – Timeline of major Italian school safety regulations.*

From early decrees to present legislative frameworks such as DLgs 81/2008, to illustrate how the legislative framework concerning the risk assessment in schools has changed.




Globally, frameworks such as the United Nations' Sendai Framework for Disaster Risk Reduction (2015–2030) bring to the forefront the need to enhance the resilience of critical infrastructure systems, particularly schools. This framework encourages risk assessment, investment in prevention, and enhanced institutional capacity for resilience towards ensuring the continuity of the delivery of educational services when disaster strikes. These principles have been endorsed by the Italian government, but there is still much to be done at the local level, especially in a city like Torino, where older buildings pose dangerous risks to people's safety.

Risk assessment is also multi-functional. It allows the municipalities to first identify and classify hazards from structural failures to fire hazards and unsound sanitary and electrical systems. Secondly, it sets out an approach for prioritizing interventions by urgency, cost, and feasibility. Lastly, it encourages dialogue with actors involved – on behalf of municipalities, engineering services, schools, councils, decision-makers, and parents – by converting technical risks into decision-making support.

There are also more general social and economic implications. Hazardous school infrastructure can harm education by forcing emergency closures, shaking confidence in a community, and even potentially opening public authorities up to legal liability. Post-event response is up to four times more expensive than prevention and risk rewards.

Faced with these difficulties, various national authorities, including Italy, have been gradually resorting to structured forms of risk assessment that take inspiration from both qualitative and quantitative risk assessment approaches. And those frameworks, especially when they are intended for public schools, must be simple enough for local governments to follow and yet be based on science and comply with regulations. Doing so can keep all students and faculty safe and also help to empower data-based decision-making on resource allocation.

School risk assessment, though, is not merely a technical exercise, but a multisided one touching upon ethics, policy, community confidence, and the public's health. It is a necessity not just to avoid catastrophic examples but because every child has the right to study in a safe and nurturing atmosphere. Within the Torino context, the research is particularly timely and relevant, as it will contribute to local planning, the adoption of safety measures in older school buildings, and local as well as national and international efforts to ensure that public facilities are updated and modernized in accordance with applicable standards.

## 1.2 Research Objectives

This work intends to develop an easy-to-use and practical qualitative risk assessment model for school buildings and to apply the model to a real school in Torino as a case study. This model is developed jointly with the local administration, where the author conducted an internship under supervision.

The aim is to develop a tool that is based on theory and legislation, but still easy to use for municipal engineers/laypeople. The work is motivated by the fact that we were able to carry out an internship at a municipal office of the City of Turin, providing first-hand experience in real maintenance and structural plans as well as data from safety inspections for school buildings. This hands-on experience contributed to the methodological development of the thesis and provided a guarantee that the model was calibrated considering real administrative limitations and data availability.

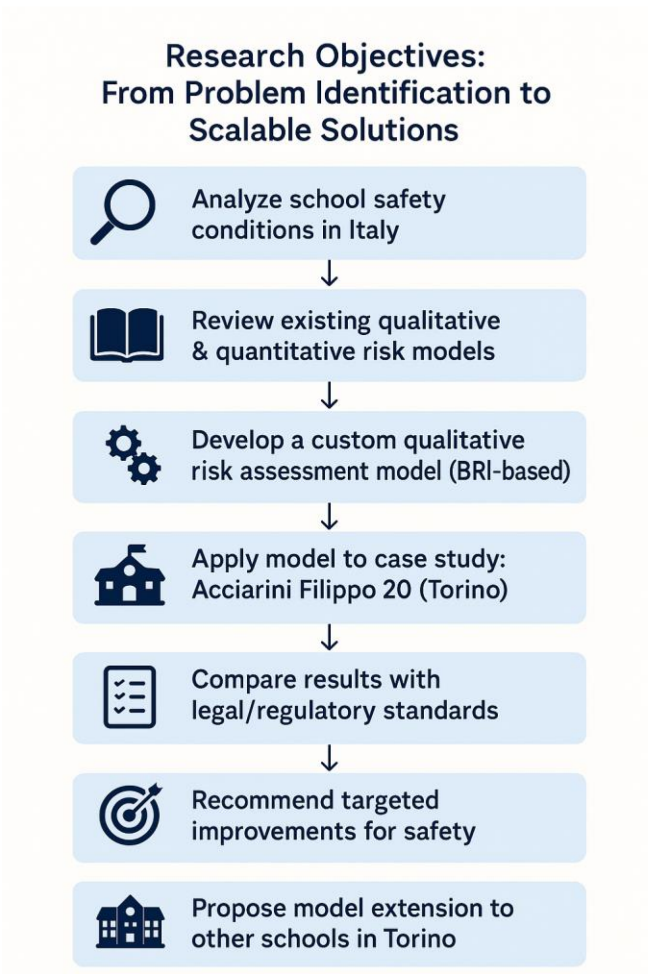
The goals of this thesis can be enumerated as follows:

1. To examine the prevailing condition for school safety in Italy based on types of risk, such as structural safety, fire preparedness, emergency management, and building site maintenance.
2. To survey the existing qualitative and quantitative models applied in risk consideration for educational buildings in Europe and other countries.
3. To construct a matrix type-mode by integrating weighted risk scores using field data, literature benchmarks, and municipal reports.

4. To implement a case study on a school building in Torino, utilizing actual data, including work schedules of maintenance staff, the planimetry of the building, and observations on the building.
5. To assess the findings compared to regulation thresholds and propose pragmatic measures to mitigate risks.
6. To propose guidelines for its expansion to other schools in Torino or the region.

*Figure 5 – Sequential flow of research objectives.*

Figure 5 outlines the logical process from the recognition of safety issues in Italian schools to the definition and use of a risk assessment model and its wider spread application.



The goal of this model is to drive change and offer hope to schools, offering viable solutions to public schools that are currently vulnerable, especially to schools in our urban communities that have aged facilities and buildings that do not support modern safety measures.

This research will therefore inform decision-making by local government and the wider arena of public building risk management.

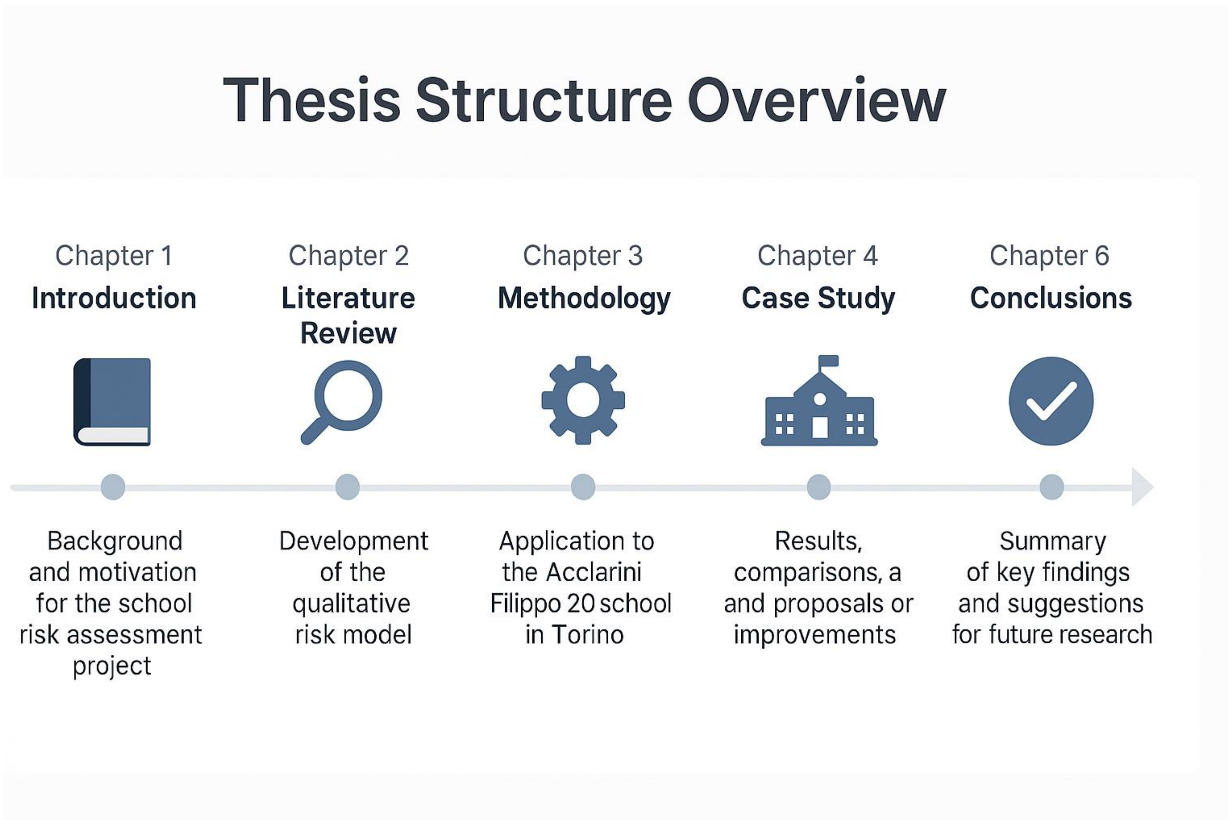
## 1.3 Thesis Structure

In order to meet the aforementioned goals, this thesis is organized in six chapters, which together constitute a full analysis of the school safety risk assessment:

- Chapter 1 presents the background motivation, goals, and structure of the thesis. It clarifies why school safety is a serious issue and situates the problem in the Italian and European reality, with specific attention to the city of Torino.
- Chapter 2 reviews the definitions, regulatory models, and ways to assess this risk. It investigates the distinctions between qualitative and quantitative models and pinpoints places for potential improvement in practice.
- Chapter 3 provides a methodological description of the construction of the qualitative risk assessment model, the assumptions for the model's parameters, and the system for risk scoring.
- Chapter 4 uses the developed model on a real school building in Torino. It considers risks to the building in the structural, fire, emergency preparedness, and maintenance domains and then creates a holistic risk index.
- Chapter 5 presents the findings of the risk assessment, on the basis of which the study compares the standards of the law and those of road safety. It recognizes some "obviously dangerous" sites that require immediate mitigation and recommends practical responses, from inexpensive safety measures to an overhaul of certain structures.

- Chapter 6 wraps up the thesis, presenting the main findings, how they can impact school safety, and some lines for the future. It stresses the importance of such models for public policy and facility management.

*Figure 6 – Thesis Structure Overview*



# Chapter 2 – Literature Review

## 2.1 Definition of Risk Assessment in School Buildings

Risk Assessment in School Premises is the systematic examination of risks within the school educational environment to enable informed judgments to be made as to whether risks are acceptable or need to be removed or controlled. Risk assessment is key because schools are settings that contain a vulnerable population—children—who aren't going to react to an emergency in the same way as an adult might. In addition to addressing state ranking, structural, fire safety, and emergency preparedness criteria, schools are exposed to an array of vulnerabilities that require comprehensive planning to ensure the safety of students, educators, and the greater public.

In such a context, identifying and operating in the space of risk assessment that can bring together technical and social elements (e.g., structural analyses, fire safety system evaluation; child response to emergencies, evacuation security) is crucial. ISO/IEC 31010:2019 presents some of these parts of a risk assessment, consisting of the following and set in context: identification of the risks, analysis of the causes and consequences of the risks, evaluation of the risks against established (or for other purposes determined) criteria.

The school setting presents a set of specific issues for assessing risk, such as the psychological vulnerability of children, their reduced mobility, the high number of occupants, and complex evacuation procedures. Effective school hazard assessment should accordingly consider structural elements and behavioral responses of students and staff in emergencies.

## 2.2 Relevant Regulations (Italian, European, International)

In Italy, there are several national laws regarding the safety of school buildings. Among older documents still valid today is that of the Ministerial Decree 18 December 1975 containing the minimum space, facility and hygiene requirements for schools.

This document is still referred to the construction and restoration of schools in Italy today. But since schools built before 1970 predate today's modern safety codes, many schools struggle to keep up when it comes to basic structural soundness and fire safety systems.

It is also associated with the Testo Unico sulla Sicurezza (DLgs 81/2008), one of the main health and safety laws in Italy. It requires school buildings to undergo periodic risk assessments and to keep safety documentation up to date.

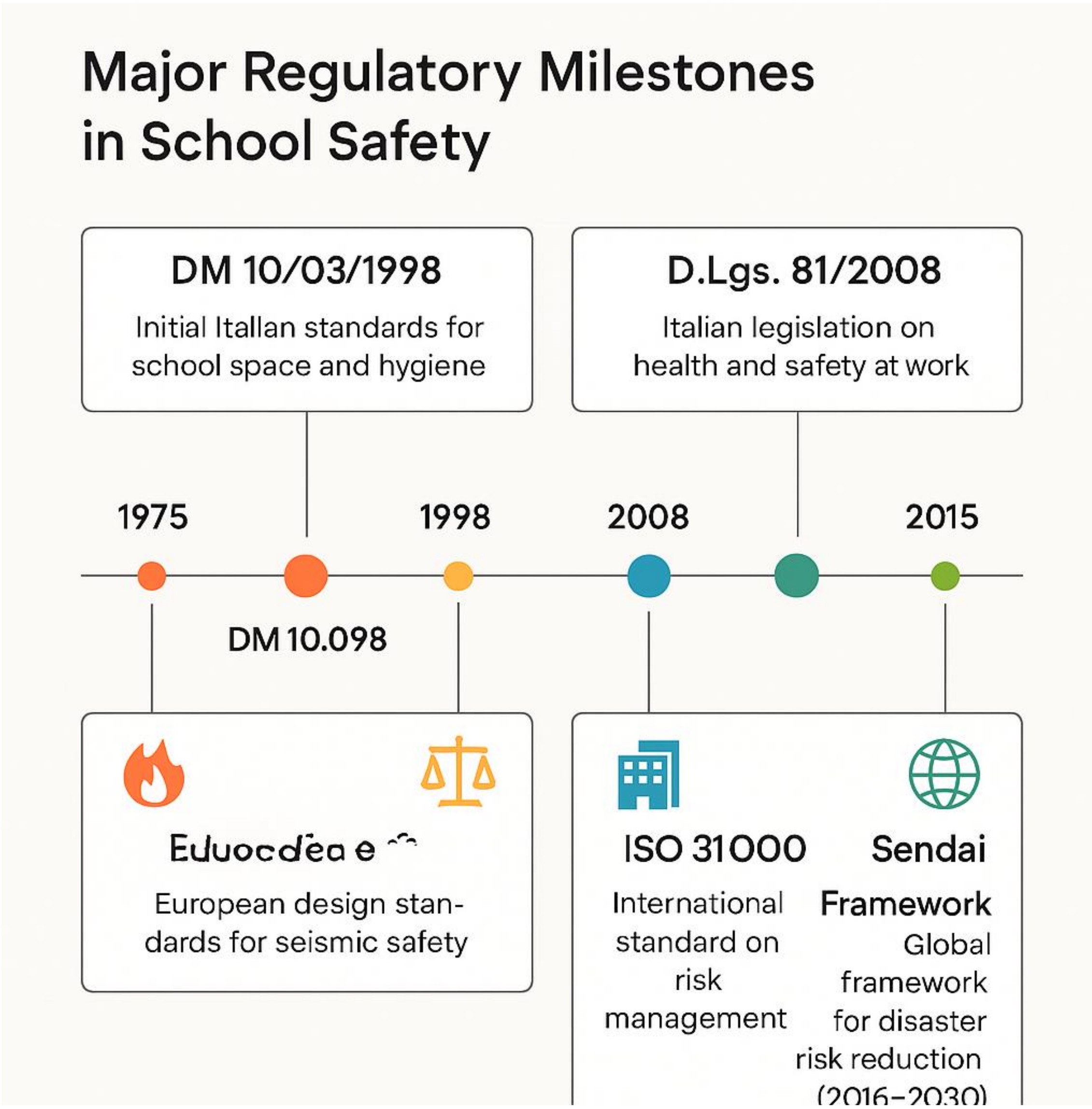
This follows European Health and Safety Directive and will lay out the approach for assessing and controlling safety hazards in all public buildings, including schools.

Eurocode 8 (EN 1998) has dealt with the seismic design of buildings, attaching great importance by considering that schools, as a facility open to the public and the occupation rate of buildings, must achieve the specific seismic safety requirements. Specifically, lack of seismic retrofitting in many old buildings, for example, structures constructed prior to 1981, leaves many of the Italian schools classified as highly seismic risk.

At an international level, documents such as the Sendai Framework for Disaster Risk Reduction (2015–2030) by the United Nations underline the relevance of the resilience of critical infrastructure including schools. It is a preventive framework which seeks to reduce risk before it becomes a disaster, i.e., preparedness and readiness towards the alarms systems.

Indicative of this regulatory controls were the national and international codes, which have been incorporated in developing the risk assessment model adopted in this study with reference to structural stability, fire risks and emergency response.

*Figure 7 – Major regulatory milestones in school safety at national and international levels.*



## 2.3 Existing Approaches to Risk Assessment (Quantitative vs. Qualitative)

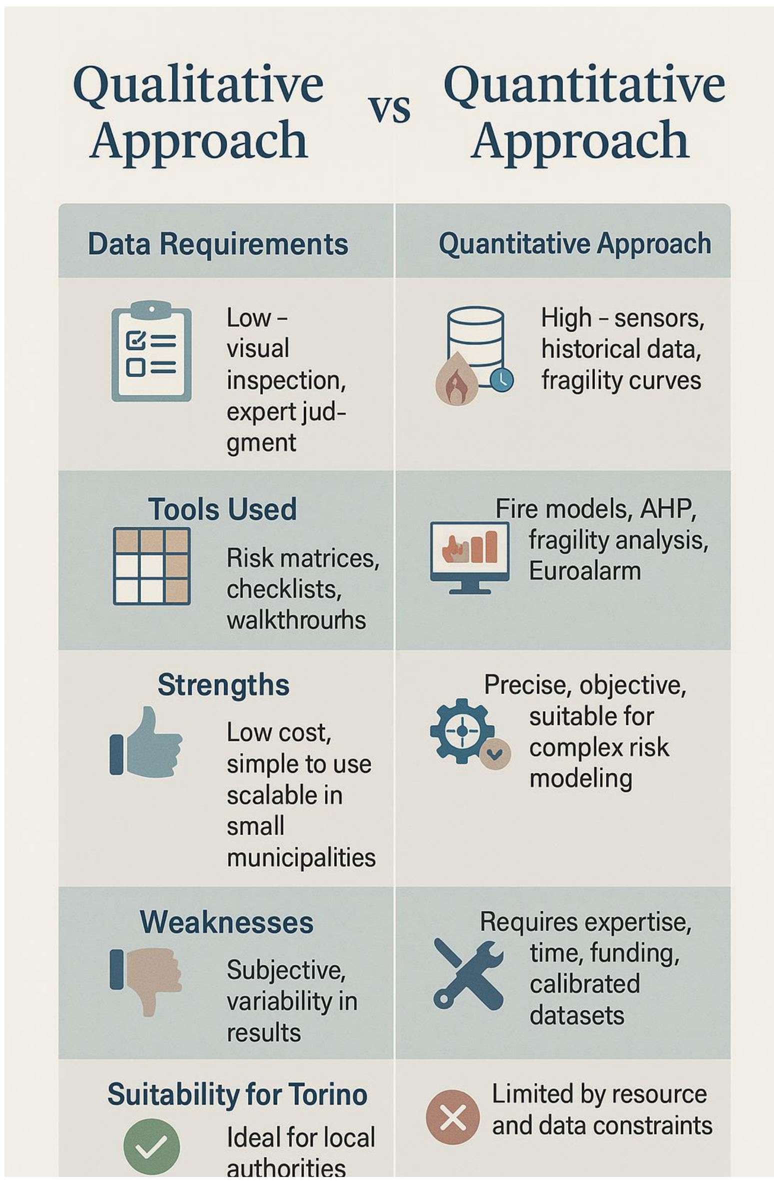
Quantitative approaches frequently depend on models that are data-driven, for example, fragility curves for structure safety or fire models such as Euroalarm. These models produce a numerical measure of risk through input of building characteristics—e.g., geometry, fire loading, occupant action. Though precisely accurate, and potentially very effective in some situations, these models also demand lots of data and technical know-how that aren't always available in smaller localities.

On the other hand, qualitative-type risk assessment techniques (e.g., expert judgment and visual inspection) are subjective assessments of visible characteristics of the inspected components, usually with the help of the Risk Matrix. Such techniques are relatively easier and less expensive, particularly for small towns with limited means. For instance, the commercial Rapid Visual Screening (RVS) methodology utilizes visual inspections for estimating the seismic vulnerability of buildings, based on their construction type and visible damage indicators. Qualitative methods for approach are also cost-effective, but they might add some subjectivity.

This thesis uses a methodology which is based on a mixture of the expert-based qualitative approach and visual inspection qualitative approach with the quantitative structure of risk matrices. This approach makes the model simple, scalable, and flexible to local authorities' constraints and based on scientific evidence and regulatory requirements.

*Figure 8 – Comparison between qualitative and quantitative risk assessment approaches.*

The table compares two dominant school safety evaluation models. Visual methods (appearing generally on the internet if you run a 'search') assessments being carried out by eyes or expert eyes, they are the most feasible in a resource-deprived city like Torino as compared with the numerical methods, which are accurate but need specific knowledge, instruments, and data.



## 2.4 Models and Methodologies Used in Previous Studies

Over the past two decades, numerous methodologies have been developed for assessing the safety of school buildings, reflecting diverse disciplinary approaches and regional hazard contexts. While differing in scope and technical requirements, these studies share a common objective: to provide decision-makers with actionable, evidence-based risk evaluations.

One of the foundational contributions to the field is the Risk-UE framework, introduced by *Lagomarsino and Giovinazzi (2006)*, which developed both macroseismic and mechanical models for assessing building vulnerability and damage potential. Initially intended for urban seismic scenarios, this methodology has been adapted for public facilities, including schools, offering a structured approach to evaluating structural weaknesses against seismic loading.

In the European context, the Adriseismic methodology (*Predari et al., 2023*) has been specifically designed for the rapid seismic assessment of unreinforced masonry buildings. Applied extensively across the Adriatic–Ionian region, it provides a parameter-based scoring system that considers construction typology, geometry, and observable damage. A comparative study by *Marinković et al. (2024)* demonstrated that Adriseismic, while conservative in its scoring, can reliably identify schools with high seismic vulnerability, especially those constructed prior to the enforcement of modern seismic codes.

Beyond purely structural considerations, integrated approaches such as the MM Risk model (*Marinković et al., 2024*) combine technical (structural and non-structural) indicators with socio-organizational variables, typically using a 60/40 weighting scheme. This model has been applied in Latin American and European contexts where complete engineering datasets are unavailable, enabling local authorities to obtain meaningful vulnerability rankings despite data limitations.

Multi-hazard methodologies have also been advanced. The VISUS (Visual Inspection for the definition of Safety Upgrading Strategies) method (*Grimaz and Malisan, 2020*) adopts a territorial perspective, allowing for the simultaneous evaluation of multiple hazards—structural, non-structural, and functional—across an entire portfolio of educational facilities. Its flexible visual inspection protocol has been used by UNESCO to prioritize safety interventions globally.

For fire safety and evacuation risk, *Kobes et al. (2010)* conducted an extensive literature review and simulation-based analysis of occupant behaviour during fires in public buildings, including schools. Their findings underscored that overcrowding and insufficient evacuation routes can significantly increase evacuation times, justifying higher weighting for occupancy-related parameters in qualitative risk models.

At the policy and operational level, *Paci-Green et al. (2020)* undertook a global baseline survey of comprehensive school safety policies, identifying critical gaps in the integration of structural safety, disaster management, and risk education. This work reinforces the value of multi-domain assessment tools that can inform both technical upgrades and institutional preparedness.

Geospatially integrated systems, such as RiskSchools (*Karafagka et al., 2024*), merge rapid visual screening with detailed structural analysis in a GIS environment. Deployed in the Central Macedonia Region (Greece), RiskSchools generates spatially explicit priority rankings for school retrofitting, enhancing resource allocation efficiency. However, as *Panahi et al. (2014)* note in their GIS-based seismic vulnerability assessment of Tehran's schools, such approaches often require specialized technical expertise and comprehensive datasets, which may be beyond the capacity of smaller municipalities.

**Relation to the Present Study**

The model proposed in this thesis draws on the strengths of these established methodologies while directly addressing their practical limitations in the context of the City of Torino. Specifically:

1. It maintains the multi-domain integration of structural, fire, emergency preparedness, maintenance, and social risk factors, as recommended by VISUS and Paci-Green et al. (2020).

2. It applies to a weighted scoring system inspired by MM Risk but calibrated to locally available data and regulatory benchmarks.

3. It adopts the simplicity and accessibility of rapid visual screening (Adriseismic, RiskSchools) to ensure usability by municipal engineers and non-technical staff without compromising methodological rigor.

4. It avoids dependency on advanced GIS or simulation capabilities, enabling consistent application even in resource-constrained administrative environments.

In this way, the proposed model bridges the gap between technically robust but resource-intensive methods and the operational realities of local school safety management.

*Figure 9 – Comparative Overview of Risk Assessment Models for School Buildings.*

This figure summarizes key risk assessment methodologies identified in the literature, indicating their primary domain focus, level of resources required for implementation, and relevance to the present study. Models such as Adriseismic and MM Risk demonstrate high applicability due to their adaptability to incomplete datasets and their emphasis on integrating structural and socio-organizational parameters. VISUS and RiskSchools provide multi-hazard or geospatial integration capabilities, although the latter may require specialized GIS expertise. Fire safety and evacuation models, as reviewed by Kobes et al. (2010), highlight the importance of occupancy and evacuation dynamics, which are partially incorporated into the proposed model. The comparative analysis illustrates that the proposed Torino-specific model adopts the strengths of existing approaches while prioritizing operational simplicity and accessibility for municipal application.

| Model | Domain Focus | Resources | Relevance |
|---|---|---|---|
| Risk-UE<br>(Lagomarsino & Giovinazzi, 2006) | Seismic | High | Moderate |
| Adriseismic<br>(Predari et al., 2023) | Seismic | Low | High |
| MM Risk<br>(Marinković et al., 2024) | Multi-domain | Medium | High |
| VISUS<br>(Grimaz & Malisan, 2020) | Multi-hazard | Medium | High |
| Fire Safety / Evacuation<br>(Kobes et al., 2010) | Fire/Evacuation | Medium | Medium |
| Comprehensive Policy<br>(Paci-Green et al., 2020) | Policy/Institutional | Low | High |
| RiskSchools<br>(Karafagka et al., 2024) | Seismic (GIS + Visual) | High | Medium |
| GIS-based Tehran Study<br>(Panahi et al., 2014) | Seismic (GIS) | High | Low |

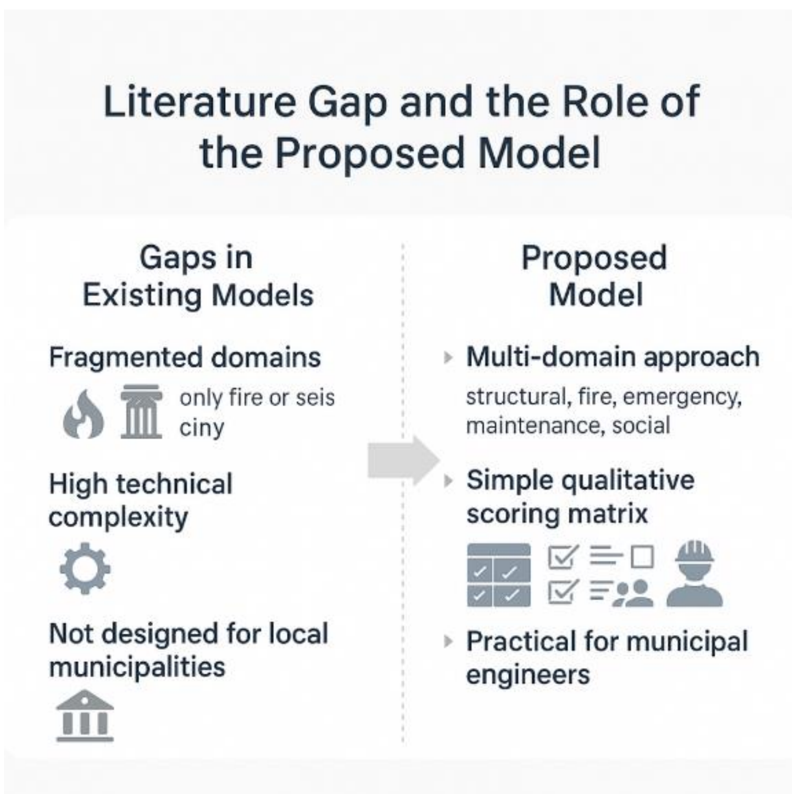
## 2.5 Literature Gaps and Contribution of This Research

However, in the field of school safety, there are still several limitations in developing risk assessment instruments. Existing models tend to be complicated, require expertise or cutting-edge technology, which may be less accessible to local authorities, especially to those from smaller municipalities. There is also a dearth of models that combine numerous risk domains (e.g., structural, fire, and maintenance) that are accessible and actionable to an administrator of the school.

This study addresses these gaps in fundamental research by developing a qualitative risk assessment model in which several domains (structural, fire, emergency preparedness, and maintenance) are cross-linked. The model is based on literature but has been adapted for applications to the reality of a local municipality such as Torino, where available data for school safety analysis has often been scarce and insufficient for the purpose.

*Figure 10 – Addressing literature gaps with the proposed model.*

This drawing illustrates the main drawbacks that characterize the existing models for school safety risk assessment—including single-domain focus, high degree of technicality, and low local adaptability—and shows how the proposed model offers an integrated, practical, and accessible tool for municipalities.



# Chapter 3 – Research Methodology

## 3.1 Overview and Philosophy of the Research Approach

This study subscribes to a pragmatic paradigm of research in its application of problem solving for school safety. Its investigative quality is thick and thin, having on the one hand the abstraction associated with theory (risk assessment) and on the other side application.

The methodology includes the methods of case study analysis, model development, and qualitative evaluation, with strong support of empirical data, that have been gathered by the author during her internship at the Comune di Torino.

The study aims to contribute to practice by linking theoretical knowledge to the complexity of safety in school buildings. This is especially critical in the setting of scarce resources of local governments where they commonly use simple models for risk assessment.

As a result, the selected approach emphasizes accessibility and usability, making the model user-friendly for municipal engineers and non-technically orientated stakeholders, but still scientifically based and compliant with the regulations.

We opted for this pragmatic approach because:

1. Public schools have little access to quantitative information, especially with respect to sensors and high-tech monitors.
2. The significance of identifiable, repeated problems (e.g., expired fire signs, obstructed exits, lack of drills) requires a qualitative approach.
3. We aim to establish a reproducible model that local technicians with scarce computational resources can readily use.

## 3.2 Development of the Qualitative Risk Assessment Model

A qualitative risk assessment model that will produce a Building Risk Index (BRI) for school buildings is the focus of this study. The model applies to a weighted score mechanism for assessing critical risk areas as outlined in Chapter 2. The areas/domains of risk primarily evaluated are:

- Structural Safety
- Fire Safety
- Emergency Preparedness
- Maintenance
- Social

The model sums risk scores from these categories to generate an overall risk profile for the school facility. The BRI is intended to demonstrate the gravity of each risk and to prioritize them for attention. The scoring was prescribed by the ISO 31000 standard for risk management, which provides a logical methodology for evaluating the probability and impact of a recognized risk. This structure was modified for school buildings to guarantee the risk scores obtained are suitable and actionable. The framework adopts a matrix structure in which various elements under consideration are given a score ranging between one (low) and five (high). The scores are then weighted by frequency and impact, which are based on academic literature and city reporting.

The general formula for the BRI is expressed:

$$BRI = \Sigma\ (W_i \text{ x } S_i)$$

Where:

- $W_i$ is the weight assigned to each parameter (ranging from 0 to 1, with the sum of all weights equal to 1).
- $S_i$ is the score for each parameter, ranging from 1 to 5.

Risk classifications are defined as follows:

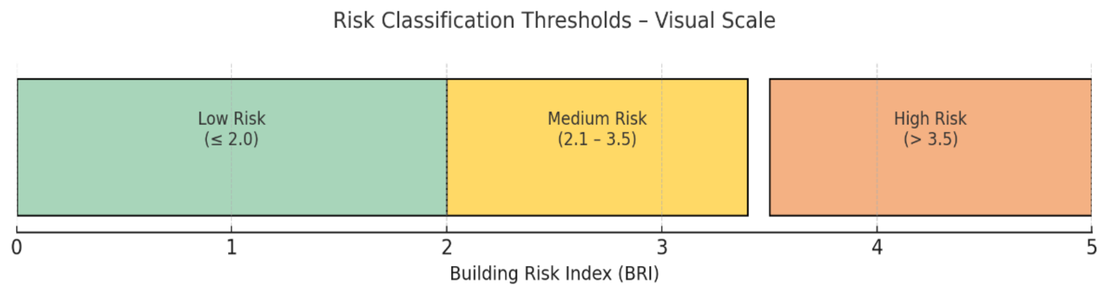
- Low Risk: BRI ≤ 2.0
- Medium Risk: 2.1 ≤ BRI ≤ 3.5
- High Risk: BRI > 3.5

*Figure 11 – Workflow Diagram of the Qualitative Risk Assessment Model*

This diagram shows the methodology steps adopted in this thesis, which started by collecting field and regulation data, scoring parameters, risk weighting, calculating BRI, and finally outputting recommendations. The step-by-step procedure guarantees transparency, replicability, and practical usability of the developed model for local decision-makers.

*Figure 12 – Visual Scale of BRI-Based Risk Classifications*

This figure represents the classification thresholds for interpreting the Building Risk Index (BRI). Low, Medium, and High categories are color-coded and include their respective scoring range labels to facilitate intuitive perception during assessment.




## 3.3 Identification of Risk Parameters

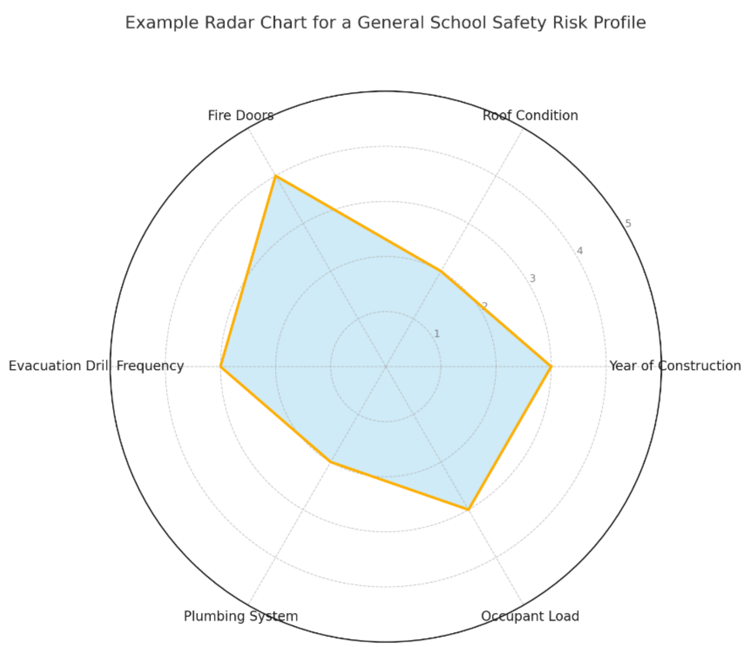
The inputs used in the qualitative risk assessment model were determined based on their importance and availability in previously reported risk assessment models. The subsequent six parameters were selected because they can cover diverse types of hazards existing notably in school buildings:

1. Year of Build (Structural) – The risk of potential seismic damage and standard ageing issues increase with the age of a building.
2. Occupant Load (Social) – Evacuation time and panic during disasters are likely affected by crowdedness.
3. Fire Doors (Fire Safety) – Quality and quantity of fire-rated doors are important in the event of a fire to evacuate safely.
4. Evacuation Drill Frequency (Emergency Preparedness) – How often are evacuation drills being conducted?
5. Plumbing Status (Maintenance) – Water leaks and maintenance problems can be sources of danger such as water damage, mold, or fire risk.

6. Roof Condition (Structural) – The vulnerability of the entire structure to external stresses is indicated by the overall roof condition.

*Figure 13 – Example Radar Chart for a General School Risk Profile*

This figure shows a simplified radar chart to profile the safety of a school over six main domains according to qualitative scoring. It is commonly used as a general visualization tool to apply the risk model produced in this study.



Every parameter has been chosen for the role it plays in risk mitigation and its contribution to the overall safety of the school. The following frequencies were weighted per category according to their relative severity (and frequency in comparable risk assessments):

- Year of Construction: 25%
- Fire Doors: 20%
- Roof Condition: 15%
- Plumbing System Status: 10%
- Occupancy Load: 15%
- Evacuation Drill Frequency: 15%

These weights represent the relative contribution of each criterion to the overall safety of the school. For instance, structural-related issues (such as year built and the condition of the roof) have high weights because they can result in failures of catastrophic proportions, while evacuation and occupant load are weighed slightly less but still considered critical aspects of safety.

*Figure 14 – Weighted Risk Score Contribution by Domain*

These bars show the percentages each risk factor accounts for of the overall Building Risk Index. Structural safety and fire preparedness rank highest in importance by both assigned weight and the average score received, validating intervention priorities.

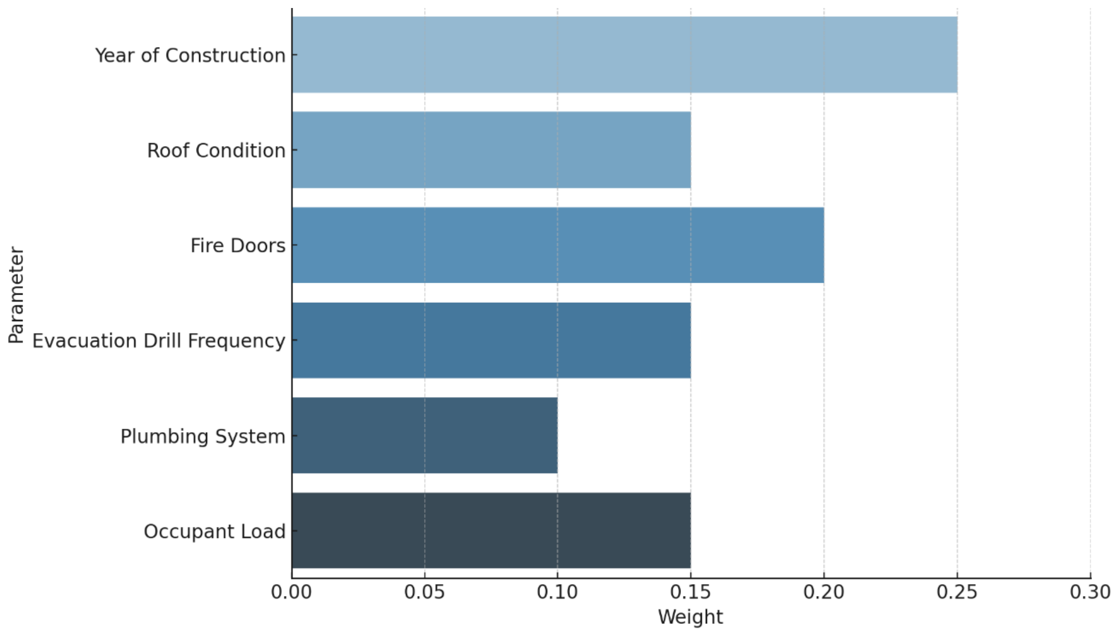


*Figure 15 – Parameter-Level Contribution to the Total Risk Score*

This pie chart shows the relative contribution of each variable to the school's total risk score. It is a rapid summary of the key decision-making influences.

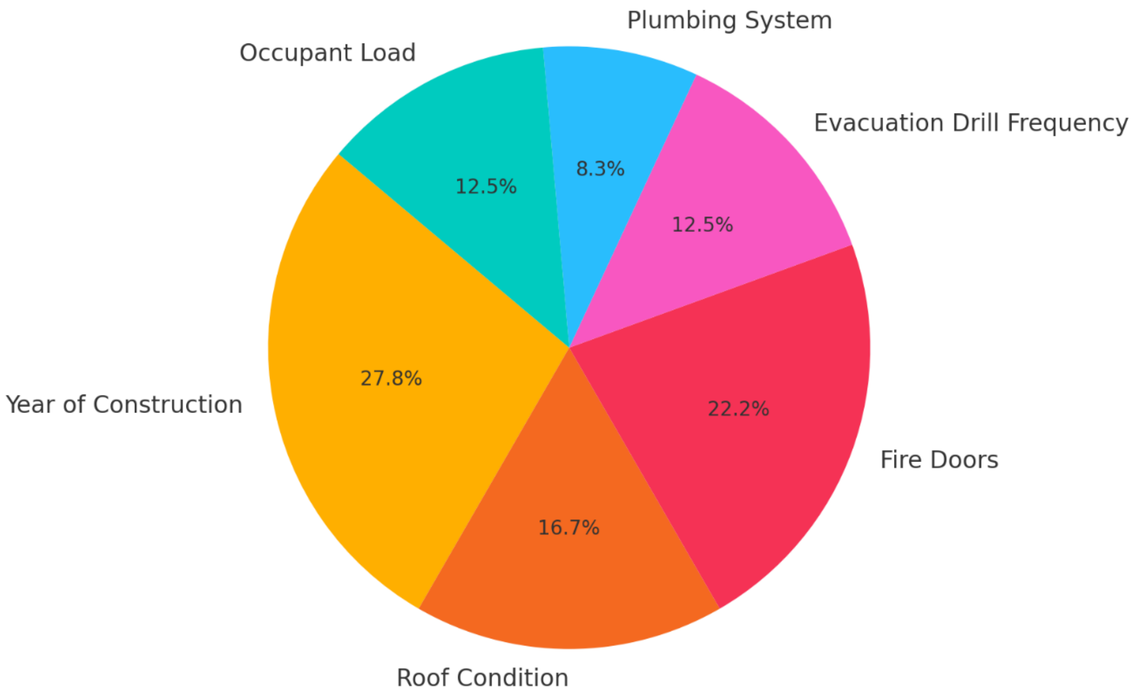


*Table 16 – Scoring Criteria Reference Table*

The following reference table outlines how each parameter is scored on a scale from 1 to 5. It is used during on-site inspections to ensure standardized scoring across school buildings:

| Parameter | Score 1 | Score 2 | Score 3 | Score 4 | Score 5 |
|---|---|---|---|---|---|
| Year of Construction | After 2010 | 2000–2010 | 1980–1999 | 1960–1979 | Before 1960 |
| Fire Doors | 100% compliant | Minor non-compliance | Moderate gaps | Only one certified | None certified |
| Roof Condition | Renovated within last 5 years | Minor wear | Routine aging | Visible leaks | Structural deformation |
| Plumbing System Status | Fully upgraded | Minor fixes needed | Routine issues | Frequent user complaints | Critical failures / corrosion |
| Occupant Load ($m^2$/student) | >15 $m^2$ | 13–15 $m^2$ | 11–13 $m^2$ | 9–11 $m^2$ | <9 $m^2$ |
| Evacuation Drill Frequency | 2 or more per year | 1 per year | 1 every 2 years | Rare and undocumented | No drills |

## 3.4 Tools and Analytical Techniques

This research is hinged on these three basic analytic tools in order to optimize data collection and analysis:

- Risk Checklist - A comprehensive binary risk and ordinal checklist consisting of over 30 questions categorized into the 4 main risk domains (structural, fire, emergency, and maintenance). By using this instrument, all high-risk factors are measured across all buildings in all schools taken.
- Weighted Risk Matrix: Operated in Excel, it derives the Building Risk Index (BRI) by inputting the scores for each criterion. The overall score is automatically recalibrated by the MATRIX according to the weights of the risk factors, thus a fast and data-driven manner to quantify the risk.
- Visual Inspections – carried out by the author during the internship; the qualitative findings complement the quantitative information here. They took pictures and field notes to test the building's physical condition and how well it meets safety codes.

The use of these tools together results in a robust risk assessment that provides both quantitative and qualitative information on which to base a structured Building Risk Index. Computing the BRI is automated by the Risk Matrix; this makes the method efficient and scalable.

## 3.5 Validity and Reliability of Methodology

To ensure the validity and reliability of the methodology, several safeguards were implemented:

- Construct Validity: The parameters used in the model are derived from widely cited risk assessment frameworks, including MM Risk and Euroalarm, ensuring that the model accurately represents relevant real-world risk factors.

- External Validity: The checklist-based approach used in this model is designed to be easily replicated across other municipalities. This ensures that the results are not overly specific to the case study school in Torino and can be adapted for use in other settings.
- Reliability: The scoring criteria used in the model are predefined, based on objective conditions such as building age and documented maintenance records. The field inspections were conducted under the supervision of officials from the Comune di Torino, ensuring consistency and accuracy.
- Data Accuracy: Inconsistent access to historical data, such as fire drill records and maintenance logs, was acknowledged as a potential source of variability. These data gaps were noted during the study and will be addressed in future model iterations.

## 3.6 Limitations of the Proposed Approach

In order to safeguard the validity and reliability of the approach, a number of precautions have been taken:

- Construct Validity: The model parameters are based on highly cited "real" risk assessment frameworks such as MM Risk and Euroalarm, ensuring the model faithfully represents valid elements of real-world risk.
- External Validity: This model adopted a checklist-based methodology to replicate the proof of concept of the model from my is designed to be scalable and replicable in other environments. It can be easily adapted by other municipalities. This is to avoid being too specific with respect to the case study school in Torino and to enable the tool to be used also in other contexts.
- Credibility: The scores in the model are pre-determined based on objective criteria such as age of building and documented maintenance history. The site inspections were moderated by officers from the Comune di Torino to maintain uniformity and accuracy.

- Data Accuracy: Inconsistent availability of historical information like fire drill records and maintenance logs were recognized as a source of variance. These data deficiencies have been identified and will be incorporated in subsequent implementations of the model.

# Chapter 4 – Model Application: The Case Study

## 4.1 Description of the Selected School – Acciarini Filippo 20

The field of this study is Acciarini Filippo 20 (AFe 20), a public lower secondary school situated in the Zona Sud area of Torino, Italy. The school was chosen by an author during his stage at the Comune di Torino, as a typical case of many schools in old buildings, which need deep safety control and intervention in order to be renovated and updated with modern standards.

**Summary About the School:**

- School Name: Acciarini Filippo 20
- Type of School: Scuola Secondaria di Primo Grado (Lower Secondary School)
- Where: Zona Sud, Torino, Italy Zona Sud, in Torino, where both older and more modern structures mix, where the school is located. It’s a high-density area, so public safety is of even greater importance to the health of both students and staff.
- Location: Acciarini 20, 10100 Torino, Italy
- Year of Construction: 1967 The school was built in 1967 and did not meet the standards for safety from earthquakes and fires. The building's age is partly to blame for its vulnerability because it has outdated structural characteristics and insufficient fire protection, according to critics.
- Construction System: School is of Reinforced concrete frame structure having GF + 2 Floors. The building houses classrooms, an office, a gym, areas like hallways and bathrooms and utility rooms. The structure has not been updated since it was built in the 1960s, stirring concerns about its ability to meet modern safety regulations.
- Tenant Population: The facility accommodates about 270 students and 40 staff members, resulting in a total population equivalent to 310. The building, however, was initially built during less populous times. This class and overcrowding also taxes the school's evacuation and emergency preparedness protocols.

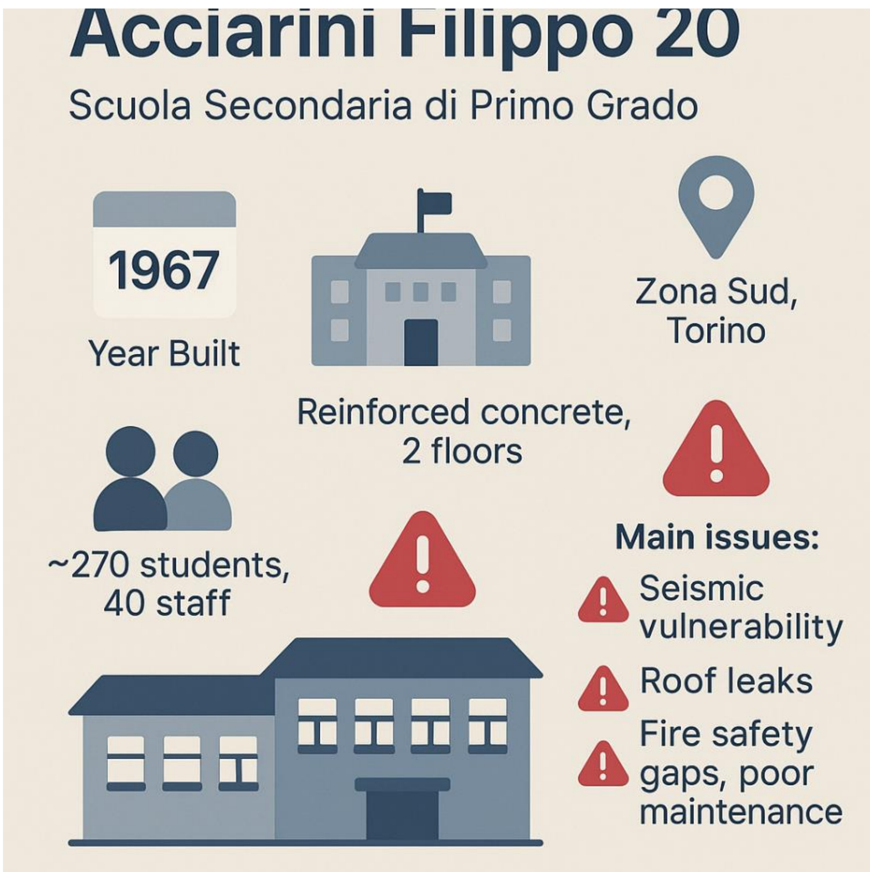
- Recent Upgrades: Partial repairs to the roof were done in 2012 in an effort to address problems of water penetration. It was leaking, the roof needed to be repaired, and we put a new roof on it, and then fixed the leaks, there were a couple of leaks. Yet, problems with water damage continue, especially in the northwest corner, where mold is clearly visible, they said. The building has undergone no significant renovations or seismic upgrading since its construction.
- Seismic Risk: Since this building was built before the application of obligatory seismic norms (post-1981) it does not have the seismic reinforcements. LACK OF SHEAR WALLS/EXPANSION JOINTS/STRUCTURAL UPGRADES PRESENT: The lack of shear walls and other important structural improvements subject the building to great risks in the event of an earthquake, as it could suffer substantial structural damage, as well as potential loss of life in the event that the building collapses or partially collapses.
- Fire Safety: The school does not have adequate fire safety. There is one fire door which is approved, this is not enough for a building of that size. They also found outdated fire extinguishers on the premises and said fire exit signs had been removed and covered up. The back-up generator system also did not kick in during a recent test. These deficiencies underscore the urgency of implementing improvements in fire safety systems.
- Plumbing and Maintenance: The school's plumbing system is in very poor condition. The teacher's bathrooms have leaked on separate occasions in 2019 and then in 2022. There was rust on the exposed metal conduct, and budget constraints have postponed repairs. The roof also leaks, adding to maintenance woes at the school.
- Occupancy and Space Layout: The design of the school was for fewer students and there are some overwhelmed classrooms and hallways. This congestion puts a lot of pressure on evacuation and emergency system planning, including more

evacuation times for an already small amount of space in times of emergency, for example.

- Building Amenities and Services: The school has minimal amenities, including heat, electricity, and plumbing, yet many of these systems are outdated and in disrepair. The continuing plumbing service problems and roof leaks will further degrade the building's infrastructure. This underscores the critical need for upgrade and improvement to maintenance in such places to prevent any user hazard.

*Figure 17 – Overview of the case study school: Acciarini Filippo 20.*

This profile provides a portrait of the specific school (in Zona Sud, Torino) selected, overall profile parameters as well as construction year (date), structural features, population, and the main school-specific safety weaknesses traced during the preliminary estimation.



## 4.2 Assessment of Structural Safety

The structural security of Acciarini Filippo 20 is worrisome for age (built in 1967) and absence of seismic adjustment. The building was designed prior to the development of the compulsory seismic standards implemented post-1981 in Italy and so is very seismically vulnerable. Structural deficiencies were noted based on visual observation and review of historical building files.

**Key Findings:**

- Earthquake Danger: The structure does not meet current seismic codes. The lack of shear walls, expansion joints, and cast-in-situ concrete structures risks that building will be seriously damaged in an earthquake.
- Condition of the Roof: Roof damage: Partial repairs were made in 2012 but the roof is still compromised and causing water intrusion; this has resulted in visible mold, fatigue, and damage present in the building, particularly in the northwest corner. All these are flaws that undermine the integrity of the overall building envelope.
- Cracks and Wear: Minor cracks and continued water damage were witnessed throughout the building, suggesting a decay of the building material.

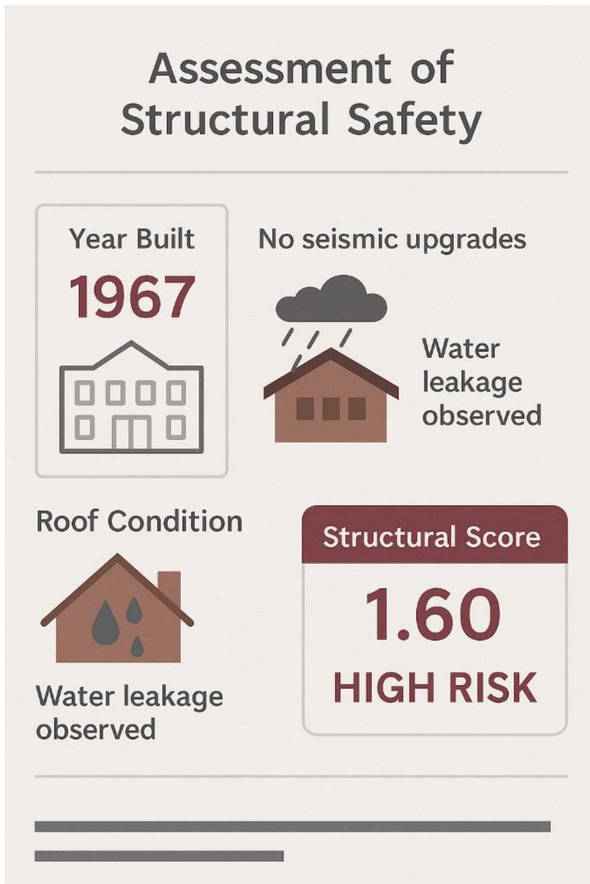
The structure has not been seismically retrofitted and due to the poor roof condition, the structure risk is high.

The weighted structural risk score for this domain is given by:

- Year Built (1967): 4 (25% weight)
- Roof Condition (Visible water infiltration): Score 4 (15% weight)
- Subtotal Structural Risk: (0.25 x 4) + (0.15 x 4) = 1.60 (High Risk)

*Figure 18 – Structural safety assessment of Acciarini Filippo 20.*

The following background are the most important features of the school, considered as main structural vulnerabilities: the construction year (1967), the fact the school was not seismically retrofit, persistent leaks through the roof and the corresponding classification of the building to high risk by the Building Risk Index (BRI) scoring model.




## 4.3 Analysis of Fire Safety Measures

Fire safety at Acciarini Filippo 20 is not satisfactory, especially under time-critical evacuation. With the current occupant load, even small deficiencies (e.g., one certified exit only, expired extinguishers, poor wayfinding, failed emergency lights) can stack up and significantly lengthen pre-movement and travel time, increasing overall risk during a real event.

**Key Findings:**

- Fire Doors (exits/separation). The school currently has one certified EI fire door where at least two compliant exits are required for the building's size and population (and for elevator lobby separation). A single certified exit offers no redundancy: if that route is smoke-logged or obstructed, evacuation flow will bottleneck, especially from upper floors.

  What to fix now: install a second EI fire door with panic hardware and self-closer, confirm door swing in direction of egress, and keep the landing clear (no storage). Verify labelling and maintain a monthly door-operation check (self-closing, latch, free swing).
- Fire Extinguishers (first-attack readiness). Many units are out of date (last full service 2021) and some are not readily accessible. This lowers the chance of containing an incipient fire and makes a full evacuation more likely.

  What to fix now: bring all units into date, ensure agent suitability (e.g., $CO_2$ near electrical panels, water/foam for corridors/classrooms), and maintain $\leq 30$ m travel distance along routes. Add a simple cabinet/tag checklist to monthly safety rounds.
- Fire Signage (wayfinding). Certain corridors lack exit signs or signs are obscured, which slows route choice and creates congestion at decision points (stairs/landings) when people cannot see the correct direction quickly.

  What to fix now: restore standardized pictograms and directional arrows at every change of direction and final exit; mount/position signs to remain visible under typical smoke layer heights; keep them free from noticeboards and furniture.
- Emergency Illumination (tenability during power loss). The emergency lighting system failed the latest manual test in at least one sector, meaning escape routes and

stairs may be under-lit if mains power drops during an alarm. Poor lighting slows flow and elevates slip/fall risk.

What to fix now: replace failed batteries/luminaires, carry out a full duration test (≥ 1 h autonomy), verify coverage/spacing on stairs, landings, corridors, and final exits, and log monthly function checks.

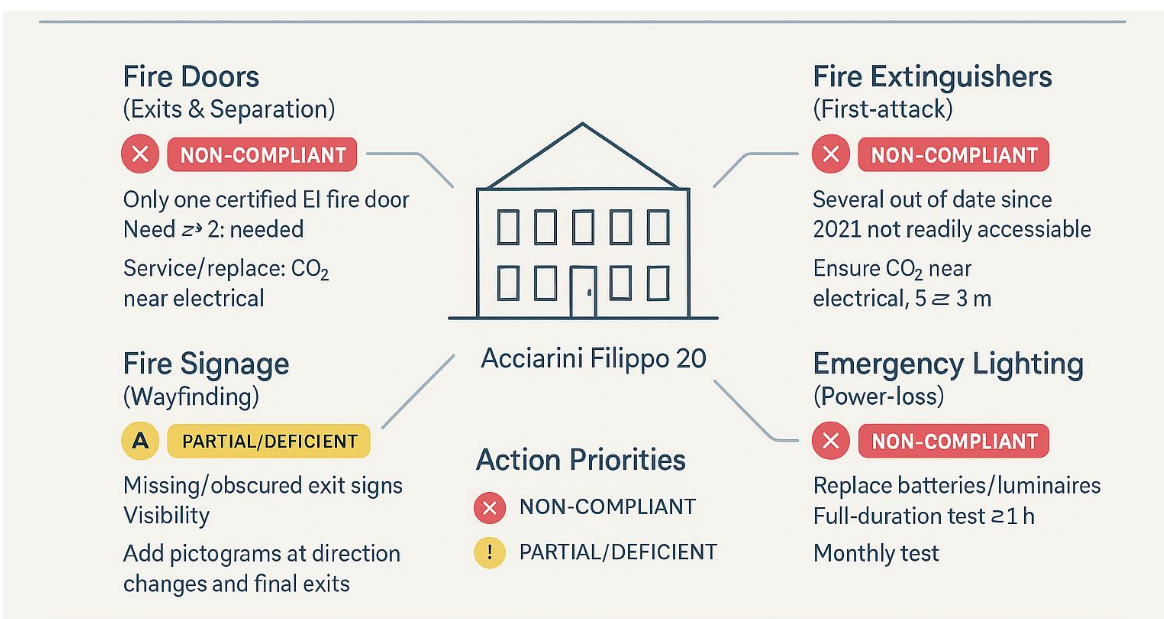
Overall assessment & evacuation implications:

In combination, insufficient certified exits, expired/inaccessible extinguishers, deficient signage, and failed emergency lighting, the building's fire-safety state is high-priority for corrective action. Addressing the second EI door, emergency light reliability, and signage will deliver the largest, fastest reduction in evacuation time and risk.

Weighted fire safety risk score:

- Fire Doors: Rating 4 (20% weight)
- Subtotal Fire Risk: (0.20 x 4) = 0.80 (High)

*Figure 19 – Fire safety assessment of Acciarini Filippo 20.*



## 4.4 Evaluation of Emergency Preparedness

Emergency preparedness in Acciarini Filippo 20 is deficient, particularly with evacuation drills and the preparedness of staff. By law, a drill must be held twice a year, but the school performs one drill each year. This inadequate drill deprives the school of readiness for actual emergencies.

**Key Findings:**

- Frequency of Evacuation Drills: The school only conducts a single evacuation drill per year; it is supposed to conduct at least two. This undermines the self-sufficiency of the school as both the staff and students may not be familiar with the evacuation mechanism in an emergency.
- Staff Training: Staff are trained on basic evacuation instruction, but not on additional crises such as a fire occurring at the same time as a structural failure. Finally, the length of the drills is not documented, precluding assessment of the drills' duration.
- Medical Equipment: There was no observable First Aid equipment or medical emergency kits found on the inspection, which showed that the home health care agency was not prepared for medical emergencies.

The low frequency of evacuation drills and deficient emergency training lead to moderate emergency preparedness risk. The weighted emergency preparedness risk score for this subcategory is defined as:

- Frequency of Evacuation Drill: Factor 3 (Weighting 15%)
- Emergency Risk Subtotal: $(0.15 \times 3) = 0.45$ (Moderate risk).

*Figure 20 – Emergency preparedness assessment of Acciarini Filippo 20.*

Summary of shortage of readiness protocols and emergency response capabilities in school premises, ranging from the lack of drills to the absence of visibility of basic first aid requirements and concluding with lack of advanced trained teachers' support, depicting the school at a moderate risk category.


## 4.5 Maintenance and Building Services

This section deepens the analysis of technical risks tied to the school's maintenance regime and building services, in line with the model parameters ("Plumbing system condition" and "Roof condition / infiltrations") and based on on-site observations and municipal records gathered during March–April 2025. The focus is on how recurrent defects, lack of preventive maintenance, and moisture pathways elevate risk for users and for the reliability of safety systems.

**Key Findings:**

- **Plumbing system – technical risk mechanisms and evidence:**
  Field notes and municipal reports document two leak events (2019, 2022), visible corrosion on exposed metal piping and ceiling conduits, and the absence of a formal inspection logbook (reactive, not preventive maintenance). These conditions are consistent with a moderate degradation state of the network. From a technical standpoint, the main risk mechanisms are:
    - Progressive material loss and joint failure due to corrosion, increasing the probability of renewed leaks and acute service interruptions.
    - Secondary hazards: water intrusion near electrical runs or panels can create short-circuit initiation points and localized fire ignition risk; wet floors elevate slip/fall risk.
    - Hygienic risk in stagnation points after vacations (long dwell times), potentially worsening indoor environmental quality if not flushed and monitored.

  The case-study evidence supporting the assigned score includes: (i) leaks recorded in 2019 and 2022; (ii) corrosion on lines; (iii) missing routine inspection records/logbook.
- **Roof and moisture pathways – interface with services:**
  Although the roof envelope is treated structurally elsewhere, maintenance-driven waterproofing deficits interact strongly with services. The school underwent partial roof repair in 2012, yet persistent infiltrations and mold remain visible (notably in the northwest sector), with staining and spalling reported in northern corridors. Technically, this rises:

- Moisture transport through the envelope and into shafts/ceilings, increasing corrosion rates on metal services and fixings.
- Reliability risk for overhead services (e.g., conduits, lighting) and finishes; repeated wetting–drying cycles accelerate failures and can compromise anchorage of suspended elements.
- Indoor air quality deterioration in affected rooms/corridors due to mold growth and damp materials.

  These observations substantiate the elevated moisture-exposure context cited in Chapter 4 and the appendices (plan annotations of "attention areas"), and explain why roof/drainage maintenance is repeatedly flagged alongside plumbing in the case-study narrative.

- **Maintenance regime – from reactive to preventive:**

  Across the building, maintenance is described as reactive, with no formal logbook for plumbing or roof inspections. In practice, this increases likelihood (L) in the risk matrix because incipient defects (slow leaks, seal failures, clogged drains) are discovered late, often only after secondary damage appears (stains, spalls, mold). For our model, this operational reality is the key reason the maintenance domain does not fall to "Low" despite a limited parameter count. The evidence base (leak chronology, corrosion sightings, absence of periodic records) underpins the Moderate classification already presented in the chapter's figures.

  Immediate, model-consistent actions:

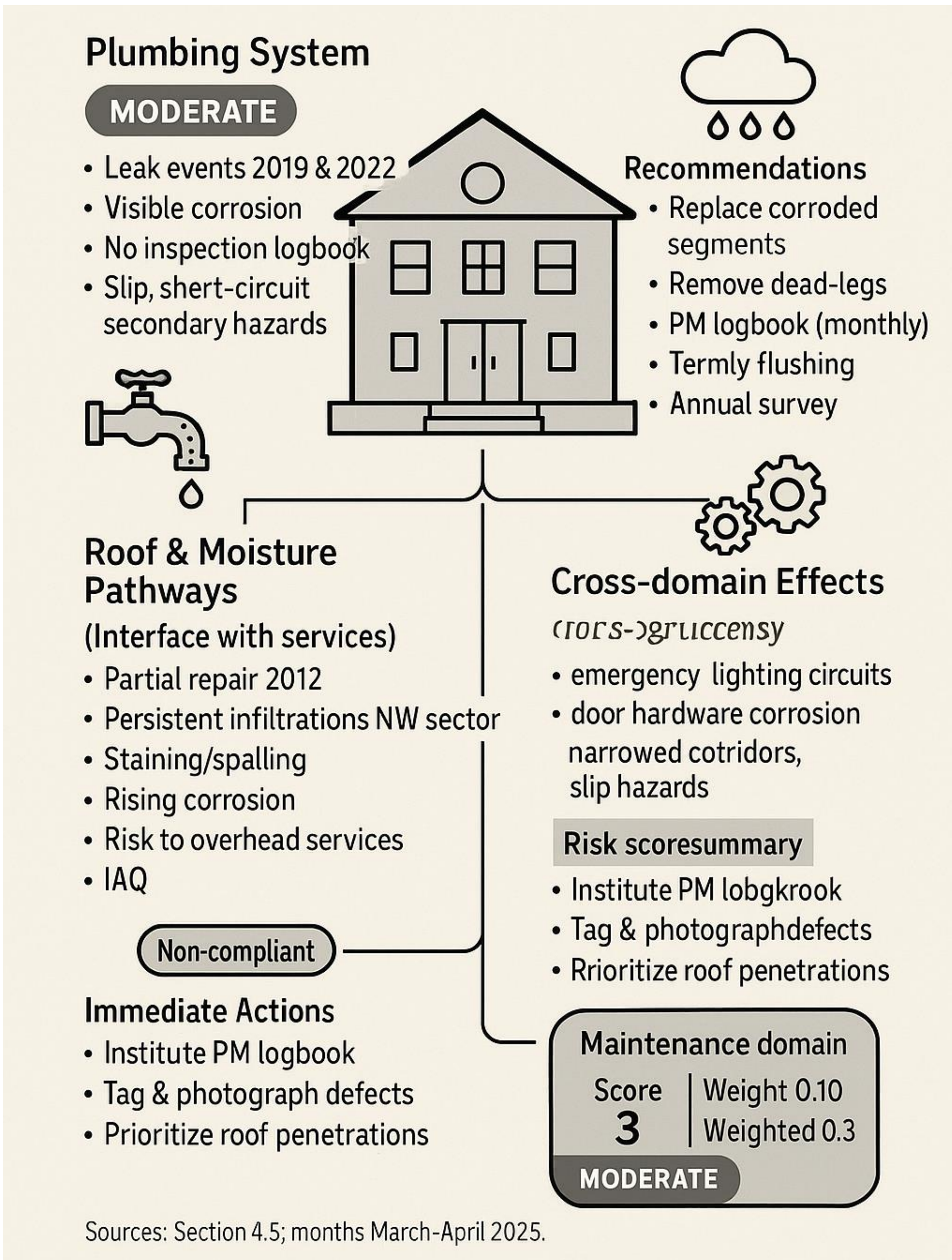
  - Institute a Preventive Maintenance (PM) logbook (monthly visual checks; termly drain/roof outlet clearing; annual condition survey of risers, manifolds, and wet rooms), linked to the scoring parameters already used in this chapter.
  - Tag and photograph every recurring defect (leak points, stained tiles, corroded segments) to build a baseline and track trend.
  - Prioritize junctions between the roof envelope and service penetrations (vents, stacks, cable trays) where waterproofing laps and sealants commonly fail.

- **Cross-domain interactions (why maintenance matters for safety):**
  - Fire/Egress systems: moisture can impair emergency lighting circuits and corrode door hardware, indirectly affecting evacuation reliability.
  - Social/Occupancy: water-damaged corridors narrow usable width and create slip hazards during evacuations, effectively increasing exposure time for ~310 occupants.

Weighted domain maintenance risk score is determined as follows:

- Result: Maintenance domain retained at Moderate, with Plumbing System, consistent with the case-study evidence: $(0.10 \times 3) = 0.30$. Moderate Risk.

*Figure 21 –Maintenance and building services summary.*



## 4.6 Social Risk

The Acciarini Filippo 20's occupant load is another important risk factor, as it influences evacuation times and the potential number of occupants' exposure. There are believed to be about 310 occupants, including 270 students and 40 staff members, in the school, which is more than the designed capacity.

**Key Findings:**

- Occupant Density: The building was planned for a lower number of occupants and the number of people per area is 12.9 m²/person, worsening the delay in the evacuation in case of fire. The overcrowding of some classrooms and corridors might also raise the risk of panic and disorganization when evacuating.
- Occupant Load: Score 3 (weighted 15%)
- Subtotal Social Risk: (0.15 × 3) = 0.45 (Moderate Risk)

*Figure 22 – Social risk assessment based on occupant load and density.*

Although the space per occupant (12.9 m²/person) might be okay on the basis of space per occupant alone, it exceeds the original design of the building when occupancy load is considered. This condition could potentially delay evacuation and increase risk in emergencies, thus providing a moderate risk rating.

## 4.7 Total Risk Score and Classification

Building Risk Index (BRI) for Acciarini Filippo 20 is 3.60, placing it in the high-risk category. This score indicates urgent attention is required in several areas, specifically in fire and structural safety and maintenance.

*Figure 23 – Unified safety assessment Acciarini Filippo 20.*

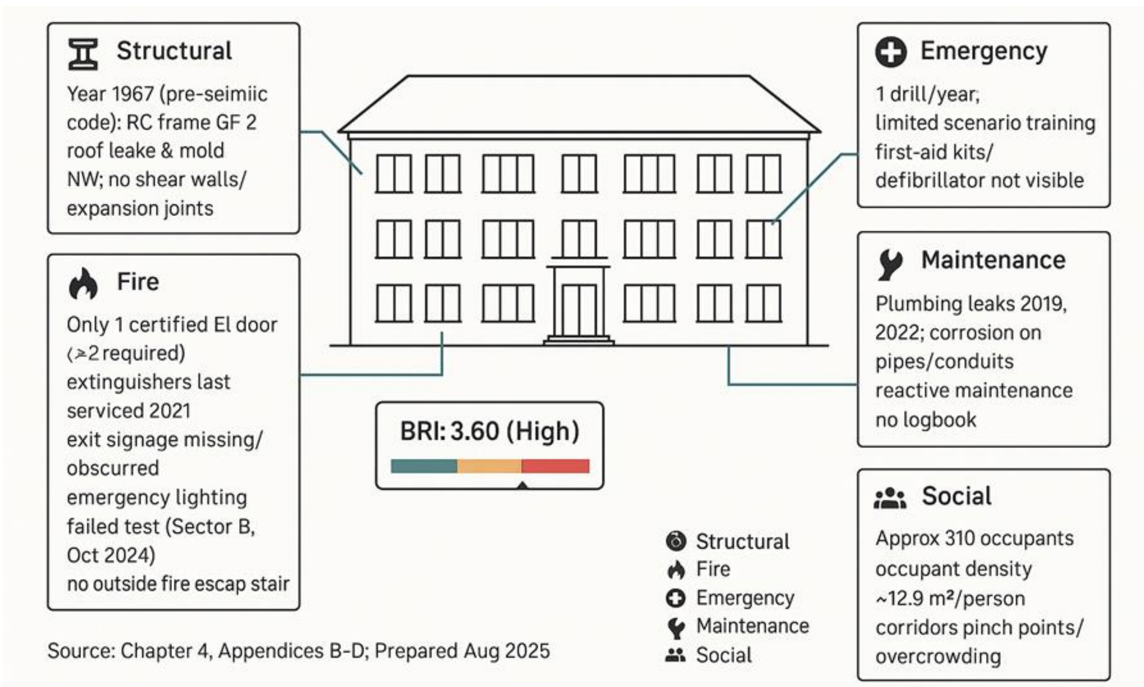


*Figure 24 – Summary of weighted scores and final BRI for Acciarini Filippo 20.*

| Risk Domain | Parameter | Score | Weight | Weighted Score |
|---|---|---|---|---|
| Structural | Year of Construction | 4 | 0.25 | 1.00 |
| Structural | Roof Condition | 4 | 0.15 | 0.60 |
| Fire | Fire Doors | 4 | 0.20 | 0.80 |
| Emergency Preparedness | Evacuation Drill Frequency | 3 | 0.15 | 0.45 |
| Maintenance | Plumbing System | 3 | 0.10 | 0.30 |
| Social | Occupant Load | 3 | 0.15 | 0.45 |
| | Total | | | 3.60 |

*Figure 25 – Contribution of Each Domain to building Risk Indexes*

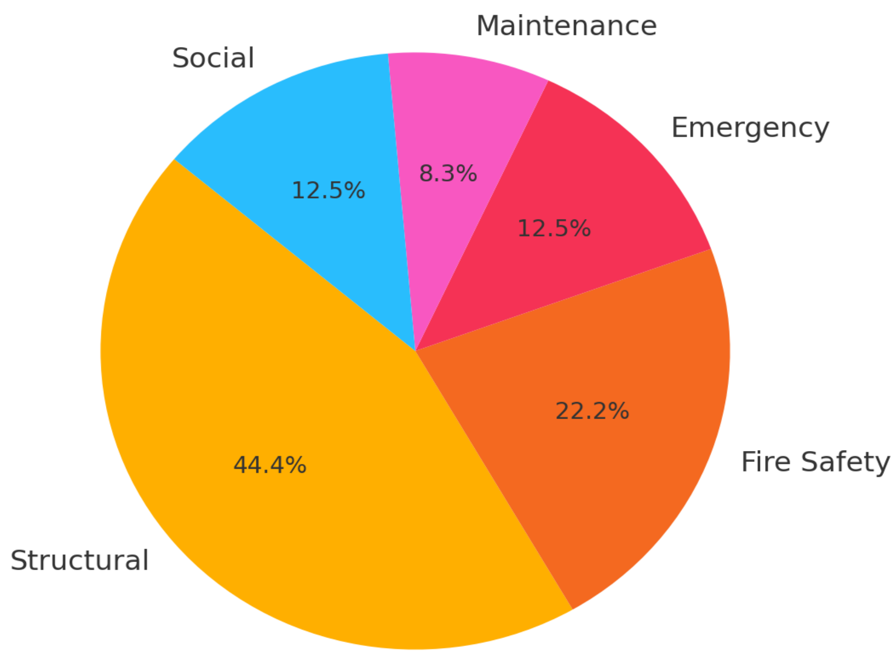
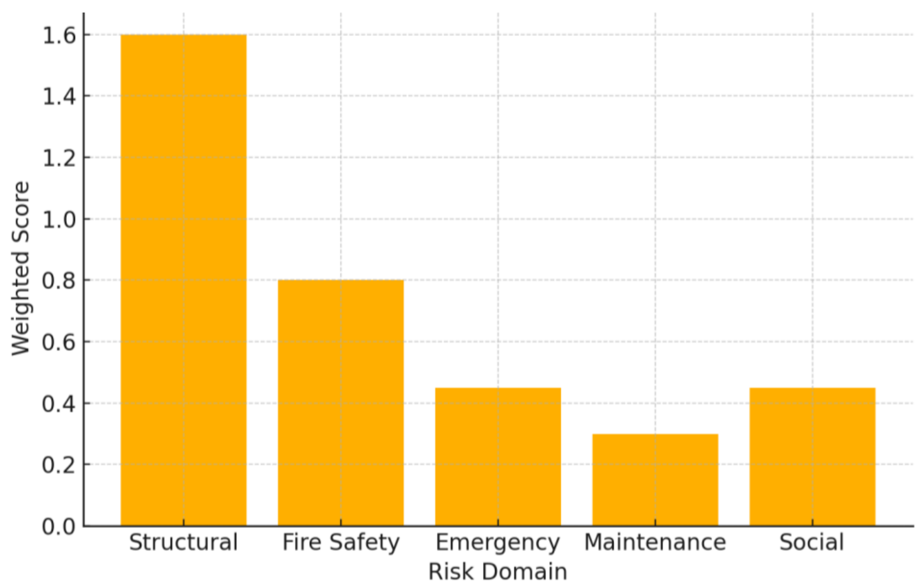



*Figure 26 – Risk Domain Weighted Scores*



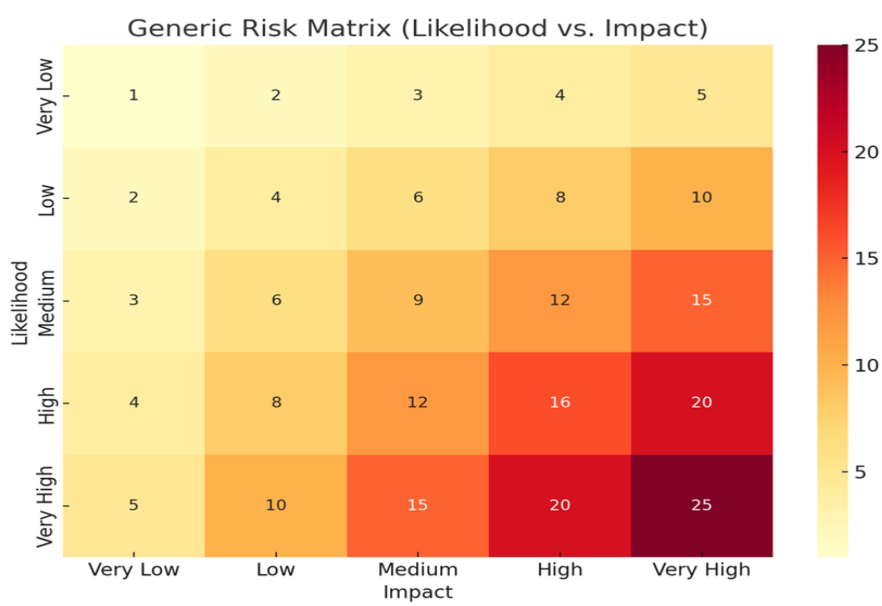
Final Building Risk Index (BRI): 3.60 → Classification: HIGH RISK

Recommended Actions:

- Fire Safety: Installation of additional fire doors and replacement of the extinguishers.
- Structural Safety: Immediate roof repairs and structural safety assessment of seismic retrofitting.
- Emergency Preparedness: Conduct more evacuation drills and conduct scenario-based training for staff.
- Maintenance: Immediate repairs to plumbing and roof leaks.
- Social: Mitigate overcrowding through reallocation of space, added facilities, or tools to better serve the existing student body.

*Figure 27 – Standard Risk Matrix: Likelihood vs. Impact*

The matrix is similar to the BRI model's scoring framework in theoretical nature. It shows how risks are risk-rated based on their likelihood and consequences according to ISO 31000.



# Chapter 5 – Discussion of Result and Improvement Proposals

## 5.1 Comparison of Results with Relevant Regulations and Norms

In this part of the dissertation, we compare BRI of Acciarini Filippo 20, computed in Chapter 4, with the national and international codes and standards or guidelines. The BRI of 3.60 means the school is high risk, with numerous relative deficiencies highlighting the big problems where the school falls short of the established safety benchmark.

- Risk of Collapse: The school is old (built-in 1967) and is not seismically retrofitted with a high risk of collapse. This is a clear breach of Italian seismic regulations, such as DLgs 81/2008, which require seismic checks and upgrades of all buildings where children are educated. Such large buildings, where there are no shear walls, no expansion joints – in direct contradiction to Eurocode 8 (EN 1998-1), a building code specifying seismic safety regulations for public buildings, schools, among others.
- Fire Safety: Fire safety is not according to the law as the school failed in terms of fire door compliance. DM 10/03/1998 (Italian legislation on fire safety) requires at least two fire-resistant exits for buildings that have more than 100 people. The requirement is violated by the existence of a single approved fire door. Also, having obsolete fire extinguishers and not having fire exit signs further puts the school outside of the minimum requirements for fire safety protocols.
- Emergency Plan: The school actually runs only one evacuation exercise per year, while the Italian law (D.M 81/2008) sets at least twice per year for schools with some students (and teachers). In turn, this lack of adherence places the safety of the students and staff at risk.
- Maintenance: The school has put off maintenance, particularly in the plumbing system and the condition of the roof. Aside from stemming from matters of health (e.g., water contamination, growth of molds), this is also in contrast with the Italian Hygiene Code, which mandates that works facilities should have sanitary systems in working condition.

- Structural Vulnerability: Social: Occupant load: According to surveys, the school serves 270 students in a building that should accommodate 200 students. There are concerns about overcrowding, possible delays in evacuation, and greater exposure to risks in the event of emergencies.

*Figure 28 – Compliance comparison against Italian regulations and norms.*

This table shows Acciarini Filippo 20's conformity to applicable safety standards of national and European safety standards. It highlights that the building is shy in structure and fire, partly shy in emergency preparation and maintenance, and marginally shy in occupancy space — emphasizing the need for multi-domain intervention.

| Domain | Regulation Reference | Compliance | Notes |
|---|---|---|---|
| **Structural** | DLgs 81/2008 Eurocode 8 | ❌ Non-compliant | No seismic retroffitting |
| **Fire Safety** | DM 10/03/1998 | ❌ Non-compliant | Only one fire exit |
| **Emergency Preparedness** | DM 81/2008 | ⚠️ Partial | One drill/year |
| **Maintenance** | Civil Code Hygiene Code | ⚠️ Partial | Corroded pipes, leaks |
| **Social Risk** | DM 18/12/1975 | ✅ Acceptable | Exceeds design capacity |

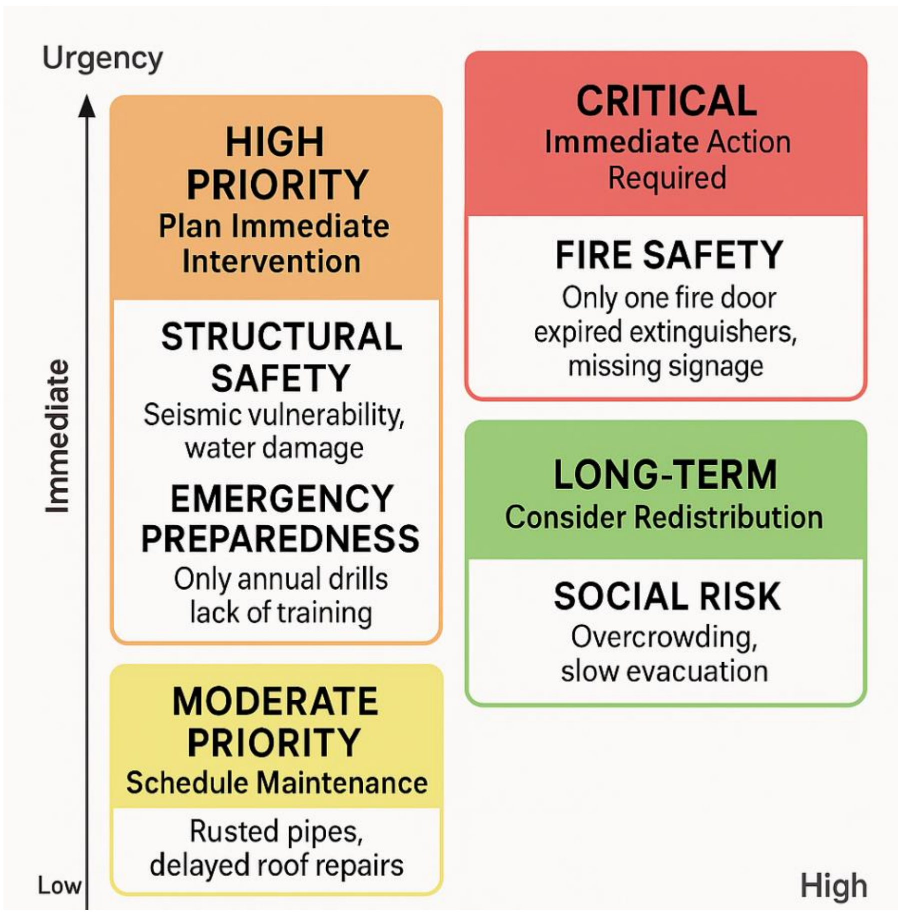
## 5.2 Identification of Critical Areas and Intervention Priorities

The results of Chapter 4 possess a direct implication of relevant areas for immediate intervention. It is important to prioritize these interventions to minimize risk for everyone (students, employees, visitors). By considering the BRI results, we prioritized the following areas:

1. Fire Safety (Critical – Must act on immediately):
- Missing fire exits and antiquated fire extinguishers are the top concerns. Additional fire doors and a fire-safe system should be installed immediately.
- Failure of the emergency lighting system demonstrates your emergency systems require a full upgrade.
2. Structural Safety (Urgent - Not safe - Make it safe now):
- The roof is in poor condition and has evidence of leaks and mold growth; it needs to be addressed immediately to protect the building envelope.
- The university's vulnerability because it's never had seismic retrofitting, and a responsible public agency would be immediately studying the seismic hazard and mitigation options.
3. Emergency Preparedness (Moderate – High Priority):
- Evacuation drills will increase most of all. Two school evacuation drills must be held a year according to law.
- It is important that staff are trained with complex scenarios (e.g., fire and structural collapse at the same time) so that all staff are fully prepared.
4. Maintenance (Moderate – High Priority)
- The plumbing system and the roof have to be fixed right away to avoid water damage and health hazards (mold comes to mind).
- Regular proactive maintenance should be commenced to rectify persistent problems and prevent further decay.
5. Social Risk (Moderate – Medium to long term action):
- Overcrowding in classrooms and hallways would require larger projects for resolving, such as space reallocation or additional space construction, to achieve and maintain occupancy counts and evacuate better.

*Figure 29 – Priority matrix of safety interventions for Acciarini Filippo 20.*

This is the matrix for ranking the threats that have been identified at the school according to urgency and risk. A high priority is given to fire safety and structural and emergency planning. Maintenance matters are firmly in the medium scheduling and social risk space (condition and overcrowding) in the long term.




## 5.3 Proposals for Improving School Safety

The proposals below are derived directly from the evidence, scoring, and compliance gaps documented in Chapter 4 and from the weighting scheme of the qualitative model. The guiding logic is: (1) start from observed deficiencies and municipal records (leaks in

2019/2022; corrosion; persistent roof infiltrations despite the 2012 partial repair; a single certified EI fire door for a population >100; deficiencies in emergency lighting/signage; one evacuation drill per year; reactive maintenance without a logbook; occupant density around 12.9 $m^2$/person), (2) map each issue to the affected model parameter and its weight, (3) select the lowest-cost, highest-impact actions that close regulatory gaps and reduce the parameter score, and (4) sequence them so that egress capacity and life-safety reliability are restored before secondary optimizations.

**Action 1 — Fire Doors & Egress Reliability**

Concretely, the single most penalizing gap in our scoring is the Fire Doors parameter (score 4; weight 0.20). Installing a second certified EI door with compliant swing and panic hardware, together with basic wayfinding corrections, directly addresses the bottleneck observed on site and allows the parameter to drop from 4 to 2 in the current model, reducing the weighted contribution from 0.80 to 0.40. In parallel, the supporting egress reliability issues identified—emergency lighting failures and inconsistent signage—are resolved by replacing failed units, performing a full-duration test, and introducing a simple quarterly verification routine. While these measures are not represented as a distinct primary parameter in the current model, they reduce the likelihood component that underpins evacuation performance and ensure the door upgrade translates into effective egress.

**Action 2 — Roof Condition**

The second cluster of actions responds to Roof Condition (score 4; weight 0.15) and its cross-effects on safety systems and indoor conditions. The site evidence—localized mold in the northwest sector, staining/spalling in corridors, and recurring damp after rain—indicates incomplete waterproofing continuity and blocked outlets. A targeted repair program is therefore proposed: trace and reseal the waterproofing laps; clear/guard roof outlets; reseal penetrations at vents, stacks, and cable trays; and remediate damp/mold in affected interiors. This level of intervention is proportionate to the defects documented and is expected to reduce the roof parameter from 4 to 3 (weighted 0.60→0.45). An important side benefit is improved reliability of overhead services (conduits, luminaires, door hardware), which are vulnerable to moisture. Because water is the common failure driver, these works should precede the reinstatement of sensitive components to avoid rework.

**Action 3 — Plumbing System & Preventive Maintenance**

The third set of measures addresses Plumbing System condition (score 3; weight 0.10) and the observed reactive maintenance pattern. The two recorded leak events (2019 and 2022), visible corrosion on exposed runs, and the absence of a formal inspection logbook point to predictable failures rather than random shocks. Accordingly, we recommend replacing the locally corroded segments, removing obvious dead-legs/low-flow branches, and instituting a preventive maintenance (PM) regime with a simple logbook: monthly visual checks in wet rooms and risers; termly flushing and drain/outlet clearing; and an annual condition survey with photographs and corrective actions. This moves the plumbing parameter from 3 to 2 (weighted 0.30→0.20) and stabilizes the roof and egress improvements by reducing re-wetting incidents. Because the building has school-year idle periods, the PM routine should include post-holiday flushing to minimize stagnation effects.

**Action 4 — Emergency Preparedness (Drill Frequency)**

Next, we intervene on Emergency Preparedness via drill frequency (score 3; weight 0.15) and staff readiness. The current practice of one drill per year is below the benchmark that informed our scoring. Instituting at least two scheduled drills per year—one announced, one unannounced—while documenting timings and choke points, plus adding short scenario-based staff training (e.g., fire with a blocked route; alarm during bad weather), provides an immediate, low-cost reduction in this parameter from 3 to 1 (weighted 0.45→0.15). This change not only improves the numeric profile but also operationalizes the door/lighting upgrades, ensuring that the building's egress capacity is matched by practiced behavior.

**Action 5 — Occupant Load Optimization**

Finally, we propose modest, fast-acting measures on Occupant Load (score 3; weight 0.15). With an average of ~12.9 $m^2$/person, the building sits near the upper bound of the current score band. Minor timetable and room-use adjustments (redistributing larger classes to rooms with the best net usable area, de-cluttering corridor pinch points, and reconsidering the placement of bulky furnishings) can raise the effective $m^2$/person above the 13 $m^2$ threshold used in the model, reducing this parameter from 3 to 2 (weighted 0.45→0.30) without construction work. If short-term redistribution is insufficient, a light reconfiguration study can identify low-cost partition changes to unlock additional area where beneficial.

**Outcome — Expected BRI Reduction**

Taking these targeted actions together—and holding constant the Year of Construction proxy (score 4; weight 0.25), which will not change absent structural intervention—the immediate, model-consistent effect is to reduce the BRI from 3.60 (High) to approximately 2.65 (Medium) within the same parameter set. The pathway is transparent: Fire Doors 4→2 (−0.40), Roof 4→3 (−0.15), Drills 3→1 (−0.30), Plumbing 3→2 (−0.10), Occupancy 3→2 (−0.15 possible if ≥13 $m^2$/person), while the construction-year proxy remains at 1.00. Beyond the immediate horizon, two longer-term moves can consolidate gains: (i) a limited roof rehabilitation package to eliminate the residual infiltration risk and lock in service reliability and IAQ, and (ii) maintaining the PM logbook discipline across academic years so that new defects are caught early and scored conservatively in future assessments. Structural retrofitting measures—while outside the current six-parameter scope—can be introduced in a future iteration of the model by adding explicit seismic-strengthening indicators; until then, the “Year of Construction” parameter continues to act as a conservative proxy that keeps attention on the strategic need for structural study.

**Closing — Traceability & Sequence**

In summary, each proposal traces back to (and is justifiable by) the case-study observations in Chapter 4, the parameter scores and weights of the model, and the compliance and operational gaps identified on site. The sequence—egress capacity and reliability first; watertight envelope second; preventive maintenance and preparedness third; occupancy optimization last—ensures measurable risk reduction with lean resources, while preserving transparency for decision-makers and auditability for future reassessments.

*Figure 30 – Measures & Effects*

This table summarizes the evidence from the case study, the targeted parameters with their current scores and weights, the proposed safety measures, their priority level, indicative costs, and the expected impact on the Building Risk Index (BRI). It provides a clear roadmap for prioritized interventions as described in Section 5.3.

| Case-study evidence (Chapter 4) | Targeted parameter (score; weight) | Proposed measure (what to do) | Priority | Expected cost (indicative) | Expected effect on BRI |
|---|---|---|---|---|---|
| Only one certified EI fire door for >100 occupants; potential egress bottleneck. | Fire Doors (4; 0.20) | Install a second EI door with panic hardware; verify door swing and free width; ensure compliant wayfinding at door heads. | Urgent / High | €5,000 | Parameter 4→2 → weighted 0.80→0.40 (ΔBRI ≈ −0.40). |
| Emergency lighting failed duration test; inconsistent exit signage. | Egress reliability (supporting, not a primary parameter) | Replace failed units; perform full duration test; reinstate directional signage; add quarterly function checks. | Urgent | €3,000 (lighting) + €500 (signage) | Qualitative reduction in likelihood; ensures door upgrade yields effective evacuation. |

| | | | | | |
|---|---|---|---|---|---|
| Persistent roof leaks and localized mold (NW sector); staining/spalling in corridors; defects recurring post-2012 partial repair. | Roof Condition (4; 0.15) | Trace and repair waterproofing laps; clear/guard outlets; reseal roof/service penetrations; remediate damp/mold internally. | Urgent | €12,000–€15,000 | Parameter 4→3 → weighted 0.60→0.45 (ΔBRI ≈ −0.15 initially; more after full rehab). |
| Two plumbing leaks (2019, 2022); corrosion on exposed runs; no inspection logbook (reactive maintenance). | Plumbing Status (3; 0.10) | Replace corroded segments; remove dead-legs; institute PM logbook (monthly visual checks; termly flushing/outlet clearing; annual condition survey). | High | €7,000 + €2,000/yr PM | Parameter 3→2 → weighted 0.30→0.20 (ΔBRI ≈ −0.10). |
| One evacuation drill per year; limited staff scenario training. | Drill Frequency (3; 0.15) | Conduct ≥2 drills/year (one announced, one unannounced) with timed routes and choke-point notes; add brief scenario-based staff training. | High | €1,200/yr training | Parameter 3→1 → weighted 0.45→0.15 (ΔBRI ≈ −0.30). |
| Average 12.9 m²/person; localized crowding in some classrooms/corridors. | Occupant Load (3; 0.15) | Timetable/room-use adjustments to push effective area ≥13 m²/person; de-clutter corridor pinch points; minor layout tweaks if needed. | Medium | €2,000–€5,000 (study & minor works) | If ≥13 m²/person is achieved: 3→2 → weighted 0.45→0.30 (ΔBRI up to −0.15). |

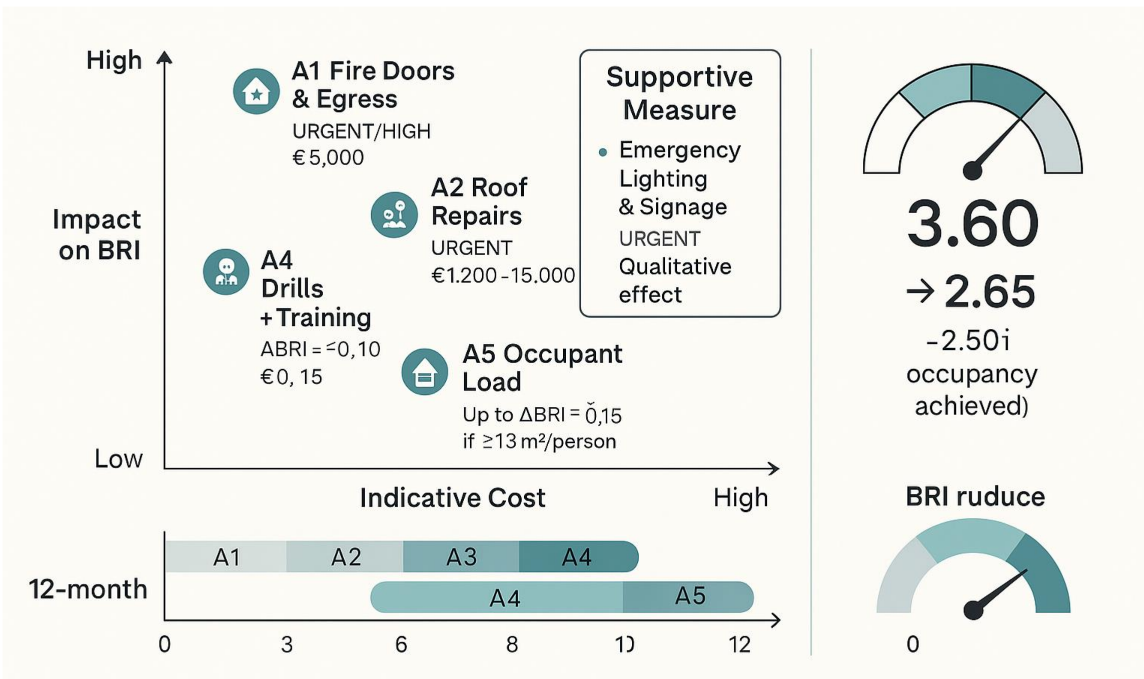
*Figure 31 – Parameter Deltas → Building Risk Index (BRI)*

This table details the weighted values of each parameter before and after implementing the immediate fixes outlined in Table 1. It also shows the change (Δ) for each parameter and the overall BRI reduction, including a scenario with further occupancy optimization.

| Parameter | Current weighted | After immediate fixes | Δ |
|---|---|---|---|
| Year of Construction (0.25×4) | 1.0 | 1.0 | — |
| Roof Condition (0.15×4 → ×3) | 0.6 | 0.45 | -0.15 |
| Fire Doors (0.20×4 → ×2) | 0.8 | 0.4 | -0.4 |
| Evacuation Drills (0.15×3 → ×1) | 0.45 | 0.15 | -0.3 |
| Plumbing Status (0.10×3 → ×2) | 0.3 | 0.2 | -0.1 |
| Occupant Load (0.15×3) | 0.45 | 0.45 | 0.0 |
| **Total BRI** | 3.6 | 2.65 | **−0.95 (High → Medium)** |
| *Total BRI if occupancy ≥13 m²/person* | — | 2.5 | **−1.10 (additional −0.15)** |

*Figure 32 – Priority–Impact Matrix & Roadmap.*

This diagram visualizes the improvement measures from Section 5.3 in terms of their urgency (priority) and their expected effect on the Building Risk Index (BRI). Each intervention is positioned according to its relative importance and potential impact, enabling decision-makers to quickly identify high-priority, high-impact actions such as installing an additional fire door and improving evacuation drills. Lower-priority, moderate-impact actions, like optimizing occupant load, are placed for medium-term planning.



## 5.4 Study Limitations and Future Research Directions

Although the proposed model provides a simple and powerful tool to evaluate the safety of schools in a practical and easy-to-use way, some limitations should be considered in future research:

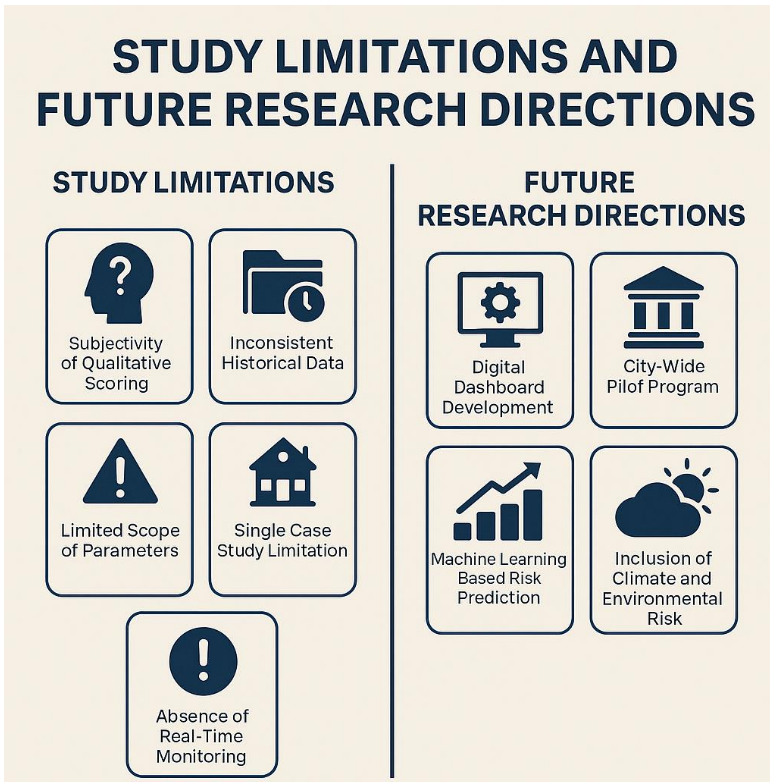
1. Human Judgment: This qualitative approach is based on human expert judgment. Even though standard scoring criteria exist, subjectivity may differ among examiners. Future iterations of the model might factor in digital tools or AI to ensure more consistent and impartial assessments.
2. Inconsistent Historical Data: Some schools may not have access to their historical data. Risks may not be accurately evaluated if the record is incomplete or nonexistent. Upcoming investigations, on the other hand, should be directed toward digitalizing the records and establishing a standardized method for data collection among all schools.
3. Model Scope: This model only involved six parameters. There are also additional factors like climate risks or mental health concerns that would enrich the model. Further research might wish to consider these elements in the parameter set.
4. Dynamic Environmental Features: The model does not include dynamic features (e.g., weather, air quality). By adding IoT sensors to assess structural soundness, water leaks, and air quality, it's possible this model could become even smarter.

Future Research Directions:

- Extend the model in other cities to verify the validity of the model and calibrate the parameters.
- Use real-time, sensor-based IoT data to enhance monitoring and prediction of risk.
- Pilot the model as part of a city-wide school safety initiative to assess its impact and scalability.
- Develop a digital “dashboard” of real-time data and trends by school.

*Figure 33 – Summary of study limitations and future research opportunities.*

This picture illustrates the five contributions and limitations to the current study—e.g., Subjective, Small scope of parameters and future research directions, e.g., Implementation of the model to the city scale, Integration of the model to artificial intelligence model, and Integration of the model to the climate-related risk.



# Chapter 6 – Conclusions

## 6.1 Summary of Key Findings

This thesis developed and applied a qualitative, evidence-based risk assessment model for school buildings that is both technically rigorous and operationally simple for municipal use. The model structures six parameters—Year of Construction, Fire Doors, Roof Condition, Plumbing System Status, Evacuation Drill Frequency, and Occupant Load—into a weighted Building Risk Index (BRI) consistent with ISO-style risk logic. Applied to the Acciarini Filippo 20 case study in Torino, the approach proved transparent, auditable, and aligned with Italian and European safety expectations while remaining feasible for day-to-day adoption by local administrations.

The case study established a baseline BRI of 3.60 (High risk) driven by a small number of critical, well-documented deficiencies. The largest single contributor was Fire Doors (score 4; weight 0.20; weighted 0.80), reflecting the presence of only one certified EI exit where at least two are required for the building's occupancy and code context. Year of Construction (1967) remained a fixed structural-age proxy (score 4; weight 0.25; weighted 1.00). Roof Condition (score 4; weight 0.15; weighted 0.60) captured persistent infiltrations and localized mold despite a 2012 partial repair. Three additional parameters registered moderate contributions: Evacuation Drill Frequency (score 3; weight 0.15; weighted 0.45), Occupant Load (~12.9 m²/person; score 3; weight 0.15; weighted 0.45), and Plumbing System (score 3; weight 0.10; weighted 0.30), supported by records of leak events (2019, 2022), visible corrosion, and the absence of a preventive-maintenance logbook. Qualitative fire-egress issues (failed emergency lighting, inconsistent signage) compounded evacuation risk even when not modeled as primary parameters.

From these findings, the thesis derived targeted, low-cost/high-impact proposals directly traceable to the scored gaps: (i) install a second certified EI fire door and correct wayfinding; (ii) restore emergency lighting performance and standardize exit signage; (iii) perform targeted roof waterproofing (laps, outlets, penetrations) with interior remediation; (iv) replace corroded plumbing segments and institute a preventive-maintenance (PM) logbook with routine checks and flushing; (v) raise drill frequency to at least two per year with brief scenario-based staff training; and (vi) implement occupancy/room-use adjustments to exceed the 13 $m^2$/person threshold. The sequence prioritizes egress capacity and reliability first, then watertightness, then PM and preparedness, and finally space optimization assuring the quickest, most defensible reduction of risk with available resources.

The expected near-term effect of these measures is a model-consistent improvement from BRI 3.60 (High) to ≈2.65 (Medium) within the current six-parameter set, with transparent parameter deltas: Fire Doors 4→2 ($\Delta \approx -0.40$ weighted), Roof 4→3 (−0.15), Drills 3→1 (−0.30), Plumbing 3→2 (−0.10), and Occupancy 3→2 if ≥13 $m^2$/person (up to −0.15), while Year of Construction remains unchanged. Over the medium term, a limited roof rehabilitation package and disciplined PM logbook practices consolidate these gains, reducing the likelihood of regression. Looking ahead, the framework can be extended to credit seismic strengthening explicitly (beyond the age proxy), enabling future structural retrofits to be reflected more directly in the BRI.

In sum, the thesis demonstrates that a structured, scalable qualitative model, calibrated to municipal data realities, can (1) diagnose multi-domain school safety risks with clarity, (2) translate technical findings into prioritized, cost-aware actions, and (3) provide decision-makers with a defensible roadmap from evidence → score → proposal → risk reduction. The case study confirms both the urgency of intervention in older assets and the practicality of implementing measurable safety improvements within existing administrative constraints.

## 6.2 Implications for School Safety

The assessment and proposals carry implications that extend beyond the single case study, informing how municipalities, school administrators, and technical offices can structure safety governance across an entire portfolio of buildings. At a strategic level, the thesis shows that a compact, evidence-based qualitative model—grounded in a small set of weighted parameters—can meaningfully orient decisions without requiring prohibitive data or complex analytics. At an operational level, it demonstrates that targeted, low-cost interventions (e.g., a second EI fire door, emergency lighting restoration, localized roof repairs, preventive-maintenance routines, drill frequency increases, and occupancy/space-use optimization) can convert diagnosis into measurable risk reduction within the constraints typical of public administration.

1) Governance and policy.

The model's transparency (parameters, weights, and scoring rules explicitly stated) creates a defensible basis for prioritization and budget allocation. For municipal leaders, this enables (i) portfolio-wide comparability of schools; (ii) annual "risk budgets" tied to expected BRI reduction rather than ad-hoc requests; and (iii) auditability of decisions over time. Because the parameters mirror regulatory expectations and operational realities, they offer a pragmatic bridge between policy objectives and site-level implementation. The approach also supports equity in allocation, allowing scarce resources to be directed to buildings and cohorts with the greatest risk exposure.

2) Asset management and procurement.

The case study confirms that many high-impact actions are maintenance-centric rather than capital-intensive. Embedding a preventive-maintenance (PM) logbook—with monthly visual checks, termly flushing/outlet clearing, and annual condition surveys—turns sporadic, reactive fixes into a repeatable operational process. In procurement terms, municipalities can frame small-lot contracts explicitly around risk-reduction deliverables (e.g., "reduce Fire Doors parameter from 4→2," "reduce Roof Condition from 4→3"), improving vendor accountability and enabling post-work verification through re-scoring. The model thus becomes a contract-management tool as well as an assessment tool.

3) Operations and preparedness.

Increasing drill frequency to at least two per year and introducing short scenario-based staff training has dual value: it reduces the model score and, more importantly, improves real-world response under stress. Because the egress actions (door capacity, emergency lighting, signage) are sequenced before drills, the organization practices what actually exists, reinforcing correct behavioural patterns and shortening evacuation times. Over time, a simple repository of drill timings and “choke points” can inform iterative adjustments to layout and supervision without requiring structural works.

4) Technical risk coupling and moisture control.

The analysis underscores how water is a systemic risk amplifier: roof infiltrations compromise electrical reliability, egress hardware, finishes, and indoor air quality. Prioritizing envelope watertightness before service reinstatement is therefore not only efficient, it is a precondition for durable safety gains. In practice, the implication is to sequence roof waterproofing and penetrations sealing before replacing sensitive components, reducing rework and safeguarding OPEX.

5) Data discipline and continuous improvement.

Even with a qualitative framework, data discipline matters. Minimal artefacts—dated photos, short inspection notes, a log of corrections and failures—are enough to sustain reliable re-assessments and to detect regression. The BRI thus becomes dynamic: re-scored after each intervention cycle, it signals whether risk is trending down as intended. This enables annual learning loops and supports transparent reporting to stakeholders (parents, staff, and school leadership).

6) Portfolio scaling and planning.

Applied at scale, the method supports programmatic planning: (i) a rolling 12–18-month plan focused on immediate risk reductions (doors, lighting, targeted roof repairs, PM start-up); (ii) a 3–5-year plan targeting consolidation (limited roof rehabilitation where residual risk persists, sustained PM discipline); and (iii) a strategic horizon for structural/seismic studies where the "Year of Construction" proxy indicates enduring vulnerability. In this way, the model integrates CAPEX and OPEX perspectives, avoiding the common gap between one-off projects and day-to-day operations.

7) Communication and accountability.

Because each proposal is traceable from evidence → parameter/weight → expected BRI delta, decision-makers can communicate clearly why a given school, floor, or corridor is prioritized, and what outcome is expected. This traceability lowers the risk of contestation, fosters stakeholder buy-in, and provides a clear narrative for grant applications or inter-departmental funding requests.

8) Methodological implications.

The results validate the usefulness of a lean, modular risk model for public buildings: few parameters, explicit weights, and qualitative evidence are sufficient to guide impactful decisions. At the same time, the work highlights where future extensions can add value—most notably, explicit seismic-strengthening indicators to complement the construction-year proxy, and optional metrics for non-structural restraint and indoor environmental quality. These additions would preserve the model's practicality while improving sensitivity to structural risk and health-related outcomes.

Overall implication.

For municipalities and school owners, the key takeaway is that material safety improvements are achievable within existing administrative capacity when actions are (i) evidence-anchored, (ii) weight-aware, and (iii) sequenced to reflect how risks interact in real buildings. The Acciarini Filippo 20 case confirms that the approach can move a school from High to Medium risk in the near term, with a clear pathway to further reduction as maintenance culture, envelope performance, and preparedness mature.

## 6.3 Potential Future Research and Model Developments

This work demonstrates that a compact, evidence-anchored qualitative model can guide municipal decision-making with limited data. Building on the case-study results and the practical lessons from 5.3, future research should focus on external validation, methodological refinement, and digital/organizational integration so the model becomes both more predictive and more portable across schools and municipalities.

A) External validation and generalizability

- Multi-school validation: apply the model to a larger, diverse sample (age, typology, occupancy) and assess score stability, inter-rater agreement, and predictive validity (e.g., correlation with incidents/near-misses).
- Cross-municipality benchmarking: test portability in different Comuni/Regions to calibrate thresholds/checklists to local practices and budgets.
- Temporal re-scoring: re-assess the same buildings annually to quantify drift and confirm that targeted actions produce the expected BRI deltas.

B) Methodological refinements (risk science)

- Weight calibration & sensitivity: move from expert-assigned weights to AHP/Delphi-assisted or data-driven weights; run global sensitivity analyses to identify parameters that most influence BRI.
- Uncertainty & confidence bands: add Bayesian/MCMC or Monte Carlo layers to express parameter uncertainty and propagate it to BRI ± CI, improving decisions under uncertainty.
- Decision thresholds: formalize High/Medium/Low cut-offs with outcome-based cost–loss optimization rather than fixed judgment, consistent with your risk-class logic.

- Coupled-risk modeling: treat water ingress as a latent driver affecting multiple parameters (electrical reliability, IAQ, egress hardware) via causal diagrams; quantify compounded likelihood effects.

C) Expanded technical scope

- Structural/seismic dimension: add explicit indicators (knowledge level, local mechanisms, diaphragm/anchorage checks) so seismic improvements are credited directly, not only through the Year of Construction proxy.
- Non-structural restraint: include scored checks for suspended ceilings, tall furnishings, parapets, luminaires, and services.
- Health & IAQ metrics: integrate $CO_2$ time-profiles, ventilation effectiveness, filtration class, and Legionella controls with simple, auditable measures.
- Egress reliability metric: add a lightweight sub-index for emergency lighting/signage/alarms (availability, test pass-rate, corrective-action lag), consistent with how egress reliability currently supports but is not a primary parameter.

D) Digitalization and data pipelines

- BIM/CMMS integration: link parameters to a BIM asset registry and CMMS (the PM logbook) so inspections, faults, and closures auto-update scores/evidence.
- IoT augmentation: pilot low-cost sensors ($CO_2$, temperature/humidity, leak detection) to reduce observation bias and enable event-triggered re-scoring after anomalies.
- Computer vision: test photo-based classifiers to flag damp, spalling, or missing signage, producing reproducible evidence sets for audits.

E) Human factors and preparedness

- Drill analytics: collect drill times, route choices, and choke-points to refine layouts/supervision; evaluate whether increased frequency sustains performance.
- Behavioral nudges: test signage placement, staff micro-training, and student briefings as low-cost levers; measure impact on preparedness.

F) Economics and planning

- Cost–risk optimization: pair ΔBRI with unit cost to compute €/ΔBRI and solve annual portfolios as knapsack/robust optimization under budget/work-window constraints.
- Life-cycle effects: model how sustained PM reduces failure rates and capital needs (roof, plumbing), supporting OPEX ↔ CAPEX trade-offs.

G) Equity, accessibility, and compliance evolution

- Equity lenses: add modifiers for vulnerable cohorts so the same technical gap carries higher urgency when exposure is greater.
- Norm updates: maintain a versioned ruleset so changes in national/European norms automatically update compliance mapping and scoring.

**Concrete research recommendations:**

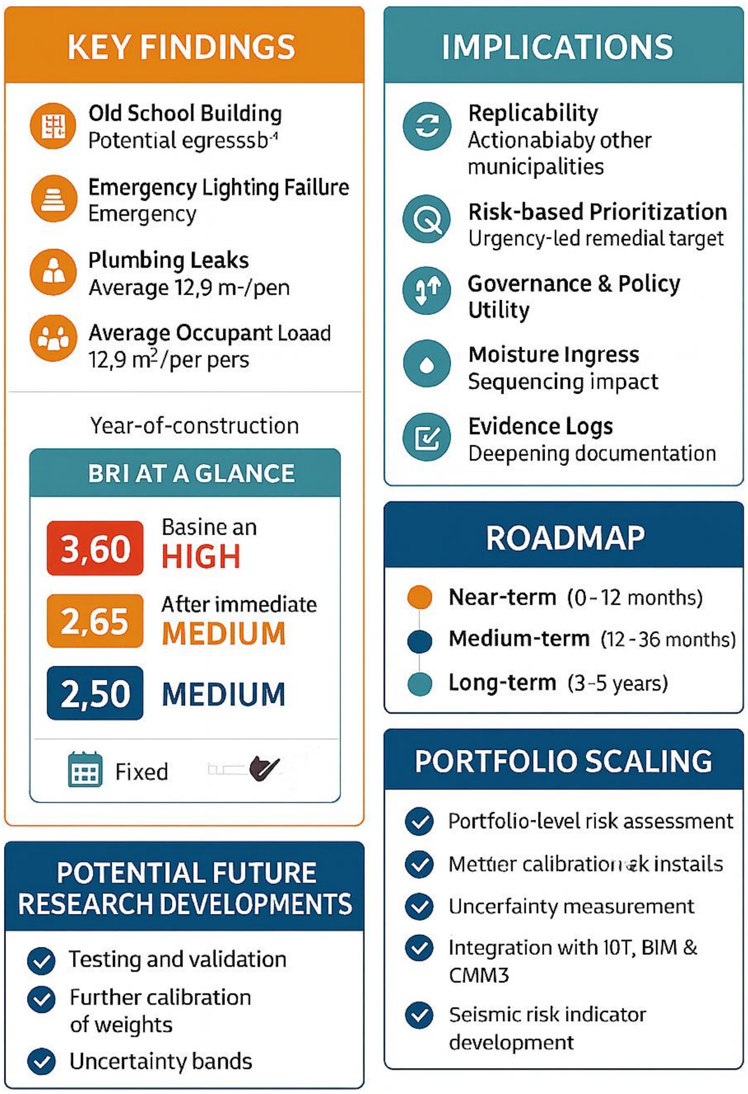
1. Calibrate and validate weights with multi-school data; publish sensitivity/uncertainty analyses and confidence bands for BRI.
2. Add explicit seismic and non-structural indicators to complement the construction-year proxy.
3. Introduce an egress-reliability sub-index tied to maintenance evidence (tests, corrective-action lag).

4. Integrate IAQ/Legionella controls using simple sensor/logbook inputs maintainable by school staff.
5. Connect the model to BIM/CMMS so inspections and work orders automatically update scores and evidence.
6. Adopt a cost–ΔBRI optimizer for yearly planning with transparent return on risk-reduction.
7. Pilot IoT and computer-vision aides to standardize evidence and reduce assessor variability.
8. Establish an annual re-scoring protocol (post-works and post-holiday checks) to sustain continuous improvement and portfolio dashboards.

By pursuing these lines, future work can turn the present, practical framework into a repeatable, data-aware decision system that maintains municipal usability while achieving higher accuracy, fairness, and long-term impact across school portfolios.

*Figure 34 — Section 6 Conclusions: From Findings to Action.*

*Short description:* A large end-of-chapter poster that consolidates the case-study's key findings, the BRI trajectory (3.60 High → ≈2.65 Medium, ≈2.50 if ≥13 m²/person), practical implications for school safety, a phased roadmap, portfolio-scaling notes, and a focused research agenda (validation, weight calibration, uncertainty, IoT/BIM-CMMS, seismic indicators). Designed to be readable at A3/A4 with consistent styling to earlier visuals.



## Appendices

### Appendix A – Comprehensive Risk Assessment Checklist

This checklist was created during the development of the qualitative risk assessment model so that school buildings would be assessed in a consistent and structured manner. It is consistent with the six domains of the BRI and can be used as both a data collection and institutional assessment tool.

| Risk Domain | Assessment Item | Format | Scoring / Output |
|---|---|---|---|
| Structural | Year of Original Construction | Ordinal | 1 = after 2010 → 5 = before 1960 |
| Structural | Roof Integrity (leaks, deformation) | Ordinal | 1 = no visible issues → 5 = structural damage or persistent leaks |
| Fire Safety | Number of certified EI fire doors | Count (converted) | 1 = 100% compliant → 5 = none certified |
| Fire Safety | Fire Extinguisher Certification | Binary / Date | 1 = certified → 5 = expired / missing |
| Fire Safety | Emergency Lighting Functionality | Binary | 1 = works properly → 5 = fails during test |
| Fire Safety | Exit Signage Visibility | Binary | 1 = all visible → 5 = mostly missing or blocked |
| Emergency Prep. | Evacuation Drills (last 12 months) | Quantitative | 1 = 2+ drills/year → 5 = no drill documented |

| | | | |
|---|---|---|---|
| Emergency Prep. | Staff Training for Multi-risk Scenarios | Binary / Qualitative | 1 = all trained → 5 = nontrained or aware |
| Emergency Prep. | First Aid Kit Visibility | Binary | 1 = kits clearly marked → 5 = not visible |
| Maintenance | Plumbing Condition | Binary / Observational | 1 = recently upgraded → 5 = critical failures or rust exposed |
| Maintenance | Last Plumbing Inspection | Date (recorded) | 1 = <12 months → 5 = unknown or >5 years |
| Maintenance | Roof Condition (moisture, mold) | Visual | 1 = dry/clean → 5 = visible mold, stains, water damage |
| Social / Occupancy | Occupant Density ($m^2$/student) | Computed | 1 = >15 $m^2$/student → 5 = <9 $m^2$/student |
| Social / Occupancy | Population vs. Design Capacity | Ratio / Binary | 1 = within design range → 5 = significantly exceeded |
| Social / Occupancy | Occupant Density ($m^2$/student) | Computed | 1 = >15 $m^2$/student → 5 = <9 $m^2$/student |

**Appendix B – Referenced Regulations and Frameworks**

The risk analysis model was developed according to national, European, and international regulations. The following table summarizes major sources, listed by the level of jurisdiction:

| Jurisdiction | Regulation / Framework | Code / Reference |
|---|---|---|
| National (Italy) | Ministerial Decree – School building minimum standards | DM 18/12/1975 |
| National (Italy) | Occupational Health and Safety Law | DLgs 81/2008 |
| National (Italy) | Fire Safety Regulation for Public Buildings | DM 10/03/1998 |
| European | Seismic Design of Structures | Eurocode 8 – EN 1998 |
| European | Directive on Worker Safety and Health | Directive 89/391/EEC |
| International | Risk Management Guidelines | ISO 31000 |
| International | Risk Assessment Techniques | ISO/IEC 31010 |
| International | Disaster Risk Reduction Framework | Sendai Framework 2015–2030 (UNDRR) |

## Appendix C – Case Study Data: Acciarini Filippo 20

This appendix includes the full summary of the observational, archive, and monitoring data acquired during the internship and monitoring-based assessment of the 20 Acciarini Filippo school building. This information was used to calculate the Building Risk Index (BRI) on the basis of the evaluated domains: structural, fire, emergency plan, maintenance, and social risk.

| Data Category | Details / Observations |
|---|---|
| Building Name | Acciarini Filippo 20 |
| Location | Zona Sud, Torino, Italy |
| Type of School | Scuola Secondaria di Primo Grado (Lower Secondary School) |
| Year of Construction | 1967 – prior to Italy's mandatory seismic safety codes. |
| Structural System | Reinforced concrete frame (piano terra + 2 floors). No shear walls or expansion joints. |
| Construction Documentation | No retrofitting permits or structural upgrades on record. |
| Structural Observations | Visual signs of aging structure, wall cracking, roof infiltration. |
| Roof Condition | Partial roof repair in 2012. Persistent water infiltration; visible mold in northwest corner. |
| Seismic Safety Compliance | Non-compliant with Eurocode 8 and DLgs 81/2008. No seismic retrofitting performed. |
| Total Occupancy | Approx. 310 occupants: 270 students + 40 staff. |
| Design Capacity (Estimate) | Likely under 250 based on floorplan and 1970s design standards. |
| Occupant Density | 12.9 m²/person – legal but functionally overcrowded. |

| | |
|---|---|
| Fire Safety Doors | Only one certified EI fire door present. DM 10/03/1998 requires a minimum of two exits. |
| Fire Extinguishers | Last certified in 2021. Some units blocked or inaccessible. |
| Exit Signage | Missing in several corridors. In some cases, signage was obscured or defaced. |
| Emergency Lighting | System failed manual test (Sector B, October 2024). |
| Fire Escape Compliance | No designated fire escape stairwells outside the main staircases. |
| Evacuation Drills | Only one evacuation drill is conducted annually. |
| Emergency Preparedness | Staff trained in basic evacuation only. No multi-risk training protocols. |
| Medical Response Capability | No defibrillators or visible First Aid kits observed during site visit. |
| Maintenance Records | No formal logbook for plumbing or roof inspections. Maintenance is reactive. |
| Reported Failures | Plumbing leaks recorded in 2019 (teacher washroom) and 2022 (staff corridor). |
| Corrosion Observations | Rust present on visible metal piping and ceiling conduit. |
| Roof Water Damage | Staining and spalling concrete in northern corridors. Likely related to roof failure. |
| Visual Inspection Notes | Blocked exit doors, poor signage, evidence of mold and water damage. |
| Audit Team | Conducted by thesis author under supervision of Comune di Torino officials, March–April 2025. |

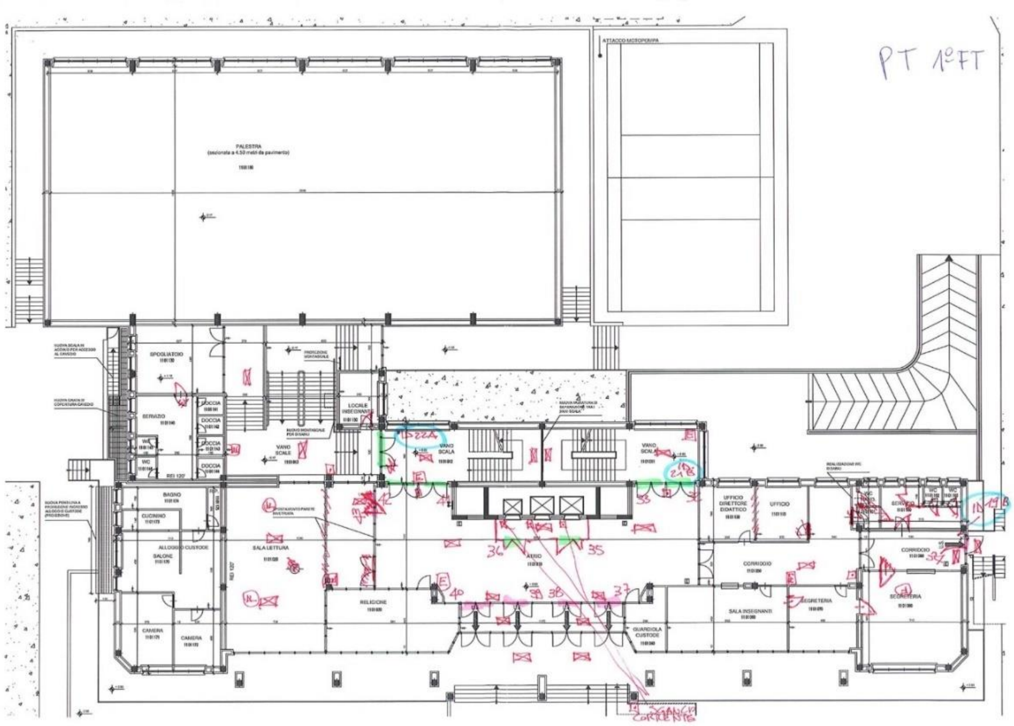
**Appendix D – Architectural Drawings and Evacuation Layouts**

This appendix reports on the architectural documentation of the case study building, Acciarini Filippo 20, within the southern area of Torino. The drawings consist of labeled floor plans for each floor of the school, official inspection plans, and door classification tables issued by the city as a result of the safety audits.

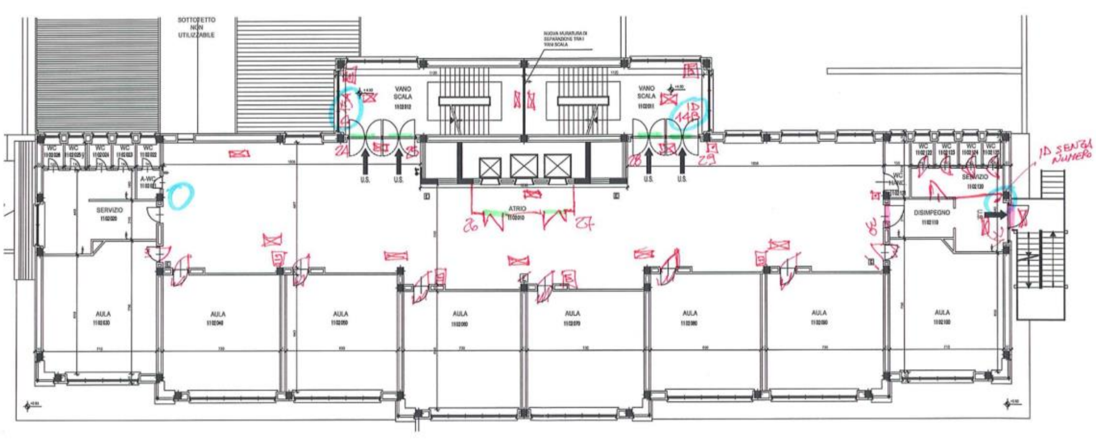
They were necessary to perform the spatial analysis of building form, travel flow between occupied units, and fire-code compliance. Notes have been added to the plans to indicate the following:

- Fire doors and emergency exits
- Obstructed or absent fire signage
- Fire extinguisher locations
- Physical constraints (corridor pinch points, overcrowding)
- Attention areas (e.g., roof damage zones, mold)

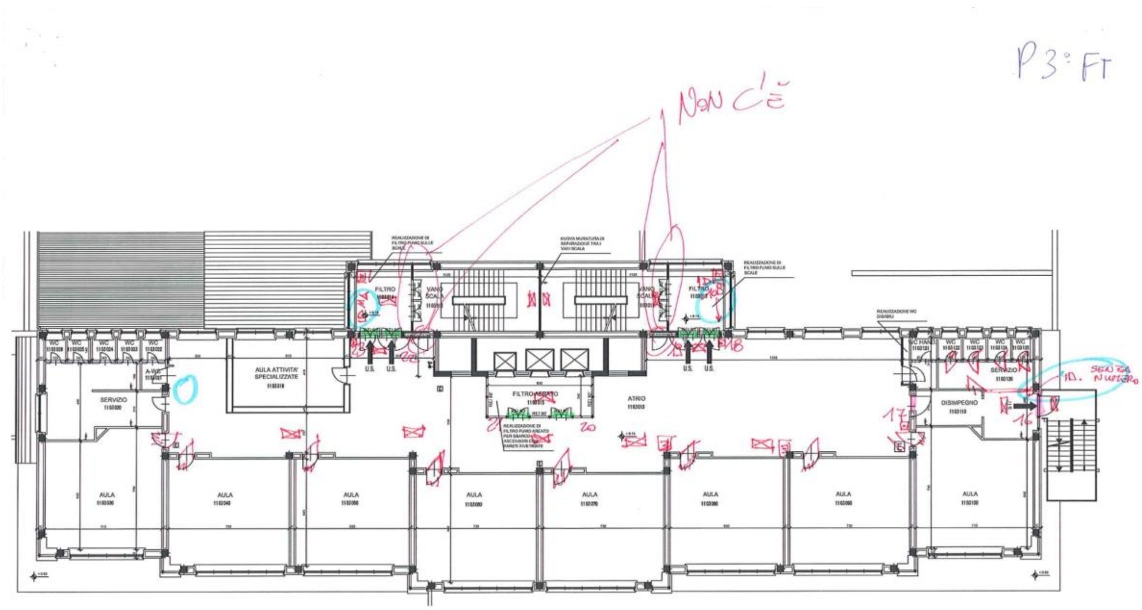
All layouts were drawn up to assist with the qualitative scoring methodology described in Chapter 3 and were visually utilized during the risk categorization exercise (discussed in Chapter 4). Through this appendix, we guarantee transparency and traceability of the method.



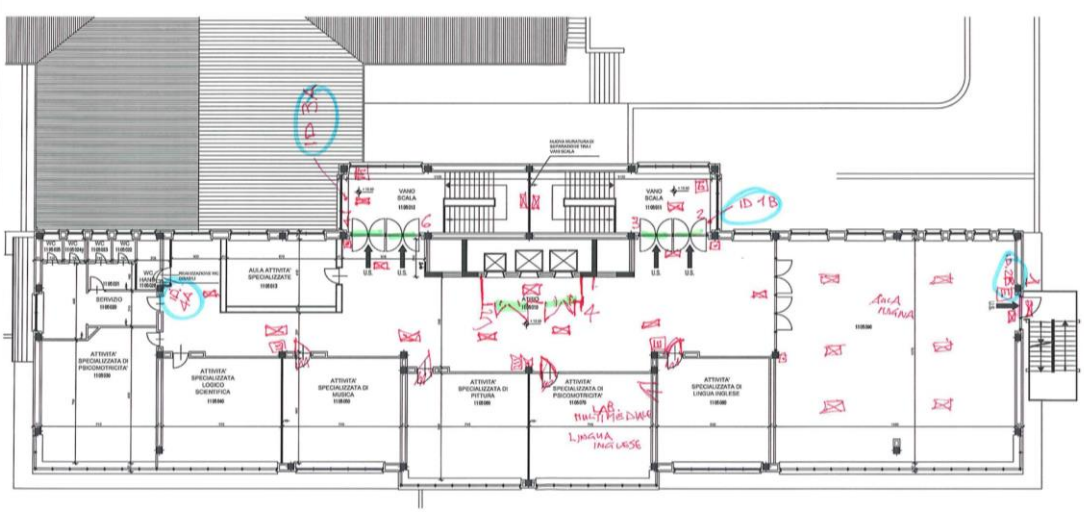
*Annotated basement plan of Acciarini Filippo 20 including gym, exits, and storage zones.



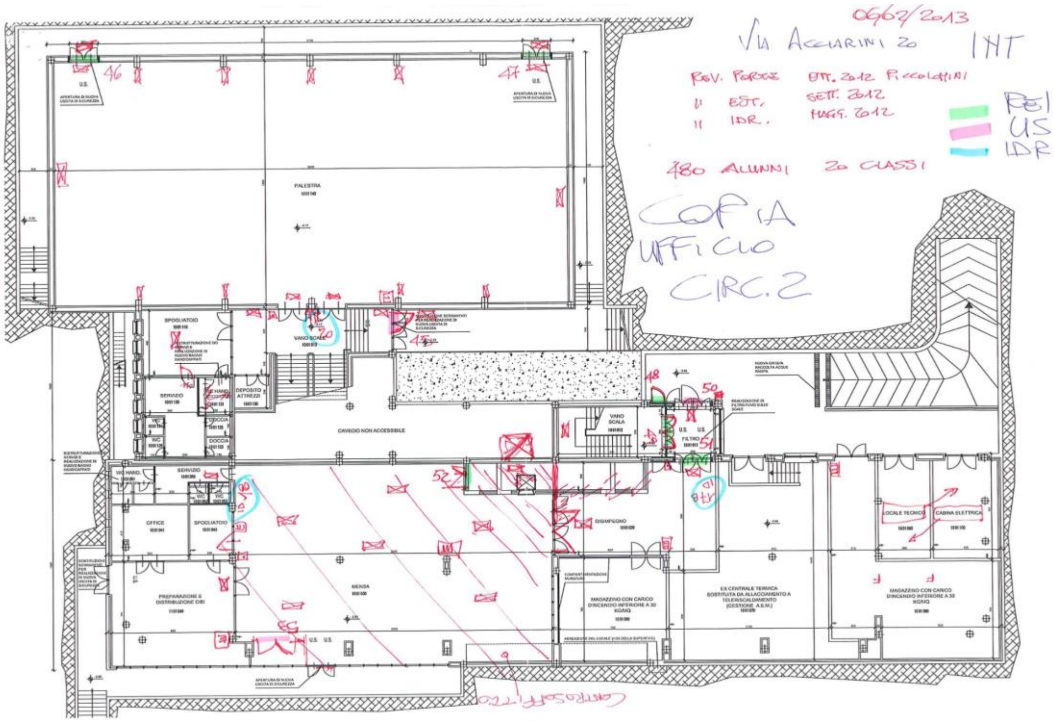
*Ground floor layout with fire doors, emergency exits, and administrative areas.



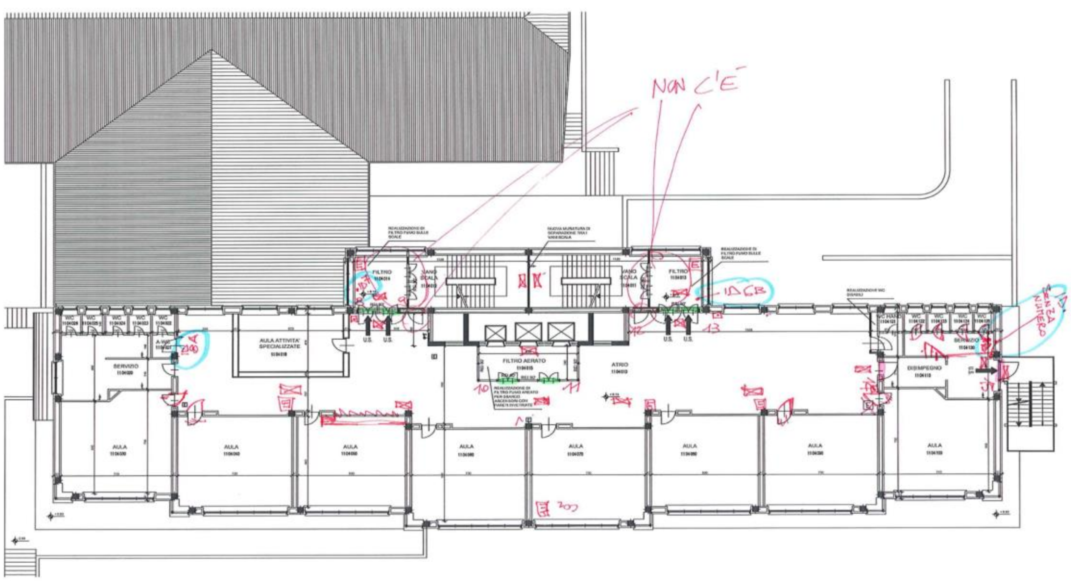

*First floor classrooms and corridor safety annotations.



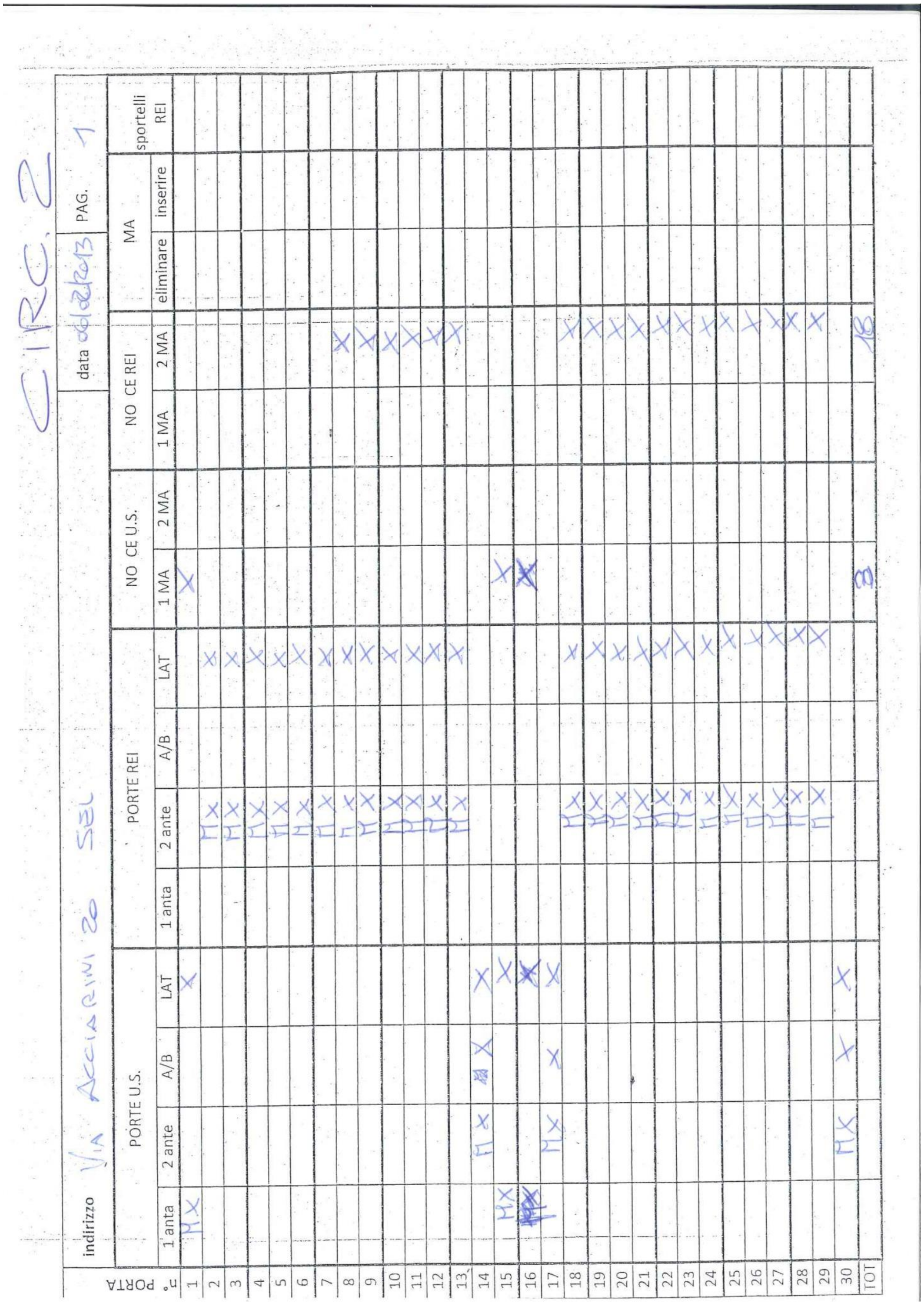

*Second floor inspection with signage and access issues marked.




*Fourth floor plan with marked exits and structural constraints.




*Specialized classroom floor (art, science) with crowding notes.

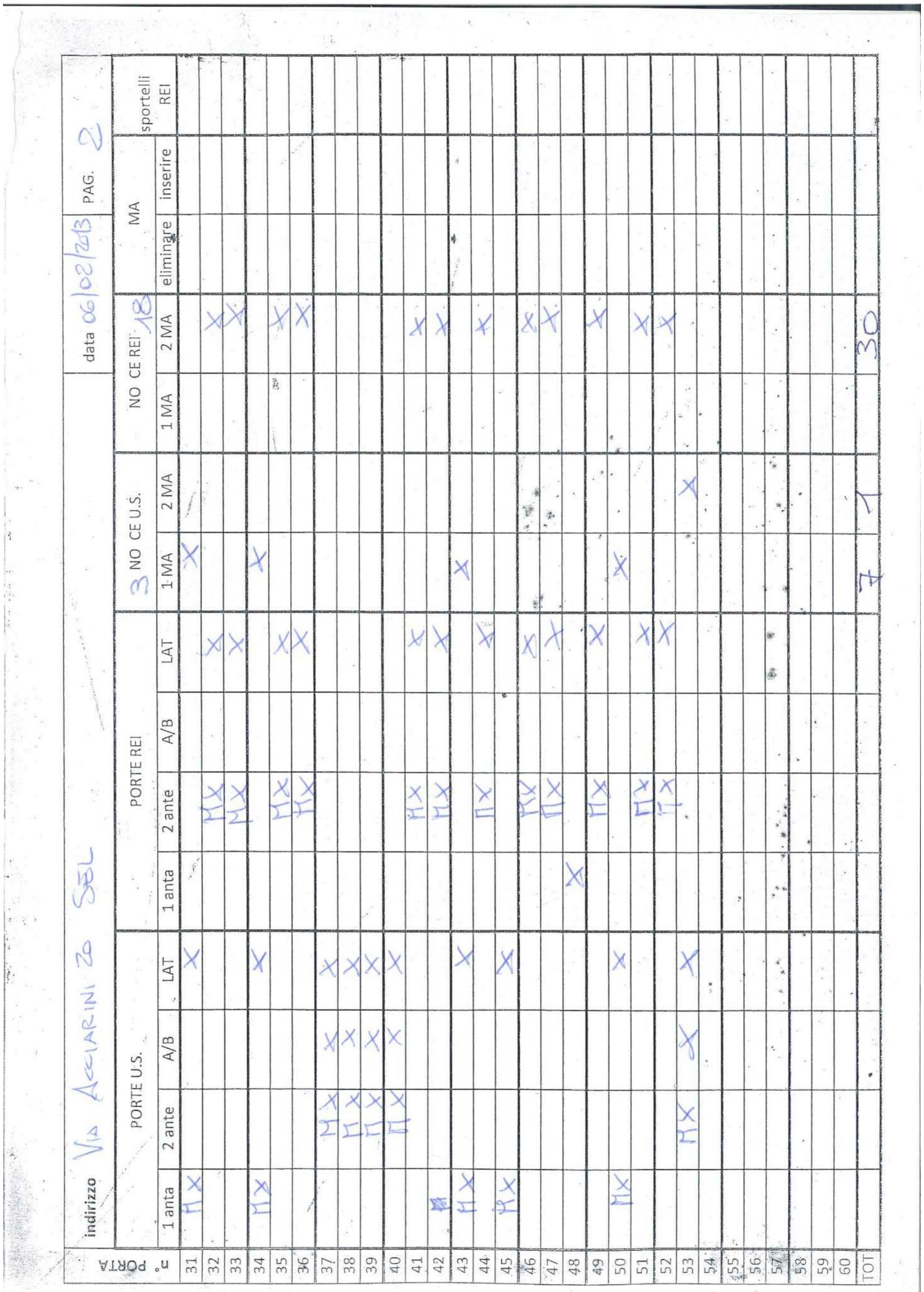


CIRC. 2

indirizzo Via Acciarini 20 SEL — data 06/02/2013 — PAG. 1

| n° PORTA | PORTE U.S. | | | | PORTE REI | | | | NO CE U.S. | | NO CE REI | | MA | | sportelli REI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 anta | 2 ante | A/B | LAT | 1 anta | 2 ante | A/B | LAT | 1 MA | 2 MA | 1 MA | 2 MA | eliminare | inserire | |
| 1 | MX | | | X | | | | | X | | | | | | |
| 2 | | | | | | MX | | X | | | | | | | |
| 3 | | | | | | MX | | X | | | | | | | |
| 4 | | | | | | MX | | X | | | | | | | |
| 5 | | | | | | MX | | X | | | | | | | |
| 6 | | | | | | MX | | X | | | | | | | |
| 7 | | | | | | MX | | X | | | | | | | |
| 8 | | | | | | MX | | X | | | | X | | | |
| 9 | | | | | | MX | | X | | | | X | | | |
| 10 | | | | | | MX | | X | | | | X | | | |
| 11 | | | | | | MX | | X | | | | X | | | |
| 12 | | | | | | MX | | X | | | | X | | | |
| 13 | | | | | | MX | | X | | | | X | | | |
| 14 | | MX | X | X | | | | | | | | | | | |
| 15 | MX | | | X | | | | | X | | | | | | |
| 16 | [illegible] | | | X | | | | | X | | | | | | |
| 17 | | MX | X | X | | | | | | | | | | | |
| 18 | | | | | | MX | | X | | | | X | | | |
| 19 | | | | | | MX | | X | | | | X | | | |
| 20 | | | | | | MX | | X | | | | X | | | |
| 21 | | | | | | MX | | X | | | | X | | | |
| 22 | | | | | | MX | | X | | | | X | | | |
| 23 | | | | | | MX | | X | | | | X | | | |
| 24 | | | | | | MX | | X | | | | X | | | |
| 25 | | | | | | MX | | X | | | | X | | | |
| 26 | | | | | | MX | | X | | | | X | | | |
| 27 | | | | | | MX | | X | | | | X | | | |
| 28 | | | | | | MX | | X | | | | X | | | |
| 29 | | | | | | MX | | X | | | | X | | | |
| 30 | | MX | X | X | | | | | | | | | | | |
| TOT | | | | | | | | | 3 | | | 18 | | | |

*Door schedule and emergency classification matrix (Page 1)



indirizzo Via Acciarini 20 SEL | data 06/02/2013 | PAG. 2

| n° PORTA | PORTE U.S. | | | | PORTE REI | | | | 3 NO CE U.S. | | NO CE REI 18 | | MA | | sportelli REI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 anta | 2 ante | A/B | LAT | 1 anta | 2 ante | A/B | LAT | 1 MA | 2 MA | 1 MA | 2 MA | eliminare | inserire | |
| 31 | MX | | | X | | | | | X | | | | | | |
| 32 | | | | | | MX | | X | | | | X | | | |
| 33 | | | | | | MX | | X | | | | X | | | |
| 34 | MX | | | X | | | | | X | | | | | | |
| 35 | | | | | | MX | | X | | | | X | | | |
| 36 | | | | | | MX | | X | | | | X | | | |
| 37 | | MX | X | X | | | | | | | | | | | |
| 38 | | MX | X | X | | | | | | | | | | | |
| 39 | | MX | X | X | | | | | | | | | | | |
| 40 | | MX | X | X | | | | | | | | | | | |
| 41 | | | | | | MX | | X | | | | X | | | |
| 42 | [illegible] | | | | | MX | | X | | | | X | | | |
| 43 | MX | | | X | | | | | X | | | | | | |
| 44 | | | | | | MX | | X | | | | X | | | |
| 45 | MX | | | X | | | | | | | | | | | |
| 46 | | | | | | MX | | X | | | | X | | | |
| 47 | | | | | | MX | | X | | | | X | | | |
| 48 | | | | | X | | | | | | | | | | |
| 49 | | | | | | MX | | X | | | | X | | | |
| 50 | MX | | | X | | | | | X | | | | | | |
| 51 | | | | | | MX | | X | | | | X | | | |
| 52 | | | | | | MX | | X | | | | X | | | |
| 53 | | MX | X | X | | | | | | X | | | | | |
| 54 | | | | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | | | | |
| 56 | | | | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | | | | |
| 58 | | | | | | | | | | | | | | | |
| 59 | | | | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | | | | |
| TOT | | | | | | | | | 7 | 1 | | 30 | | | |

*Door schedule and emergency classification matrix (Page 2)

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